Evaluation of the Vertical Tube Evaporator and the Multistage Flash Desalination Processes

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Evaluation of the Vertical Tube Evaporator and the Multistage Flash Desalination Processes

By The Fluor Corp., Ltd., Los Angeles, California, for the Office of Saline Water, Chung-ming Wong, Director; Everett N. Sieder, Chief, Distillation Division; Paul G. Tomalin, Project Engineer

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UNITED STATES DEPARTMENT OF THE INTERIOR • Walter J. Hickel, Secretary
Carl L. Klein, Assistant Secretary for Water Quality and Research

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FOREWORD

This is one of a continuing series of reports designed to present accounts of progress in saline water conversion and the economics of its application. Such data are expected to contribute to the long-range development of economical processes applicable to low-cost demineralization of sea and other saline water.

Except for minor editing, the data herein are as contained in a report submitted by the contractor. The data and conclusions given in the report are essentially those of the contractor and are not necessarily endorsed by the Department of the Interior.

COMPARISON OF CAPABILITIES AND COSTS
OF THE
VERTICAL TUBE EVAPORATOR (VTE) PROCESS
AND THE
MULTISTAGE FLASH DISTILLATION (MSF) PROCESS

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1.0 - INTRODUCTION

In July 1968, The Fluor Corporation, Ltd. was awarded a study contract from the Office of Saline Water (OSW) to determine, compare and evaluate the relative thermodynamic and engineering characteristics and economics of the Vertical Tube Evaporator (VTE) and the Multistage Flash (MSF) processes. The contract included a determination and assessment of the relative reliability, maintainability, and potentials of the two types of plants.

The evaluation is made on both large and small plants of each process. For the large plant comparison, OSW furnished conceptual designs of 250 million gallon per day (MGD) plants prepared by Oak Ridge National Laboratory (ORNL), in which the VTE plant used double-fluted vertical tubes. For the small plant comparison, Fluor was provided with A-E designs on three 2.5 MGD plants. Two of these were VTE plants furnished in two alternate designs made by the Stearns-Roger Corporation - one using smooth tubes, and the other using enhanced-surface tubes (double-fluted falling-film, and corrugated water-filled tubes). The MSF plant provided for comparison was the 2.5 MGD Universal Plant designed by Burns and Roe, Inc. for the OSW.

These designs were reviewed by Fluor and altered where necessary to make the process and engineering design bases the same for each plant. Capital costs and operating costs were then determined, using ground rules and procedures approved by OSW.

2.0 - SUMMARY AND CONCLUSIONS - 250 MGD AND 2.5 MGD PLANTS

2.1 Large (250 MGD) Plants

Summary

The large plant designs which were furnished for comparison are conceptual designs considered in some respects to be beyond the current limit of the state of the art; however, additional development programs should enable plants of this size to be built in the 1975-1980 period.

The reference Vertical Tube Evaporator (VTE) and Multi-Stage Flash (MSF) plants are each considered to be coupled to a nuclear-powered electrical power plant. Only the water plant portion of the complex is evaluated here, but steam and power costs and some capital costs are based on the dual-purpose nuclear power-water plant concept.

Each plant consists of four trains, with each train producing 62.5 MGD of fresh water. The performance ratio of each plant is essentially the same - 12.89 and 12.84 lbs. of product/1000 Btu for the VTE and the MSF plants, respectively.

Each train of the VTE plant combines a 50-stage flash feed preheater with a 15-effect vertical tube evaporator. The vertical effect tubes are copper-iron alloy with fluted surfaces to obtain high heat transfer performance; the horizontal feed preheater tubes are smooth 90-10 copper-nickel. Each train of the plant is contained in a trapezoidal reinforced concrete structure, with the vertical tube effects located above the MSF preheater. The plant operates with a maximum brine temperature of 260 F.

Each train of the MSF plant consists of 48 heat recovery stages and 2 heat reject stages. Smooth tubes of 90-10 copper-nickel are specified. Each train is contained in a structure designed of steel for the portion of the plant operating above 200 F and of reinforced concrete for the low-temperature end.

Laboratory tests of enhanced-surface horizontal tubes indicate heat transfer rates much higher than obtained from smooth horizontal tubes. If field tests show that the high rates can be sustained, an MSF plant utilizing enhanced tubes could be substantially reduced in size and cost.

An obvious difference between the VTE and MSF plants is in the number of pumps needed for each. Principally because of its effect pumps, each train of the VTE plant requires 20 major pumps, compared to only 5 for each MSF train. These pumps are expected to be quite reliable, and unscheduled shutdowns should be infrequent. Nevertheless, the failure of an effect pump will stop operation of the entire VTE portion of the train involved; the failure of any other pump (in either plant) will completely shut down the train affected. Loss of the VTE portion of a train will cut the train production by about 83%, and of the entire plant by about 20%. To partially compensate for the greater risk of pump outage in the VTE plant, warehouse spares have been provided for the effect pumps, together with a special gantry for quick pump replacement. With this arrangement downtime from failure of an effect pump should be limited to no more than 12 hours, including startup, and the 90% on-stream factor specified in the ground rules should be achieved. The average maintenance material cost of the more numerous pumps of the VTE plant is more than offset by the larger sizes of the MSF plant pumps and other components. However, the maintenance crew for the VTE plant is estimated to be larger because of the more numerous components to maintain.

The continuing escalation of prices must be considered in estimating the cost of building plants in the future. For the purposes of this study, the hypothetical plants are assumed to be started immediately. If such plants were to be built starting in January 1969, most material and labor expenditures for construction would occur in 1971, and water could be produced in 1972; therefore, costs have been escalated to those years.

Estimated costs, based on 4-1/4% interest for capital and a 30-year plant life, favor the VTE plant by a substantial margin. They are as follows:

	VTE Plant	MSF Plant
Capital cost (escalated to 1971), dollars	115,000,000	166,000,000
Product water cost (escalated to 1972), cents per 1000 gallons	25.9 to 25.0	30.2

Experience with the copper-iron vertical tubes of the VTE plant is limited and may not warrant the assumption of a 30-year life. For this reason, the water cost of the VTE plant has been estimated in two ways: 25.9¢/1000 gallons if tubes must be replaced in 15 years, and 25.0¢/1000 gallons if tubes last 30 years. The higher cost of water over a 30-year period reflects the estimated tube replacement cost that would be incurred during the 15th year. The replacement cost, in addition to new material and installation costs, includes the value of salvaged material and the cost of product lost during the replacement period.

The capital cost figures include extra contingency based on a "first-of-a-kind" plant of this capacity and conceptual design.

Conclusions

For large size plants, a VTE plant based on the reference design* appears to have a distinct economic advantage over the corresponding MSF reference design,** according to the findings of this study.

Use of enhanced surface tubes in the MSF plant would reduce its cost to some extent, but the cost of the VTE plant would still be substantially lower.

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*Design Study of 250 MGD VTE Desalination Plant by Oak Ridge National Laboratory, ORNL-4260.

**Design Study of 250 MGD MSF Distillation Plant, ORNL-3912.

Before large desalting plants of the reference designs can be considered ready for construction, however, additional research and development efforts are needed on the following:

For the VTE Plant

a. Life and heat transfer rates of the vertical enhanced tubes under actual field service conditions.

b. An acceptable structural design that is safe in the event of a failure of an effect pump.

c. Module tests for investigating problems in coupling an MSF section with the VTE section.

For Both Plants

a. Durability of reinforced concrete in a brine and in a distilled water and vapor environment when the reinforced concrete is in tension.

b. The possibility of reduced cost through use of polymer concrete.

c. Applicability of linings under development for steel and concrete suitable for 260 F temperatures.

d. Cost of in-place reinforced concrete with a steel inner liner.

2.2 Small (2.5 MGD) Plants

Summary

The three small plant designs which were furnished for comparison have been engineered and specified by others to the extent that guaranteed cost proposals could be provided. Two of the designs are for VTE plants - one with conventional smooth tubes and one with enhanced surface tubes - and the third is for an MSF plant. Each of the small plants consists of a single unit capable of producing 2.5 MGD of desalted water. The performance ratio (pounds of product water per 1000 Btu of heat input) of each plant is approximately the same - 11.6 for each of the two VTE plants and 11.5 for the MSF plant.

The two VTE plants were designed by and their cost estimated by Stearns-Roger Corporation. The MSF plant is a modified version of Plant No. 4 of the OSW "Universal Plant Design." This design was modified by The Fluor Corporation, Ltd., to correspond to the conditions of a hypothetical site, and to place the design on the same basis as the VTE plants. Fluor then made a definitive cost estimate of this "normalized" MSF plant for comparison with costs of the VTE plants. OSW agreed that the Stearns-Roger estimates of the selling prices of these plants would be an acceptable basis for comparison with Fluor's cost estimate of the MSF Universal plant. Fluor made a considerable number of process and physical changes to the Universal Plant Design No. 4 to place it on a basis comparable to the VTE plant. These changes are listed and discussed in Section 11.3, page 138.

Each of the small VTE plants has 14 effects and operates with a maximum brine temperature of 258 F. Unlike the large (250 MGD) VTE plant evaluated in this report, in which the feed preheating was done in an associated MSF unit, all feed heating in the small plants is done by means of the preheater tube bundles in each effect. All VTE tubes, whether smooth or enhanced, are of 90-10 copper-nickel, including the vertical falling-film tubes and vertical and horizontal exchanger tubes. For improved reliability, all pumps in the VTE plants are provided with installed spares. The 14 falling-film feed pumps have one spare for each two pumps; all other pumps in the plant each have an installed spare.

The small MSF plant consists of 39 flash stages for heat recovery and three for heat rejection. Maximum brine temperature is 250 F. The MSF plant includes five separate heat recovery vessels, a heat rejection vessel, and a separate brine heater. All heat-exchange tubes are smooth and made of 90-10 copper-nickel. Except for the brine recycle pumps, all pumps in the MSF plant are provided with installed spares. The brine recycle pumps are designed to operate in parallel, with each pump rated at 55% of the normal plant design requirement. Loss of one of these pumps would limit plant capacity to about 1 - 1.25 MGD.

2.2 Small (2.5 MGD) Plants (Cont'd.)

The relative reliability of the small VTE and MSF plants is judged to be approximately equal. With respect to reliability, there are 14 effect pumps in the VTE plants which must share a spare with another pump, while in the MSF plant one major service has no spare pump but does have two half-capacity pumps. All other components in the two types of plants appear to be comparable with respect to number and reliability of components.

With respect to maintenance, again the two types of plants appear to be about equal, the extra maintenance of the more numerous pumps and exchangers in the VTE plants being offset by the larger pumps and larger piping of the MSF plant. For installation in a remote location, however, the VTE smooth tube plant, and to a lesser extent, the VTE enhanced tube plant, does present maintenance difficulties because of its height. A mobile crane with a long boom is needed to remove effect covers, feed heater heads, and tube bundles. Purchase of this type of maintenance equipment usually cannot be justified for a small plant, and in some locations it cannot be hired on short notice.

The continuing escalation of prices has been considered in estimating capital costs and product water cost. For this study, it is assumed that if detailed design on a 2.5 MGD plant were started in 1969, most of the material and labor expenditures and the start of water production would occur during the following year; therefore, costs have been escalated to 1970.

The estimated costs, based on 4¼% interest for capital and a 30-year plant life, are as follows:

	VTE Plant Smooth Tubes	VTE Plant Enhanced Tubes	MSF Plant Smooth Tubes
Capital costs - 1968	$4,687,500	$4,457,700	$4,834,100
(escalated to 1970)	4,900,000	4,680,000	5,060,000
Product water costs per 1000 gallons - 1968	$1.03	$1.02	$1.08
(escalated to 1970)	1.08	1.07	1.14

The capital costs and water costs developed in this study for 2.5 MGD plants are high in relation to recent bid prices for plants of this size; however, it must be remembered that these capital costs do include land and other owner costs plus all offsite facilities except the boiler plant, and escalation to 1970 prices. One major item of capital cost for all three plants in this study is a cost of more than half a million dollars for the submarine seawater intake line. Higher-than-usual land and site grading costs also contributed to high capital costs, and continuous chlorination added to the cost of production. For a Southern Florida or Caribbean site the capital costs of each plant would probably be about $1,000,000 less than the 1968 capital costs shown above, and the corresponding water costs would be about 12¢/1000 gallons lower.

Conclusions

For plants of 2.5 MGD size, capital costs and production costs for the two types of plants evaluated (VTE and MSF) are very nearly the same. The enhanced tube VTE plant has the lowest cost, but the total spread in costs between the three plants evaluated is about 5%. This does not represent a significant economic advantage for either of the VTE plants over the comparable MSF plant.

One potential improvement which might modify the economic balance is the use of enhanced surface (corrugated) tubes in the MSF Universal Plant design. Several types have shown improved heat transfer characteristics in short-term tests. If extended tests bear out these advantages without disclosing serious drawbacks, enhanced tubes may net significant reductions in capital and production costs after allowing for higher pumping and tube costs.

Some discussion seems in order to explain why in very large plant sizes, the VTE process exhibits a striking advantage over the MSF, yet in small sizes, its advantage is marginal. There appears to be two main reasons for this. First, in the large plants, the percentage of the total capital cost represented by heat transfer tube bundles is very high, on the order of 40%. Therefore, any design change that results in an increase or decrease in heat transfer surface has a pronounced effect upon the total plant capital cost. In small plants, however, where the tube bundle cost totals only 20% of plant investment, plant cost is much less sensitive to this cost. Second, the 250 MGD VTE plant employs an MSF preheating scheme which improves the thermodynamic efficiency of the plant and, therefore, for a given performance ratio, reduces the total heat transfer requirement. The small VTE plant does not make use of this feature.

3.0 - TECHNICAL SUMMARY - 250 MGD PLANTS

3.1 VTE Plant Description - Process and Physical

General Process

The process employed in this plant is a forward-feed, falling-film vertical-tube multiple-effect evaporator with a 50-stage flash evaporator feed heater. The vertical tubes are the "double-fluted" type to enhance heat transfer. The plant has a performance ratio of 12.89 pounds of product water per 1000 Btu thermal input. The process flow is shown on Dwg. V-3.

The incoming seawater is screened and chlorinated, then acidified and pumped to the deaerator where it constitutes approximately 70% of the feed to the evaporation cycle. Another portion of the incoming seawater flows through the tubes of the final heat reject condenser where it is warmed to 104°F. Two-thirds of this seawater is returned directly to the ocean as the major heat reject stream; the remaining one-third is acidified and pumped to the deaerator to provide the other 30% of the feed. The warm 104°F seawater stream is sprayed into the first side of the evacuated deaerator where it is deaerated and cooled to 77°F by the action of water vapor flashing from the surface of the droplets and carrying away dissolved gases. The colder 65°F seawater stream is sprayed into the second side of the deaerator where it is deaerated and heated to 77°F by the vapor which was evolved from the warm seawater stream on the first side of the deaerator. The noncondensibles are continuously removed from both sides by a three-stage ejector system with barometric condensers. Seawater at 65°F serves as coolant for the barometric condensers

The combined deaerated feed at 77°F is pumped into the condenser tube bundles of the multistage flash evaporator at Stage 50. The continuous tubing carries the seawater through all 50 MSF stages as its temperature is increased to 246.5°F by vapor that condenses on the tubes in each stage. The condenser tubing continues into the brine heater where steam from the power plant raises the brine temperature to 260°F. Steam condensate from the brine heater is returned to the power plant for boiler feed.

The brine leaving the brine heater passes through a pressure control valve and thence to a distribution chamber. One stream from this distribution chamber flows through an orifice into the first flash evaporator stage where steam flashes off at the reduced pressure, cooling the seawater approximately three degrees. The released vapor passes through the entrainment separator, condenses on the feed heater tube bundles, and falls into the product trough which is on the same floor level but separated from the flashing brine. The brine and condensate then flow separately through orifices into Stage 2 where both streams flash again. The vapor from both streams condenses on the feed heater tube bundles and falls down to join the condensate stream. This process continues through Stage 50 at which point the condensate, now at 90°F, is pumped to the product water system. The brine, now at a concentration 2.5 times that of normal seawater, and a temperature of 92.8°F, is returned to the ocean.

The 15 vertical-tube effects are located directly above the flash evaporator stages. The second stream of brine mentioned in the paragraph above flows from the distribution chamber to the Effect I pump and is then pumped to the brine chest above Effect I. Here it enters the vertical fluted tubes through individual nozzles. Steam supplied by the power plant to the steam chest of Effect I condenses on the outside of the tubes and is then returned to the power plant as boiler feed. The latent heat of condensation of the steam is transferred through the vertical tubes to the seawater inside, causing an equivalent amount of vapor to evaporate isothermally from the falling film of brine on the inside of the tube. Both steam and noncondensibles are carried down through the center of the tube. The vapor disengages from the brine in the space beneath the tube bundle, passes through the entrainment separator at the face of the Effect II bundle, and condenses on the vertical tubes in Effect II. The brine is then returned to the MSF brine stream. Noncondensibles are withdrawn at the outside top of each tube bundle. A similar process is repeated for each succeeding effect, with brine being withdrawn from the appropriate MSF stage, partially evaporated in the VTE effect, and then returned at the same temperature to the same MSF stage from which it was withdrawn. To prevent the slightly enriched brine from being again pumped to the same effect, it is returned by gravity flow through ducts in the stage floor at a point downstream of the suction connection of the effect pump. Except as described above for Effect I, condensed vapor from the outside surfaces of each vertical tube bundle flows by gravity to the product tray in the flash stage which is at the same pressure as the condensate. Vapor equalization passages are provided between each effect and its associated stage to accommodate design and operation uncertainties.

This process requires that there be a flash evaporator stage at the same saturation temperature as each vertical-tube effect. This means that the inter-effect temperature decrement must be spanned by some whole number of flash evaporator stages. Effects II through XII are each spanned by three stages; Effects XIII through XV each by four stages; and the first condenser by five stages.

Physical Plant

The plant is housed in four trapezoidal reinforced-concrete structures, each containing one parallel and independent train. Each train has the multistage feed heater on the lower floor and the vertical tube effects on the upper floor, and is divided along the plant length into 50 flash evaporator stages and 15 vertical tube effects. The brine heater is integral and forms a continuation of the feed heater. The final condenser and deaerator are also contained within the evaporator shell.

The bundles of 10-ft-long, 3-in OD. double-fluted vertical tubes are constructed in 10-ft-deep by 20-ft-wide rectangular units; each unit has its own noncondensable gas cooler and vent removal section. Hook and vane entrainment separators are mounted at the face of the bundle. The vertical tube bundles will be prefabricated with appropriate tube spacing for each effect and will be installed with partial bundles as needed to provide the specified number of tubes for each effect. The width of the train (and of the entire plant structure) is determined by the number of bundles required to supply the total number of vertical tubes needed in each effect. Principal plant equipment is described in Section 9.1.

A standard vertical tube bundle is 10 ft deep (in direction of vapor flow) and 20 ft wide. The distance between the top and bottom surfaces of the tube sheets is 10 ft 3 in, and the tubes project 3/4 in below the bottom tube sheet and 1/4 in above the top tube sheet, as shown in Dwg. V-8. The polypropylene baffles separate each bundle into two regions - the main vapor-condensing section, and the noncondensable cooler and removal section. The unit bundle is of such a size as to be transportable, so that the machining and assembly operations can be done wherever is most economical. The vertical tube bundles contain an array of 3-in OD. by 0.049-in wall double-fluted tubes made of CDA 194 copper-iron alloy. Tube density varies from 13 to 8.72 tubes per square foot of tube sheet, progressing from Effects I to XV. Tube sheets are 1-1/2 in thick, the top sheet made of carbon steel and the bottom sheet of carbon steel clad on the brine side with 90-10 copper-nickel. The brine side of the top sheet is protected by the layer of cement in which the bases of the ceramic nozzles are imbedded.

Brine entry into each individual vertical tube is controlled by a ceramic nozzle cap mounted over it and held in place by a suitable cement. These nozzles perform the dual function of regulating the flow of brine to each tube and of distributing the brine over the inner tube surface. The top of each nozzle cap is shaped like a hat or slender dome, with a single 1/4-inch diameter hole formed on the side of the dome. The hole is directed slightly off-center so that the brine enters with a tangential component. The brine jet impinges on the inner surface of the nozzle cap and descends into the evaporator tube with a pronounced swirl, insuring complete wetting of the evaporating surfaces of the tube. For additional discussion on the ceramic nozzles, refer to Section 8.2.

3.1 VTE Plant Description - Process and Physical (Cont'd.)

The top tube sheet of each vertical tube bundle is made slightly wider than the bottom, which eases installation and provides for supporting the upper sheet on built-in shelves in the evaporator. Once the tube bundles are set in place, the support edges of the upper tube sheet are seal welded to the evaporator liner. Type 316 stainless steel flexible seals are welded between the tube sheets of adjacent bundles, both top and bottom, and between the bottom sheet edges and the evaporator shell.

The design contemplates that replacement bundles are fabricated and installed in the same fashion.

The feed heater bundles are continuous 371.6-ft-long tubes from stage 50 through the brine heater, and are installed by inserting the individual tubes through the stage separator sheets in place and rolling the tubes into the end sheets.

Hook-and-Vane Entrainment Separators

The separators will be in standard sheets approximately eight stages deep by 9 ft long for the VTE effects and 6 ft long for the MSF stages. Sections approximately 10 ft wide will be assembled by hand using spacers and four tie rods, two at the bottom and two at the top of each unit. The units will be lowered into the partitioning walls and clamped at the top and bottom by two braces and bolts per 10-ft-wide unit. The units for the MSF stages will be mounted in a similar manner from the floor of the feed preheater section.

Materials of Construction

The various materials of construction used in the VTE plant are described in Section 8.8 of this report.

3.2 MSF Plant Description - Process and Physical

General Process

The process and mechanical design of this plant was developed by ORNL under a previous contract, and was reviewed and modified as necessary by Fluor for this study.

The process flow diagram is presented in Drawing M-3, and is of conventional MSF design. A 2500 MWt nuclear reactor generates high pressure steam which first drives a turbine generator and is then utilized to provide the thermal energy to the waterplant. ORNL has optimized the water plant for a performance ratio of 12.84 pounds of water per 1000 Btu thermal input.

The incoming seawater is first screened to remove ocean debris and chlorinated to control the growth of marine organisms within the plant. It is then pumped into the condenser tubes of a two-stage heat rejection section. In the reject condenser, the seawater receives a quantity of heat nearly equal to the plant steam input rate. Of this total flow, two-thirds is rejected to the sea. The remaining seawater, used for process feed, is acidified and pumped to the deaerator.

The deaerator is constructed as an integral part of the heat rejection section. It consists of two stages of brine spray with a countercurrent flow of water vapor, the latter being obtained from the final brine flash chamber. Condensation of most of the stripping vapor is accomplished by direct contact with treated, cold seawater. The inerts and remaining water vapor are withdrawn at a temperature of 80 F and discharged to the atmosphere by a three-stage ejector system.

The acidified, deaerated seawater feed is combined with a much larger stream of recycle brine and pumped at an average temperature of 91.6 F, through the tubes of the 48 heat recovery stages. Water vapor from flashing brine condenses on the tubes and heats the seawater inside the tubes to 238.7 F as the brine stream passes through the successively hotter MSF stages. From the condenser tubes, the seawater enters separate brine heaters and is further heated to 250 F with saturated exhaust steam from the power plant turbine generator. The hot brine then flows back through all the MSF stages, with additional flashing of water vapor occurring in each successively lower pressure stage.

The vapor from the flashing brine in each stage passes through demisters, condenses on the tubes, and is collected as product water in trays located beneath the tube bundles. This product is flashed from stage to stage in similar fashion to the brine, with the accumulated product pumped from the last stage to battery limits.

The plant is designed with the flashing brine flowing on two different levels. This is done to permit a narrower and therefore less costly evaporator building. Space is provided between sections of the upper brine tray to permit the passage of steam flashed from the lower level to the condenser above.

3.2 MSF Plant Description - Process and Physical (Cont'd.)

Interstage vapor pressure differentials provide the driving force to maintain the brine flow from stage to stage. Additional static head is provided by stage elevation changes at the low temperature end of the plant, where the stage-to-stage vapor pressure differential alone is insufficient to maintain brine flow. In the heat rejection section, the temperature decrement per stage is increased to promote brine flow.

The dissolved gases removed from the seawater in the deaerator are withdrawn from the plant by steam-jet ejectors. Traces of noncondensibles resulting from in-leakage and incomplete deaeration are carried with the water vapor to the condenser bundles. Gas cooling and gas removal sections in the interior of the condenser bundle serve to remove the noncondensibles which collect at each stage. The stages above atmospheric pressure are vented separately; the subatmospheric stages are served by the central ejector system.

Physical Plant

The plant consists of four trains. Each train is 692 ft. long and is 90 ft. wide on the high-temperature end of the plant and 105 ft. wide at the low-temperature end.

The flash chamber design incorporates two flashing brine levels and a product water tray. The condenser tubing is 3/4" OD. x .035" wall, 90-10 copper-nickel alloy in the heat recovery section and 3/4" OD. x .049" wall, 90-10 copper nickel in the heat reject section, both with an assumed 30-year life. The flashing brine flow is ducted through the evaporator stages in two levels. The condenser tube bundles are located at the top of the evaporator structure, and the product water collected on the tube bundles drains into the product tray immediately below the bundles. The product is flashed to downstream stages in the same fashion as the brine.

Each plant train is stepped between the heat recovery and the heat reject sections so that condenser tubes can be inserted from either end of the heat recovery section and from deaerator end of the heat reject section. A single water box is used at the midplane of the heat recovery vessel.

The floor of the plant is a concrete slab with a 1/4" steel liner. The roof and the side walls of the high-temperature end (above 200 F) of the plant structure are of 1/2" arch construction steel. At the lower temperature end of the structure, 12" concrete with a 1/4" steel liner is used.

Separate brine heaters are provided for each train (two per train). The heater tubing is 3/4" OD. x .035" thk. 90-10 copper-nickel alloy. Each tube is 24.2 ft. long.

Principal plant parameters and items of equipment are described in the MSF Equipment List, Section 10.1.

Tubes

The tubes for the evaporator condenser bundles are 90-10 copper-nickel alloy, 3/4" OD, with .035" wall thickness in the heat recovery section and 0.049" wall thickness in the heat reject section. Continuous straight lengths of 238.5 ft. and 241.5 ft. will be utilized in the heat recovery section, and 67.5 ft. lengths will be used in the heat reject section.

The tubes for the brine heater are 90-10 cu-ni alloy, 3/4-in OD, with 0.035 in. wall thickness and 24.2 ft. length.

Materials Selection

Materials used in the principal portions of the plant are discussed in Section 8.8.

Structural Design

The evaporator structure is designed of structural steel for that portion of the plant operating above 200°F, and of reinforced cast-in-place concrete for the low-temperature end.

Steel stage walls are of stiffened flat plate supported from beams and columns.

Expansion joints are located at each tube sheet end to absorb the differential expansion between tubing and structure.

Tube Bundle Design

Each of the four 62.5 MGD trains has five tube bundles in the heat recovery section and five tube bundles in the heat reject section, located above the product water trays. The continuous long-tube concept is used, with the heat recovery bundle being in two lengths. The first length is 238 ft 6 in long, extending from stage 1 through stage 25. The second length is 241 ft 6 in long, extending from stage 26 through stage 48. The heat reject tube bundles are 67 ft 6 in long.

Tube sheets at the water boxes are 3-in. thick steel, Cu-Ni clad on the brine side. Tube sheets at the stage walls are 1-in. thick steel. Intermediate tube supports are 1/2-in. thick steel.

The tube spacing for the 3/4-in. tubes is 1" at the high temp. end, 1-1/8" at the low temp. end, 1-1/16 " in the heat reject section and .975" in the brine heater, center-to-center spacing in an equilateral triangular array.

The two tube bundle layouts for the heat recovery section have a conventional circular cross section and each contains 12,398 tubes. The tube bundle layout for the heat reject section has an elliptical cross section and contains 5,098 tubes.

3.3 Study Procedure

Process Optimization - VTE & MSF

The plant performance ratio has been established by ORNL at 12.89 pounds product water per 1000 Btu thermal input for the VTE plant and 12.84 for the MSF plant. These numbers are extremely close and for all practical purposes may be considered the same. It is our understanding that ORNL optimized the MSF plant using steam, utility, operating, and fixed costs which differ from those used in the current study. The VTE plant was then designed for the same performance ratio.

Ideally, each process should be optimized separately. In such case, the optimum plants could conceivably have widely different performance ratios. However, based on previous optimization work with sea water distillation plants, it is known that these plants display characteristically flat optimums. In other words, an independent variable may be changed by a significant amount with only an insignificant change in the optimized variable--water cost, in this instance. It is virtually inconceivable that a comparison made using equal plant performance ratios would be significantly different from a comparison between separately optimized plants.

A difficulty in comparing plants of different performance ratios and the same output is that differing unit heat costs have to be developed since the cost of thermal energy is a function of the size of a nuclear reactor.

In view of the preceding, Fluor believes that the equal plant performance ratio approach taken by ORNL is a valid one. To fully confirm this, we understand that the OSW intends to have ORNL perform additional optimization studies on both processes, using unit costs as developed by this study.

Submergence Losses - VTE and MSF

Submergence allowances used in the MSF plant and the MSF section of the VTE plant are in accordance with the latest information on this subject developed by AMF under contract to the OSW. For the MSF section of the VTE plant, for example, submergence losses used by ORNL in the design, range from 0.8 to 1.9 F.

Brine Distribution - VTE

Distribution of brine in pumping from the MSF stages to the VTE effects and in returning the brine to the MSF stages will have to be carefully designed in a real plant. Fluor believes the concept developed by ORNL is workable and that adequate distribution and mixing can be achieved. However, pressure drop calculations indicate the brine ducts carrying brine from each VTE effect back to the stage from which it was pumped are too small. Accordingly, a second duct the same size as the existing one was added on the opposite side of each train. It was necessary to locate certain horizontal portions of the second duct above the MSF floor to avoid interference with other transverse ducts.

Distribution connections from the transverse header back to the MSF stage must be sized for a higher velocity than exists in the header to assure adequate transverse distribution across the stage. Distribution of brine flowing from the MSF stage to the effect pump suction is probably less important, but would be achieved in the same manner.

The consequences of poor distribution have not been carefully evaluated, but incomplete mixing of the enriched returning brine with elevated boiling point would cause thermodynamic losses due to loss of thermal driving force. However, except for gross mal-distribution, the penalties involved are believed to be small.

Stage Lengths - VTE and MSF

The MSF stage lengths shown on ORNL drawings do not agree exactly with those shown in the computer printouts. ORNL made small adjustments in these lengths to permit standardization of construction details and, in the case of the VTE plant, to facilitate vertical alignment of structural members in the MSF and VTE sections of the plant. Fluor considers this to be good practice. The effects on the thermodynamic efficiencies of the plants will be negligible.

Recycle Pump Suction Conditions - MSF

The original ORNL design called for a stepped plant width when viewed in plan, with the train width narrowing suddenly at the point where the last stage joins the deaerator. At about this same point the brine drops several feet into the pump suction funnel, creating additional turbulence. This abrupt reduction in width and brine waterfall would create a violently disturbed flow and unsatisfactory pump suction conditions. The brine flow rate moving to the pump suction exceeds 2,500,000 lb/hr per foot of width. This flow rate is far beyond the highest demonstrated design (800,000 lb/hr per foot at the OSW's MSF Test Module), and is almost certain to result in unsatisfactory pump suction conditions. The maximum flow rate and other hydraulic features could only be determined by model test. Further, the indicated brine level of about 2 feet over a suction line diameter of 13.5 feet almost assures severe vortexing.

In order to improve the recycle pump suction conditions, Fluor has squared off the evaporator structure as viewed in plan, and contoured the evaporator floor to obtain a deeper brine pool and increased flow cross section leading into the recycle pump suction. The pump was also lowered several feet to provide a large, smoothly-contoured, low-velocity suction conduit designed to prevent vortexing and allow deentrainment of vapor. (See Dwgs. M-5 and M-7.) Placement of the suction line relative to the walls is also considered important but no changes were made. For a real plant design, model tests of the pump suction configuration would be required.

3.3 Study Procedure (Cont'd.)

Maximum Brine Temperature

The maximum brine temperature in the MSF plant is 250 F, whereas in the VTE plant it is 260 F. However, since the VTE is a "once-through" plant, the VTE brine heaters handle single-strength seawater, while the MSF brine heaters handle seawater concentrated by a factor of 1.72. For this reason, the VTE brine heaters actually operate further removed from $CaSO_4$ hemihydrate scaling conditions than the MSF heaters. However, the VTE process may be susceptible to localized over-concentration in the boiling thin film, so that proper design would call for operation further away from scaling conditions. The Freeport VTE pilot plant has demonstrated long-term scale-free operation at temperatures of 260 F and higher, while the Point Loma MSF plant has demonstrated sustained 250 F operation. It is Fluor's opinion that the design maximum temperatures for these two processes are equitable, reflecting the level of current technology for the two types of plant.

To maintain product water costs on an equitable basis, the VTE plant is charged for its steam at a higher unit cost to reflect its higher level of available energy.

Demisters - MSF

The "stepped" layout of the wire mesh demisters specified by ORNL for the MSF plant was checked to be certain that sufficient room was available to install the specified area of demisters. Layout sketches for Stages 48 and 50 were made; in both cases there was found to be ample room.

Fluor has calculated the pressure and temperature losses to be expected during steam flow through the wire mesh demisters and compared these figures with ORNL data. The Fluor approach to this calculation is to double the dry drop calculated from the Poppele and York(1) data.

The comparison between the Fluor and ORNL figures is tabulated below:

	Temperature Loss, °F	
Stage	Fluor	ORNL
1	.0184	.033
15	.047	.072
30	.110	.157
40	.224	.299
45	.356	.444
48	.416	.502
49	.400	.497
50	.408	.512

The agreement between these calculations methods is quite good, the maximum difference being about 0.1 F. Neither method is supported by actual operating data.

The ORNL calculated temperature loss is accepted.

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(1) Poppele, E. W. and D. H. York, Chemical Engineering Progress, 59(6) 45-50 (1963).

3.3 Study Procedure (Cont'd.)

Bundle Loss-MSF

The pressure drop required for steam to penetrate through the condenser bundle to the annulus was calculated using a procedure developed previously by Fluor, and compared to the ORNL value. For Stage 48, the value predicted by the Fluor method was 0.55 F whereas ORNL calculated 0.51 F. This is considered excellent agreement; no changes were indicated in the ORNL design.

The above losses do not include the losses incurred in passing through the "air-cooling" section. This loss is usually greater than through the main field, but since the number of tubes in the air-cooling section is relatively few, the overall effect on reduction in MTD is not great.

In calculating mean temperature difference, ORNL employed the figures for total loss through the main field. An average or effective value is normally used. Since this is conservative and is similar to the procedure used on the VTE, no changes in the ORNL design were indicated.

Evaporator Design Pressure - VTE and MSF

To determine the design pressures for the external walls for both plants, 5 F was added to the normal operating temperature, and the corresponding saturation pressure obtained from the steam tables and specified as design pressure. Since the brine typically has a BPE of about 2 F, the overall safety factor is about 7 F. For a real plant design, additional study would be required to determine whether this allowance is adequate to cover all dynamic conditions of startup, shutdown, and upset. For this study, neither the method nor the time was available. In a real plant, a process simulation computer program would probably be required.

Design Pressure of Internal Walls - VTE and MSF

In an MSF plant, adjacent stages are connected by relatively large orifice openings. Although these openings are liquid-sealed during normal operation, in cases where differential pressure between adjacent stages rises, the seal will be lost and steam will blow through the orifice, thereby limiting the pressure differential that can exist. Standard practice in MSF plants, therefore, has been to design stage partition walls for the normal operating differential pressures with no factor of safety. This procedure has been employed in this study for the MSF plant and for the MSF section of the VTE plant.

In the VTE design, the design of the partition walls between effects is not so simple. Other means must be sought to prevent exceeding some design limitation on partition walls between effects during any or all excursions of process conditions. At least five possible ways of accomplishing this are listed in Section 8.1 "Evaporator Structure."

Evaluation of these schemes is clearly a complex problem beyond the scope of this study. At present, Fluor tends to favor oversized vapor equalizing ducts for the high temperature stages and using a design safety factor for the low temperature stages that would be safe under any conceivable condition. Rather than select any scheme, however, Fluor has included an arbitrary allowance of $200,000 in the cost estimate to provide the necessary changes.

Computer Printouts

The computer printout for the 250 MGD VTE plant used by Fluor in this comparative study program is different from the one included in the ORNL VTE Report 4260. The changes were necessary to put the VTE and MSF plants on an equal basis. After these process changes had been made, the altered conditions were transmitted to ORNL for incorporation into their computer program, and a new computer run was made. The changes included increasing the fouling factor from .0003 to .0005 in the preheater section, and increasing the nonequilibrium allowances to be consistant with those used in the MSF plant. The MSF computer output used for this study is unchanged from that shown in ORNL MSF Report 4214.

Both the updated VTE printout and the MSF printout are included in the Appendix of this report for ready reference.

Heat Transfer Coefficient

The validity of the process comparison undertaken in the current study relies to a large extent upon the selection of proper and comparable overall heat transfer coefficients for each process.

In both processes, the fouling factor assumed by the investigator has a pronounced influence in the determination of overall coefficient. It is especially important in the VTE plant, since the film conductances are so high that fouling factor is a higher percentage of the total resistance to heat transfer than in the MSF.

In the recovery stages of the MSF plant and in the MSF section of the VTE plant a fouling factor of 0.0005 was assumed. In each MSF unit equal tubeside brine velocities were used. Overall coefficients computed on these bases are in general agreement with those in use by industry.

The ORNL method of determining overall heat transfer coefficient for the double-fluted VTE plant is presented in detail in their report, and will not be repeated here. In this procedure they evaluated data obtained in the General Electric pilot plant at Wrightsville Beach, North Carolina, and by ORNL in their single-tube test apparatus at Oak Ridge. The data evaluation did not permit separate identification of fouling factor. In addition, the reduction in thermal driving force due to pressure loss of steam through the inside of the tube was obscured and could not be identified. Further, inside and outside film coefficients were not separated. The correlation developed was simply for U value versus evaporation temperature, with approach temperature and salt concentration as parameters. Oak Ridge chose what appears to be a conservative interpretation of the data, with the U values they used falling below almost all of the data points.

Despite the conservative approach taken by ORNL, it is recognized that this is all laboratory test data, not long-term plant operating data. The principal uncertainty involved is whether the high transfer coefficients observed in the laboratories can be maintained over many years of operation, or whether a progressive accumulation of scale and/or dirt will reduce performance.

Long-term operation at Freeport has shown that U values for smooth tubes do not progressively deteriorate and that a constant heat transfer coefficient is soon reached. The double-fluted tube might be more sensitive to fouling for several reasons:

1. With the double-fluted tube, a small amount of fouling has a greater percentage increase in total resistance than with a smooth tube.

2. The grooves on the tube's inside surface might be preferential spots for scale or dirt to lodge, although no actual observations have been reported to support this conjecture.

There is now a double-fluted module in service at the OSW's Freeport facility. In the few months of operation so far accumulated, there has been no tendency for U value to deteriorate with time, according to the operators. Further, their calculations show they are achieving a U value of 1400 in Effect #9, which operates at a brine temperature of about 182 F. This agrees almost exactly with the ORNL correlation on which this design was based. Visual inspection of the inside of the double-fluted tubes after a few months operation showed them to be just as bright as the smooth tubes.

It would be desirable to develop a better fundamental understanding of the heat transfer mechanism involved with double-fluted tubes. However, this is a highly complex problem and a complete analytical treatment is not easily accomplished. For example, one phenomenon not readily understood is why higher heat transfer coefficients have been consistently observed for salt water than for fresh water.

In summary, the available evidence indicates that the overall heat transfer coefficients chosen by ORNL for the two plants are realistic and do not favor one process over the other. However, the inherent differences between the tube configurations and the processes themselves, add a factor of uncertainty to this comparison. Substantial improvement in comparison of the VTE and MSF processes must await reliable long-term data from an operating double-fluted VTE unit.

Non-Equilibrium Allowances

The ORNL computer program employs a term called "alpha" which is a summation of chemical boiling point elevation, entrainment separator loss, and temperature loss from steam flowing across the condenser bundle. This figure is subtracted from the gross mean temperature difference (MTD) for each effect to determine the actual thermal driving force. The ORNL design was made prior to tests they performed on hook-and-vane type entrainment separators. These tests showed pressure drops through these devices to be substantially higher than ORNL initially believed. Consequently, it was necessary for Fluor to review the figures to see whether any design changes were indicated.

Chemical BPE data used by ORNL in these calculations are from the work of Stoughton and Lietzke at Oak Ridge. Fluor has no reason to question this data, and it is assumed to be reliable.

The ORNL tests and calculation procedure for pressure drop through the hook-and-vanes was reviewed and they are believed to be valid.

3.3 Study Procedure (Cont'd.)

ORNL employs their own computer program to calculate the pressure drop experienced by steam passing through the condenser bundle. This program was not readily available to Fluor. Furthermore, the ORNL vertical tube bundle design specifies a varying tube pitch within each individual tube bundle, but from the available ORNL information Fluor was able to deduce only the average tube density within an effect. Accordingly, it was necessary for Fluor to assume a tube pitch for each section of tubing within an effect, using standard pitches specified by ORNL. With these assumptions, the pressure drops were computed, using a technique that had previously been developed by Fluor.

The bundle loss used by ORNL in their calculations is the total loss experienced by the steam in flowing all the way through the bundle. This is obviously conservative, since only the last tube row is exposed to the full loss, and every other row sees steam at a higher pressure. For the triangular-shaped tube bundle employed here, the effective loss for each section is approximately 60% of its total loss.

Fluor examined five different effects, and found the following results:

	EFFECT				
	II	VIII	XI	XIII	XV
Average tube density, tubes/ft.^{2} (1)	14.6	13.4	12.3	11.1	9.35
S/D, 1st section (2)	1.15	1.3	1.3	1.3	1.45
S/D, 2nd section	--	1.15	1.15	1.15	1.30
% of tubes in 1st section	100	16.4	49.9	90.6	70.7
% of tubes in 2nd section	--	83.6	50.1	9.4	29.3
Total temperature loss, °F	0.47	1.03	1.29	1.00	1.72
Effective temperature loss, °F	0.28	0.52	0.40	0.48	0.47

(1) Determined from computer printout, allowing 28 feet of plant width for interior walls and baffles.

(2) S/D is pitch-to-diameter ratio.

Using the effective values for bundle loss instead of the total, a comparison of "alpha" values is made in the table below:

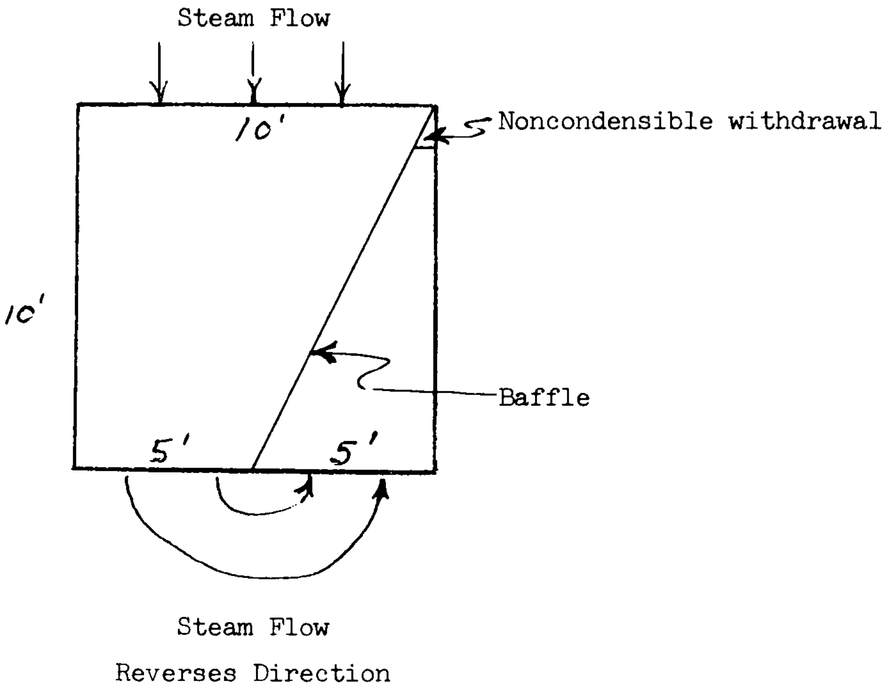
	EFFECT				
	II	VIII	XI	XIII	XV
BPE, °F	1.203	1.403	1.515	1.615	1.736
Hook-and-vane loss, °F	.009	.035	.065	.249	.878
Effective bundle loss, °F	.28	.52	.40	.48	.47
Total (Alpha)	1.492	1.958	1.980	2.344	3.084
"Alpha" used by ORNL	1.4958	2.3677	2.7476	3.0255	4.2511

3.3 Study Procedure (Cont'd.)

The ORNL values average significantly higher than those calculated by Fluor. Had the total temperature loss been used instead of the effective loss in the table above, the agreement between Fluor and ORNL would have been excellent. However, a portion of the difference would be required for the steam leaving the tubes of one effect to make three right angle turns before entering the next effect. Also, some loss is encountered in passing from the trapezoidal-shaped section of the bundle, reversing direction, then entering the triangular section. Even allowing several velocity heads for this, the numbers used by ORNL are concluded to be conservative. Consequently, no changes seem indicated in the ORNL design.

In calculating the bundle losses, it is apparent that ORNL used quite high values of Reynolds number for the steam flow. For example, using tube diameter as the significant length dimension, Fluor calculates for Effect II a Reynolds number of greater than 370,000 at the entrance to the tube field. This is higher than ordinarily used in MSF plants. No intrinsic reason appears why these high Reynolds numbers cannot be used. However, for a real plant design a suboptimization program is recommended to determine whether a wider tube spacing with reduced temperature loss might be more economical. It is interesting to note that Dr. A. Dukler of Houston University advocates the use of higher steam velocities with smooth tubes in order to increase film coefficients.

As advised by ORNL, the preferred tube layout can be represented by a number of 10-foot wide modules baffled as shown below:



3.3 Study Procedure (Cont'd.)

Evaporator Design

The MSF plant design calls for two separate brine levels. As far as is known, no plant of this type, either pilot or commercial, has ever been built. Consequently, this design, representing a departure from proven technology, was subject to review by Fluor. The incentive for using separate brine levels is evident--it permits the use of narrower and less costly evaporator structures by providing far more brine surface than could be obtained from a single level plant of equal width.

A satisfactory multilevel plant design must accomplish the following:

1. Brine from the brine heater must be divided so that each level receives its proper share of the total brine stream.

2. Brine tray design must be such that little or no brine splashes from the upper level to the lower level.

3. Upper trays must not unduly interfere with the flow of flashed vapor from the lower level to the tube bundles.

Because the final heat recovery stage is usually the limiting stage for the design, Fluor chose the design of stage 48 for review. The general arrangement of the brine trays is shown in Drawing M-8. The vertical velocity of steam passing between the two upper brine trays was found to be about 70 feet per second. To the best of Fluor's knowledge, this is considerably higher than is used in any commercial plant. Nevertheless, it is Fluor's opinion that if sufficient vertical distance or headroom is provided, deentrainment should be no worse than with a conventional design. Fluor believes that ORNL has provided sufficient height, but certainly a demonstration of this 2-level design would be required before a real plant could be built. At worst, it appears that several more feet of evaporator height would be needed to effect satisfactory deentrainment. This would, of course, result in an increase in shell cost, but the percentage increase would not be great and would have no more than a minor effect upon water cost.

Fluor believes that the brine tray design would be improved by extending the sides of the upper tray upward to join the sides of the product water tray above. This will prevent any splashing of brine from the upper tray to the lower tray, but will not interfere with the upward passage of steam.

Cross-troughs for equalizing liquid levels in the several brine trays were added by Fluor and included in this estimate.

3.0 - TECHNICAL SUMMARY - 250 MGD PLANTS

3.4 - CAPITAL COST SUMMARY

	VTE Plant	MSF Plant
Developed site cost:		
Land (for water plant)	$ 1,780,000	$ 2,600,000
Site development	8,358,100	9,488,000
Subtotal, developed site cost	$ 10,138,100	$ 12,088,000
Desalination plant cost (erected):		
Tube bundles	$ 37,977,000	$ 67,958,700*
Evaporator structure	19,943,000	32,710,700
Other plant equipment	23,812,500	22,299,400
Subtotal, desalination plant cost	$ 81,732,500	$122,968,800
Engineering design, procurement, inspection, etc.	$ 9,032,900	$ 10,553,500
Interest during construction	$ 5,989,800	$ 8,672,000
GRAND TOTAL ERECTED COST (1968 DOLLARS)	$106,893,300	$154,282,300

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*Includes cost of separate brine heaters.

3.0 - TECHNICAL SUMMARY - 250 MGD PLANTS

3.5 - PRODUCT WATER COST SUMMARY

	VTE Plant Assuming Vertical Tube Replacement in 15 Yrs.	VTE Plant Assuming No Tube Replacement	MSF Plant Assuming No Tube Replacement
Total Capital Cost - 1968 Dollars	106,893,300	106,893,300	154,282,300
1971 Dollars(1)	115,000,000	115,000,000	166,000,000
Annual Cost, Dollars			
Capital charges(2)- includes interest, amortization, interim replacement and insurance	7,550,000	7,000,000	10,120,000
Annual Charge to repay for water production lost during tube replacement in 1983	115,500	--	--
Utilities(3)			
Steam	6,511,000	6,511,000	6,121,000
Electricity	928,000	928,000	1,570,000
Materials and Supplies(3)			
Chemicals(4)	2,678,500	2,678,500	3,193,000
Misc. Maintenance Supplies	820,000	820,000	820,000
Labor, including overhead(3)			
Operation	300,000	300,000	285,000
Maintenance	242,800	242,800	219,300
Total Annual Cost, Dollars	19,145,800	18,480,300	22,328,300
Annual Net Water Production, Gallons	$81,950 \times 10^6$	$81,950 \times 10^6$	$82,025 \times 10^6$
Cents per 1000 gallons - 1968 dollars	23.4	22.6	27.2
Cents per 1000 gallons - 1972 dollars(5)	25.9	25.0	30.2

(1) 2.3% escalation/yr
(2) For fixed charges see Section 5.2
(3) For breakdown see Section 7.2
(4) Includes continuous chlorination of seawater
(5) 2.4% escalation/yr

4.0 - DEVELOPMENT POTENTIALS - 250 MGD PLANTS

Use of Enhanced Tubes

In one respect, the comparison between the two processes is not on an equal footing. The VTE plant uses enhanced double-fluted tubes for two-thirds of the heat transfer surface, whereas the MSF plant employs all smooth tubes. Using 1968 technology, this is quite proper, since enhanced or extended surface heat transfer has been successfully demonstrated in the VTE process but not in the MSF. Because of inherent differences in the process, the double-fluted tube cannot be used in the MSF process. However, if some other type of enhanced tubes can be employed to advantage in the MSF process in the near future, it would improve the economics of the MSF process and perhaps influence the conclusions reached in the course of this study.

In this connection, Fluor has consulted with tube manufacturers regarding enhanced surface tubes suitable for horizontal orientation. These are being actively developed and show promise of substantial improvement in performance. The University of Michigan, in a recent publication[1], reported on the results of an extensive test program which compared the performance of smooth tubes with a proprietary design of spirally-corrugated tubes[2] for use in seawater distillation and other heat transfer operations. ORNL also is known to be working on applying corrugated tubing to the MSF process.

The Michigan report includes data on inside and outside film coefficients and pressure drop for both plain and corrugated tubes. Based upon information presented in this report, Fluor has developed a design for a corrugated-tube MSF plant. Estimates of tube cost were furnished by the manufacturer.

The basis chosen for comparison was to design the corrugated-tube plant for a tubeside pressure drop approximately the same as in the smooth tube design, and to use the same fouling factor. This results in a lower superficial tubeside brine velocity; however, because of the corrugations, the turbulence and resulting resistance to deposition of dirt is probably no worse than for a smooth tube. Heat and material balance for the corrugated tube plant were taken as identical to the smooth tube design.

This comparison must be considered only approximate, since the design of the corrugated tube plant was prepared by designing Stage 25, comparing the stage lengths required, and factoring the stage lengths for all other stages. The salient design features of the corrugated-tube plant are as follows:

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[1] E. H. Young, P. J. McParland, G. T. S. Chen, D. H. Young, "The Condensing of Steam on Horizontal Corrugated and Bare Tubes," University of Michigan, Ann Arbor, Michigan, Report No. 60, September, 1968.

[2] The Michigan tests were sponsored by Wolverine Tube Company, who developed this tube configuration and own the applicable patents - U.S. Patents 3,217,799 and 3,128,821.

	Corrugated-Tube Plant	Smooth-Tube Plant
Tube material	90-10 Cu-Ni	90-10 Cu-Ni
Outside diameter	0.937" (1" nominal)	0.75"
Wall thickness	0.038"*	0.035"
Total tube length, recovery stages	327 feet	480 feet
Total tubes for 250 MGD, recovery stages	220,000	247,960
Differential head on recycle pump	207 feet	189 feet
Incremental KW for 250 MGD plant	4920	Base
Tubeside brine velocity (stage 25)	3.08 ft/sec	4.37 ft/sec

*Tube is formed from 1" OD. .035" wall smooth tube.

Using an estimated tube cost provided by the manufacturer, and the comparative stage lengths calculated above as a basis, Fluor estimates the following savings would accrue if corrugated tubes were used throughout the MSF plant:

Evaporator shell	$ 6,400,000
Heat transfer tubing	8,200,000
Land and excavation	500,000
	$15,100,000
Interest during construction	900,000
Total Estimated Savings	$16,000,000

These figures include indirect costs, and assume that corrugated tubes are used in the brine heater as well as in heat recovery and heat rejection stages. This savings reduces the total estimated cost of a corrugated-tube MSF plant to approximately $137 million, as compared to $153 million for the smooth-tube plant.

Of course, the corrugated-tube concept, if it is advantageous for the MSF plant, could be applied to the MSF section of the VTE plant as well. However, since the preheater surface in the ORNL design is only about a third of the total surface, the cost improvement would be relatively less. Furthermore, because of geometric considerations it might prove difficult to adapt the ORNL evaporator configuration chosen for this design to an all-enhanced arrangement. If the MSF stages were shortened and the total length of the plant reduced in accordance, the plant would have to be widened in order to provide sufficient plan area for the VTE tubes. If the stage lengths were kept the same and fewer preheater tubes used, velocity would be increased and pressure drop through the preheater section would be more than tripled. Of course, some basic changes in the evaporator configuration might be made to accommodate the use of corrugated-tubes in the preheater section, but consideration of such extensive changes is beyond the scope of this study.

This analysis shows the corrugated-tube design to good advantage. However, it must be recognized that the comparison is only approximate, and this tube has never been demonstrated. Further, the comparative pricing by the manufacturer, although presumably made in good faith, must be considered somewhat speculative at this time, as this tube is not in commercial production. Nevertheless, the tube appears to hold promise for flash evaporation plants and further investigation seems warranted.

5.0 - BASES FOR COST ESTIMATES - 250 MGD PLANTS

5.1 Bases for Capital Cost Estimate - 250 MGD Plants

General Comments

The basic purpose of the estimates of the VTE and MSF 250 MGD plants is to compare the capital costs and the water costs for these two types of plants. The MSF design was more complete and therefore the MSF estimate is considered to be somewhat more accurate. However, both estimates were based on conceptual designs, and are subject to the limitations on accuracy implicit in such designs. In the following paragraphs specific portions of the capital cost estimate are discussed, with comments, where appropriate, on the assumptions and method of approach to each.

Scope

The capital cost estimate for the 250 MGD desalination plant includes only the water plant and associated requirements. Although it is assumed the water plant is built in conjunction with a nuclear reactor and electric power generating plant, these are excluded from consideration in this study.

Source for Process and Conceptual Designs

For the 250 MGD Vertical Tube Evaporator plant, the Oak Ridge National Laboratory Report 4260, dated August, 1968.

For the 250 MGD Multistage Flash Evaporator plant, the Oak Ridge National Laboratory Report 4214 - 1967 Technology.

Site Preparation

The large plants are assumed to be located on a Southern California coastal site, with a 200-ft. wide beach rising to an elevation of 35 ft. at the base of the coastal cliffs. At the cliff the terrain is assumed to rise 50 ft. to a level plateau at 85-ft. elevation, which extends inland beyond the site limits. The prepared site is to be at elevation 35 ft. An allowable soil bearing pressure of 4000 psf is assumed.

The major expense in site preparation is excavation and grading. For the VTE plant, more than 1 million cubic yards must be removed; for the MSF plant, because of its greater length, the figure is nearly 2 million cubic yards. It was assumed that this excavated material could be used either in other portions of this facility or on some location adjacent to the plant site. Some of the cut material could be used to build a temporary sea wall while the intake and outflow lines were being installed at the ocean breaker line.

Since there will be excavation for both plants which will be below sea level, sheet piling may have to be installed. Such areas include the pump pits and sumps, underground pipe lines and electrical ducts, and the intake structures. Dewatering points will be driven inside the piping and the water level pumped to below the work area.

Structures

Concrete is priced on the basis that a batch plant will be set up at the jobsite, justified by the large amount of concrete required. Concrete unit costs will average $147.00 a cubic yard for the MSF and $114.00 a cubic yard for the VTE plant. The cause of the higher unit concrete costs for the MSF plant is that more reinforcing steel is required for adequate strength, and the construction of forms will be more difficult (for example, the product and brine trays). In contrast, the concrete pours are more massive for the VTE plant, providing lower costs per yard of concrete. In both plants, where concrete is lined by steel, it was assumed the steel shell would be put into place and braced to serve as forms for the concrete.

The cost allowed for evaporator lining material is on the basis of using polypropylene, which was specified in the reference design. This material may not be suitable for the plant operating temperatures, but it is assumed that a suitable material at no greater cost will be available before the plant is built.

The structural steel calculations are straightforward, with the exception of the roof structures. It appears that the connection for the roof structure could be simplified for less cost. Investigation into a bolted roof section is suggested.

Buildings

The only building directly considered in Fluor's estimates is a switchgear building in the MSF case. This is for use of indoor type electrical equipment which in the voltages required is less costly than outdoor type. In this account Fluor has also included 1/3 of the cost for the buildings required for the entire complex, prorated to the water plant.

Piping

The piping estimate includes the lines from the seawater feed pumps, as well as the steel piping carrying flows to and from the pumps and evaporator structure. Also included is the cost of expansion joints associated with piping entering and leaving the structure.

Heat Exchanger Tubes and Tube Bundles

Both the horizontal and the vertical tubes for which estimates were secured were unusual items. The horizontal tubes were quoted as long tubes, extruded and coiled at the factory and shipped to the field in coil form. They would be straightened and inserted in the tube sheets in one operation at the site. The 3-inch vertical tubes were specified as being made of CDA alloy 194, with double-fluting to promote heat transfer.

The copper-iron-phosphorous alloy CDA 194 is presently manufactured only by Olin Brass, a division of the Olin Mathison Chemical Corporation. Fluor has therefore relied solely on Olin for the prices of the 3-inch tubes. The fluting configuration was developed by General Electric; they have provided a quotation for fluting the tubes at the jobsite. Specifications of the smooth-walled tube priced for this study call for a minimum wall thickness of 0.065 inches (that is, the negative tolerance is zero). After the fluting operation, the developed wall thickness of the fluted tube will be 0.047 inches plus the positive tolerance of the original smooth tube. The fluting price allows for leaving the tube ends unfluted to facilitate rolling them into the tube sheets. Other vendors were contacted for the fluting operation, but none quoted prices lower than those from General Electric.

The preparation of the tube sheets accounts for a considerable portion of the VTE bundle expense. The estimate is based on 1-1/2" carbon steel A-285-C flange grade, with a bottom sheet having a 1/8" 90-10 copper-nickel cladding on the brine side.

Nine fabricators were contacted regarding the drilling of the tube sheets. None were found who felt they could drill 3-inch holes in a variable-pitch tube sheet with multiple spindles, using existing equipment. Most of the vendors felt they would do the work with several independent spindles working on one tube sheet, drilling and/or trepanning, with possibly some final boring and grooving. With nearly 1-1/4 million 3-inch holes to drill, there appears to be no basic reason why a multiple-spindle machine could not be designed to accomplish the purpose, especially if the tube pitch were held constant on any one tube sheet. For an optimized plant, an economic trade-off calculation should be performed, balancing the added cost of variable-pitch tube sheet drilling against the anticipated improvement in evaporator efficiency. Other hole-forming techniques were investigated, including casting and flame cutting plus reaming, but drilling or trepanning remains the method of choice.

The vertical tube bundle cost estimate is based on rolling the tubes into the tube sheets, rather than welding. The cost for hydrotesting is included. It is Fluor's opinion that the estimated cost for the VTE tube bundles is realistic, based on current technology, and that with more advanced drilling methods the cost of the tube bundles could be reduced.

Pumps

There was considerable variation in estimated costs of the very large pumps from the manufacturers contacted. The figures used in the cost estimate are average values.

5.1 Bases for Capital Cost Estimate - 250 MGD Plants (Cont'd.)

Instrumentation

The cost estimate for instrumentation is based on the contractor performing all field engineering work, including calibration, loop and function checks, the setting of pressure switches, alarms, shut-downs, and stroking and adjusting of solenoids and final control elements. It also includes an Instrument Engineer for consultation during start-up.

Common Facilities

The following facilities common to both the nuclear power plant and the water plant are included in the water plant costs at the percentage shown:

a. Access railroad - portion shown on plot plan

b. Site preparation - portion shown on plot plan

c. Plant roads, parking & fencing - portion shown on plot plan

d. Compressed air system - 33%

e. Utility water system - 33%

f. Control Bldg., Administration Bldg. and Warehouse - 33%

g. Sanitary sewer system - 33%

h. Building fire protection system - 33%

Owner's Costs

The following owner's costs are included in the plant capital costs:

a. Cost of land occupied by Water Plant - assumed at $100,000 per acre.

b. A&E costs, owner organizational costs, permits, etc.

c. Bond financing costs

d. Interest during construction

e. Start-up costs - labor, chemicals, etc.

Contingency

The allowance for contingency includes an additional risk-factor cost allowance for a first-of-a-kind facility.

Product Water Treatment

The product water is assumed to be delivered at the plant boundary under a pressure of 25 psi. No capital costs are included in this estimate for product water treatment or storage.

5.1 Bases for Capital Cost Estimate- 250 MGD Plants (Cont'd.)

Price Level

Labor and equipment pricing is based on 3rd quarter 1968 prices, then escalated to 1971 level based on a 3-year engineering-construction schedule.. Annual escalation from 1968 to 1971 is assumed to be the same as the average annual escalation 1958 to 1968 in Southern California. Escalation is estimated to have averaged 4.2% annually for labor and 2.1% for material. It should be noted that escalation rates during the last five years are much higher than the ten-year average.

Labor Availability

Except for some shift work and overtime by concrete workers and riggers, this estimate assumes a 40-hour work week. Travel and subsistence to the site are included.

Equipment Pricing

Only U. S. manufacturers were contacted for equipment prices.

Spare Parts

An allowance for spare parts is not included except that in order to obtain the same reliability for the VTE plant as assumed for the MSF plant, warehouse spare pumps are included for the effect brine transfer in the VTE costs.

Taxes

It is assumed the owner will be tax exempt and, therefore, the California State Sales Tax of 5% on materials is not included.

Form of Estimate

The breakdown is presented in essentially the form and detail shown in Appendix F of the 1965 Saline Water Conversion Report.

5.2 Bases for Product Water Cost - 250 MGD Plants

Escalation

It is assumed that the plant could be operational in early 1972 if started in early 1969. Product water costs are estimated on the basis of the purchasing power of 1968 dollars, and operational costs then escalated to 1972, using the average annual escalation experienced from 1958 to 1968. Escalation is estimated at 4.2% annually for labor and 2.1% for material. It should be noted that escalation rates of the last five years have been much higher than for the ten-year period.

Cost of Money

Municipal bond financing is assumed. Bond interest rate is taken as 4.25%.

Cost of Bond Financing and Interest During Construction

Underwriters and bond counsel fees and interest during construction are included in the capital costs.

Repayment Period

Investment costs are amortized over a 30-year period corresponding to the estimated life of the desalination plants. The annual amortization factor of 1.71% is based on a sinking fund repayment method over a 30-year period at 4.25% interest.

Interim Replacement

Both the VTE and the MSF plants are expected to have a useful life of 30 years; however, a 0.35% factor is included for replacement of portions of the plants (other than tubes) not expected to last the full 30 years.

Basis for VTE Tube Replacement Estimate

Copper-nickel tubes in both plants are assumed to last the life of the plant; however, the copper-iron vertical tubes of the VTE plant are assumed to require complete replacement after 15 years of service. To provide for this replacement, water costs of the VTE plant have been calculated on two different bases - first, assuming a 15-year life, and, second, assuming a 30-year life. To provide for replacement of the vertical tubes in 15 years, a replacement factor of 0.51% is included in the fixed charges in addition to the interim replacement factor of 0.35% for other portions of the plant. An annual fixed charge of 0.51% of the plant capital costs, when deposited at 4.25% interest, is estimated to provide sufficient funds at the end of 15 years to replace 65% of the tube bundles. Funds to replace the balance of the tube bundles, if borrowed at 4.25% interest, are repaid over the following 15 years by the annual fixed charge of 0.51% of plant capital cost.

5.2 Bases for Product Water Cost- 250 MGD Plants (Cont'd.)

The cost for replacing the VTE tube bundles after the 15th year has been estimated on a 1968 (3rd quarter) material and labor basis. The assumption is made that the four trains will require only one additional set of tube sheets, and that the removed tube sheets can be reused. By purchasing one additional set of tube sheets, the replacement tube bundles can be prepared prior to plant shutdown in order to minimize shutdown time. Once the tube replacement in the first train is complete, the tube sheets for that train will be cleaned and reused for the tube bundles for the subsequent train. No consideration has been given for the scrap material for the first set of tube sheets. It is assumed that 75% of the tube scrap will be recovered and sold at current scrap copper prices.

The tube bundle replacement procedure is expected to be carried out as follows. It is assumed that the roof can be removed in 40-foot sections and lifted to the edge of the building with a gantry crane designed for this purpose. It is further assumed that no lifting lugs are required for either the roofing section or the tube bundles. A crawler crane at the edge of the building will pick up the roofing section and load it on a waiting truck for transport to a temporary storage area. It is assumed that this can be done without seriously damaging either the roof liner or the outer insulation material. After the roof has been removed, the same gantry will be used to remove the tube bundles for transport to an adjacent work area.

The new tube bundles are now lifted into place, and the tube sheet seal welds and expansion joints completed. Sealing material is poured onto the top tube sheet, and new ceramic caps are placed over the tubes and embedded into the sealant-coated tube sheets. The roof is then replaced and the liner and insulation is repaired where necessary.

The cost estimate for the replacement is based on accomplishing this work on a 3-shift-per-day basis. Cost for purchasing, inspection, expediting, scheduling and overall project coordination is included in the replacement cost estimate.

5.2 Bases for Product Water Cost- 250 MGD Plants (Cont'd.)

Fixed Charges on New Plant Costs

The total annual fixed charge is based on the following percentages of capital investment:

		VTE Plant 15-yr life on vertical tubes	VTE & MSF Plants 30-yr life on all tubes
a.	Cost of money	4.25%	4.25%
b.	Bond amortization factor (30-year basis)	1.71%	1.71%
c.	Plant replacement factor	None	None
d.	Plant interim replacement factor	.35%	.35%
e.	Tube interim replacement factor	.51%	None
f.	Property damage insurance	.25%	.25%
g.	Taxes	None	None
		7.07%	6.56%

Energy Costs

Energy costs from the nuclear electric power plant were estimated by ORNL:

		VTE Plant	MSF Plant
Prime steam			
342 F saturated, 121 psia	¢/10^6 Btu	16.1	16.1
Exhaust steam			
270 F saturated	¢/10^6 Btu	12.0	-
260 F saturated	¢/10^6 Btu	-	11.2
Electric power	¢/Kwhr	0.327	0.327

Chemical Costs (delivered to site)	Price, 100% Basis		
Sulfuric acid (93%)	$/ton	24.00	23.00
Caustic soda	$/ton	73.00	71.00
Chlorine	$/ton	72.00	70.00
Anti-foam solution	$/lb	.40	.40
Sodium Sulphite	$/ton	100.00	100.00
Ferrous sulphate	$/ton	60.00	60.00

Maintenance Materials and Supplies

The annual cost of plant maintenance materials and supplies is estimated at 0.6% of direct capital.

5.2 Bases for Product Water Cost - 250 MGD Plants (Cont'd.)

Insurance

The annual insurance premium on the desalination plant is estimated to be 0.25% of capital cost.

Taxes

It is assumed that the owner will be a tax-exempt municipal or governmental agency, and that no city, county, state or federal tax or tax equivalent payments are applicable.

Load Factor

It is assumed the plants will be operating at full design load (250 MGD) all of the time that they are on stream.

On-stream Factor

For a dual purpose (power and water) plant, it is assumed that the desalination plant will be available or on-stream 90% of the time. It is assumed to be shut down for maintenance, repairs, power plant outages, etc., the remaining 10% of the time.

In calculating VTE plant water costs, when a 15-year life is assumed for the vertical tubes, an additional penalty is incurred through loss of production revenue during the replacement period. This is estimated to be 2 months for each train. Loss of revenue is assumed to be the same as the water production cost. For convenience in calculating water costs the revenue which is lost in 1983 is converted to an equivalent 30-year annual cost.

Average Production Rate

Since the maximum daily gross capacity of each plant is 250 MGD, the yearly average capacity is 225 MGD (90% of 250). The net capacity is the gross capacity less plant useage for bearing cooling, glands, flushing, etc.

Product Water Pumping Requirements

Product water is delivered to the plant boundary at 25 psig and 90 F. No other pumping, passivation, or handling charges are included since conveyance pipeline and storage facilities are not considered plant costs.

5.2 Bases for Product Water Cost - 250 MGD Plants (Cont'd.)

Operation and Maintenance Labor

Operation and maintenance labor costs are based on a single staff and a single control room for both power and water plants. Personnel and estimated cost are shown in Section 7.2.

Owner's Administration and General Costs

These costs are estimated at 30% of operation and maintenance labor costs. The 30% includes payroll burdens of 20% (vacations, sick leave, State Disability Insurance, Unemployment Compensation Disability Benefits, and Federal Insurance Compensation Act.

Interest on Working Capital

Interest on working capital is included in the Administration and General portion of operating costs, and is calculated at $4\frac{1}{4}\%$.

The location assumed for the 250 MGD desalination plants included in this study is at an unspecified location along the Southern California coast. The typical terrain in this area rises gradually from the water's edge to an elevation of 35 feet at the base of the coastal cliff, 200 feet inland. The cliff is 50 feet high, and the terrain is assumed to extend inland from the edge of the cliff at an elevation of approximately 85 feet above MLLW.

Transportation facilities are conveniently available to the site. U. S. Highway 101 and the Santa Fe railroad both parallel the coastline in this general area, and overland access to the site presents no problems. No dock or harbor facilities are presently available in this area to accommodate water transport. However, barging of large items could be accomplished at the expense of building barge-unloading facilities.

For the 250 MGD plants, the seawater pumps and screens will be located at approximately the original waterline, and the cold end of the evaporator structure itself will be 250 to 300 feet inland from the pumps. The original overburden will be excavated down to meet the design grade of approximately 35 feet above mean sea level, on which the distillation plant will be constructed. The typical sedimentary deposits in this area are readily excavated, yet provide good bearing capability.

With respect to the large (250 MGD) plants, this study is limited to consideration of the facilities required for the water plant, and excludes the nuclear power plant. The water plant facilities are shown on the plot plans (Drawings V-1 for the VTE plant and M-1 for the MSF plant). The MSF plant will require a plot area approximately 1,000 feet wide and 1,100 feet deep, measured from the water's edge. The VTE plant, being somewhat more compact, requires approximately the same 1,000 foot width but a depth of only 725 feet.

7.0 - TABLES - 250 MGD PLANTS

7.1 Capital Cost Breakdown

		VTE Plant Enhanced Tubes	MSF Plant Smooth Tubes
I.	Land (For water plant only)	$1,780,000	$2,600,000
II.	Site Development and Offsites		
	1. Site excavation, roads, grading, parking, etc.	527,000	891,600
	2. Buildings (prorated)	156,800	165,000
	3. Submarine pipelines	5,416,800	6,206,700
	4. Seawater pump structure	1,569,100	1,532,400
	5. Screens and miscellaneous equipt. for intake (seawater pumps below)	604,300	593,300
	6. Utilities (service water, service air, sewers, etc.)	84,100	99,000
	Subtotal - Section II	$ 8,358,100	$ 9,488,000
III.	Conversion Plant (Erected on site):		
	1. Evaporators		
	a. Bundles	37,977,000	63,487,700
	b. Structure (incl. shell)	19,943,000	32,710,700
	2. Brine heaters (For VTE, incl. in Evaporator cost)	---	4,471,000
	3. Noncondensables removal equipment		
	a. Condensers	111,400	97,000
	b. Ejectors	192,300	277,500
	c. Sump pumps	81,800	80,400
	d. Miscellaneous equipment	---	47,700
	4. Pumps and drivers		
	a. Seawater intake	1,040,000	1,105,000
	b. Booster	253,500	---
	c. Brine recycle	---	4,121,900
	d. Make-up brine	1,172,600	---
	e. Deaerator feed	---	546,300
	f. Blowdown	235,300	339,000
	g. Effect	3,960,600	---
	h. Product water	580,200	580,200
	i. Miscellaneous	25,700	25,200
	5. Make-up Pretreatment Systems		
	a. Chemical feed system (incl. pumps and tanks)	773,300	783,800
	b. Deaerator internals	1,330,500	1,618,400
	6. Excavation, foundations and concrete (excl. structure)	210,200	290,700
	7 Piping and pipe supports		
	a. Seawater and brine	3,016,000	2,842,400
	b. Product water	354,000	213,900
	c. Steam and condensate	354,300	669,500
	d. Noncondensables	698,500	1,145,700
	8. Electrical installation (incl. controllers and switchgear)	3,601,900	2,995,300
	9. Instrumentation		
	a. Instruments and controls	2,559,300	1,677,200
	b. Control panel	85,800	64,300
	c. Instrument air system (incl. compress., receiv., driers)	173,600	88,000
	10. Insulation	2,672,000	2,247,300
	11. Painting	329,700	442,700
	Subtotal - Section III	$81,732,500	$122,968,800
IV.	Engineering, Design, Procurement, Construction Management and Inspection, Owner Organization Costs and Owner Startup Costs	$ 9,032,900	$ 10,553,500
V.	Interest During Construction	$ 5,989,800	$ 8,672,000
	GRAND TOTAL - 1968 DOLLARS	$106,893,300	$154,282,300

7.2 Water Cost Breakdown - 250 MGD Plants

1968 Production Costs

		VTE Plant	MSF Plant
Daily Production	MGD	250	250
On Stream Factor	%	90	90
Gross Production	MGY	82,200	82,200
Prod. Water Usage in Plant	MGY	250	175
Net Production	MGY	81,950	82,025
Steam - Saturated			
Heating Steam	lbs/hr x 10^6	7.165	7.124
	Btu/hr x 10^6	6690	6715
	¢/Btu x 10^6	12.0	11.2
	$/hr	803	752
	$/day	19,270	18,050
	$/yr	$6,330,000	$5,940,000
Ejector Steam	lbs/hr x 10^6	0.12	0.12
	Btu/hr x 10^6	143	143
	¢/Btu x 10^6	16.1	16.1
	$/hr	23	23
	$/day	552	552
	$/yr	$ 181,000	$ 181,000
Subtotal - Steam	$/yr	$6,511,000	$6,121,000
	¢/1000 gals	7.96	7.46
Power	kw	36,000	61,000
	¢/kwh	0.327	0.327
	$/hr	118	199
	$/day	2,820	4,790
Subtotal - Power	$/yr	$ 928,000	$1,570,000
	¢/1000 gals	1.13	1.92
Subtotal - Energy	$/yr	$7,439,000	$7,691,000
	¢/1000 gals	9.09	9.38

7.2 Water Cost Breakdown - 250 MGD Plants (Cont'd.)

1968 Production Costs

		VTE Plant	MSF Plant
Chemicals			
Acid - 66° Be (93%)	tons/day	225	270
	$/ton	24	23
	$/day	5,400	6,200
	$/yr	$1,780,000	$2,040,000
Caustic - Dry Basis	tons/day	8	10
	$/ton	73	71
	$/day	584	710
	$/yr	$192,000	$233,000
Chlorine	tons/day	16	22
	$/ton	72	70
	$/day	1150	1540
	$/yr	$378,000	$506,000
Miscellaneous Chemicals Anti-foam Sodium sulfite Ferrous sulfate	$/day	1000	1260
	$/yr	$ 328,500	$ 414,000
Subtotal - Chemicals	$/yr	$2,678,500	$3,193,000
	¢/1000 gals	3.27	3.89
Miscellaneous Maintenance Materials			
Charts, Rags, Gaskets, Lube Oil, Paint, Fittings & other supplies	$/day	2500	2500
Subtotal - Misc. Material	$/yr	$ 820,000	$ 820,000
	¢/1000 gals	1.00	1.00
Operating & Maintenance Labor			
Operation	$/yr	187,750	178,250
Maintenance	$/yr	158,250	138,250
Supervision	$/yr	71,800	71,800
Subtotal - O&M Labor	$/yr	417,800	388,300
Administration & General	30%	125,000	116,000
Subtotal - O & M	$/yr	$ 542,800	$ 504,300
	¢/1000 gals	.66	.61
Grand Total, Water Production Costs[1]	$/yr	$11,480,300	$12,208,300
	¢/1000 gals	14.0	14.9

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[1] Excluding fixed charges on capital cost

7.0 - TABLES - 250 MGD PLANTS

7.3.1 ANNUAL OPERATING AND MAINTENANCE LABOR COST ESTIMATE FOR 250 MGD VTE PLANT(1)

	1968 Annual Rate So. Calif.	Personnel Req'd for Pwr. & Water Plant	Personnel Chargeable to Water Plant	Annual Cost Water Plant
Plant Management				
Station Supervisor	$20,000	1	1/2	$10,000
Chief Engineer	15,000	1	1/2	7,500
Secretary-Typist	6,600	1	1/2	3,300
Clerk	6,000	1	1/2	3,000
Guard	7,000	5	2-1/2	17,500
Sub-total		9	4-1/2	41,300
Technical Staff				
Nuclear Engineer	15,000	1	None	
Water Plant Engineer	15,000	1	1	15,000
Health Physics Supervisor	11,000	1	None	
Chemist	9,000	1	1/2	4,500
Laboratory Technician	8,000	2	1	8,000
Clerk	6,000	1	1/2	3,000
Sub-total		7	3	30,500
Operating Staff				
Shift Supervisor	12,500	5	2-1/2	31,250
Water Plant Operator	10,000	9	9	90,000
Power Plant Operator	10,000	9	None	
Auxiliary Operator	9,500	5	2-1/2	23,750
Instrument & Monitoring Technician	9,500	9	4-1/2	42,750
Sub-total		37	18-1/2	187,750
Maintenance Staff				
Maintenance Supervisor	12,500	2	1	12,500
Mechanic-Machinist	10,000	7	3-1/2	35,000
Pipefitter-Welder	10,000	5	2-1/2	25,000
Electrical Mechanic	10,000	5	2-1/2	25,000
Instrument Mechanic	10,000	5	2-1/2	25,000
Helper	8,500	3	1-1/2	12,750
Storekeeper	9,000	2	1	9,000
Laborer	8,000	2	1	8,000
Janitor	6,000	2	1	6,000
Sub-total		33	16-1/2	158,250
Total Direct Labor		86	42-1/2	417,800

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(1) When operated in conjunction with a 2500 Mwt Nuclear Power Plant

7.3.2 ANNUAL OPERATING AND MAINTENANCE LABOR COST ESTIMATE
FOR
250 MGD MSF PLANT(1)

	1968 Annual Rate So. Calif.	Personnel Req'd for Pwr. & Water Plant	Personnel Chargeable to Water Plant	Annual Cost Water Plant
Plant Management				
Station Supervisor	$20,000	1	1/2	$10,000
Chief Engineer	15,000	1	1/2	7,500
Secretary-Typist	6,600	1	1/2	3,300
Clerk	6,000	1	1/2	3,000
Guard	7,000	5	2-1/2	17,500
Sub-total		9	4-1/2	41,300
Technical Staff				
Nuclear Engineer	15,000	1	None	
Water Plant Engineer	15,000	1	1	15,000
Health Physics Supervisor	11,000	1	None	
Chemist	9,000	1	1/2	4,500
Laboratory Technician	8,000	2	1	8,000
Clerk	6,000	1	1/2	3,000
Sub-total		7	3	30,500
Operating Staff				
Shift Supervisor	12,500	5	2-1/2	31,250
Water Plant Operator	10,000	9	9	90,000
Power Plant Operator	10,000	9	None	
Auxiliary Operator	9,500	5	2-1/2	23,750
Instrument & Monitoring Technician	9,500	7	3-1/2	33,250
Sub-total		35	17-1/2	178,250
Maintenance Staff				
Maintenance Supervisor	12,500	2	1	12,500
Mechanic-Machinist	10,000	5	2-1/2	25,000
Pipefitter-Welder	10,000	6	3	30,000
Electrical Mechanic	10,000	4	2	20,000
Instrument Mechanic	10,000	3	1-1/2	15,000
Helper	8,500	3	1-1/2	12,750
Storekeeper	9,000	2	1	9,000
Laborer	8,000	2	1	8,000
Janitor	6,000	2	1	6,000
Sub-total		29	14-1/2	138,250
Total Direct Labor		80	39-1/2	388,300

(1) When operated in conjunction with a 2500 Mwt Nuclear Power Plant

8.0 - 250 MGD CONCEPTUAL DESIGN - VTE AND MSF PLANTS

8.1 Evaporator Structure

Applicable Codes and Standards

Uniform Building Code

ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318-63)

AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings

ASME - Used for stability of arched steel roof only

Note: Since the conditions inherent in the vessel design which require lower stresses do not exist in this structure, the full stresses recommended for a given material in the above codes have been used.

Materials

Design is based on use of the following materials:

a. Structural steel, including liner plate and arched roof

Carbon steel, ASTM Grade A-36

b. Reinforcement steel

ASTM A-15, intermediate grade

c. Concrete

Compressive strength (F'_c) of 4000 psi

With limestone aggregates and calcareous sands and gravel to improve heat resistance of concrete.

With cements low in tricalcium aluminate content, such as Type V Portland cement, or Type II Portland cement as second choice. This will reduce concrete damage from sulfates present in the brine.

With pozzolan addition and mixed with a low water-cement ratio. Concrete should be dense and well-cured to resist water permeation.

With all reinforcement covered with a minimum of 2 inches of concrete; 3 inches is recommended.

Reinforced Concrete Design Comments

There has been evidence reported from Bureau of Reclamation tests[1] that reinforced concrete specimens showed only limited amounts of deterioration when submerged in hot flowing synthetic brine. Nevertheless, Fluor still has reservations about the use of reinforced concrete as a highly-stressed construction material under actual desalination plant operating conditions.

In a plant such as the 250 MGD VTE plant, reinforced concrete is simultaneously exposed to elevated temperatures, varying mechanical stresses, differential fluid pressures across the member, and an environment of hot flowing seawater. In the Bureau of Reclamation tests the specimens were exposed to elevated temperatures, no mechanical stresses, no differential fluid pressures across the specimen, and an environment of hot flowing synthetic brine. In addition, the test specimens were cast under controlled laboratory conditions, whereas the actual plant members would be subject to the less rigorous quality control of field construction. There are enough differences between these two sets of conditions to raise doubts as to the applicability of the reported findings.

It has been reported by some writers that concrete performs a corrosion-inhibiting function which acts to prevent the corrosion of its reinforcing steel. In the Bureau of Reclamation tests[1] it is reported what several reinforced concrete specimens were deliberately cracked before being exposed to brine corrosion tests. The presumption is that these cracks allowed the brine to penetrate to the reinforcing steel, with the objective of observing their corrosion rates, and comparing them with those of uncracked specimens. As far as can be determined, however, the results of the corrosion tests of cracked specimens have not been reported.

Aside from the problem of possible corrosion of reinforcing steel, there is also the question of the ability of the concrete itself to withstand the hot brine environment. After conducting tests at various temperatures, the Bureau of Reclamation reported:

a. After 18 months at 290 F in recirculating brine, concrete specimens exhibited deterioration to a depth of approximately 1/4 inch.

b. After 6 months at 203 F, 225 F, and 250 F, in recirculating brine, specimens exhibited a degree of surface change. Because of the short test period, the Bureau said it was not possible to predict the useful life of concrete under these test conditions.

In view of the uncertainties with respect to the resistance of reinforced concrete structures to a hot seawater environment, Fluor feels that further testing will be required before building a plant of this size designed for a 30-year life.

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[1] Evaluation of Concrete and Related Materials for Desalination Plants, General Report No. 37A, U. S. Department of Interior, Bureau of Reclamation, June, 1968

8.1 Evaporator Structure (Cont'd.)

Soil - Assumed Conditions

Allowable bearing pressure	4000 psf
Allowable passive (lateral) resistance	200 psf/ft depth.
Coefficient of friction	0.4

Loadings

Roof (live load)	20 psf
Wind	15 psf
Earthquake (no allowable stress increase used)	0.2 g
Pressures	See Figs. 8.1.1 and 8.1.2
Temperature expansion coefficient for both steel and concrete	0.65×10^{-5}

Loading Combinations - Both Plants

$D + L$

$D + L + E$

$D + L + T$

$D + L + P_o + E$

$D + L + P_o + E + T$

$D + P_{f.v.} + T$

D - dead load

L - live load

E - earthquake

T - temperature

P_o - design operating pressure

$P_{f.v.}$ - full vacuum

VTE Design Pressure

Determination of design pressures to be used for the VTE structure proved to be a complex problem. For this study, the structure was designed using the design criteria shown in Figure 8.1.1. The internal walls were designed for the normal differential in operating pressure plus a 50% safety factor.

It is recognized, however, that under certain upset conditions this might not be sufficient. Several means to provide complete structural safety which were considered are as follows:

a. Design the internal walls to resist the maximum differential pressure that would exist during any credible incident. To establish these conditions would require a careful and detailed study of the process dynamics for quite a complicated system (VTE plus MSF) for many different operating situations, including failure of any one or combination of items of mechanical or electrical equipment, instrumentation, power, or steam. Costs to strengthen the walls in the higher temperature effects for such contingencies would be substantial because of the large pressure differentials.

⚠2 REDRAWN 10/7/68

CALCULATIONS and SKETCHES
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SHEET NO. FIG. 8.1.1
DATE 10·7·68
BY M.Shut CHK'D ILM
JOB NO. 4334

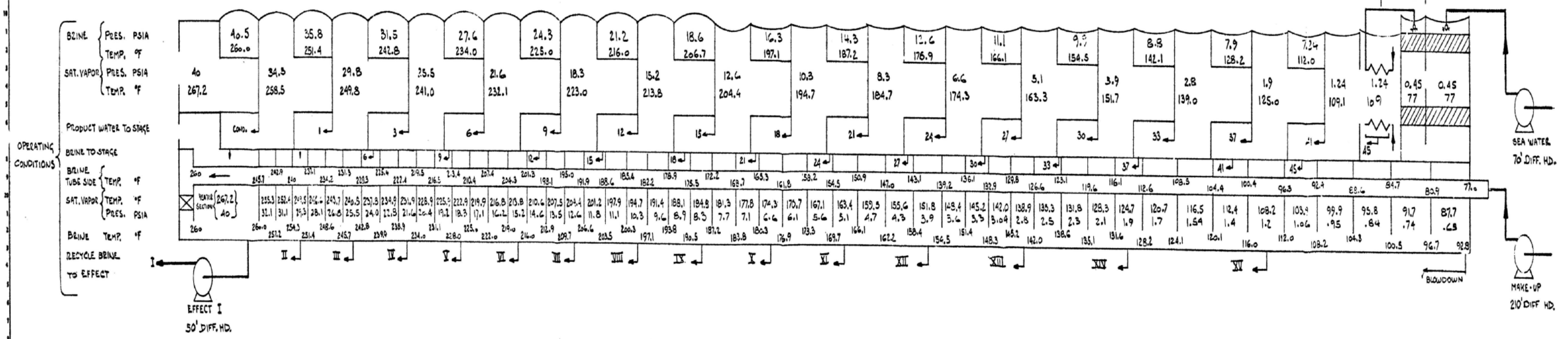
V.T.E/M.S.F PLANT
DESIGN CRITERIA

CONDITION BETWEEN EXP. JOINTS

← Δp: 8.3 DES. 13.2 PSIG → | ← Δp: 7.2 DES. 10.8 PSIG → | ← Δp = 8.0 DES. 12.0 PSIG → | ← Δp: 5.2 DES. 7.8 PSIG → | ← Δp = 3.2 DES. 4.8 PSIG →

V.T.E DESIGN CONDITION		I BRINE (TYP)	I (VAPOR (TYP))	II	II	III	III	IV	IV	V	V	VI	VI	VII	VII	VIII	VIII	IX	IX	X	X	XI	XI	XII	XII	XIII	XIII	XIV	XIV	XV	XV	FINAL COND. UPPER SHELL	FINAL COND. UPPER TUBE	SPRAY HEADER	SPRAY HEADER
TEMP °F	273	264	264	255	255	246	246	237	237	228	228	219	219	209	209	200	200	190	190	179	179	168	168	157	157	144	144	130	130	114	114	114	109	109	82
PRES. PSIA	44	44	38	39	33	34	28	30	24	26	20	23	17	20	14	17	11	15	9	13	7	11	6	10	4	9	3	3	2	7.5	1.5	1.5	20	20	20

	FINAL COND. LOWER SHELL	FINAL COND. LOWER TUBE		DEAERATOR
TEMP °F	114	109	82	82
PRES. PSIA	1.5	20	.54	.54



M.S.F DESIGN CONDITION	WATER BOX	BRINE	HEATER SHELL	HEATER TUBE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
TEMP. °F	265	265	273	265	260	257	255	252	249	246	243	240	237	234	231	228	225	222	219	216	213	209	206	203	200	196	193	190	186
PRES. PSIA	106	38	44	106	35	34	33	31	29	28	26	25	24	22	21	20	19	18	17	16	15	14	13	12	11	11	10	9	9

M.S.F DESIGN CONDITION	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	WATER BOX
TEMP. °F	183	179	176	172	168	165	161	157	153	150	147	144	140	137	133	130	126	122	117	113	109	105	101	97	93	82
PRES. PSIA	8	7	7	6	6	5	5	4	4	4	3	3	3	3	2	2	2	2	2	1	1	1	1	1	1	106

NOTE : 1) INTERNAL WALLS TO BE DESIGNED FOR DIFFERENTIAL OPERATING PRESSURE PLUS 50%

2) EXTERNAL WALLS TO BE DESIGNED:
(A) MINIMUM OF INTERNAL DESIGN PRESS. OR 16.7 PSIa.
AND (B) FULL VACUUM

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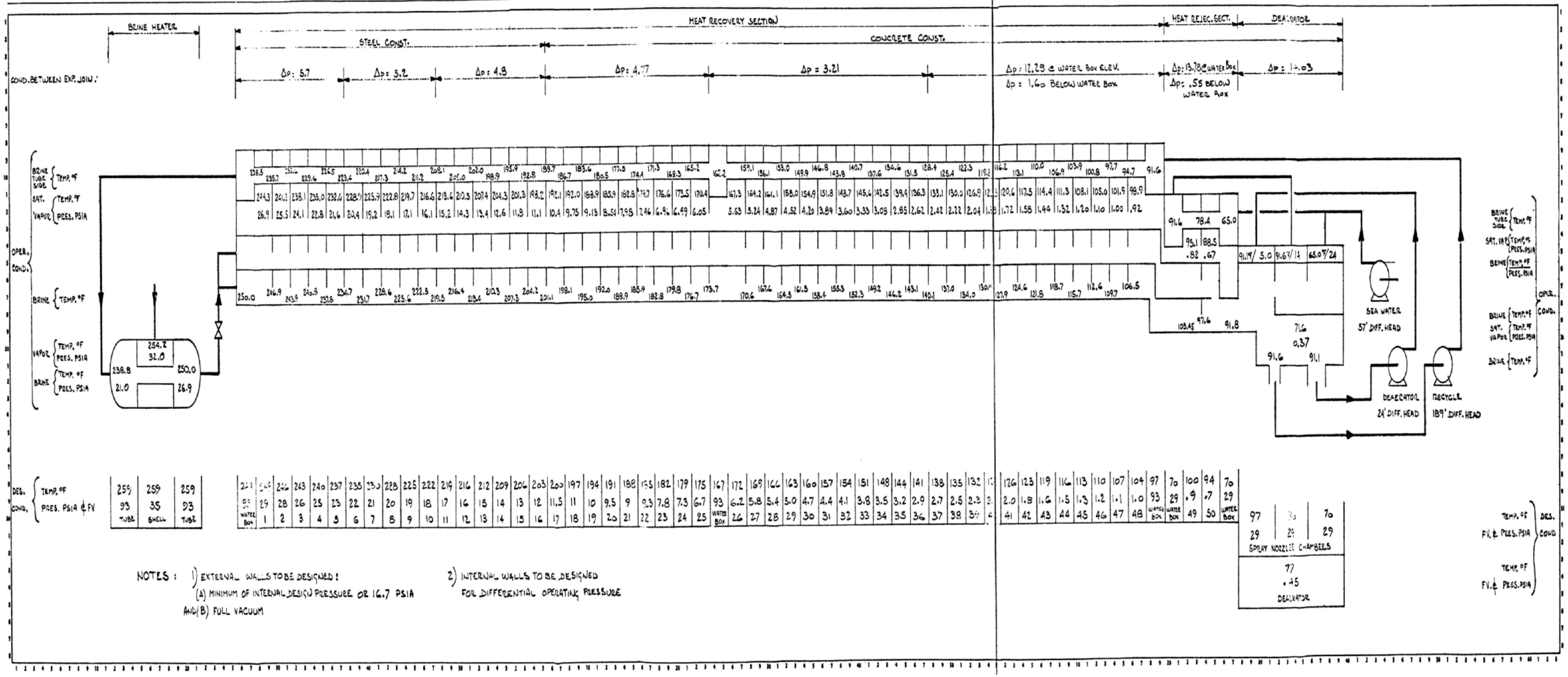
SHEET NO. FIG. 8.1.2
DATE 0-14-68
BY M. COURT· ACHK'D [illegible]
JOB NO. 4334

M.S.F PLANT
DESIGN CRITERIA



NOTES: 1) EXTERNAL WALLS TO BE DESIGNED:
(A) MINIMUM OF INTERNAL DESIGN PRESSURE OR 16.7 PSIA
AND (B) FULL VACUUM

2) INTERNAL WALLS TO BE DESIGNED
FOR DIFFERENTIAL OPERATING PRESSURE

b. Provide internal relief valves in the partition walls set to open at design differential pressure plus some modest safety factor such as 50% of the normal differential. Inspection and/or adjustment of these would be impossible during operation. Furthermore, unless these were to reseat themselves, a complete plant shutdown would be necessary every time an overpressure incident occurred. The cost in lost production of one such incident would probably justify a more expensive system not requiring shutdown. In Fluor's view rupture devices are, therefore, an unsatisfactory answer. Standard spring-loaded relief valves are also impractical due to the extremely high volumes of steam that would have to be relieved to limit the threatened overpressure.

c. Oversize the brine ducts which carry brine from each effect to the MSF stage normally operating at the same pressure, plus including a safety factor of, say 50% in the design of the effect partitions. In this manner any tendency for overpressure in an effect will be relieved by conveying the excess steam to the corresponding MSF stage. Part of the excess steam delivered to the stage will be relieved by increased condensation in the MSF stage and increased brine flow to the next stage. If stage pressure exceeds the brine leg in the orifice, the water seal will blow out and the steam will pass through to the next MSF stage. This scheme is complicated by the difficulty of predicting two-phase (brine plus steam) flow through the brine duct, as well as by the uncertainties of undesirable dynamic effects, such as water hammer and brine pendulation.

d. Oversize the vapor equalizing ducts between each effect and its equal-pressure stage counterpart, allowing for a reasonable overpressure in each effect, such as 50% of the normal differential pressure. In this manner, excess steam in, say, Effect (n) would be transmitted to the corresponding flash stage, through the next several flash stages to the flash stage connected to Effect (n+1), and thence to Effect (n+1), where it would act to decrease the differential pressure across the partition separating Effects (n) and (n+1). The vapor equalizing duct sizes provided by ORNL would have to be increased by a factor of 10 or 20 times to serve this purpose.

The most practical routing for such large ducts appears to be in the floor between the VTE and MSF portions of the plant. A double slab floor would be required, with the ducts located between the slabs. The MSF portion of the plant has a total headroom of 10'-6", which seems to be more than required. Accordingly, sufficient vertical distance appears to be available for such ducts. However, because of the longitudinal displacement of many of the effects with respect to their corresponding stages, at some positions in the length of the evaporator three separate parallel ducts would be required in each train. It might become a problem to find sufficient room for all the ducts, particularly at the low temperature end of the plant where the specific volumes of the steam are high and the differential pressures are small. Although a complete analysis has not been made, it is possible that installation of these ducts might allow the plant to continue in operation even though an effect pump was out of service.

e. Provide water or brine seals between adjacent effects, arranged to blow out the water seal at a differential pressure between effects of, say, 150% of the normal differential pressure. Partition walls between effects would be designed to withstand the differential pressures permitted by the water seals. In this scheme, the downstream leg of the water seal carries a higher level than the upstream leg, and would be designed for a "no-flow" condition. Such a method could better be applied to the low temperature end of the plant where differential pressures are only a few feet. For the higher temperature effects, the design becomes more difficult because the higher differential pressures require greater brine depths in the water seal. Another problem associated with this design is that when relieving, the leg must pass both liquid and steam, so that possible undesirable dynamic effects must be considered. Another problem is the fact that the liquid in the top of the downstream leg is exposed to the pressure in the downstream effect and so will boil and pass some steam into this effect Consequently, additional brine will flow into the leg to replace the material evaporated. The density of the downstream leg will be reduced since the fluid will be two-phase, and a greater free-board will be needed to prevent carry-over. Thermodynamic losses will be incurred due to flashing of brine directly from one effect to the next rather than through the flash train.

Evaluation of each of these schemes is beyond the scope of this study. For cost estimating purposes, an allowance sufficient for a combination of scheme a and d is included in the cost of the structure.

External walls of the VTE plant were designed for an internal pressure equal to normal operating pressure (but not less than 2.0 psig), and also for full vacuum.

Effect chambers over the vertical tubes, deaerator chambers, and water boxes were designed for pressures equal to 120% of the normal discharge pressure of the pump feeding them. The 20% overpressure is to accommodate the pump shut-in head in case it should be inadvertently applied to the system.

MSF Design Pressure

Design pressures in the MSF plant were more readily determined than in the VTE. Since adjacent stages are connected by orifices normally closed with a liquid seal, any interstage pressure that was substantially different than normal would be able to relieve itself by blowing out the water seal and relieving into the adjacent stage. Internal walls were therefore designed for normal operating differential pressures. External walls were designed for an internal pressure equal to operating pressure, but not less than 2.0 psig, and also for full vacuum.

Deaerator chambers and water boxes were designed for pressures equal to 120% of the normal operating head of the pump supplying them. The added 20% is to care for the possibility of pump shut-in head being inadvertently applied to the system.

Problems Encountered in Design Check of VTE Structure

The VTE evaporator structure, like the MSF, is essentially a large pressure vessel, with added problems created by its higher temperatures and pressures. Even more important, however, is the fact that the differential pressures between effects in the VTE structure are much greater than the differential pressures between stages in the MSF plant. The high temperatures to which the structure are exposed require several expansion joints. The segments created by these transverse expansion joints tend to be pushed apart where the internal pressure is positive, or forced together by atmospheric pressure in the case of internal vacuum. These pressures generate horizontal forces which in some cases are nearly five times as large as those generated by design magnitude earthquakes.

The above conditions created problems in the VTE structure that, in Fluor's opinion, were not adequately covered by the ORNL design. These include:

a. Sliding - Since there are no other provisions in the design to resist them, all the horizontal forces generated by pressure and earthquake loadings must be balanced by the lateral passive resistance of soil against the keys beneath the structure, plus the friction between the structure and the supporting soil, to prevent the segments from moving. In the present design, there is not enough resistance under the structure segments (in cold and hot ends) to prevent sliding.

8.1 Evaporator Structure (Cont'd.)

Example:

Consider the portion of the evaporator structure lying between expansion joihts and including Effects II, III and IV, and a typical bay 10' wide. This segment has a length of 44' and a height of 33'. The loads on the 10' bay are:

Total weight = 1057 Kips per 10' width

Total horizontal force H = 597^k (from 2.64 ksf net pressure)
+ 134^k (from earthquake)
= 731 Kips

Frictional resistance of soil = .4 x 1057 = 423^k

Passive resistance of soil bearing against ducts = 3 x 60 = $\underline{180^k}$

Total resisting force = 603^k

Since the horizontal force of 731^k is greater than resisting force of 603^k, the segment will slide.

b. Overturning - Large horizontal forces also tend to overturn the segments. To prevent overturning, a heavy slab is added (8' thick at the hot end). This overturning, however, increases soil bearing pressures in some segments to double the permissible limits ORNL's plan to use piles to reduce local high bearing pressures is acceptable, although in most cases mixing piles with spread footing is undesirable because of the likelihood of differential settling. For a real plant a thorough soil investigation and foundation analysis will be required before this procedure could be accepted.

c. Beams - The horizontal forces mentioned above must be transmitted from the effect walls to the foundations through a system of columns and beams. This system is inadequate and cannot be economically modified to become adequate.

8.1 Evaporator Structure (Cont'd.)

Example:

Consider a column in Effect II:

Weight of structure, etc. = 146 Kips

Internal pressure = 33 psia
Atmos. pressure = 14.7 psia
Net pressure = 18.3 psi or 2.64 ksf outward

Total pull (uplift) on column = 2.64 x 10 x 11 = 280^k

Net uplift = 280-146 = 134 Kips

Horizontal force/column = 731 Kips (see item a)/seg.
= 731/4 = 183 Kips/col.

Then the minimum moment in column = 183 x 10/2 = $915'^k$. To resist an axial tensile force of 134 Kips and a bending moment of 915 ft-Kips would require a column so massive as to be impractical.

d. Differential expansion - A relatively thin stage wall heated on both sides will expand quite rapidly during plant start-up while the thick slab supporting it, and heated on only one side, will not. Differential expansion will cause very high stresses in the walls, expecially at the tray openings, causing large cracks or even local failure of the wall (it will shear at the base).

e. Common division wall - Using a common division wall between two trains without an expansion joint is impractical.

f. Underground ducts which project a key of concrete into the soil will tend to prevent movement of the floor slab due to passive or lateral resistance of soil. This will either reduce the effectiveness of the expansion joints or will shear the soil in front of the ducts and they will lose their effectiveness as shear keys.

g. Lining of floor slab with 1/4" steel plate creates one of two problems:

   (1) If the plate terminates at columns and walls, there will be a break in the plate's continuity at the junction of columns and walls with the floor slab.

   (2) If the plate is continuous, the connection of columns and walls to the slab is complicated.

Changes to the VTE Structure Introduced by Fluor

Because of the number of major structural problems which appear in the ORNL design, it is Fluor's opinion that fundamental design changes would be advisable before a plant were to be built, rather than simply reinforcing and strengthening the present design. However, such a major redesign is beyond the scope and available time for the present study. Therefore, modification to the ORNL design has been elected so as to provide a cost estimate within the required time frame. These are based on what are considered to be reasonable assumptions, and checked with short-cut calculations, but have not been thoroughly analyzed. The cost estimate is based on this approach and Fluor believes the estimated costs are sufficient to build a VTE plant following a design that Fluor would sponsor. The modifications are as follows:

a. To prevent sliding, shear keys were added. No safety factor was included in calculating frictional resistance against the soil, although a safety factor of 1.5 on coefficient of friction is usually recommended.

b. To provide for excessively high soil bearing pressures, the concept of combining piles with spread footings was assumed workable, and additional piles were introduced.

c. To resist the large horizontal forces, the beam and column system was replaced in the VTE portion with shear walls, and diagonal struts were added in MSF portion. The large outward pressures causing tension in walls and columns necessitated the use of heavy tie rods in the walls and steel pipes in the columns.

d. No provision was made in the cost estimate for means of controlling the differential expansion between walls and floor slab. It is assumed that suitable design modifications could solve this problem without additional cost.

e. Two independent walls were used between the trains to accommodate lateral and differential longitudinal expansion.

f. No provision was made in the estimate for dealing with problems created by ducts.

g. A continuous steel floor plate was assumed.

Recommendations for Design of the VTE Structure

Several recommendations are introduced as major design changes which Fluor believes would provide a more workable VTE structure and at less cost. A more complete evaluation of these concepts would be required before Fluor could include them as sponsored designs. Fluor recommends the evaporator floor under the MSF portion of the VTE plant be built of double-slab construction, with two slabs of approximately equal thickness.

A shear key midway between expansion joints anchors the upper slab to the lower, with provision made for sliding between slabs at other points. The steel plate liner is installed between the two slabs instead of on top of the evaporator floor. Figure 8.1.3 illustrates this modification.

The use of a double-slab floor for the VTE structure shows the following advantages:

a. Expansion joints are a troublesome and inherently weak portion of the evaporator structure. Because the length of segments between transverse expansion joints can be increased by this construction, the number of joints can be reduced to two, or possibly even one. At the same time, the net differential pressures at expansion joints are effectively reduced.

   Example:

   Consider the existing expansion joint in Effect II:

   Internal pressure = 33 psia

   External (atmospheric) pressure = 14.7 psia

   Resultant differential pressure = 18.3 psi, or 2.65 Ksf

   Then consider the proposed expansion joint in Effect VI:

   Internal pressure = 17 psia

   External (atmospheric) pressure = 14.7 psia

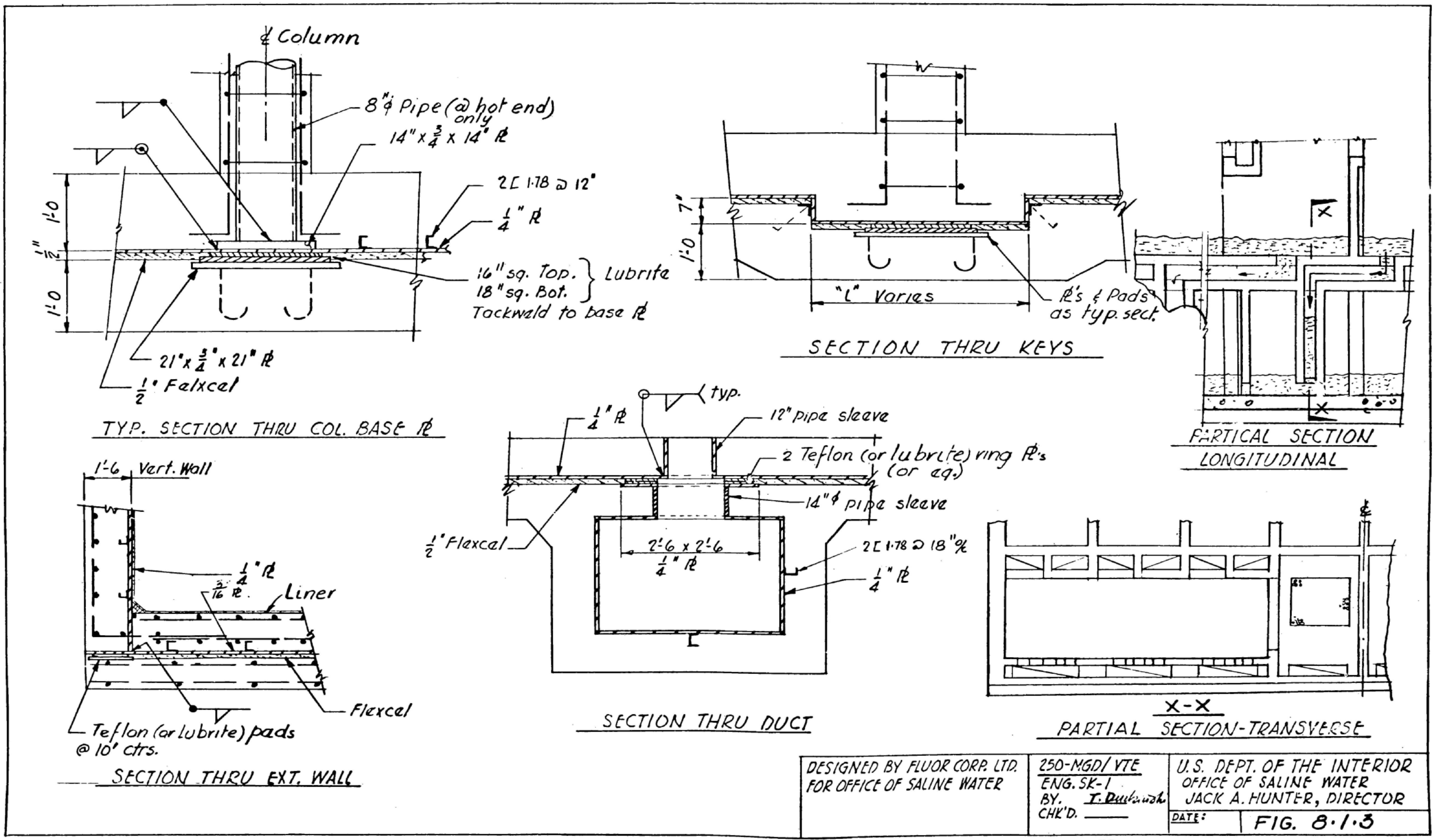
   Resultant differential pressure = 2.3 psi, or 0.33 Ksf

   Thus the net pressure differential providing the horizontal forces in the second case is 1/8 that of the first case, while the evaporator segment against which the force is acting is three times as heavy. Therefore, overturning and sliding problems are correspondingly reduced.

b. The structure will be held together by the bottom slab, eliminating the risk of sliding or overturning.

c. It will be possible to separate the brine return ducts from the main structure.

d. It will make the expansion of the top slab more nearly comparable to that in the upper structure, thereby greatly reducing internal stresses around the joints.



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FOR OFFICE OF SALINE WATER

250-MGD/VTE
ENG. SK-1
BY. T. Dulanski
CHK'D. ——

U.S. DEPT. OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

DATE:

FIG. 8·1·3

e. The reduction of net horizontal forces will make it easy to transfer horizontal shears through external walls and one additional longitudinal wall, eliminating costly and cumbersome diagonals.

f. The 1/4" steel plate will be used more effectively. Installation between the slabs eliminates the problem of sealing continuity around walls and columns.

Fluor recommends that the VTE plant brine return ducts be removed from the floor under the MSF stages and be placed in the intermediate floor between the MSF stages and the VTE effects. This would in effect create a double floor similar to the deaerator structure in the MSF plant, with the ducts formed between the two floors. (See Figure 8.1.3.) Brine leaving an effect would flow through ports in the floor into the longitudinal duct between floors, move longitudinally to the proper stage, and then drop into the transverse duct, which would distribute it across the width of the train. The transverse duct is built against the downstream wall of the stage to which the brine is returning, with the stage wall forming one wall of the duct. In depth, the transverse duct extends from the top of the stage down to near the normal brine level - a depth of more than 6 feet. Orifices are placed at frequent intervals in the bottom of the duct, discharging the returning brine into the MSF brine stream near the downstream end of the stage. Orifices are sized so that the brine level must build up a head of brine in the transverse duct to force the required flow quantities through the openings. This insures a uniform transverse distribution of returning brine, and at the same time retains the feature of self-regulating flow provided by the ORNL bottom - feed brine return design.

Moving the brine return ducts from the floor below the MSF stages to the floor above eliminates the problem of sealing the ducts. Were these ducts to remain below the MSF stages, it would be necessary to provide for vacuum-tight sliding joints between these ducts and the floor slab.

The double-floor construction, in addition to providing ample room for brine return ducts, also provides space for large pressure-equalizing vapor ducts connecting each effect and its corresponding stage. This would reduce the risk of developing a high pressure differential between effects, and might allow the reduction of the safety factor now employed in designing the walls between adjacent effects.

Problems Encountered in Design Check of MSF Plant Structure

The MSF evaporator, like the VTE, is basically a very large pressure vessel and, therefore, has design considerations of elevated temperatures and pressures not usually present in concrete structures. In Fluor's opinion, there are unresolved problems with the structure as presented in the ORNL design. These problems are:

8.1 Evaporator Structure (Cont'd.)

a. Both cold and hot ends are structurally inadequate to resist the horizontal loads derived from differential pressures. Full vacuum conditions were not originally considered by ORNL as a possible design condition.

b. Water boxes could not tolerate an accidental pressure build-up from pump shut-off head being applied to them.

c. In the deaerator structure no provision was made for the pressure differential between supply and spray chambers. As a consequence, both ceiling slabs and columns were underdesigned.

d. The tubular steel framework proposed for the hot end of the plant is not considered suitable for this type of service. Although tubular shapes have less surface area exposed to corrosion than standard rolled shapes, they exhibit, in Fluor's opinion, overriding disadvantages. Their erection costs are much higher than structural members. They are susceptible to corrosion inside the tube - an area which is not accessible for inspection.

e. Differential thermal expansion between the upper structure and the 2-foot-thick floor slab may cause difficulties. The 2-foot-thick MSF floor slab will be heated on only one side. It will expand neither as fast nor as far as the much thinner stage walls, which are heated on both sides. Since these walls are too rigid to deflect, cracks or even failure might occur between duct openings.

f. The single division wall between trains is impractical. It requires sealed expansion joints at every stage wall and at the roof level. The latter would be likely to shear off from the differential longitudinal expansion of adjacent trains.

g. There is no positive connection between the 2-foot floor slabs and the 6-inch base slab to transfer horizontal loads to the ground.

h. There is no provision for drainage of the arched steel roof.

i. Assuming the ground water table at approximately 4 feet above MLLW, the buoyant forces on the recycle pump pit could float it out of the ground under certain conditions.

Changes to the MSF Plant Structure Introduced by Fluor

Fluor's cost estimate is based on ORNL's design plus the following changes and additions:

a. Diagonal struts were added at hot and cold ends to resist horizontal loads.

b. Water boxes were redesigned. The walls were thickened and horizontal diaphragms added.

c. The deaerator ceiling and columns were strengthened.

d. Tubular steel was replaced by standard rolled shapes and the steel structure redesigned.

e. To reduce the differential thermal expansion between the upper structure and the floor slab, the horizontal joint between slabs was raised to make the thickness of the two slabs approximately equal. This reduces to 13" the thickness of the slab which is cast monolithically with the upper structure and makes its expansion more compatible with that of the stage walls. Also, the 1/4" carbon steel plate originally placed on top of the floor slab was moved to this joint to simplify the construction. Details of the construction and method of maintaining vacuum integrity are shown in Figures 8.1.4 and 8.1.5.

f. To reduce the number of expansion joints and their inherent weaknesses, a double wall was used between trains.

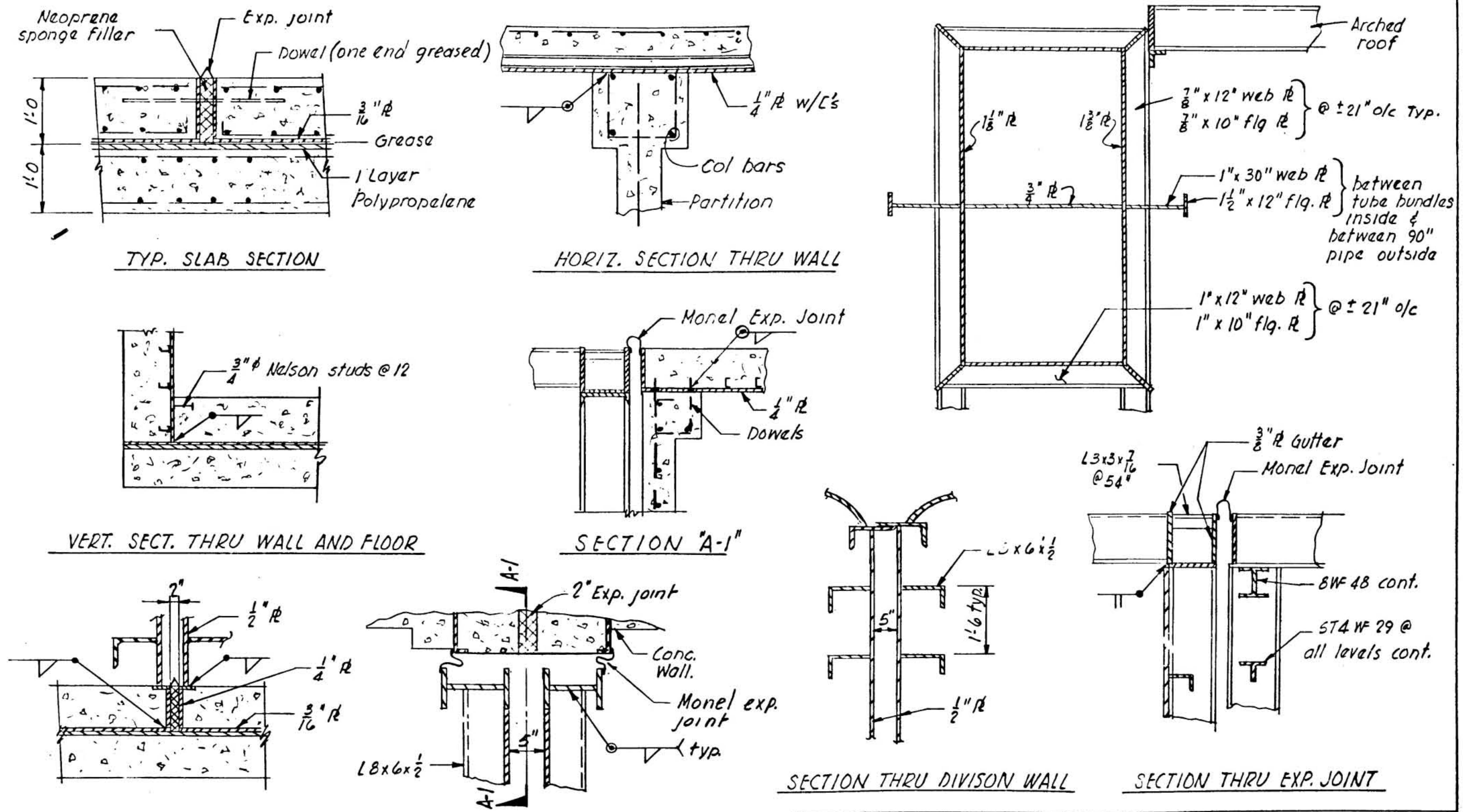
g. Shear keys in the shape of crosses were introduced in the floor slab midway between expansion joints in each segment to prevent the upper structure train sliding on the base slab.

h. Beams, "U"-shaped in cross-section, were welded to the ends of the arched roof at each transverse expansion joint to serve as gutters.

i. To counteract the buoyancy of the recycle pump pit, the floor slab was extended beyond retaining walls to engage the surrounding soil.

Recommendations for Design of the MSF Plant Structure

The following changes, while not included in the estimate, could, in Fluor's opinion, improve the structural performance and economy of the MSF plant.



HORIZ. SECTION THRU DIVISION WALL

NOTE: Read this sketch w/ O.R.N.L.'s struct. dwgs.

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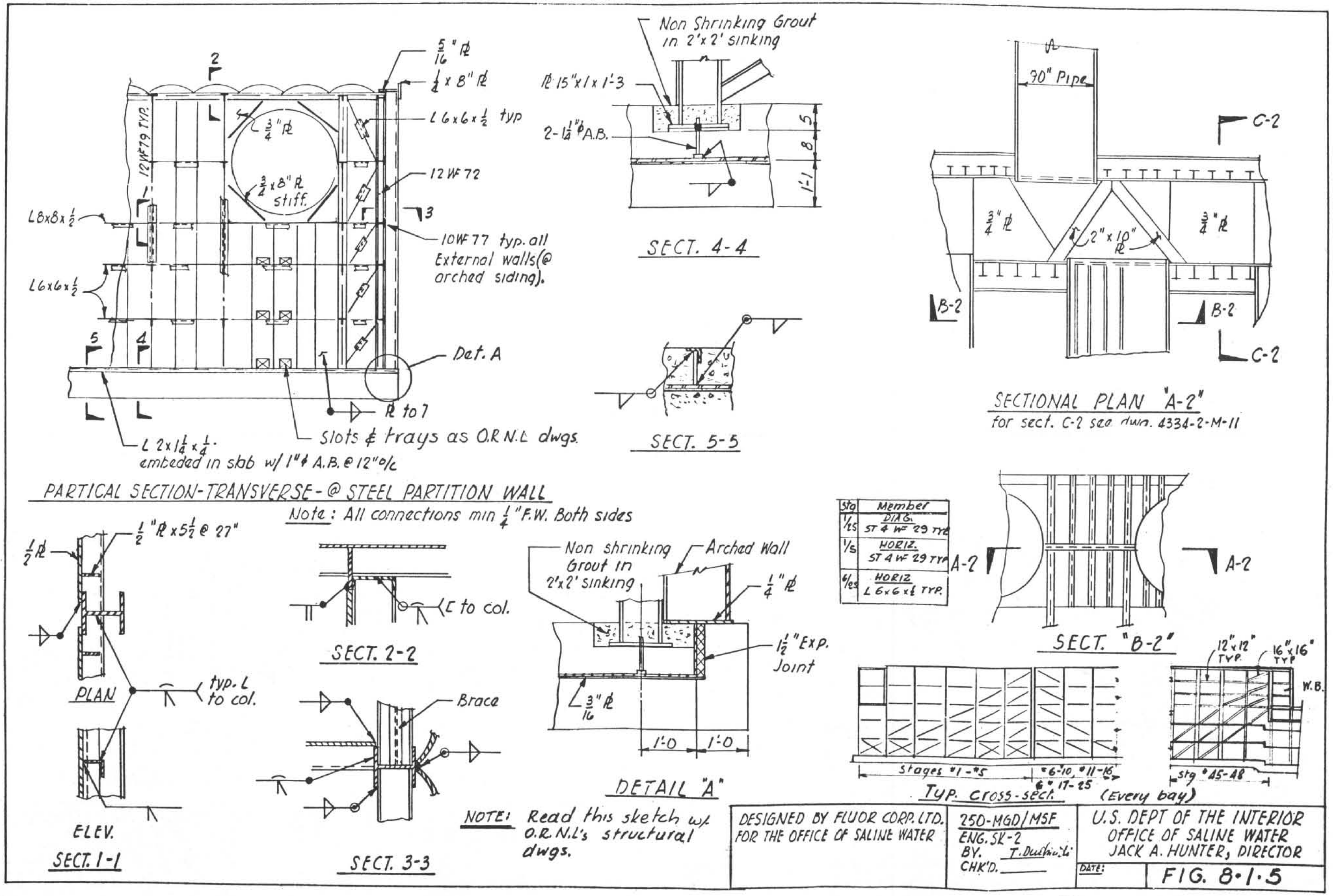
		DATE: FIG. 8·1·4



Stg	Member
1/25	DIAG. ST 4 WF 29 TYP
1/5	HORIZ. ST 4 WF 29 TYP
6/25	HORIZ L 6x6x1/2 TYP.

NOTE: Read this sketch w/ O.R.N.L's structural dwgs.

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250-MGD/MSF
ENG. SK-2
BY. T. Duchini
CHK'D. ______

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JACK A. HUNTER, DIRECTOR

DATE:

FIG. 8·1·5

8.1 Evaporator Structure (Cont'd.)

a. Make columns larger to reduce the required reinforcing steel.

b. In concrete construction, eliminate roof and stage wall beams and thicken the stage walls where necessary. Also carry the 1/4" roof plate right through the stage walls. This would eliminate many sharp corners, reducing chances of concrete spalling and also reducing the amount of coatings required.

c. Improve expansion joint sealing method. The 16-gauge monel strip appears inadequate in many cases.

d. In the horizontal floor slab joint use Teflon pads rather than continuous sheets of polyethylene.

8.2 Tube Inlet Nozzles

Most of the operating experience with seawater desalination plants has involved only MSF plants, which, in general, contain no small, critical passageways through which the brine must flow. In contrast, the conceptual design of the VTE plant as proposed by ORNL contains thousands of nozzles, each of which controls the flow of brine into an individual vertical tube.

A limited body of experience with VTE nozzles has been accumulated during operation of the Freeport, Texas pilot plant. Certain of the tube bundles there are fed through nozzles which are similar to those in the ORNL design. Other bundles are fed through slotted weir caps of various designs. Fluor was advised by Freeport personnel that no plugging problems had developed with either configuration. However, experience with the weirs extended over several years, while the nozzles had been in operation only a few weeks. When nozzles are used to distribute brine flow to the vertical tubes, the effect pump completely fills the chamber above the vertical tubes with brine under about 5 psi pressure. A single 1/4-inch tangential orifice in each nozzle meters brine into the tube in a swirling fashion designed to insure complete wetting of the inside tube surface. Part of the brine evaporates inside the tube, and the brine and vapor move cocurrently through the length of the tube. In contrast, when weirs are used to distribute the flow to the vertical tubes, the brine in the brine chamber rises only about an inch above the bottom of the weir slots and the remainder of the brine space is filled with vapor. If a nozzle becomes partially plugged, it will cause scaling in the tube it feeds; if the nozzle becomes completely plugged, or the tube develops excessive scaling, the tube will be effectively removed from service. The possibility of these VTE nozzles becoming plugged with debris from the seawater feed is a matter of some concern to Fluor.

Freeport plant personnel reported to Fluor that the seawater intake there is often loaded with mud and silt, but that sea life is usually minimal. In contrast, Southern California coastal waters contain heavy concentrations of sea plants and animals, especially at certain seasons of the year -- much more than was observed in the intake channels and on the traveling screens of Freeport or other plants. One of the sea plants frequently observed on the screens at the San Diego Test Center resembles heavy black horsehairs. Some of these would doubtless pass through or around the intake screens and might also get through the deaerator. If this occurred, they would in time be expected to partially or completely plug the 1/4-inch orifices in the VTE nozzles.

Despite the apparent lack of problems encountered at Freeport, Fluor believes that the VTE tube inlet devices could become a major source of trouble for such a plant located in Southern California. This applies particularly to nozzles, but to a lesser extent to weirs as well. Fluor believes that for a Southern California location it will be necessary to install a finer mesh intake screen than is customarily used on MSF plants.

8.2 Tube Inlet Nozzles (Cont'd.)

A mesh opening of 1/8" is recommended, in contrast to the 3/8" to 1/2" mesh commonly used in MSF plants. To prevent excessive pressure drop through a finer mesh screen, it will have to be rotated and backwashed more frequently than is usually practiced.

Certain sea life--notably mussels and barnacles-- pass through a free-swimming larval stage before they affix themselves to a suitable solid surface. In this larval stage they can readily move through even fine screens, attach themselves to walls on conduits, and continue their growth within the inlet portions of the plant. When they are later dislodged, their shells can provide debris large enough to cause serious fouling of brine flow channels. It is possible that adequate control of these animals may require a more vigorous chlorination schedule in the VTE plant than for the MSF plant. Adequate control would require that they be killed before they can grow to harmful size. It is expected that more definite information will be available before a large plant is built. Operation of the proposed VTEX plant at the San Diego Test Center should reveal the extent of this potential problem.

8.3 Deaerators

Direct comparisons between the VTE and MSF deaerators could not be made because the vapor source and operating temperatures are not the same; however, a comparison of deaeration area allotted per gpm treated, showed them to be substantially the same.

In the VTE plant, deaerator nozzles are made of Saran plastic, and are connected to pipe headers mounted at the top of the deaerating space (see Drawing V-7). Each nozzle is designed for a flow of 500 gpm, and there are a total of 580 nozzles in the plant - 145 per train. There are 45 nozzles (per train) in the hot section of the deaerator, and 100 nozzles in the cold section. A portion of the plant heat reject water at 104 F is acidified and flashed in the hot section, cooling itself to 77 F and deaerating itself in the process. Steam from the hot side of the deaerator is guided to the cold side, where it flows countercurrently to the acidified 65 F seawater spray, stripping the dissolved gases from it and warming it to 77 F. Two packed beds in series assist in providing adequate surface area for efficient deaeration. Carbon dioxide, formed by the action of acid on the seawater feed, is also removed.

The VTE plant deaerator is an untried design requiring further testing. It needs no external steam for stripping, and rejects a minimum of steam to the external barometric condensers, but will require additional development work to prove its performance.

The MSF plant design also provides for Saran deaerator nozzles, but the method of installation is different from that of the VTE plant. Deaerator feed water is pumped to reinforced concrete water boxes in each deaerator section, and the full-cone spray nozzles are mounted directly beneath the water boxes, eliminating internal piping within the deaerator. Each nozzle is rated at 1000 gpm at a differential pressure of 5 psi, and each train utilizes 172 nozzles, for a total of 688 nozzles in the entire plant.

The deaerator employs two-stage spray-nozzle type deaeration, with the water from the first stage collected and pumped to a second set of nozzles. The first stage, in turn, is divided into two sections. The first section, containing 14 nozzles in each train, introduces cold, acidified seawater at 65 F. The second section, containing 72 nozzles, feeds acidified seawater which has been warmed to 92 F in the heat reject section of the evaporator. These two streams are combined and sprayed into the second stage of the deaerator through 86 nozzles per train. Stripping steam from the final heat reject stage of the evaporator is introduced to the deaerator to assist in the deaeration and decarbonation of the feed stream.

8.3 Deaerators (Cont'd.)

The only significant and controllable difference between the deaerators of the two plants is in the internals of the deaerator itself. The VTE plant uses packing while the MSF plant relies on spray nozzles only. Since the VTE represents the more advanced technology and is the more conservative design, it was necessary to allow for the cost of packing in the MSF plant in order to make the costs truly comparable.

8.4 Pumps and Drivers

In the current study, Fluor's principal objective with respect to pumps and drivers was to be sure that pumps were provided for each required service, that they were of suitable type and size, and that they were chosen on a comparable basis for the two plants. Then prospective vendors were contacted for pricing information.

The required capacity for each pump was determined from the process flow diagram or ORNL computer printout for each stream. To arrive at the pump design flow, this quantity was then increased by an arbitrary 2.5% for all except the VTE effect pumps. This increase was to compensate for decreasing pump performance from impeller and casing wear during the period between pump overhauls. Pump heads used were those specified on the computer printout, without any contingency added. Pump driver horsepower requirements were calculated from flow and head requirements, using typical pump efficiencies derived from Bureau of Reclamation studies.[1] This figure for required pump horsepower then became the basis for driver selection, and the next larger standard electric motor size was specified.

It was noted that, for the VTE reference design, in each instance the efficiencies calculated from the computer printouts were higher than those found using the Bureau of Reclamation procedure. In contrast, the efficiencies implicit in the MSF reference design, as calculated from the computer printouts, were equal to or lower than those based on Bureau of Reclamation procedure. This would tend to make the pump power consumption somewhat low for the VTE plant and slightly high for the MSF.

Although the VTE pump efficiencies were decreased, and capacities increased, from those used in the reference designs, the latest ORNL computer printout on the VTE plant showed substantially lower head requirements for the booster and the make-up pumps. This resulted in a net effect of a very slight reduction in power requirements for the VTE plant but a substantial reduction for the MSF plant.

Vertical pumps were selected for all of the major services in both plants. Many pumps were necessarily located in pits because of NPSH requirements - a configuration well-suited for vertical pumps. The pit can be smaller than that required for a horizontal pump, and the motor can be located at ground level or in the pit as desired. Vertical pumps are also adaptible to either wet- or dry-pit construction, while horizontal pumps are not. Engineers and operators differ as to their relative merit. Both types of pump are in service at St. Thomas, and the vertical pumps are preferred. The process engineer at St. Croix also preferred vertical pumps, citing savings in foundation costs and reduced downtime and maintenance costs when compared to horizontal pumps.

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[1] Research on Pumping Unit Studies Final Evaluation Report, U.S. Bureau of Reclamation Research and Development Progress Report No. 205, September, 1966

8.4 Pumps and Drivers (Cont'd.)

Dry pit construction was chosen for most services for both plants, with the wet-pit VTE effect pumps being the major exception.

Installed spares were provided for the small pumps used to add chemicals to the make-up streams. The chemicals are necessary for plant operation, and the cost of spares for small pumps is small. For the larger pumps, however, the cost of spare pumps would be substantial, and would be more difficult to justify. For this study, therefore, it was decided to provide no spares for any of the large pumps, with the exception of the VTE effect pumps. These pumps must be considered in a different category from other pumps in the two plants for the following reasons:

a. Aside from the effect pumps, the complement of pumps in the VTE and MSF plants is quite similar - 20 major pumps in each plant. In addition to these, however, the VTE plant has 60 effect pumps. Because of these extra pumps, the VTE plant is expected to require more maintenance in this area than the MSF plant.

b. Many of the effect pumps are identical, so that one spare pump and motor could serve for a number of pumps.

c. The effect pumps are moderately sized (350 to 500 hp) and priced, so that the cost of warehouse spares would not be excessive.

Considering the above factors, it was decided that an equitable solution would be to charge the VTE plant with warehouse spares in order to equalize the reliability of two plants. Accordingly, one warehouse spare pump and motor was purchased for the 4 Effect I pumps, one for the 4 Effect II pumps, two for the 32 Effect III through X pumps, and one for the 20 Effect XI through XV pumps.

A complete tabulation of pumps and drivers is included in the equipment list for each plant - section 9.1 for the VTE plant and section 10.1 for the MSF. These pump tables also include the major performance specifications of pumps and motors, type of pump, and materials of construction. Additional comment on certain of these pumps is included below.

The design flow rate of the VTE booster pumps was increased to correspond to the process flow sheet.

The seawater intake pump in the MSF plant did not have sufficient head to feed the barometric condensers. Four (one for each train) booster pumps were added to increase the head to the condensers.

No provision had been made by ORNL in the VTE plant for transferring barometric condenser effluent from the seal pit to the reject header. Two small pumps were added for this purpose.

Although the ground rules in the reference design for the VTE plant specified using synchronous motors for motors larger than 450 hp, Fluor has specified induction motors for the 500-hp Effect I pumps. This was done in the interest of uniformity and simplicity, since all other effect pump motors are induction type.

The geometry of the suction conduit leading to the MSF brine recycle pumps was not adequately designed, in Fluor's opinion. This was modified to provide a more smoothly contoured low-velocity entrance region, with provision to minimize vortexing and vapor entrainment. This is discussed in more detail in Section 3.1.

8.5 Chemical Systems

General

Continued smooth and proper operation of both VTE and MSF plants is dependent upon the addition of small amounts of chemicals at the proper times and places, and in suitable amounts. The purposes of these additions include inhibiting marine growth, preventing fouling of heat transfer surfaces, preventing corrosion, and eleminating brine foaming. The several chemical systems are described separately in the following paragraphs, and are generally similar for both plants. Details of the chemical addition systems are shown in the P&I Flow Diagrams - Drawing No. V-4 for the VTE plant and No. M-4 for the MSF.

Chlorination

Raw seawater abounds with plants and animals, both living and dead. If no preventive measures were taken, the intake structures of desalination plants would soon become heavily populated with mussels, barnacles, and other forms of sea life. This would eventially interfere with the normal flow of water. Even more important, the shells and debris from animals growing within the plant would foul the plant internals, such as exchanger tubes, nozzles, and deaerators.

Chlorination of the seawater feed is the best method of control in most cases. The quantity of chlorine needed varies with locale and with ocean temperature, but 5 to 8 parts per million is the usual requirement. The free chlorine oxidizes organic matter in the feed water, and is consumed in the process. Chlorine requirements are usually gauged by measuring the amount of residual chlorine still remaining after the immediate demands of the feed water have been met. Sufficient chlorine is added to leave a residual of, say, 0.5 to 0.75 ppm. This is enough to kill most marine life, or at least inhibit its growth. The chlorine is injected at the intake structure, at the extreme outer end of the submarine intake conduit. Adding the chlorine at this point controls marine growth throughout the entire intake system.

Chlorine is shipped to the site as a liquified gas in 55-ton tank cars. The liquid chlorine is transferred from the tank car by its own vapor pressure, and is then vaporized in steam heat exchangers. The vapor is given 15-20 F superheat to prevent possible condensation in the line. Water jet exhausters mix the vapor with a side stream of seawater from the main intake pump, diluting it with about 500 parts of water. A centrifugal pump then forces this heavily chlorinated stream to the submerged intake structure where it blends with the main intake stream. An installed spare pump is provided to insure against pump breakdown. The chlorination system is capable of continuously adding 20 ppm chlorine to the feed stream if required. It is anticipated that about one-third of this amount will be sufficient, and that intermittent rather than continuous chlorination may accomplish the purpose. Some operators, however, report that mussels can tolerate intermittent chlorination by simply closing their shells and waiting until the chlorine is gone. If this is true, continuous chlorination will probably be required, and money has been provided for operation on this basis.

Acid Addition

Untreated seawater will begin to precipitate alkaline scale on heat transfer surfaces at temperatures well below 200 F. With proper acid treatment, evaporation temperatures can be raised to the 250-260 F. range without encountering scale deposits. Sulfuric acid, least expensive of the mineral acids, is commonly added to the make-up water of desalination plants in an amount sufficient to prevent deposition of calcium carbonate and magnesium hydroxide. The exact amount required is determined most accurately by pH measurement of the treated stream, but is usually about 120 ppm for seawater. This will require about 225 tons/day of acid for the VTE plant, and about 275 tons/day for the MSF. Sulfuric acid at 93% concentration will be delivered to the site by rail shipment and stored in a 500,000-gal tank - sufficient for 10-14 days normal plant operation.

The ORNL designs proposed the erection of an on-site captive acid plant, and showed a substantial cost savings over the purchase of acid from existing suppliers. It is not likely that permission could be secured from air pollution control authorities to erect a new acid plant in smog-conscious Southern California. Since the purpose of the current study is to provide an equitable comparison between VTE and MSF plants, it was agreed that Fluor would not include an acid plant in the plans, but would provide for purchase of acid from existing manufacturers.

Acid is supplied to the make-up water of each train by a seal-less (canned) centrifugal pump, whose pumping rate is automatically proportioned to the flow rates of make-up water. The proportioning ratio is manually adjusted as necessary to maintain the proper pH in the make-up stream. The acid is injected into the central flow of the conduit through six circumferentially-spaced Hastelloy B nozzles. Since the continuous addition of acid is essential for plant operation, an installed spare pump is provided for each train, with alarms to warn the operator if the feed pH drifts outside its prescribed limits.

Caustic Addition

Provision is made for the addition of caustic if it is required to prevent corrosion of the brine heater tubes. When sulfuric acid is added to the make-up water, it normally drives the pH down to the range of 4.5 to 5.5. The carbonate ions are broken down, forming carbon dioxide, which is dissolved in the water. In the deaerator most of the carbon dioxide is removed, along with other dissolved gases. The elimination of the carbon dioxide usually raises the pH of the water enough so that it is no longer corrosive to the heat exchanger metals. However, if the pH of the make-up water is still too low, sodium hydroxide will be added as required to adjust the pH to approximately 7.0 to 7.5.

Sodium hydroxide is delivered in carload lots as a 50% solution, and stored in a 50,000-gal supply tank. It is added to the make-up water at a point downstream of the deaerator, using a single canned centrifugal pump for the entire plant. Feed rate for each train is adjusted automatically in proportion to recycle flow rate, with reset from a pH sensing probe in the recycle line. An installed spare pump is provided to insure against breakdowns.

Anti-foam Addition

Although foaming is not always a problem in desalination plants, it has occurred at Point Loma when an anti-foaming agent is not used. Provision has been made in this study for the addition of 0.5 ppm of Hagen C-1 anti-foaming agent to the make-up water of each plant. The concentrated chemical, delivered in drums, is diluted to a 10% solution for ease in metering the flow to the plant make-up stream. Addition rate of the 10% solution is about 2 gpm for the entire plant. The 10,000-gal storage tank is provided with a mixer to facilitate blending the stock solution. A single centrifugal pump (with installed spare) provides anti-foam solution for the entire plant. The feed rate to each train is proportioned from the flow rate in the make-up stream.

Sodium Sulfite and Ferrous Sulfate Addition

Provision has been made for the addition of small amounts of two other chemicals to the system. The deaerator will remove the major portion of the dissolved oxygen in the make-up water, down to perhaps 50 ppb. To scavenge the remaining oxygen, and to react with any oxygen which leaks through the evaporator walls, the addition of 1 or 2 ppm sodium sulfite to the feed is suggested. The injection of 5 ppm ferrous sulfate on an intermittent basis is also suggested to provide a corrosion inhibiting film and reduce the incidence of tubeside corrosion. Each of these chemicals is stored as a solution of 10 or 15% concentration and is added to the make-up feed with a small centrifugal pump. Addition rates to each train are proportioned from the flow rates in the respective make-up streams.

8.6 Instrumentation

General

The instrumentation proposed for both the VTE and MSF plants is essentially in accordance with that proposed in the ORNL conceptual designs, except as noted in the following comments and discussion. For pricing purposes, instrumentation design and specifications are in accordance with Fluor standards.

A comparison of the instrument application diagrams of the VTE and MSF plants indicated a difference in concept in the instrumentation recommended. Fluor believes the MSF plant should be instrumented in as detailed a manner as the VTE plant. Instrumentation such as pressure, level, and temperature indication and recording, which Fluor believes necessary for efficient operation, have been added to the MSF plant. Alarms have been added where deemed necessary for warning of approaching abnormal operating conditions. In general, the instrumentation has been upgraded to the same concept of design as the VTE plant. A brief description of instrument systems follows:

Temperature Instruments

Conventional analog temperature recorders and controllers were applied as required for general plant operation.

Fluor would propose the use of standard electronic indicators, with selector switches, such that the operator could look at any one trouble point, or scan all points.

Thermocouples

Thermocouples used in the flash stages are a design using as a thermowell 316 S.S. tubing with closed end. These will be inserted through the concrete top of the flash stages, internally supported for mechanical strength, and sealed to prevent air leaking into the stages. Elements are single-sheath type T (copper-constantan) thermocouples.

8.6 Instrumentation (Cont'd.)

EMF-current converters are used to convert millivolt thermocouple signals to current signals for recorders and controllers.

Pressure Transmitters

Although ORNL specified 316 S.S. trim for the pressure transmitters, Fluor believes that monel would be more resistant to seawater exposure in areas not subject to contamination by hydrogen sulfide. A Southern California location meets these requirements; accordingly, Fluor has specified monel bodies and diaphragms for the pressure transmitters.

Differential Pressure and Flow Transmitters

Standard force-balance type D/P cells for all except chlorine service are specified with monel bodies and diaphragms, for reasons explained in the previous paragraph. Cells handling dry chlorine gas have carbon steel trim.

Flow Tubes

Insert type plastic "low head loss" flow tubes have been selected for flow measurement in pipe sizes up to 60". For pipe sizes over 60" tubes of plastic-coated carbon steel have been specified. These devices present a minimum of pressure drop to the system and with factory calibration the element can be guaranteed to an accuracy of 1/4%.

Liquid Levels

Liquid level probes in the brine stream of each stage will transmit a signal to the control room, using capacitance type probes for level measurement. Indication only will be provided in the control room. For the upper brine trays in the MSF plant, the arrangement of the level-sensing probes is based on the presence of cross troughs to interconnect brine trays which lie on the same elevation. These cross troughs, located at about every eighth stage, will maintain brine at approximately the same level in all trays, so that one measurement in each stage will suffice. Local indication of brine level is by means of a gauge glass in each stage.

Control Valves

Hydraulically operated butterfly valves are specified in the ORNL conceptual designs; however, Fluor believes that pneumatically-operated valves with positioners are satisfactory and will provide a substantial cost reduction. The valves are, therefore, designed to operate on 100-125 psi instrument air, with a standard 3-15 psi pneumatic positioner controling a pneumatic cyclinder. This arrangement will provide the valve torque, speed, and stability necessary for good control. Standard-shaped butterfly discs are specified here, but for a final plant design, airfoil- or fishtail- shaped discs should be investigated. These show a 30% reduction in operating torque requirements in sizes up to 36-inch.

Manufacturers are confident that this would also be true for large valves, but have no test information at this time. These streamlined discs would be advantageous for normal throttling service, and could represent a substantial saving on capital cost.

Butterfly type control valves with Ni-resist discs and bodies, 316 S.S. shafts, and Nordel tight-shutoff seats are specified. Control valves in the chemical additive systems are specified with monel bodies and trim, and no positioners.

Relief Valves

Fluor assumes that adequate pressure relief is furnished in the steam supply system and has not included this item in the water plant. Brine piping is designed for full pump shutoff head, eliminating the need for relief valves.

Switches, Alarms, and Solenoid Valves

Dual function milliamp relays with adjustable contacts are specified for alarm and shutdown. Switches and/or relays are mounted behind the control panel.

Annunciator alarm panels are solid state with backlighted nameplates and with Test and Acknowledge buttons. Switch contacts open to sound alarm, Annunciator sequence: alarm or abnormal condition - light and horn sounding; after acknowledgment, light steady and horn silent; and upon return to normal, light out and horn silent. Each panel is specified with 20% spare annunciator points.

Control Panel and Analyzers

The control panel is a console type using high density instruments, with three rows of miniature instruments in the vertical face and two rows on the inclined face. Shut-down, touch temperature panel, alarm test buttons, and hand switches are mounted on the board.

A console desk is provided for the free-standing logging typewriter. The desk also contains a touch temperature panel, manual shutdown switches, and hand switches. These switches are for ease of operation, and are connected in parallel with those on the panel.

Analyzers are furnished as a package unit for field installation and indication. They transmit a compatible signal to a board recorder.

Panel Instruments

Recorders and recorder-controllers are miniature electronic type suitable for high density mounting. Adjustments and servicing are performed from the front of the panel. Indicators are vertical scale milliameter type for high density mounting.

Miscellaneous

Electro-pneumatic transducers receive an electronic signal from the board controller and convert it to a 3-15 psi pneumatic signal to the control valve. They are suitable for field mounting on a floor stand.

The digital data system logs on a time sequence or on demand. A free-standing typewriter is provided for recording data. The data system is capable of logging 200 thermocouple temperature points and 150 pressure points. Logging is accomplished without upsetting any of the control systems.

8.7 Electrical

Primary power is supplied to the evaporator plant from the auxiliary bus in the main power plant switchyard. A radial feed system is used, with a single feeder supplying one train as shown on the Electrical One-Line Diagrams, Drawings V-10 and M-9 for the VTE and MSF plants, respectively.

In the reference designs, motors smaller than 500 hp in the VTE plant, and smaller than 600 hp in the MSF plant, were supplied from 480 volt lines. Aside from fractional horsepower motors, the MSF plant has relatively few motors in this size category - 16 motors with 3500 total connected horsepower. In contrast, the VTE plant has 76 such motors with 26,000 total connected horsepower. There would be a significant economic penalty incurred in the VTE plant in providing a 3 phase, 480 volt distribution system of this magnitude. Accordingly, Fluor has changed the secondary distribution system to 2400 volts in both plants. This reduces the electrical capital cost on the VTE plant by approximately $750,000, and results in a small saving on the MSF plant.

The four 17,000 hp motors on the brine recycle pumps in the MSF plant are provided with 13,800 volt 3 phase power from individual captive transformers. All other motors in both plants, 100 hp or larger, are supplied with 2400 volt 3 phase power. Integral horsepower motors smaller than 100 hp are provided with 480 volt 3 phase power, and 208/120 volt single phase power is available for fractional horsepower motors, control, and lighting.

Motors 600 hp and larger are synchronous type, unity power factor, with brushless exciters. Motors smaller than 600 hp are induction type.

Motors 600 hp and larger have weatherproof enclosure and are water-to-air cooled. Smaller motors are epoxy encapsulated weatherproof or totally enclosed fan cooled.

Transformers and substations are outdoor type with protection suitable for seacoast atmosphere.

Underground feeders are provided. Although the initial cost of overhead distribution is less than that for underground, the underground is relatively unaffected by weather, provides greater reliability, and is less susceptible to atmospheric contamination. Underground ducts also facilitate evaporator maintenance, since there are no overhead lines on or around the evaporator plant.

Duct banks of polyvinyl chloride conduits embedded in concrete are provided for the underground cables. Polyethylene insulation is used for 2400 and higher voltage, and THW insulation is used for lower voltages.

8.7 Electrical (Cont'd.)

All motors for the evaporator plant are remotely controlled from the control room. Underground ducts carry the control, communication, and instrument cables to the control room. Adequate alarms, metering, and indication are provided in the control room for remote operation.

Mercury vapor lighting fixtures mounted on steel poles provide lighting for streets and outdoor operating areas. A manual fire alarm system is integrated into the total plant fire alarm. The telephone system is of a commercial type.

A copper ground mat is provided which will be tied into the switchyard and power plant grid. All exposed metal will be connected to this ground system.

The total estimated load for the VTE plant is 36 mw. The estimated load for the pump motors of each train is 8.75 mw. The chlorination system and other auxiliary loads are estimated at 1 mw for the total plant.

The total estimated load for the MSF plant is 61 mw. The estimated load for the pump motors of each train is 15 mw. The chlorination system and other auxiliary loads are estimated at 1 mw for the total plant.

8.8 Material Selection

The materials of construction and protective coatings included for the major portions of both the VTE and MSF evaporator buildings are shown in Table 8.8. The selection of materials is in some instances different in one plant than in the other. This is in some cases due to the requirements or limitations of the plants. For example, more care is taken in the VTE plant than in the MSF to exclude corrosion products from the brine stream because of the danger of plugging the small holes in the distribution nozzles at the top of each tube in the vertical tube effects. In other cases the differences in constructural materials chosen reflects a difference in the philosophy of the designers at the time the plants were initially designed. As an example, when the MSF plant concept was developed, it was considered best to limit the use of concrete to temperatures below 200 F. However, when the VTE plant was being designed, concrete was used up to 240 F, and, with a polypropylene or steel liner, up to 260 F. This represents a "change in the rules," and renders the plant comparison more difficult. In the current study, the plants were placed on an equal basis where this was possible. If this represented a major design change which was beyond the scope of this study, no changes were made, but the different assumptions were noted and the probable effects discussed.

The first four entries in Table 8.8 represent the ground rules for the specific materials choices noted in the later items. The philosophy they represent may be summarized as follows:

a. Condensing vapor and distilled water will attack concrete; therefore, the concrete must be protected in vapor areas and product trays.

b. Carbon steel will be corroded at a slow rate by vapor or brine. Therefore, in the MSF plant allow 1/8" corrosion allowance. In the VTE plant, allow 1/8" corrosion allowance, and in addition cover with polypropylene sheet to prevent corrosion products from getting into the brine and plugging the nozzles on the vertical tubes.

c. Concrete is limited as to the temperatures it can stand while in contact with brine, and must be protected if these temperatures are exceeded. In the MSF plant, concrete construction is limited to temperatures below 200 F; in the VTE plant, concrete is used for brine up to 260 F, but the surface is protected with polypropylene or steel lining above 240 F.

d. The exterior boundaries of the evaporator buildings (walls, floor, roof) must be steel-lined to provide a continuous barrier against the in-leakage of air.

8.8 Material Selection (Cont'd.)

TABLE 8.8

STRUCTURAL MATERIALS AND PROTECTIVE COVERINGS EMPLOYED IN THE VTE AND MSF DESALINATION PLANTS

Structure	Basic Structural Material	Corrosion Allowance and Protective Coverings on Structural Elements	
		VTE Plant	MSF Plant
General	Concrete exposed to liquid brine only	Covered with 1/8" polypropylene (PP) sheet above 240 F; unlined below 240 F	Concrete is not used above 200 F; unlined below 200 F
General	Concrete exposed to vapor, or to liquid condensate	PP covered	PP covered
General	Carbon steel on walls on roof, exposed to vapor or brine	PP covered (to prevent corrosion products getting into brine or condensate)	Not protected by any lining or coating, but 1/8" corrosion allowance (CA) is provided.
General	Exterior walls, roof, and floor of evaporator buildings	Must contain steel membrane to prevent air inleakage (i.e., they are either built of steel, or are steel-lined)	Must contain steel membrane to prevent air inleakage (i.e., they are either built of steel, or are steel-lined)
Roof	Steel	Included 1/8" CA and PP cover	Includes 1/8" CA; unlined
Roof	Concrete, with 1/4" steel lining	Not applicable. (All roof on VTE plant is steel.)	Steel lining includes 1/8" CA
Outside walls	Concrete, with 1/4" steel lining	Includes 1/8" CA and PP cover	Includes 1/8" CA

CA = Corrosion Allowance
PP = Polypropylene

8.8 Material Selection (Cont'd.)

TABLE 8.8 (Cont'd.)

STRUCTURAL MATERIALS AND PROTECTIVE COVERINGS

Structure	Basic Structural Material	Corrosion Allowance and Protective Coverings on Structural Elements	
		VTE Plant	MSF Plant
MSF ceiling (VTE Plant)	Concrete	PP covered	Not applicable
Partitions between stages or effects (in vapor space)	Concrete	PP covered	PP covered
MSF floor	Concrete, with 1/4" steel lining	PP covered (See Note 1)	Epoxy-phenolic coating
Beams, columns, and load-bearing walls (in vapor space)	Concrete	PP covered	PP covered
Brine trays (where exposed to vapor)	Concrete	PP covered	PP covered
Brine trays (where exposed only to brine)	Concrete	Unlined	Unlined
Brine trays	Steel	Not applicable. (No steel brine trays in VTE.)	Epoxy-phenolic coated all over (See Note 2)
Product trays	Concrete	PP covered	PP covered
Product trays	Steel	No steel product trays	Epoxy-phenolic coated all over (See Note 2)

Note 1 - Fluor's estimate is for epoxy-phenolic coating

Note 2 - Fluor's estimate includes only a 1/8" corrosion allowance

TABLE 8.8 (Cont'd.)

STRUCTURAL MATERIALS AND PROTECTIVE COVERINGS

Structure	Basic Structural Material	Corrosion Allowance and Protective Coverings on Structural Elements	
		VTE Plant	MSF Plant
Wall, roof, and floor of VTE Effect I	Concrete, with 1/4" steel lining	Includes 1/8" CA on steel; coated with 1/2" Lumnite cement	Not applicable
Floor of VTE Effects II and III	Concrete	PP covered	Not applicable
Floor of VTE Effects IV thru XV	Concrete	PP covered	Not applicable
Brine ducts and vapor ducts	Cast-in-place concrete	PP covered	Not applicable
Wet pits for pumps	Concrete with 1/4" steel lining	Includes 1/8" CA on steel; PP covered	Includes 1/8" CA on steel; no other covering
Deaerator roof	Steel	Includes 1/8" CA on steel; 1/2" Lumnite cement coated	Not applicable. MSF deaerator roof is concrete
Deaerator roof	Concrete, with 1/4" steel lining	Not applicable. VTE deaerator roof is steel.	Includes 1/8" CA on steel; 1/2" Lumnite cement coated
Deaerator walls, external	Concrete with 1/4" steel lining	Includes 1/8" CA on steel; 1/2" Lumnite cement coated	Includes 1/8" CA on steel; 1/2" Lumnite cement coated
Deaerator walls, internal, and floor (this is an internal floor)	Concrete	1/2" Lumnite cement coating	1/2" Lumnite cement coating
Deaerator internals	Steel and concrete	Coated with 1/2" Lumnite cement	Coated with 1/2" Lumnite cement
Deaerator piping	Steel	Lined with 1/2" Lumnite cement, outside coated with epoxy-phenolic	Lined with 1/2" Lumnite cement, outside uncoated

e. Interior boundaries between evaporator areas with more than 2 or 3 psi differential pressure between them must be lined on the high-pressure side if lining is to be used on the low-pressure side. For example, the ceilings in the MSF stages are polypropylene lined to protect the concrete in the vapor phase. The stage ceiling also serves as the floor for the effect directly above, which operates at a higher pressure. To prevent water from seeping through the concrete and separating the polypropylene liner from the stage ceiling, a polypropylene liner is also required on the effect floor.

Polypropylene sheet has been specified as a protective covering for concrete and steel in many portions of both VTE and MSF plants. It is reported to have withstood extended life tests in an unloaded condition while submerged in 265 F brine. Since gradual creep under continued stress is a common mode of failure for thermoplastics, further tests under loaded conditions will be necessary before extensive use of polypropylene in this environment. For the purposes of this study, sufficient money has been provided to install polypropylene sheet in the plant areas indicated. It is assumed that by the time such a plant is built, continuing tests will have verified the suitability of polypropylene or some other more appropriate material of comparable cost. The reference design specified the use of all-polypropylene stage walls for Stages 34 through 50 in the VTE plant. Because of the creep characteristics of polypropylene at elevated temperatures, there is serious doubt as to its suitability as structural members. Fluor has therefore substituted concrete for the polypropylene walls, and has allowed for this in the cost estimate.

9.1 EQUIPMENT LIST FOR 250 MGD VERTICAL TUBE EVAPORATOR (VTE) PLANT

Total No. Required In Plant

Evaporators and Exchangers

4 Evaporator Vessels (buildings). (Each building contains one train)

Concrete with steel liner and steel roof sections.
Trapezoidal shape : 374' long; 64' and 118' wide at hot and cold ends, respectively; 33' to 35' high

Each evaporator vessel contains several integral parts, separately described below. Quantities shown are for a complete 250 MGD plant, unless otherwise indicated.

a. Vertical Tube Evaporator Effects : 60 total (15 each train)

Vertical tube heat transfer area : 6,113,110 ft.^{2} total
Number of vertical tubes : 611,311 total
Tube description : 3" o.d. double-fluted, 0.049" developed wall thickness, 10' long, CDA Alloy 194 (98.68% Cu, 2.3% Fe, 0.02% Phosphorous)

b. Flash Evaporator stages : 200 total (50 each train)

Horizontal tube data:
Feedheater (stages 1 - 50) : 3,996,937 ft.^{2} total area
Final brine heater stage : 236,260 ft.^{2} total area
Number of tube bundles : 8 total (2 each train)
Number of tubes : 58,017 total (7252 each bundle)
Tube size : 3/4" o.d. x 0.035" wall x 371.6' long
Tube surface : Smooth (no extended surfaces)
Tube material : 90-10 Cu-Ni alloy

9.1 EQUIPMENT LIST FOR 250 MGD VTE PLANT (Contd.)

Total No.
Required
In Plant

Evaporators and Exchangers (Cont'd.)

c. Heat Rejection Tubes

Tube area : 643,081 $ft.^2$ total (160,770 $ft.^2$ per train)
Number of tubes : 27,716 total (6929 per train)
Tube size : 1" o.d. x 0.049" wall x 88.6' long
Tube surface : Smooth
Tube material : 90-10 Cu-Ni

d. Deaerators

Description : Two-section flash co-current deaerators with counter-current stripping and double-packed bed. No external steam used

Number of spray nozzles : 580 total (145 per train)
Spray nozzle size : 500 gpm each
Spray nozzle material : Saran

e. Vapor Dampers in Deaerators

Hot side (total quantities) : 2,240 ft^2 of 3-3/4" FN-90 MASPAC or equal (top layer)
: 2,240 ft^2 of 3-3/4" FN-90 MASPAC, or equal (bottom layer)

Cold side : 5,000 ft^2 of 3-3/4" FN-90 MASPAC or equal (top layer)
: 5,000 ft^2 of 2" FN-200 MASPAC or equal (bottom layer)

9.1 EQUIPMENT LIST FOR 250 MGD VTE PLANT (Cont'd.)

Evaporators and Exchangers (Cont'd.)

Total No.
Required
In Plant

f. Entrainment Separators

Vertical hook-and-vane type for horizontal gas flow. Installed along one side of each vertical and horizontal tube bundle.

g. Flashing Brine Trays : 4 (1 per train)

h. Product Water Trays : 8 (2 per train)

Pumps and Drivers

Total No. Required In Plant	Service	GPM Each	Head	RPM	Motor HP	Materials			Pump Type
						Case	Impeller	Shaft	
4	Sea Water Intake	115,000	66'	327	2250	D-2 Ni-resist	CF8M SS	316SS	Vertical dry-pit centrifugal, synchronous motor.
4	Booster Pump	27,200	12.2'	400	100	D-2 Ni-resist	316SS	316SS	Volute, vert. shaft, bottom suction centrifugal, induction motor.
4	Make-up Pump	72,500	162'	400	3500	D-2 Ni-resist	316SS	316SS	Mixed flow, multistage, wet-pit vertical, can-type centrifugal, synchronous motor

9.1 EQUIPMENT LIST FOR 250 MGD VTE PLANT (Cont'd.)

Pumps and Drivers (Cont'd.)

Total No. Required In Plant	Service	GPM Each	Head	RPM	Motor HP	Materials Case	Materials Impeller	Shaft	Pump Type
4	Blowdown Pump	27,900	40'	600	350	D-2 Ni-resist	316SS	316SS	Mixed flow, single-stage, vertical wet-pit can-type centrifugal, induction motor
4	Product Water	44,200	109'	514	1500	D-2 Ni-resist	316SS	316SS	Mixed flow, multistage wet-pit, can-type vertical centrifugal, synchronous motor
5*	No. I Effect Pump	35,000	50'	514	500	D-2 Ni-resist	D-2 316SS	Monel	Mixed flow, single-stage, vertical, wet-pit centrifugal pumps used for all effects. All motors are induction. All shafts on effect pumps employ seals to prevent air in-leakage.
5*	No. II Effect Pump	27,500	50'	600	400	Ni-resist	316SS	Monel	
34*	Nos. III through X Effect Pump	22,400	50'	720	350	Ni-resist	316SS	Monel	
21*	Nos. XI through XV Effect Pump	22,400	50'	720	350	Ni-resist	316SS	316SS	
2	Sump Pump	3,200	45'	860	50	Ni-resist	CF8M	316SS	
	*Includes warehouse spare or spares.								
2**	Chlorine Injection Pump	5,200	65 psig	860	300	Monel			Horizontal double-suction centrifugal, induction motor
8**	Acid Injection Pump	5.1	25 psig	1750	3/4	Steel			Horizontal, centrifugal "canned-pump type", induction motor.
2**	Caustic Injection Pump	2.2	15 psig	1750	3/4	Steel			- ditto -
2**	Anti-foam Injection Pump	2.0	15 psig	1750	3/4	Steel			- ditto -
2**	Ferrous Sulfate Injection Pump	3.4	25 psig	1750	3/4	Steel			- ditto -
2**	Sodium Sulfite Pump	4.0	25 psig	1750	3/4	Steel			- ditto -

**Includes installed spares.

9.1 EQUIPMENT LIST FOR 250 MGD VTE PLANT (Cont'd.)

Air Compressors and Drivers

(1/3 chargeable to water plant - 2/3 to power plant)

Total No. Required In Plant		
2**	Non-lubricated air compressors	: 2000 SCFM @ 100 psi; 400 HP
2**	Lubricated air compressors	: 2000 SCFM @ 100 psi; 400 HP

Ejector System, Including Condensers

4	Ejector No. 1, first stage, 20" suction, Hastelloy C construction
4	Ejector No. 2, second stage, 12" suction, Hastelloy C construction
4	Barometric inter-condenser No. 1 on suction side of Ejector No. 2, 316 SS
4	Ejector No. 3, third stage, 8" suction, Hastelloy C construction, discharge to atmosphere.
4	Barometric inter-condenser No. 2 on suction side of Ejector No. 3, 316SS
Note:	Each of the above 3-stage Ejector sets evacuates the deaerator on one train.
4	High-pressure vent condenser, for vents from stages at above-atmospheric pressure; 110 ft^2 area each condenser; tube material 70-30 Cu-Ni; tube sheet material 70-30 Cu-Ni clad steel.

** Includes installed spares.

9.1 EQUIPMENT LIST FOR 250 MGD VTE PLANT (Cont'd.)

Total No. Required in Plant		Tanks and Sumps		
1	Sulfuric Acid Tank	Steel, Cone Roof	56' Diameter X 27' Deep	500,000 gals.
1	Sodium Sulfite Tank	Steel, Cone Roof	35' Diameter X 11' Deep	79,000 gals.
1	Ferrous Sulfate Tank	Steel, Cone Roof	30' Diameter X 13' Deep	66,000 gals.
1	Caustic Tank	Steel, Cone Roof	30' Diameter X 10' Deep	50,000 gals.
1	Anti-foaming Solution Tank with Mixer	Steel, Horizontal	9' Diameter X 21' Long	10,000 gals.
2	Chlorine Tank Cars, with automatic change-over equipment			55-ton capacity
4	Sumps, Make-up Pump		14' Diameter X 48' Deep	
4	Sumps, Blowdown Pump		8' Diameter X 45' Deep	
4	Sumps, Product Water		12' Diameter X 48' Deep	
4	Sumps, Effect Pump No. I		11' Diameter X 37' Deep	
4	Sumps, Effect Pump No. II		9' Diameter X 37' Deep	
28	Sumps, Effect Pumps No. III to No. IX, incl.		8' Diameter X 37' Deep	
24	Sumps, Effect Pumps No. X to No. XV, incl.		8' Diameter X 45' Deep	

9.1 EQUIPMENT LIST FOR 250 MGD VTE PLANT (Cont'd.)

Total No. Required In Plant		Electrical Components	
4	Transformers	13,800 V. to 2400 V.	10,000 KVA
2	Transformers	13,800 V. to 480 V.	750 KVA
8	Transformers	13,800 V. to 480 V.	3,000 KVA
8	Transformers	480 V. to 208/120 V.	50 KVA
4	Transformers	480 V. to 208/120 V.	25 KVA
4	2.4 KV Switchgear	2400 V., 350 MVA	Outdoor, weatherproof
8	480 V. Switchgear	480 V., 75,000 A.	Outdoor, weatherproof
8	Lighting Panels	208/120 V.	Outdoor, weatherproof
5	Circuit Breakers	13,800 V., 1000 MVA	Drawout type, air
13	Control Batteries w/chargers	125 V., 100 Amp-Hrs.	

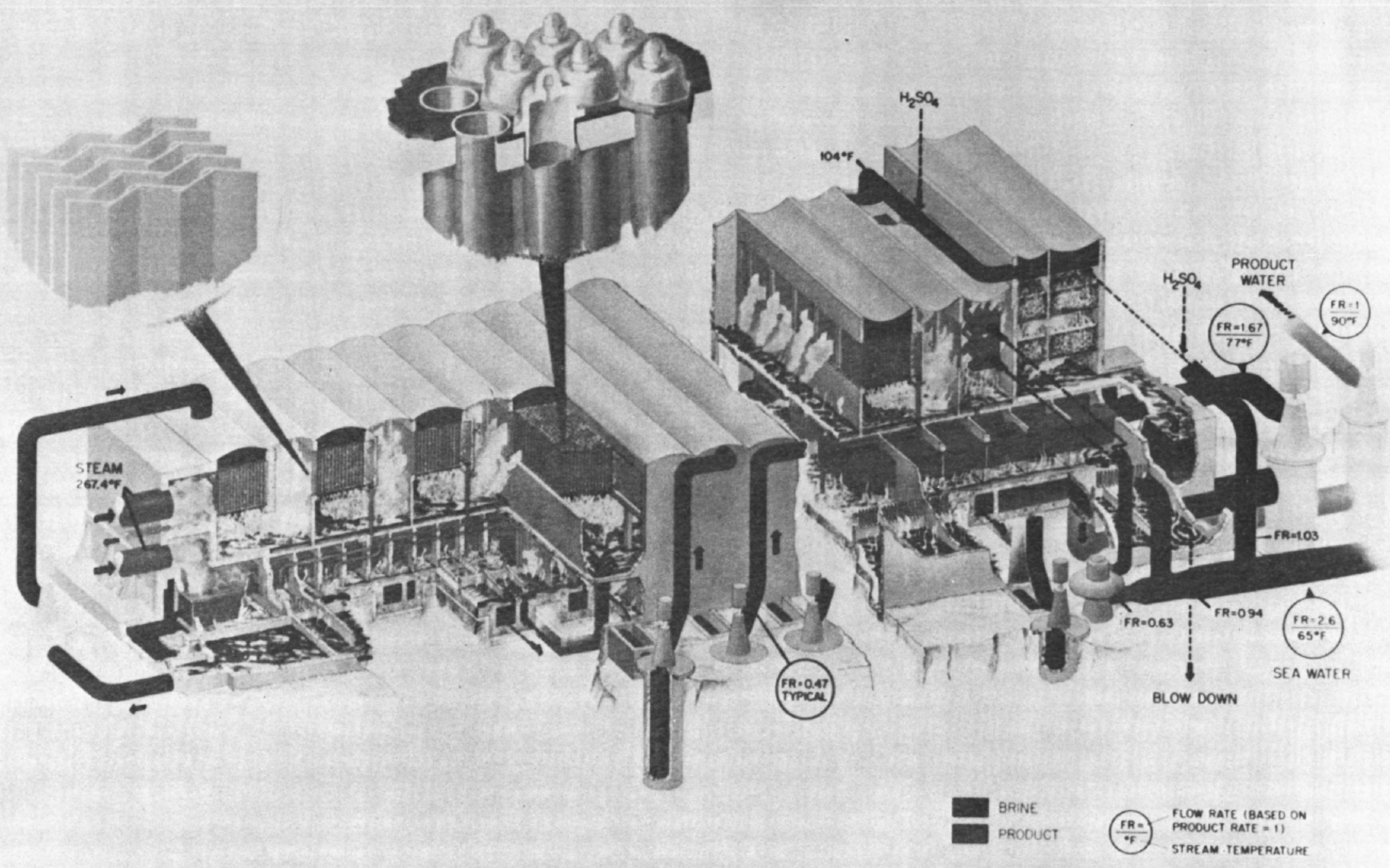
9.1 EQUIPMENT LIST FOR 250 MGD VTE PLANT (Cont'd.)

Total No. Required In Plant	Miscellaneous		
2	Chlorine Vaporizers	Total Duty:	4600 lb./hr. of chlorine vaporized (2300 lb./hr., each vaporizer)
2	Chlorine Gas Jet Eductors	Total Duty:	450 SCFM gas at 11" Hg vacuum. (225 SCFM each eductor) Mat'l. of Construction: Titanium
4	Traveling Bar Racks, with drive		
4	Traveling Screens, with drive		
1	Crane, mounted over 4 sea water pumps. (All other equipment is assumed to be serviced by mobile cranes.)		

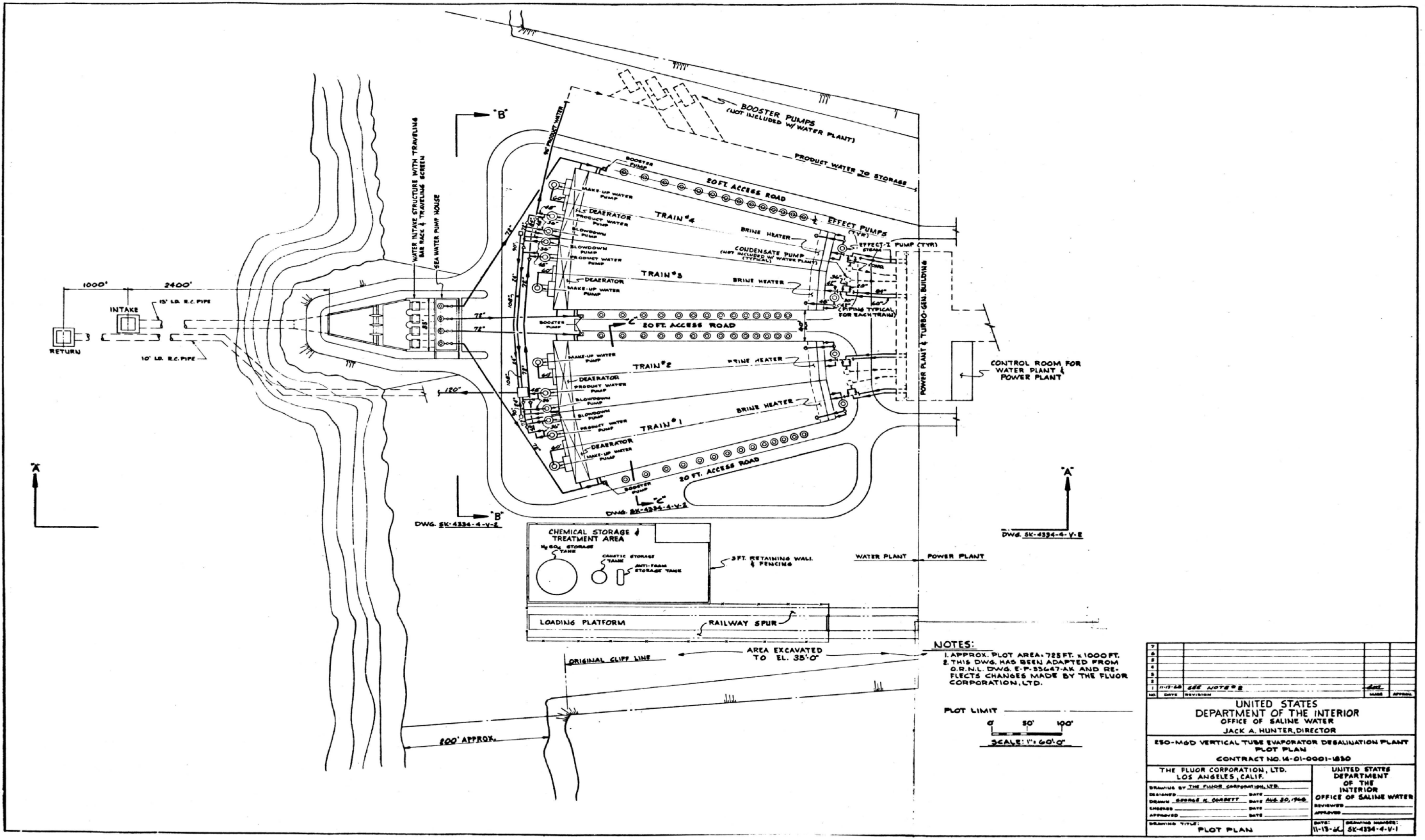
9.0 - 250 MGD VTE PLANT EQUIPMENT LIST AND DRAWING INDEX

9.2 Drawing Index

Drawing Number	Title
ORNL-A	Cutaway Drawing of VTE Plant
SK-4334-4-V-1	Plot Plan
V-2	Plot Plan Elevations and Sections
V-3	Process Flow Diagram
V-4	P&I Flow Diagrams - Chemical Systems
V-5	One Train-Plan & Elevation
V-6	Typical Effect - Plan & Section
V-7	Low Pressure End - Plan & Sections
V-8	Cross Section & Tube Bundle Detail
V-9	Longitudinal Section
V-10	Electrical One-Line Diagram



Drawing ORNL-A



NOTES:
1. APPROX. PLOT AREA: 725 FT. x 1000 FT.
2. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-P-33647-AK AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

NO.	DATE	REVISION	MADE	APPROV.
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1	11-13-68	SEE NOTE # 2		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

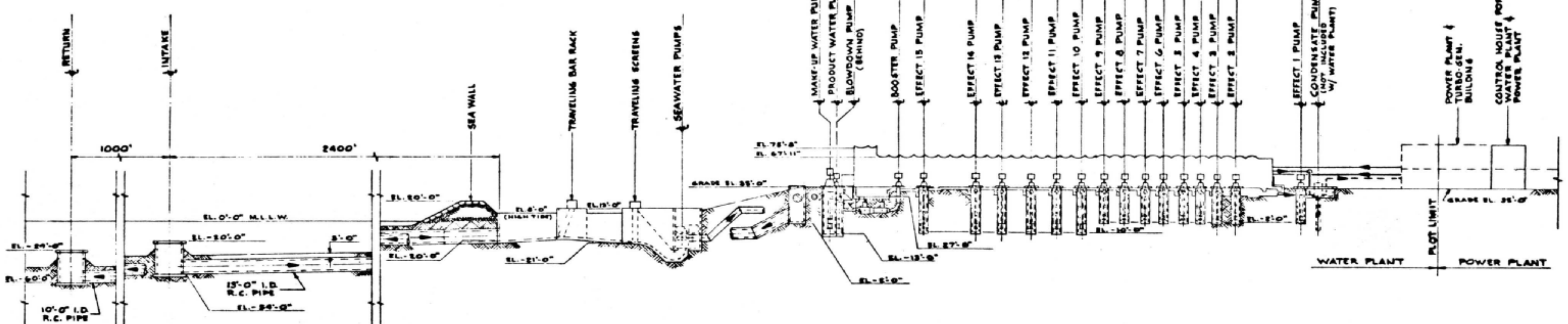
250-MGD VERTICAL TUBE EVAPORATOR DESALINATION PLANT
PLOT PLAN
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

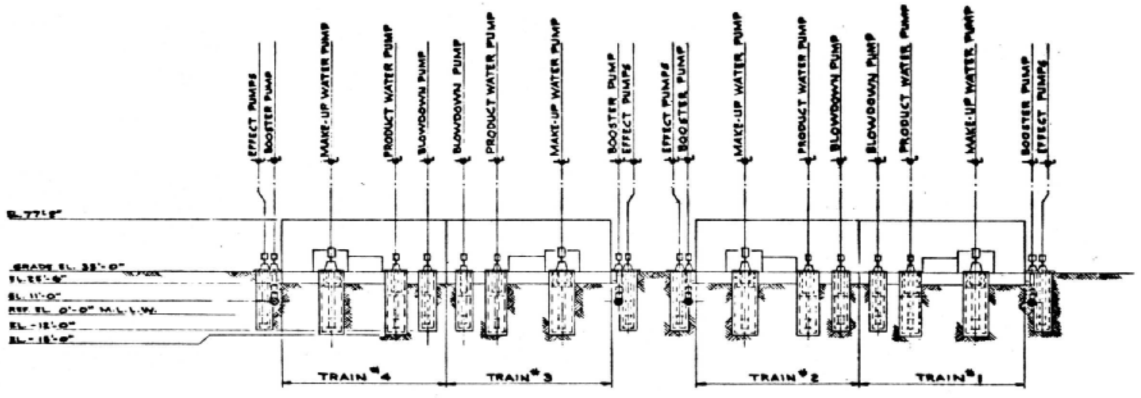
DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ______ DATE ______
DRAWN GEORGE K. CORBETT DATE AUG. 30, 1968
CHECKED ______ DATE ______
APPROVED ______ DATE ______

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

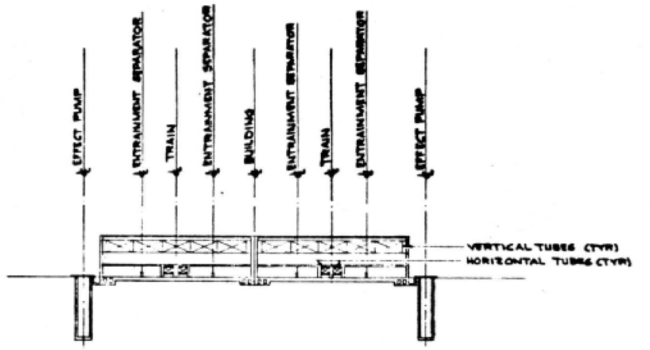
DRAWING TITLE: PLOT PLAN
DATE: 11-13-68
DRAWING NUMBER: SK-4334-4-V-1



ELEVATION "A"-"A"



ELEVATION "B"-"B"



SECTION "C"-"C"

NCTES:

1. SEE PLOT PLAN - DWG. SK-4334-4-V-1
2. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-6-33647-AD AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

0' 30' 100'
SCALE: 1" = 60'-0"

NO.	DATE	REVISION	MADE	APPROV.
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1	11-14-68	SEE NOTE #2		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

250-MGD VERTICAL TUBE EVAPORATOR DESALINATION PLANT
PLOT PLAN ELEVATIONS & SECTIONS
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ______ DATE ______
DRAWN GEORGE K. CORBETT, JR. DATE SEPTEMBER 20, 1968
CHECKED ______ DATE ______
APPROVED ______ DATE ______

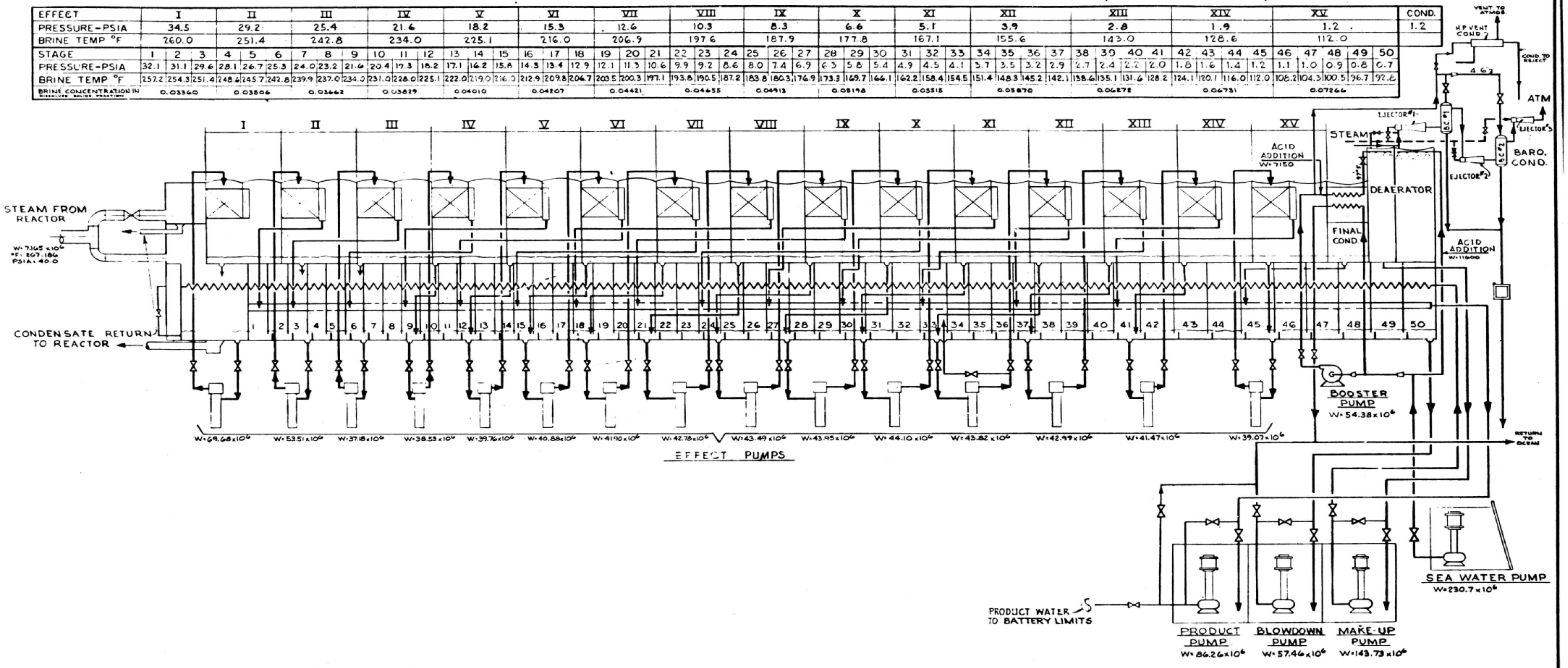
UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

DRAWING TITLE: PLOT PLAN ELEVATIONS & SECTIONS
DATE: 11-14-68
DRAWING NUMBER: SK-4334-4-V-2

EFFECT	I			II			III			IV			V			VI		
PRESSURE-PSIA	34.5			29.2			25.4			21.6			18.2			15.3		
BRINE TEMP °F	260.0			251.4			242.8			234.0			225.1			216.0		
STAGE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
PRESSURE-PSIA	32.1	31.1	29.6	28.1	26.7	25.3	24.0	23.2	21.6	20.4	19.3	18.2	17.1	16.2	15.8	14.3	13.4	12.9
BRINE TEMP °F	257.2	254.3	251.4	248.6	245.7	242.8	239.9	237.0	234.0	231.0	228.0	225.1	222.0	219.0	216.0	212.9	209.8	206.7
BRINE CONCENTRATION IN DISSOLVED SOLIDS FRACTION	0.03360			0.03506			0.03662			0.03829			0.04010			0.04207		

EFFECT	VII			VIII			IX			X			XI			XII			
PRESSURE-PSIA	12.6			10.3			8.3			6.6			5.1			3.9			
BRINE TEMP °F	206.9			197.6			187.9			177.8			167.1			155.6			
STAGE	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
PRESSURE-PSIA	12.1	11.3	10.6	9.9	9.2	8.6	8.0	7.4	6.9	6.3	5.8	5.4	4.9	4.5	4.1	3.7	3.5	3.2	2.9
BRINE TEMP °F	203.5	200.3	197.1	193.8	190.5	187.2	183.8	180.3	176.9	173.3	169.7	166.1	162.2	158.4	154.5	151.4	148.3	145.2	142.1
BRINE CONCENTRATION IN DISSOLVED SOLIDS FRACTION	0.04421			0.04655			0.04913			0.05198			0.05515			0.05870			

EFFECT	XIII				XIV				XV					COND.
PRESSURE-PSIA	2.8				1.9				1.2					1.2
BRINE TEMP °F	143.0				128.6				112.0					
STAGE	38	39	40	41	42	43	44	45	46	47	48	49	50	
PRESSURE-PSIA	2.7	2.4	2.2	2.0	1.8	1.6	1.4	1.2	1.1	1.0	0.9	0.8	0.7	
BRINE TEMP °F	138.6	135.1	131.6	128.2	124.1	120.1	116.0	112.0	108.2	104.3	100.5	96.7	92.8	
BRINE CONCENTRATION IN DISSOLVED SOLIDS FRACTION	0.06272				0.06731				0.07266					



NOTES:

1. ALL FLOW RATES ARE NORMAL RATES FOR FOUR TRAINS COMBINED, AND NOT DESIGN CAPACITIES.
2. "W" IS lbs./hr.
3. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-P-33647-AL AND REFLECTS CHANGES BY THE FLUOR CORPORATION, LTD.

NO.	DATE	REVISION	MADE	APPROV.
7				
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1	11-11-68	SEE NOTE # 3		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

250-MGD VERTICAL TUBE EVAPORATOR DESALINATION PLANT
PROCESS FLOW DIAGRAM
CONTRACT NO. 14-01-0001-1830

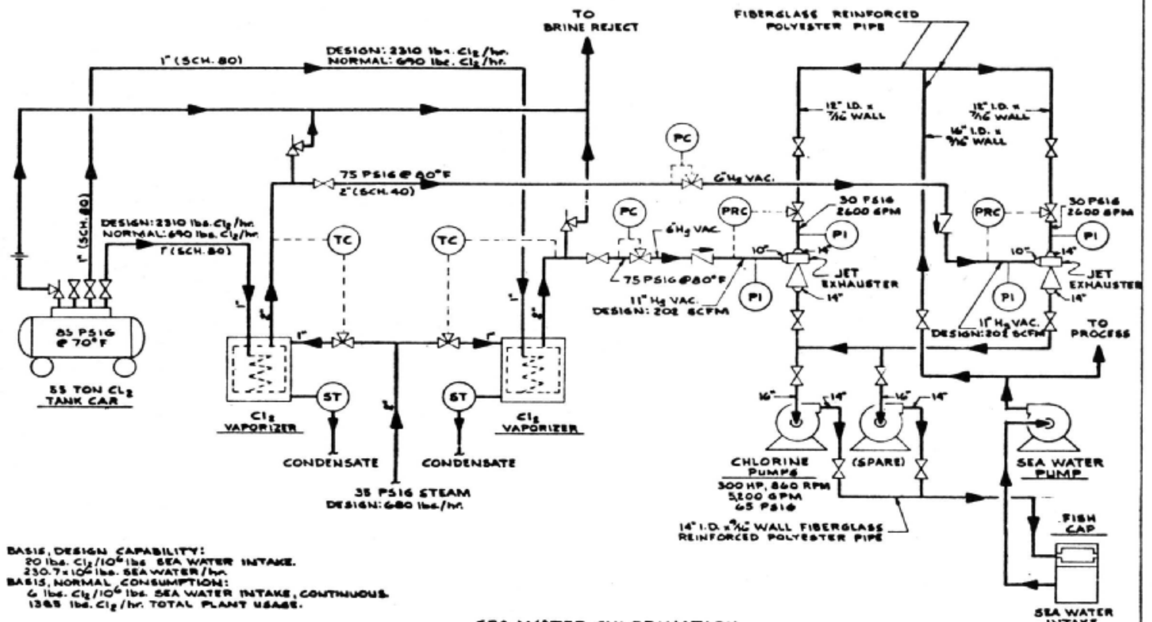
THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED
DRAWN GEORGE K. CORBETT, JR.
CHECKED
APPROVED

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED
APPROVED

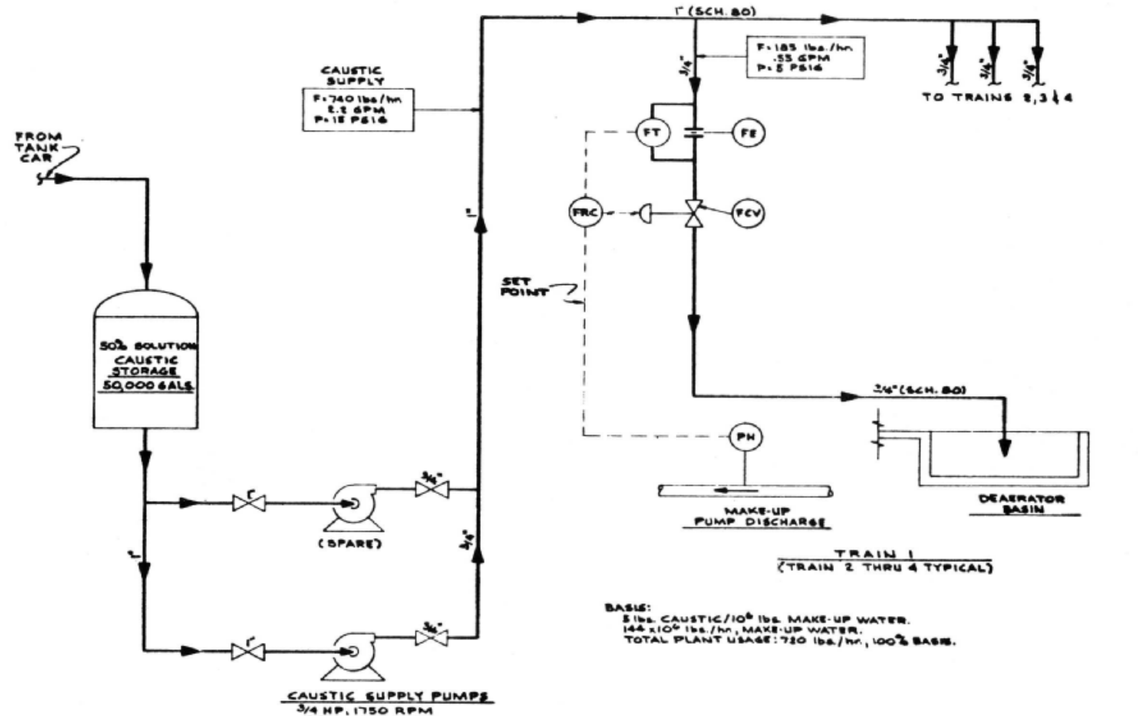
DRAWING TITLE:
PROCESS FLOW DIAGRAM

DATE 11-11-68
DRAWING NUMBER: SK-4334-5-V-3



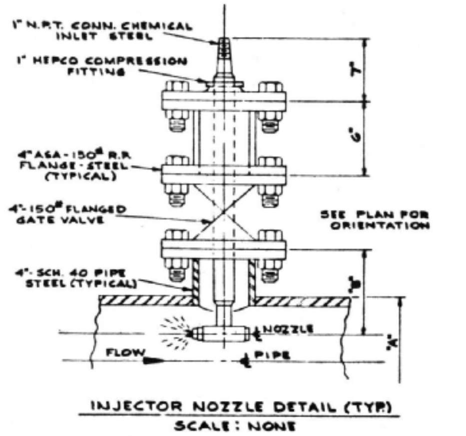
BASIS, DESIGN CAPABILITY:
20 lbs. $Cl_2/10^6$ lbs. SEA WATER INTAKE.
230.7×10^6 lbs. SEA WATER/hr.
BASIS, NORMAL CONSUMPTION:
6 lbs. $Cl_2/10^6$ lbs. SEA WATER INTAKE, CONTINUOUS.
1385 lbs. Cl_2/hr. TOTAL PLANT USAGE.

SEA WATER CHLORINATION

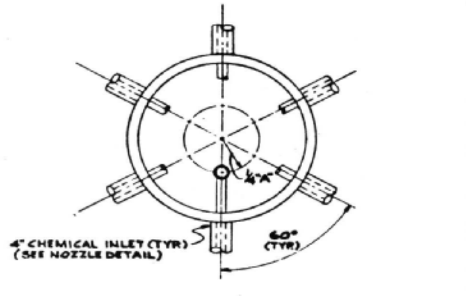


BASIS:
5 lbs. CAUSTIC/10^6 lbs. MAKE-UP WATER.
144×10^6 lbs./hr. MAKE-UP WATER.
TOTAL PLANT USAGE: 720 lbs./hr., 100% BASIS.

CAUSTIC ADDITION



INJECTOR NOZZLE DETAIL (TYP.)
SCALE: NONE



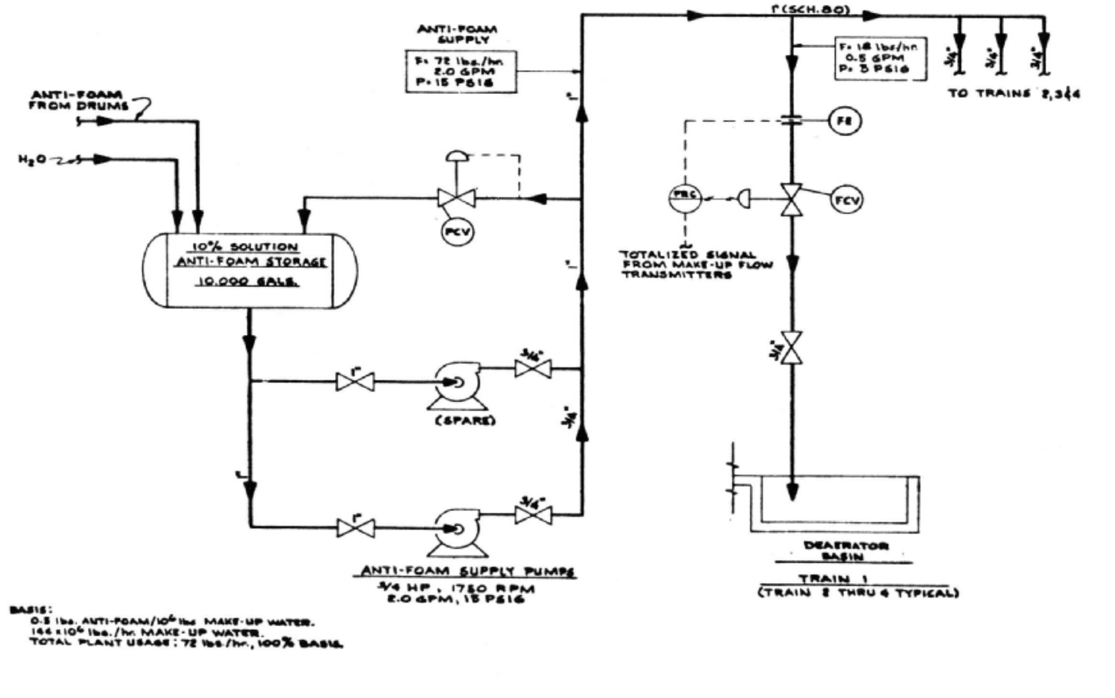
SECTION - CHEMICAL ADDITION INJECTORS
SCALE: NONE

SERVICE	NOMINAL PIPE "A"	DIMENSION "B"	NOZZLE MATERIAL
ACID	48"	28"	HASTELLOY B
ACID	36"	22"	HASTELLOY B

NOTE:
INJECTOR SHOWN IS TYPICAL. THIS UNIT IS COMMERCIALLY AVAILABLE FROM GENERAL REGULATOR CORP. MARKETED AS A TYPE 340-MA "MECHANICAL ATOMIZING DESUPER HEATER."

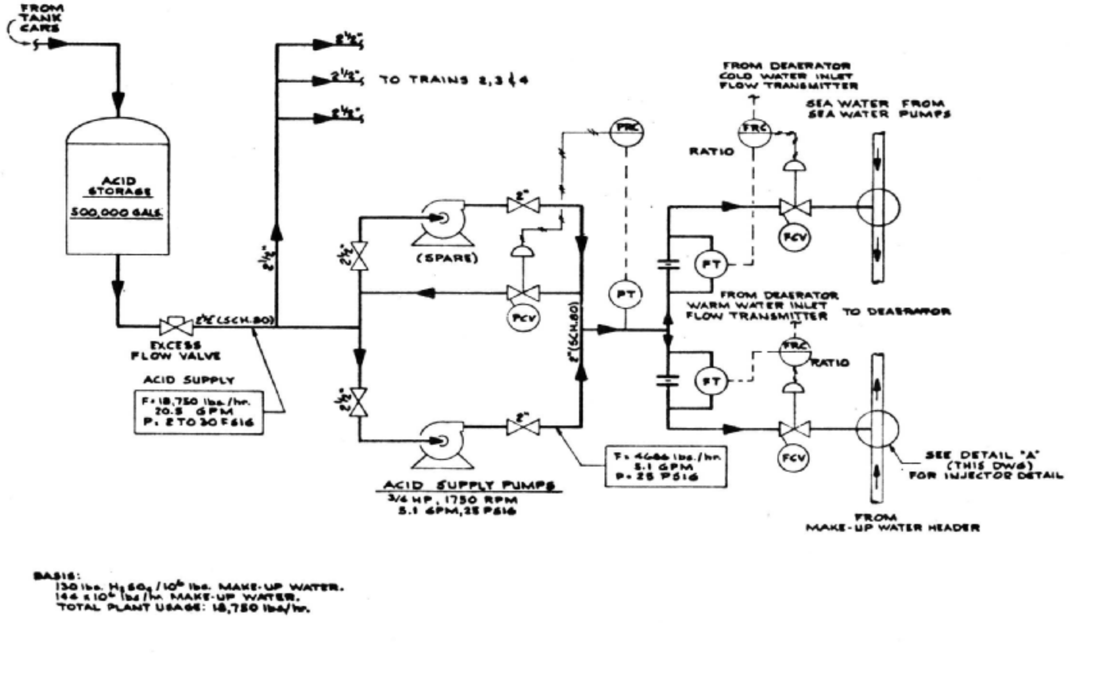
DETAIL "A"

NOTES:
1. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG'S. C-P-34787-H, J, K, L & M AND REFLECTS CHANGES MADE BY THE FLUOR CORP., LTD.



BASIS:
0.5 lbs. ANTI-FOAM/10^6 lbs. MAKE-UP WATER.
144×10^6 lbs./hr. MAKE-UP WATER.
TOTAL PLANT USAGE: 72 lbs./hr., 100% BASIS.

ANTI-FOAM ADDITION



BASIS:
130 lbs. $H_2SO_4/10^6$ lbs. MAKE-UP WATER.
144×10^6 lbs/hr. MAKE-UP WATER.
TOTAL PLANT USAGE: 18,750 lbs/hr.

SULFURIC ACID ADDITION

NO.	DATE	REVISION	MADE	APPROV.
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1	11-12-68	SEE NOTE # 1	GKC	

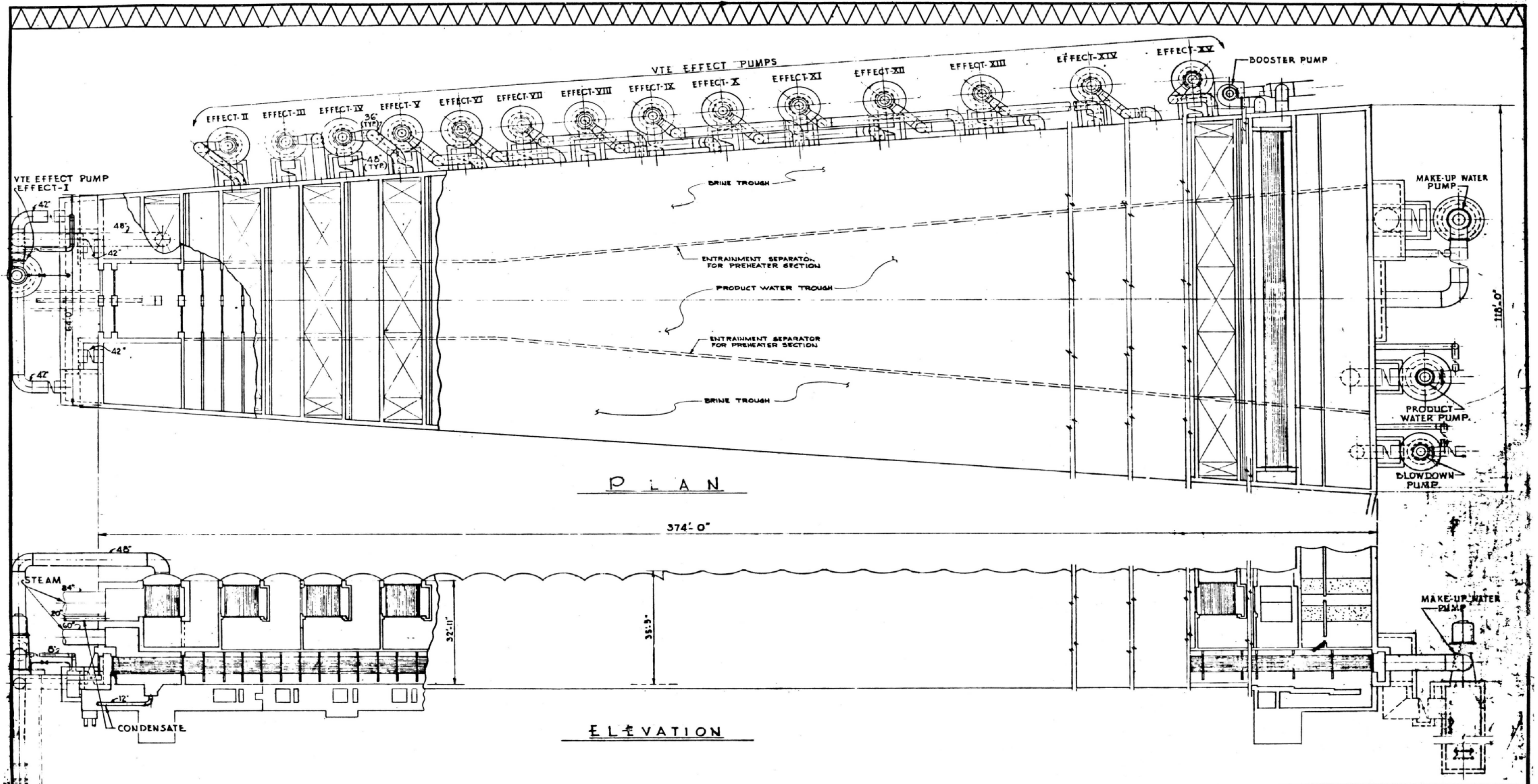
UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

250-MGD VERTICAL TUBE EVAPORATOR DESALINATION PLANT
P & I FLOW DIAGRAMS - CHEMICAL SYSTEMS
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.
DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ______ DATE ______
DRAWN GEORGE K. CORBETT, JR. DATE OCTOBER 28, 1968
CHECKED ______ DATE ______
APPROVED ______ DATE ______

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

DRAWING TITLE: CHEMICAL FLOW DIAGRAMS
DATE: 11-12-68
DRAWING NUMBER: SK-4334-4-V-4



NOTES:
1. SEE PLOT PLAN-DWG. SK-4334-4-V-1
2. SEE PLOT ELEVATION-DWG. SK-4334-4-V-2
3. SEE LONGITUDINAL SECTION-DWG. SK-4334-5-V-8
4. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-P-33647-AJ
AND REFLECTS CHANGES MADE BY THE FLUOR CORP., LTD.

0' 5' 10' 20'
SCALE: 3/32" = 1'-0"

NO.	DATE	REVISION	MADE	APPROV.
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1	11-7-68	SEE NOTE # 4		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

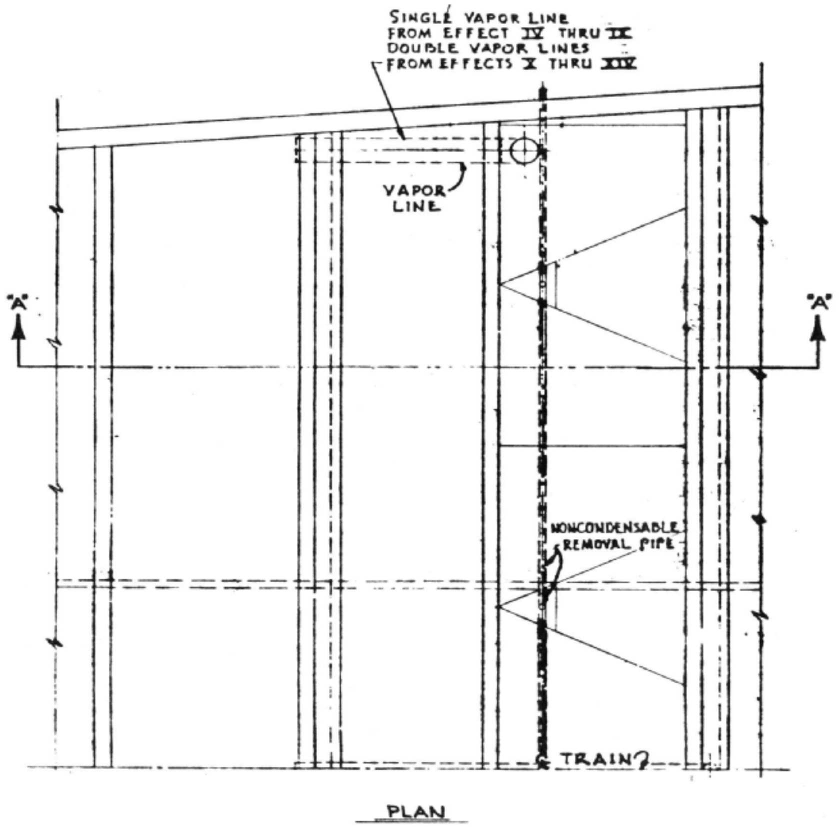
250-MGD VERTICAL TUBE EVAPORATOR DESALINATION PLANT
ONE TRAIN-PLAN & ELEVATION
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD
LOS ANGELES, CALIF.

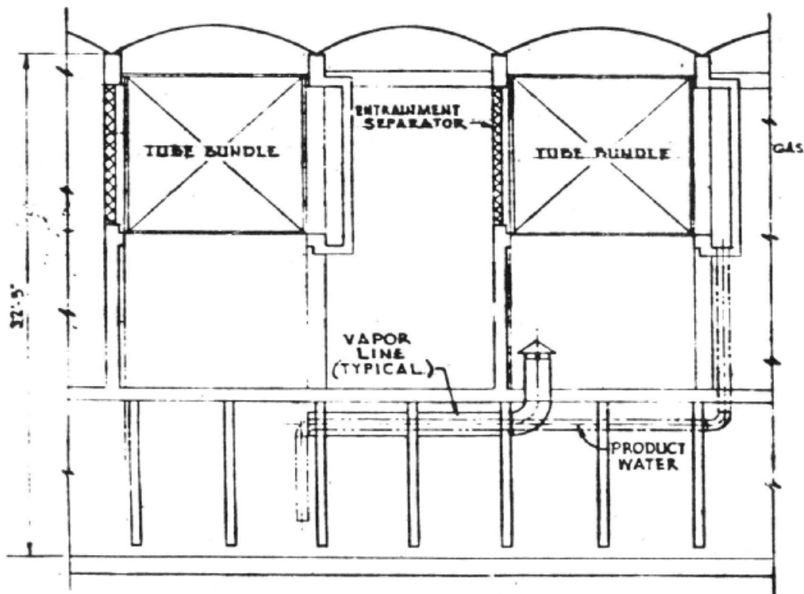
DRAWING BY THE FLUOR CORPORATION, LTD
DESIGNED ____ DATE ____
DRAWN GEORGE F CORBETT JR DATE
CHECKED ____ DATE ____
APPROVED ____ DATE ____

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ____
APPROVED ____

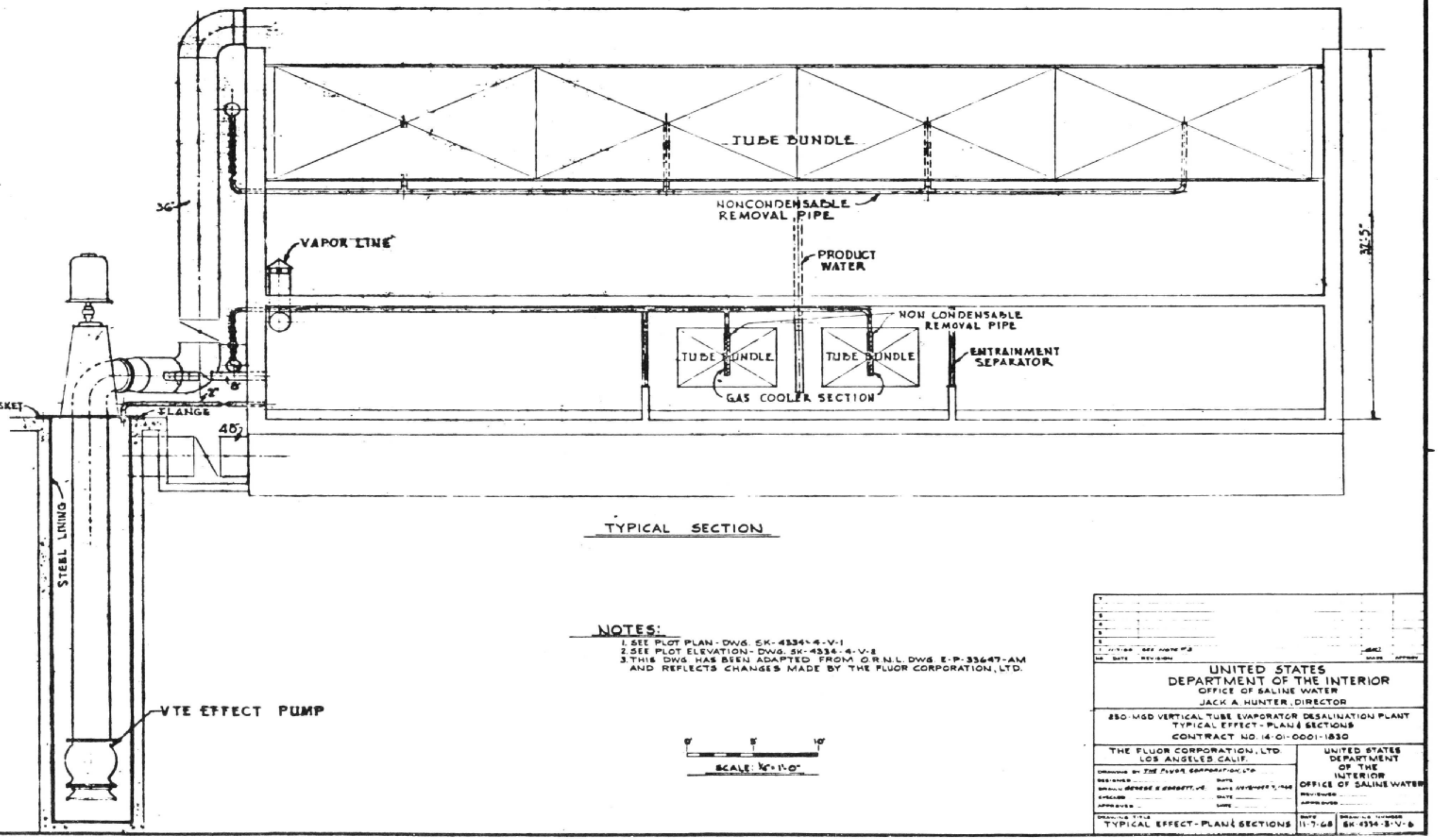
DRAWING TITLE: ONE TRAIN-PLAN & ELEVATION
DATE: 11-7-68
DRAWING NUMBER: SK-4334-5-V-8



PLAN



SECTION "A"-"A"



TYPICAL SECTION

NOTES:

1. SEE PLOT PLAN - DWG. SK-4334-4-V-1
2. SEE PLOT ELEVATION - DWG. SK-4334-4-V-2
3. THIS DWG HAS BEEN ADAPTED FROM O.R.N.L. DWG E-P-33647-AM AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

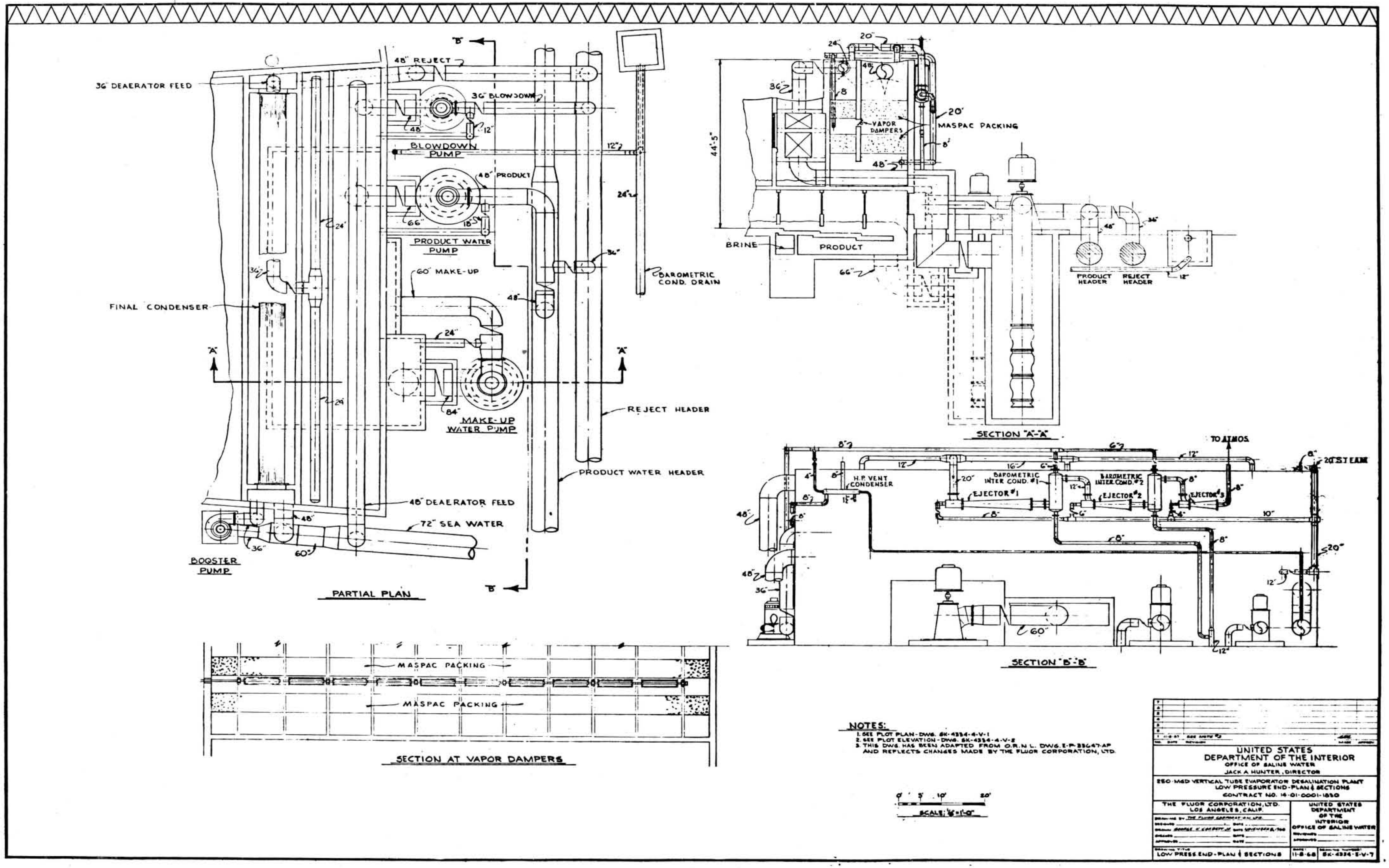
UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

250-MGD VERTICAL TUBE EVAPORATOR DESALINATION PLANT
TYPICAL EFFECT - PLAN & SECTIONS
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES CALIF.

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER

DRAWING TITLE	DATE	DRAWING NUMBER
TYPICAL EFFECT - PLAN & SECTIONS	11-7-68	SK-4334-3-V-6



NOTES:

1. SEE PLOT PLAN - DWG. SK-4334-4-V-1
2. SEE PLOT ELEVATION - DWG. SK-4334-4-V-2
3. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-P-33647-AP AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

NO.	DATE	REVISION	MADE	APPROV.
7				
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1	11-8-67	SEE NOTE #3		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A HUNTER, DIRECTOR

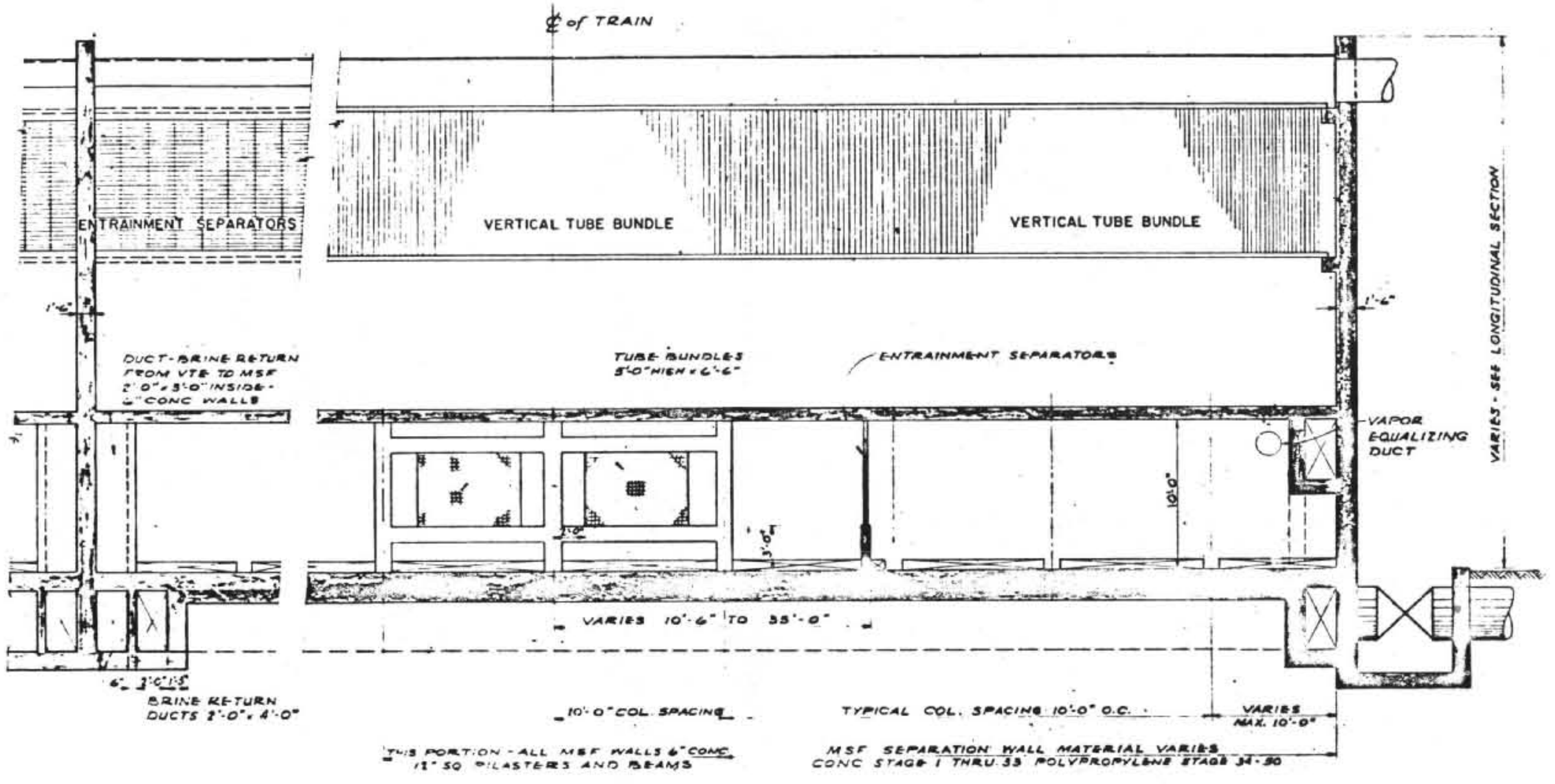
250-MGD VERTICAL TUBE EVAPORATOR DESALINATION PLANT
LOW PRESSURE END-PLAN & SECTIONS
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ______ DATE ______
DRAWN GEORGE K. CORBETT JR DATE NOVEMBER 8, 1968
CHECKED ______ DATE ______
APPROVED ______ DATE ______

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

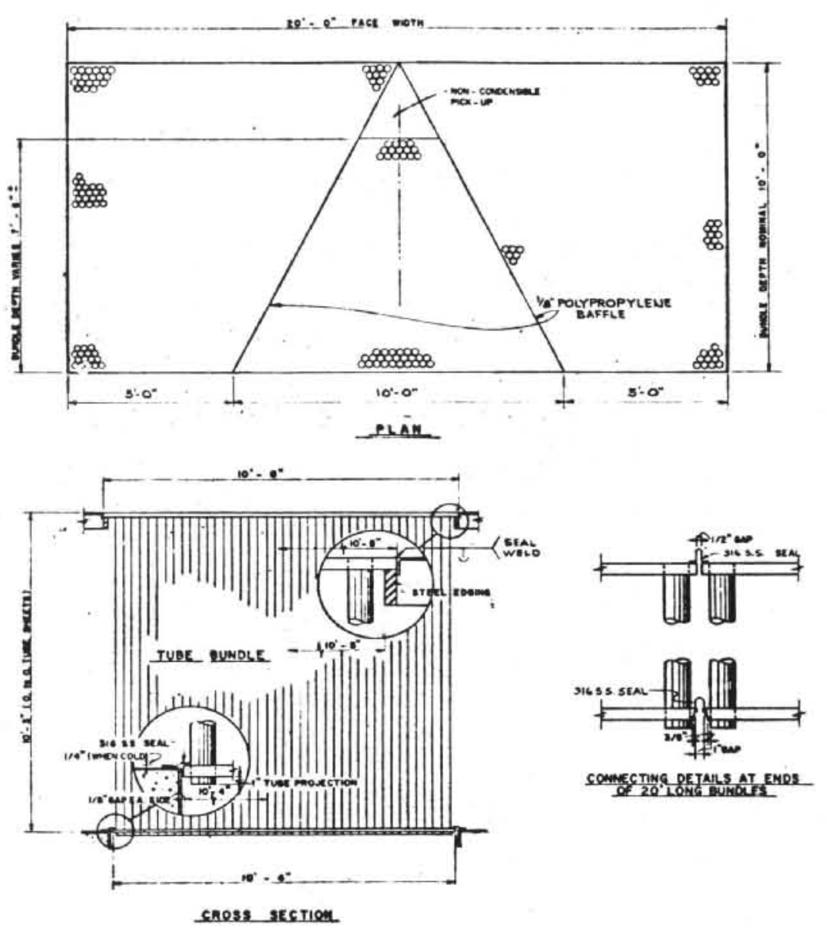
DRAWING TITLE: LOW PRESS. END-PLAN & SECTIONS
DATE: 11-8-68
DRAWING NUMBER: SK-4334-5-V-7



TYPICAL CROSS SECTION

SCALE 1/4" = 1'-0"

0' 5 10'



DETAILS — TYPICAL TUBE BUNDLE

SCALE: 1/2" = 1'-0"

0' 1 5' 10'

NOTES:

1. SEE LONGITUDINAL SECTION - DWG SK-4334-5-V-8
2. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-5-33647-AC AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

NO	DATE	REVISION	MADE	APPROV.
1	11-6-68	SEE NOTE #2		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

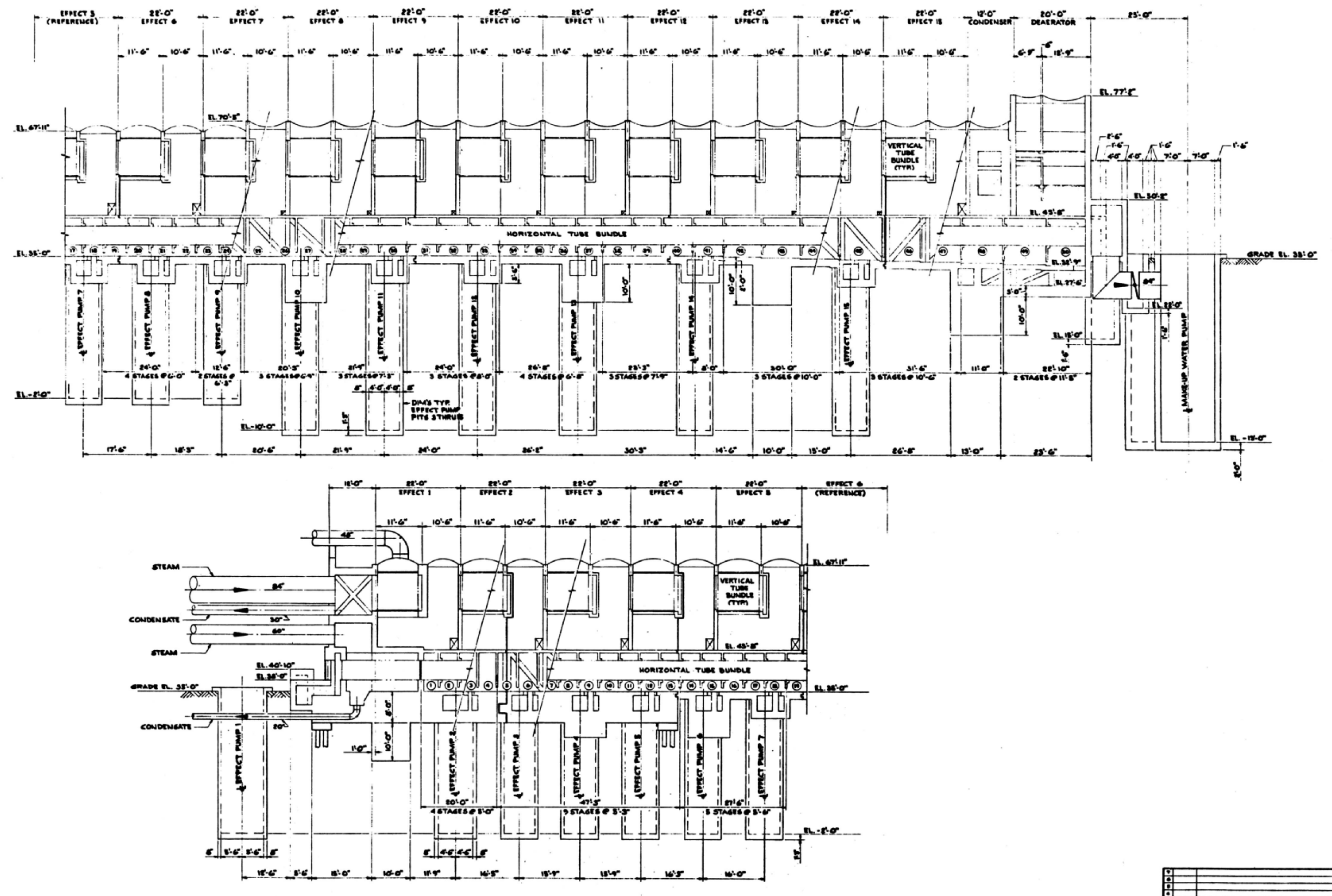
250-MGD VERTICAL TUBE EVAPORATOR DESALINATION PLANT
TYPICAL CROSS SECTION & TUBE BUNDLE DETAILS
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ____ DATE ____
DRAWN GEORGE K. CORBETT, JR. DATE NOVEMBER 6, 1968
CHECKED ____ DATE ____
APPROVED ____ DATE ____

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ____
APPROVED ____

DRAWING TITLE: CROSS SECTION & TUBE BUNDLE DETAILS
DATE: 11-6-68
DRAWING NUMBER: SK-4334-5-V-8



NOTES:
1. SEE PLOT PLAN - DWG. SK-4334-4-V-1
2. SEE PLOT ELEVATION - DWG. SK-4334-4-V-2
3. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-5-33647-AB AND REFLECTS STRUCTURAL CHANGES MADE BY THE FLUOR CORPORATION, LTD.

0' 10'
SCALE: 1"=10'-0"

NO.	DATE	REVISION	MADE	APPROV.
7				
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1	11-8-66	SEE NOTE #3		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

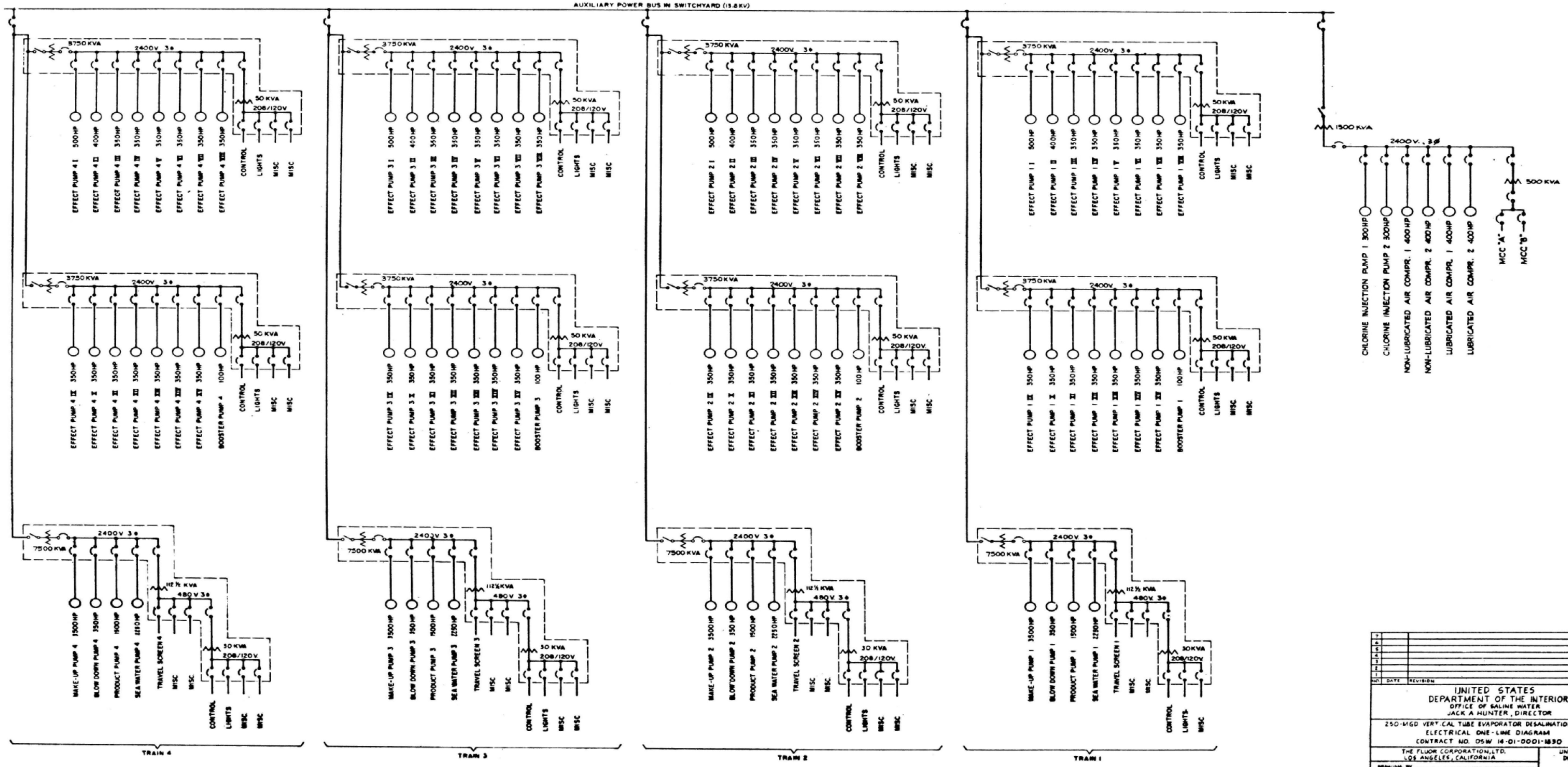
250-MGD VERTICAL TUBE EVAPORATOR DESALINATION PLANT
LONGITUDINAL SECTION
CONTRACT NO. 14-01-0001-1030

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ______ DATE ______
DRAWN GEORGE H. GARRETT JR. DATE NOVEMBER 1966
CHECKED ______ DATE ______
APPROVED ______ DATE ______

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

DRAWING TITLE: LONGITUDINAL SECTION
DATE: 11/8/66
DRAWING NUMBER: SK-4334-4-V-9



NO.	DATE	REVISION	MADE	APPROV
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1				

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A HUNTER, DIRECTOR

250-MGD VERTICAL TUBE EVAPORATOR DESALINATION PLANT
ELECTRICAL ONE-LINE DIAGRAM
CONTRACT NO. OSW 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIFORNIA

DRAWING BY
DESIGNED J. HOOPER DATE
DRAWN P. GRAY DATE
CHECKED DATE
APPROVED DATE

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED
APPROVED

DRAWING TITLE
DATE: 0-19-68
DRAWING NUMBER SK-4334-5-V-10

10.1 EQUIPMENT LIST
FOR
250-MGD MULTISTAGE FLASH (MSF) PLANT

Evaporators and Exchangers

TOTAL NO. REQUIRED IN PLANT		
4	Evaporator Vessels (Buildings) (Each contains 1 train)	
	Overall dimensions, each building:	692'L X 105'W X 24'H
	Construction, high-temperature end (approximately 152 ft.):	Structural Steel
	Construction, low-temperature end (approximately 540 ft.):	Concrete with steel liner

Each evaporator vessel contains several integral parts which will be separately itemized below. The quantities shown are for the complete 250 MGD plant unless otherwise noted.

(1) Heat Recovery Tubes (Stages 1-48)

Total surface area:	23,370,000 $ft.^2$
Total number of tubes:	247,960
Tube size:	3/4" O.D. X 0.035" X 238.5' and 241.5' long
Tube material:	90-10 Cu-Ni
Total number of tube bundles:	40 (10 per train; 5 in the low-temperature end and 5 in the high-temperature end)

10.1 EQUIPMENT LIST FOR 250 MGD MSF PLANT (Cont'd.)

Evaporators and Exchangers (cont'd.)

TOTAL NO. REQUIRED IN PLANT		
	(2) Heat Rejection Tubes (Stages 49-50)	
	Total surface area:	1,352,000 ft.^{2}
	Total number of tubes:	101,960
	Total dimensions:	3/4" O.D. X 0.049" X 67.5' long
	Tube material:	90-10 Cu-Ni
	Total number of tube bundles:	20 (5 per train)
	(3) Flashing Brine Trays:	8 (2 levels per train)
	(4) Product Water Trays:	20 (5 per train)
	(5) Wire Mesh Type Demisters, 316 SS	
	(6) Spray Deaerator	
	Number of spray stages:	2
	Number of spray nozzles:	688
	Spray nozzle size:	1000 gpm at 5 psi delta p.
	Spray nozzle material:	Saran
8	Brine Heaters (25'-8$\frac{1}{4}$" O.D. X 25'-5-3/4" tan to tan)	
	Total surface area:	1,187,000 ft.^{2}
	Total number of tubes:	250,400 (31,700 each)
	Tubes:	3/4" O.D. X 0.035" wall X 24'-1-3/4" long
	Tube material:	90-10 Cu-Ni

10.1 EQUIPMENT LIST FOR 250 MGD MSF PLANT (Cont'd.)

Pumps and Drivers

TOTAL NO. REQUIRED IN PLANT	SERVICE	GPM EACH	HEAD	RPM	MOTOR HP	MATERIALS			REMARKS
						CASE	IMPELLER	SHAFT	
4	Sea Water Intake	152,000	57'	327	3,000	316 SS Clad	CF8M	316 SS	All pumps in these five services are vertical dry-pit type centrifugal pumps with top suction and side discharge, and are driven by synchronous motors.
4	Brine Recycle	310,000	189'	225	17,000	316 SS Clad	CF8M	316 SS	
4	Deaerator Feed	86,600	24'	225	700	316 SS Clad	CF8M	316 SS	
4	Product Water	44,200	107'	514	1,500	Ductile Ni-resist Type D-2	316 SS	316 SS	
4	Blowdown	42,300	40'	450	500	316 SS Clad	CF8M	316 SS	
2	Sump Pumps	3,200	45'	860	50	Ni-resist	CF8M	316 SS	Vertical wet-pit type centrifugal with bottom suction and side discharge, and induction motors.
4	Ejector Condenser Booster Pumps	1,500	20'	1150	10	Ni-resist	316 SS	316 SS	Horizontal centrifugal with induction motor.
8*	Sulfuric Acid Injection	6.1	25 psi	1750	3/4	Steel	Steel	Steel	Horizontal centrifugal "canned pump type," with induction motor.
2*	Chlorine Injection	6,800	65 psi	860	450	Monel	Monel	Monel	Horizontal centrifugal with induction motor.

* - Includes installed spares.

10.1 EQUIPMENT LIST FOR 250 MGD MSF PLANT (Cont'd.)

Pumps and Drivers (Cont'd.)

TOTAL NO. REQUIRED IN PLANT	SERVICE	GPM EACH	HEAD	RPM	MOTOR HP	MATERIALS			REMARKS
						CASE	IMPELLER	SHAFT	
2*	Caustic Injection	2.4	15 psi	1750	3/4	Steel	Steel	Steel	Horizontal centrifugal "canned-pump" type with induction motor
2*	Ferrous Sulfate	3.4	25 psi	1750	3/4	Steel	Steel	Steel	ditto
2*	Sodium Sulfite	4.0	25 psi	1750	3/4	Steel	Steel	Steel	ditto
2*	Anti-foam	2.0	15 psi	1750	3/4	Steel	Steel	Steel	ditto

AIR COMPRESSORS AND DRIVERS

(1/3 to Water Plant - 2/3 to Power Plant)

TOTAL NO. REQUIRED IN PLANT		
2*	Non-lubricated compressors	660 SCFM @ 100 psi; 125 HP
2*	Lubricated compressors	660 SCFM @ 100 psi; 125 HP

* - Includes installed spares.

10.1 EQUIPMENT LIST FOR 250 MGD MSF PLANT (Cont'd.)

Ejector System, Including Condensers

TOTAL NO. REQUIRED IN PLANT	
4	Ejector #1, first stage, 6-inch suction, Hastelloy C construction.
4	Barometric condenser on suction side of Ejector #1, 316 SS construction.
4	Ejector #2, second stage, 4-inch suction, Hastelloy C construction.
4	Barometric condenser on suction side of Ejector #2, 316 SS construction.
4	Ejector #3, third stage, 3-inch suction, discharge to atmosphere, Hastelloy C construction.
4	Barometric condenser on suction side of Ejector #3, 316 SS construction.
	(NOTE: Each of the above 3-stage ejector sets evacuates Stages 11-48 in one train.)
4	Ejector #4, first stage, 30-inch suction, Hastelloy C construction.
4	Ejector #5, second stage, 16-inch suction, Hastelloy C construction.
4	Barometric condenser on suction side of Ejector #5, 316 SS construction.
4	Ejector #6, third stage, 10-inch suction, discharge to atmosphere, Hastelloy C construction.
4	Barometric condenser on suction side of Ejector #6, 316 SS construction.
	(NOTE: Each of the above 3-stage ejector sets evacuates the deaerator in one train.)
4	Ejector #7, hogging ejector, 10-inch suction, discharge to atmosphere, Hastelloy C construction.
	(NOTE: Each of the above hogging ejectors evacuates one train during startup operations.)

10.1 EQUIPMENT LIST FOR 250 MGD MSF PLANT (Cont'd.)

Tanks and Sumps

TOTAL NO. REQUIRED IN PLANT	
1	Sulfuric acid storage tank - steel, cone roof - 56' diameter X 27' deep, 500,000 gals.
1	Caustic storage tank - steel, cone roof - 30' diameter X 10' deep, 50,000 gals.
1	Anti-foaming solution tank with mixer - steel, horizontal, 9' diameter X 21' long, 10,000 gals.
2	Chlorine tank cars - 55 ton capacity, with automatic change-over equipment.
1	Ferrous sulfate tank - steel, with cone roof - 30' diameter X 13' deep - 66,000 gals.
1	Sodium sulfite tank - steel, cone roof - 35' diameter X 11' deep, 79,000 gals.
1	Vent pump sump - 8' X 10' X 12' deep below pump

10.1 EQUIPMENT LIST FOR 250 MGD MSF PLANT (Cont'd.)

Electrical Components

TOTAL NO. REQUIRED IN PLANT		
4	Transformers:	13,800 V. - 2400 V.; 7500 KVA
4	Transformers:	2400 V. - 480 V.; 500 KVA
4	Transformers:	480 V. - 208/120 V.; 50 KVA
4	Transformers:	480 V. - 208/120 V.; 30 KVA
4	Switchgear for 17,000 H.P. Motor	
4	2.4 KV Switchgear	2400 V.; 350 MVA
4	480 V. Switchgear	480 V.; 22,000 Amp.
8	Lighting Panels	208/120 V.
7	13,800 V. Circuit Breakers - Drawout type - Air - 1200 Amp. 1000 MVA	
6	Control Batteries w/Chargers	125 V., 100 Amp-Hr

10.1 EQUIPMENT LIST FOR 250 MGD MSF PLANT (Cont'd.)

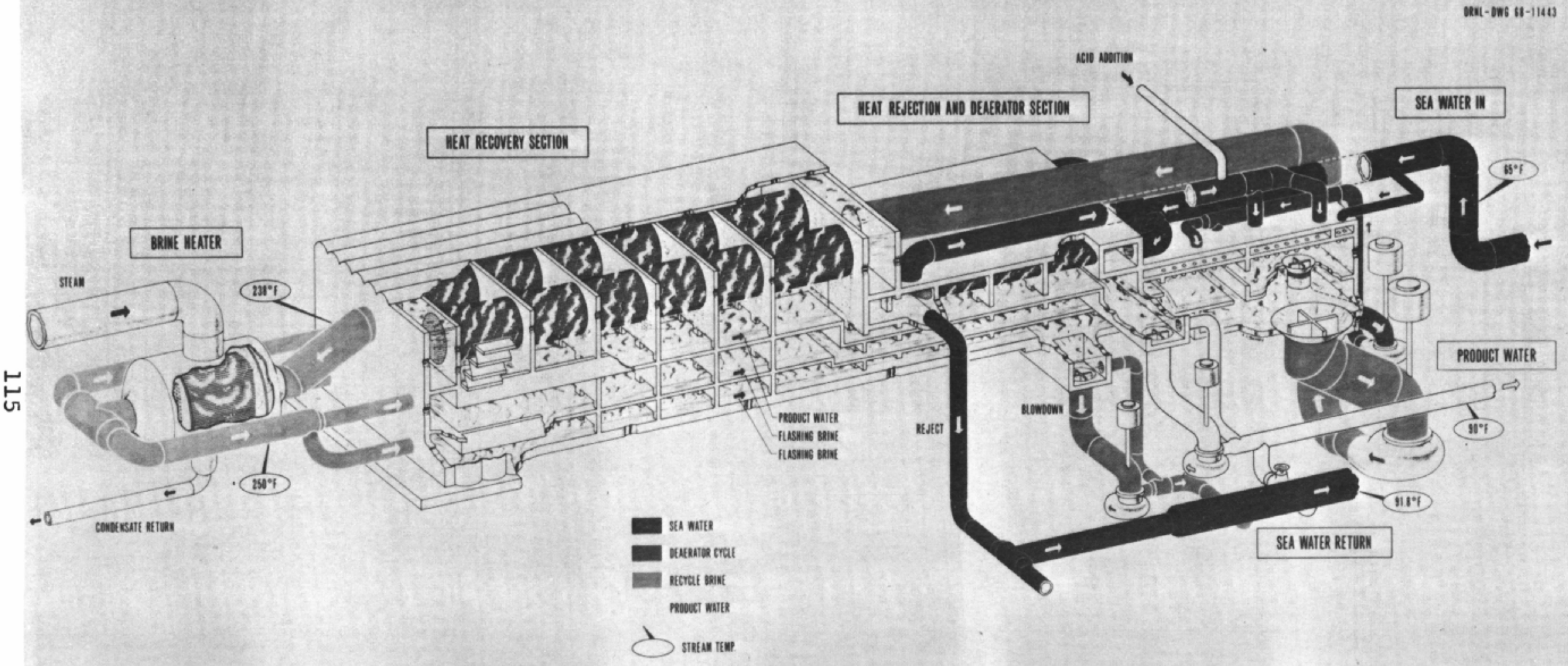
Miscellaneous

TOTAL NO. REQUIRED IN PLANT			
2	Chlorine Vaporizers	Total Duty:	6,080 lbs. chlorine vaporized per hour (3,040 lbs./hr. each vaporizer) Material of Construction: Monel
2	Chlorine Gas Jet Eductors	Total Duty:	600 SCFM gas at 11" Hg vacuum (300 SCFM each eductor) Material of Construction: Titanium
4	Traveling Bar Racks w/Drive		
4	Traveling Screens w/Drive		
1	Crane, mounted over 4 sea water pumps (All other equipment assumed to be serviced by mobile cranes.)		

10.0 - 250 MGD MSF PLANT EQUIPMENT LIST AND DRAWING INDEX

10.2 Drawing Index

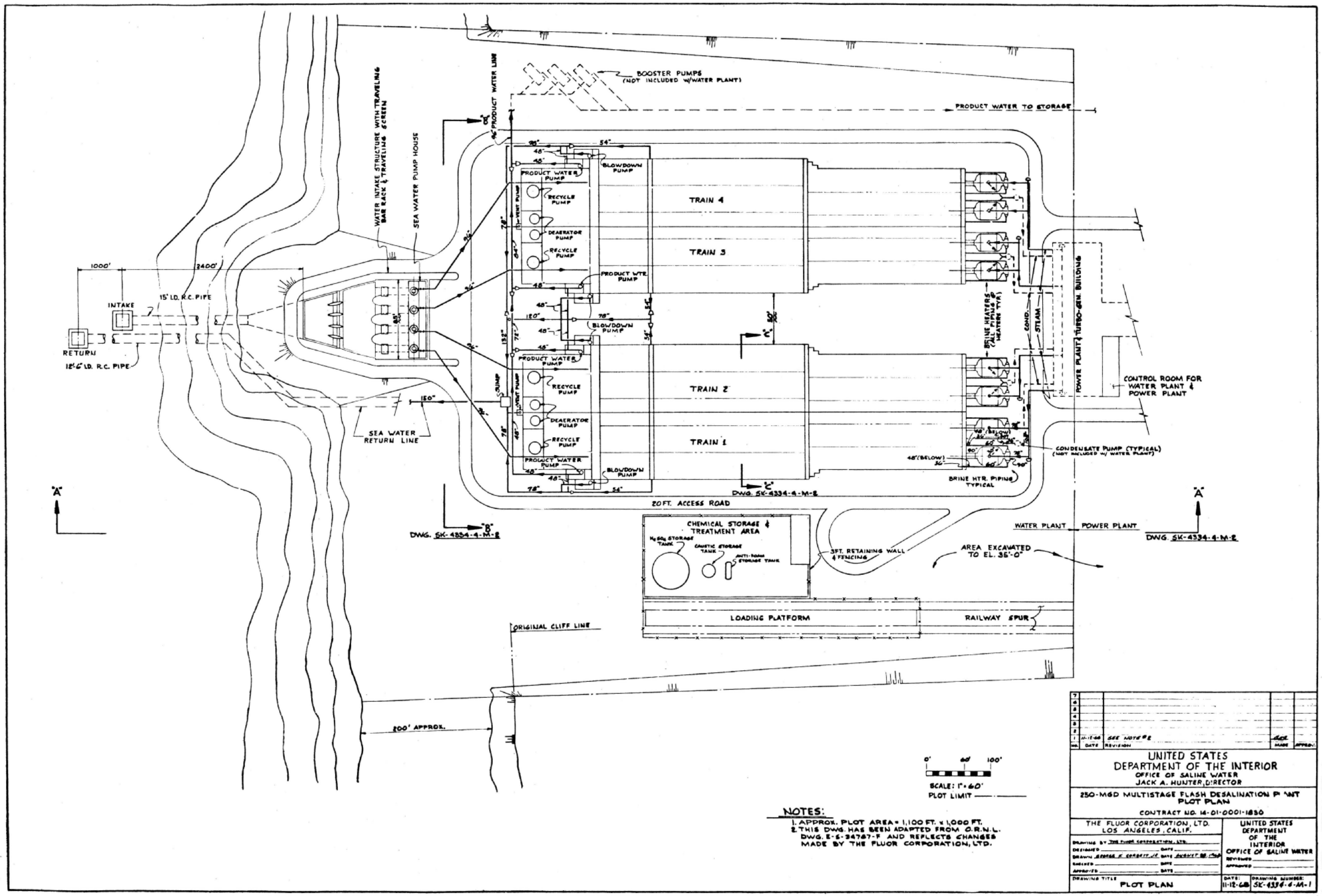
Drawing Number	Title
ORNL-B	Cutaway Drawing of MSF Plant
SK-4334-4-M-1	Plot Plan
M-2	Plot Plan Elevations & Section
M-3	Process Flow Diagram
M-4	P&I Flow Diagrams - Chemical Systems
M-5	Low Pressure End - Plan, Two Trains
M-6	High Pressure End - Plan, Two Trains
M-7	Longitudinal Section
M-8	Details
M-9	Electrical One-Line Diagram



250-Mgd MSF PLANT FLOW DIAGRAM

(1967 TECHNOLOGY)

Drawing ORNL-B



NOTES:

1. APPROX. PLOT AREA = 1,100 FT. x 1,000 FT.
2. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-5-34787-F AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

NO.	DATE	REVISION	MADE	APPROV.
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1	11-12-68	SEE NOTE #2		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

250-MGD MULTISTAGE FLASH DESALINATION PLANT
PLOT PLAN

CONTRACT NO. 14-01-0001-1830

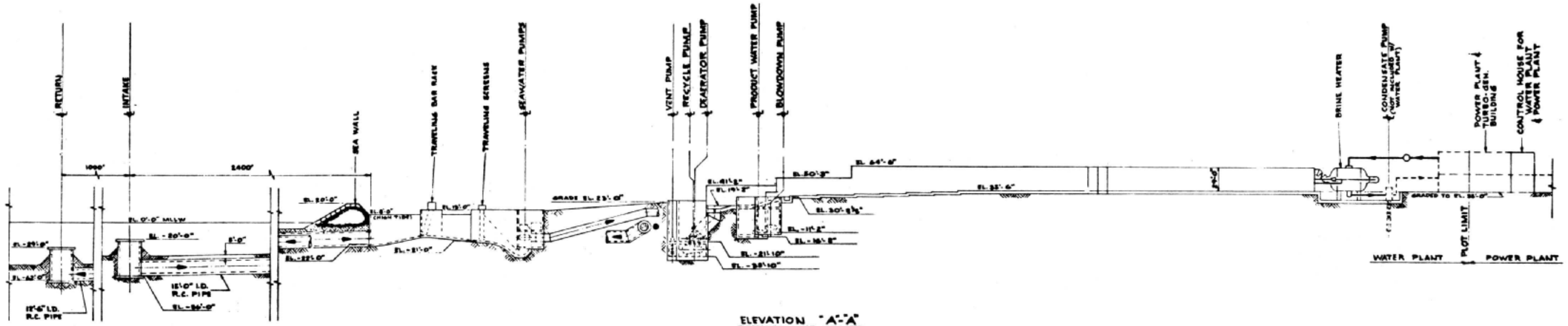
THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ________ DATE ________
DRAWN GEORGE F. CORBETT, JR. DATE AUGUST 28, 1968
CHECKED ________ DATE ________
APPROVED ________ DATE ________

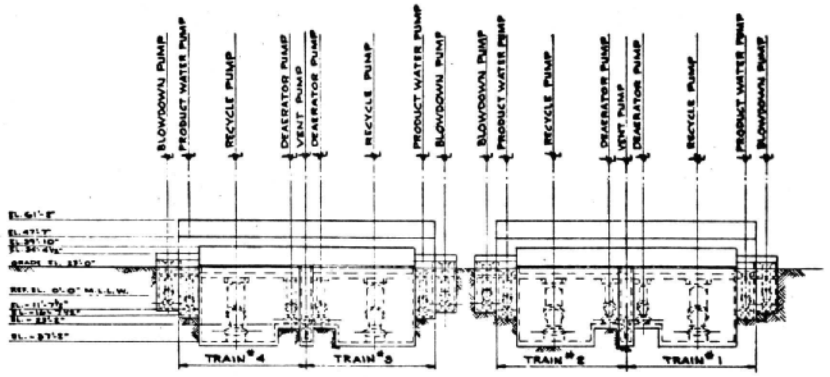
UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ________
APPROVED ________

DRAWING TITLE
PLOT PLAN

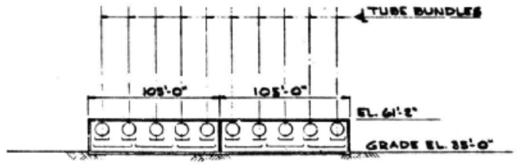
DATE: 11-12-68
DRAWING NUMBER: SK-4334-4-M-1



ELEVATION "A"-"A"



ELEVATION "B"-"B"



SECTION "C"-"C"

NOTES:

1. SEE PLOT PLAN-DWG. SK-4334-4-M-1
2. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-5-33647-AD AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

0' 60' 120'
SCALE: 1"=60'

NO.	DATE	REVISION	MADE	APPROV.
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1	11-12-68	SEE NOTE #2		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OF CE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

250-MGD MULTISTAGE FLASH DESALINATION PLANT
PLOT PLAN ELEVATIONS & SECTIONS
CONTRACT NO. 14-01-0001-1830

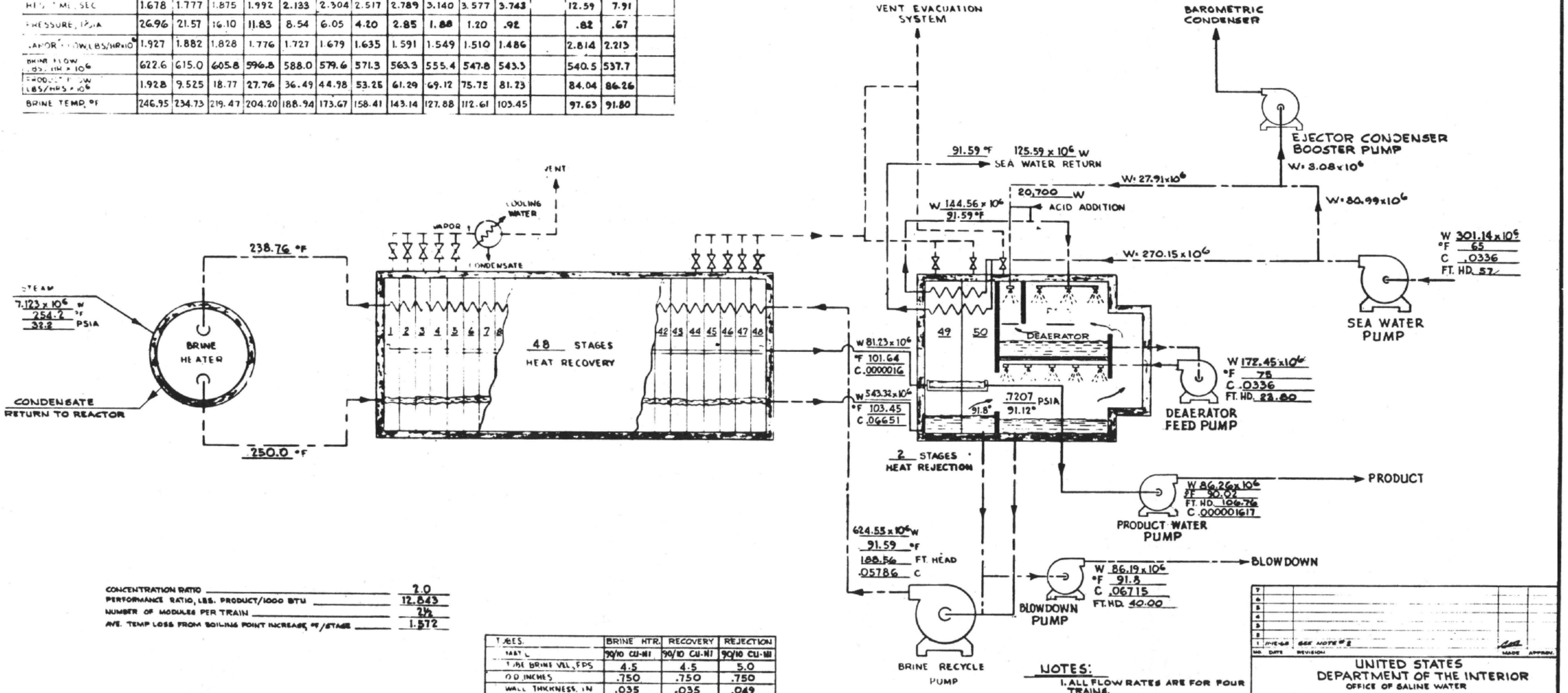
THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ______ DATE ______
DRAWN GEORGE K. CORBETT, JR. DATE SEPT. 17, 1968
CHECKED ______ DATE ______
APPROVED ______ DATE ______

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

DRAWING TITLE: PLOT PLAN ELEVATIONS & SECTIONS
DATE: 11-12-68
DRAWING NUMBER: SK-4334-4-M-2

STAGE NO	1	5	10	15	20	25	30	35	40	45	48		49	50	
$\overline{U}$	663.51	653.56	640.07	625.05	608.57	590.61	571.15	550.21	527.79	503.66	487.47		437.15	403.89	
FLASHING AREA SAFETY FACTOR	1.000	.9815	.9589	.9369	9154	1.118	1.092	1.067	1.041	1.015	1.000		.9973	.9921	
VAPOR VELOCITY, FPS	9.29	11.01	13.72	17.20	21.73	27.61	35.29	45.31	58.43	76.29	93.74		62.38	93.09	
TRAY WIDTH FEET	31.23	31.43	31.68	31.94	32.21	32.49	32.77	33.10	33.44	33.81	34.05		34.05	34.05	
RES. TIME, SEC	1.678	1.777	1.875	1.992	2.133	2.304	2.517	2.789	3.140	3.577	3.743		12.59	7.91	
PRESSURE, PSIA	26.96	21.57	16.10	11.83	8.54	6.05	4.20	2.85	1.88	1.20	.92		.82	.67	
VAPOR FLOW, LBS/HR×10^6	1.927	1.882	1.828	1.776	1.727	1.679	1.635	1.591	1.549	1.510	1.486		2.814	2.215	
BRINE FLOW LBS/HR × 10^6	622.6	615.0	605.8	596.8	588.0	579.6	571.3	563.3	555.4	547.8	543.3		540.5	537.7	
PRODUCT FLOW LBS/HRS × 10^6	1.928	9.525	18.77	27.76	36.49	44.98	53.25	61.29	69.12	75.75	81.23		84.04	86.26	
BRINE TEMP, °F	246.95	234.73	219.47	204.20	188.94	173.67	158.41	143.14	127.88	112.61	103.45		97.63	91.80	



CONCENTRATION RATIO ______ 2.0
PERFORMANCE RATIO, LBS. PRODUCT/1000 BTU ______ 12.843
NUMBER OF MODULES PER TRAIN ______ 2½
AVE. TEMP LOSS FROM BOILING POINT INCREASE °F/STAGE ______ 1.572

TUBES	BRINE HTR.	RECOVERY		REJECTION
MAT'L	90/10 CU-NI	90/10 CU-NI		90/10 CU-NI
TUBE BRINE VEL., FPS	4.5	4.5		5.0
O.D. INCHES	.750	.750		.750
WALL THICKNESS, IN	.035	.035		.049
OVERALL U	658.52	578.68		424.32
SURFACE AREA, FT²	1.1813×10^6	23.33× 10^6		1.[illegible]×10^6
LENGTH FT	24.14	480.03		51.50
NUMBER	24[illegible]	248,000		101,960
BUNDLE WIDTH, FT	▨	10'-8"	11'-8"	8'-8"
BUNDLE HEIGHT, FT	▨	10'-6"	11'-8"	6'-2"

C = WT FRACTION OF SOLIDS
W = LB / HR

——·—— BRINE
·———— PRODUCT
— — — — VENT

NOTES:

1. ALL FLOW RATES ARE FOR FOUR TRAINS.
2. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. D-P34787-N AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

NO.	DATE	REVISION	MADE	APPROV.
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1	11-12-68	SEE NOTE # 2		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

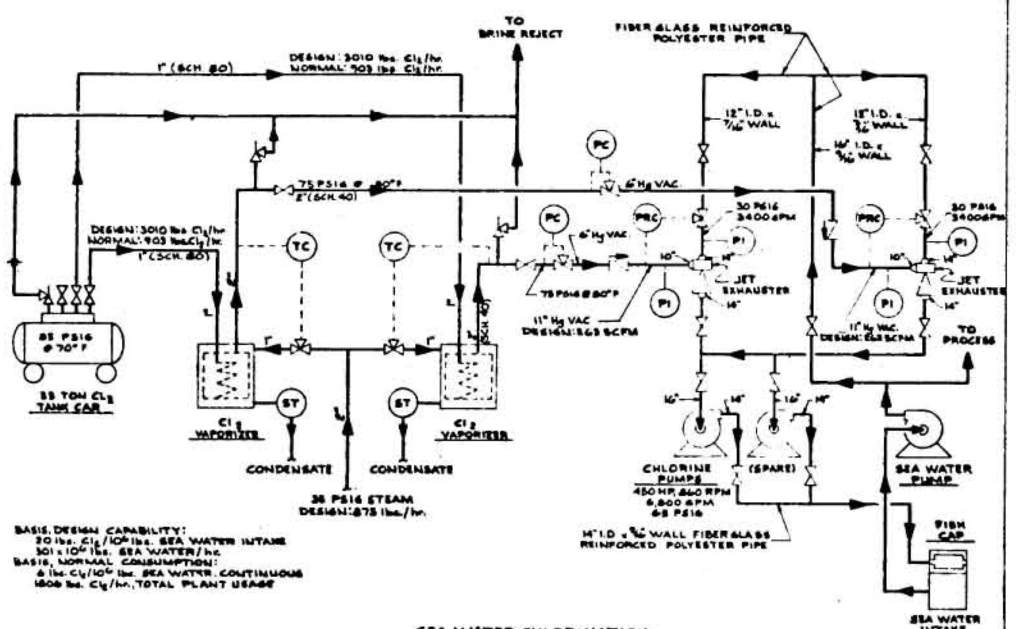
250-MGD MULTISTAGE FLASH DESALINATION PLANT
PROCESS FLOW DIAGRAM
CONTRACT NO 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ______ DATE ______
DRAWN GEORGE K CORBETT, JR DATE NOVEMBER 12, 1968
CHECKED ______ DATE ______
APPROVED ______ DATE ______

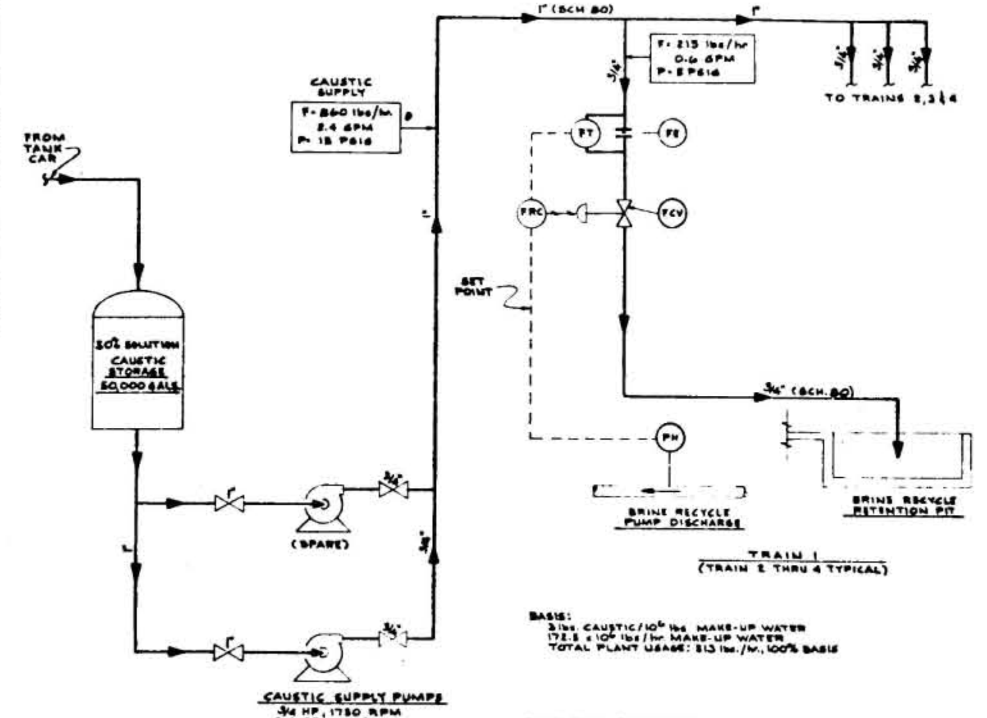
UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

DRAWING TITLE: PROCESS FLOW DIAGRAM
DATE: 11-12-68
DRAWING NUMBER: SK-4334-4-M-3



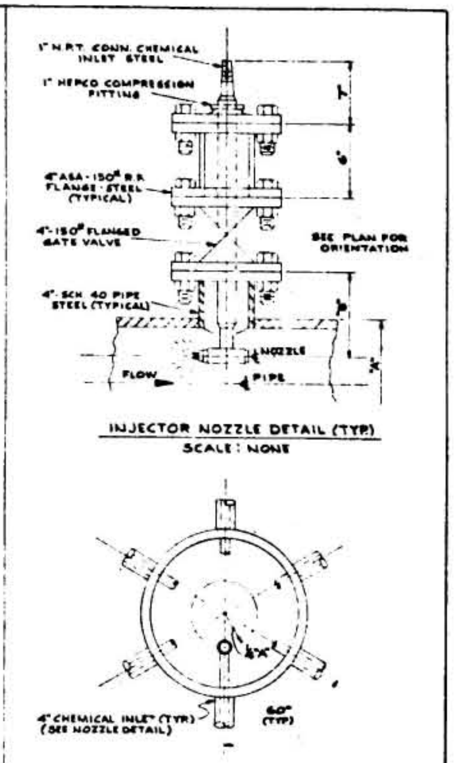
BASIS, DESIGN CAPABILITY:
20 lbs. Cl₂/10⁶ lbs. SEA WATER INTAKE
301 x 10⁶ lbs. SEA WATER/hr.
BASIS, NORMAL CONSUMPTION:
6 lbs. Cl₂/10⁶ lbs. SEA WATER, CONTINUOUS
1806 lbs. Cl₂/hr., TOTAL PLANT USAGE

SEA WATER CHLORINATION



BASIS:
3 lbs. CAUSTIC/10⁶ lbs. MAKE-UP WATER
172.5 x 10⁶ lbs/hr. MAKE-UP WATER
TOTAL PLANT USAGE: 513 lbs./hr., 100% BASIS

CAUSTIC ADDITION



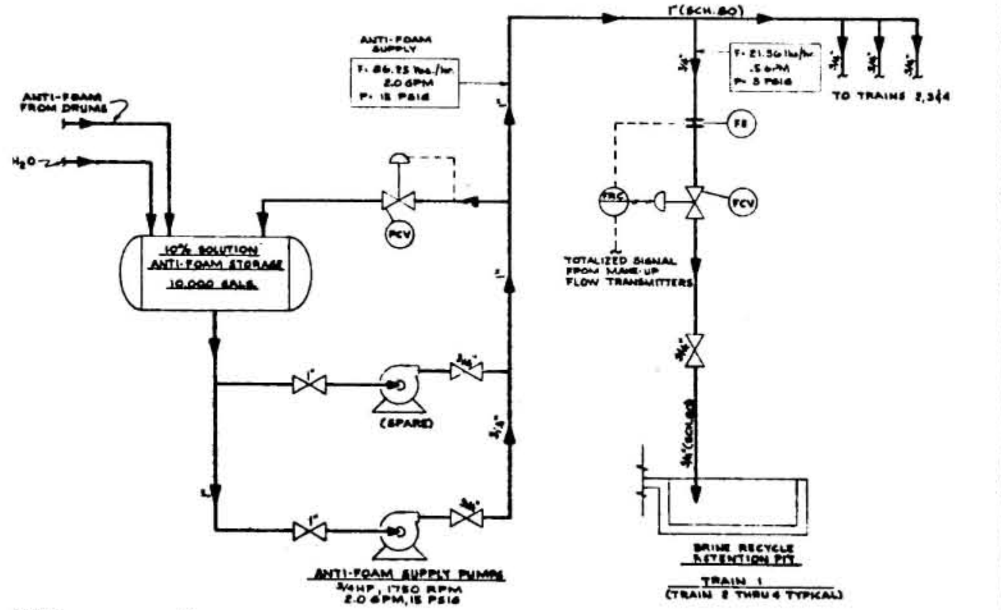
INJECTOR NOZZLE DETAIL (TYP)
SCALE: NONE

SECTION - CHEMICAL ADDITION INJECTORS
SCALE: NONE

SERVICE	NOMINAL PIPE "A"	DIMENSION "B"	NOZZLE MATERIAL
ACID	24"	16"	HASTELLOY B
ACID	66"	36"	HASTELLOY B

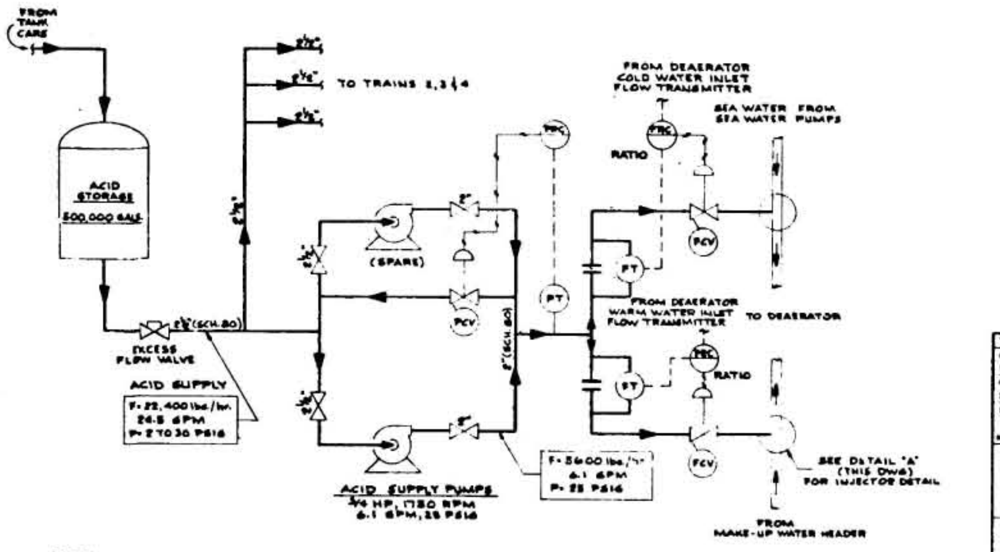
NOTE:
INJECTOR SHOWN IS TYPICAL. THIS UNIT IS COMMERCIALLY AVAILABLE FROM GENERAL REGULATOR CORP. MARKETED AS A TYPE 340-MA "MECHANICAL ATOMIZING DESUPER HEATER."

DETAIL "A"



BASIS:
0.5 lbs. ANTI-FOAM/10⁶ lbs. MAKE-UP WATER
172.5 x 10⁶ lbs./hr. MAKE-UP WATER
TOTAL PLANT USAGE: 86.25 lbs./hr., 100% BASIS

ANTI-FOAM ADDITION



BASIS:
130 lbs. H_2SO_4/10⁶ lbs. MAKE-UP WATER
172.5 x 10⁶ lbs./hr. MAKE-UP WATER
TOTAL PLANT USAGE: 22,400 lbs./hr.

SULFURIC ACID ADDITION

NOTES:
1. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG'S. C-P-34787-H, J, K, L & M AND REFLECTS CHANGES MADE BY THE FLUOR CORP., LTD.

NO.	DATE	REVISION	MADE	APPROV.
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1	11-12-68	SEE NOTE #1		

UNITED STATES
DEPARTMENT OF THE INTERIOR
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JACK A. HUNTER, DIRECTOR

250-MGD MULTISTAGE FLASH DESALINATION PLANT
P & I FLOW DIAGRAMS - CHEMICAL SYSTEMS
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.
DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED DATE
DRAWN GEORGE H CORBETT, JR DATE OCTOBER 1968
CHECKED DATE
APPROVED DATE

UNITED STATES
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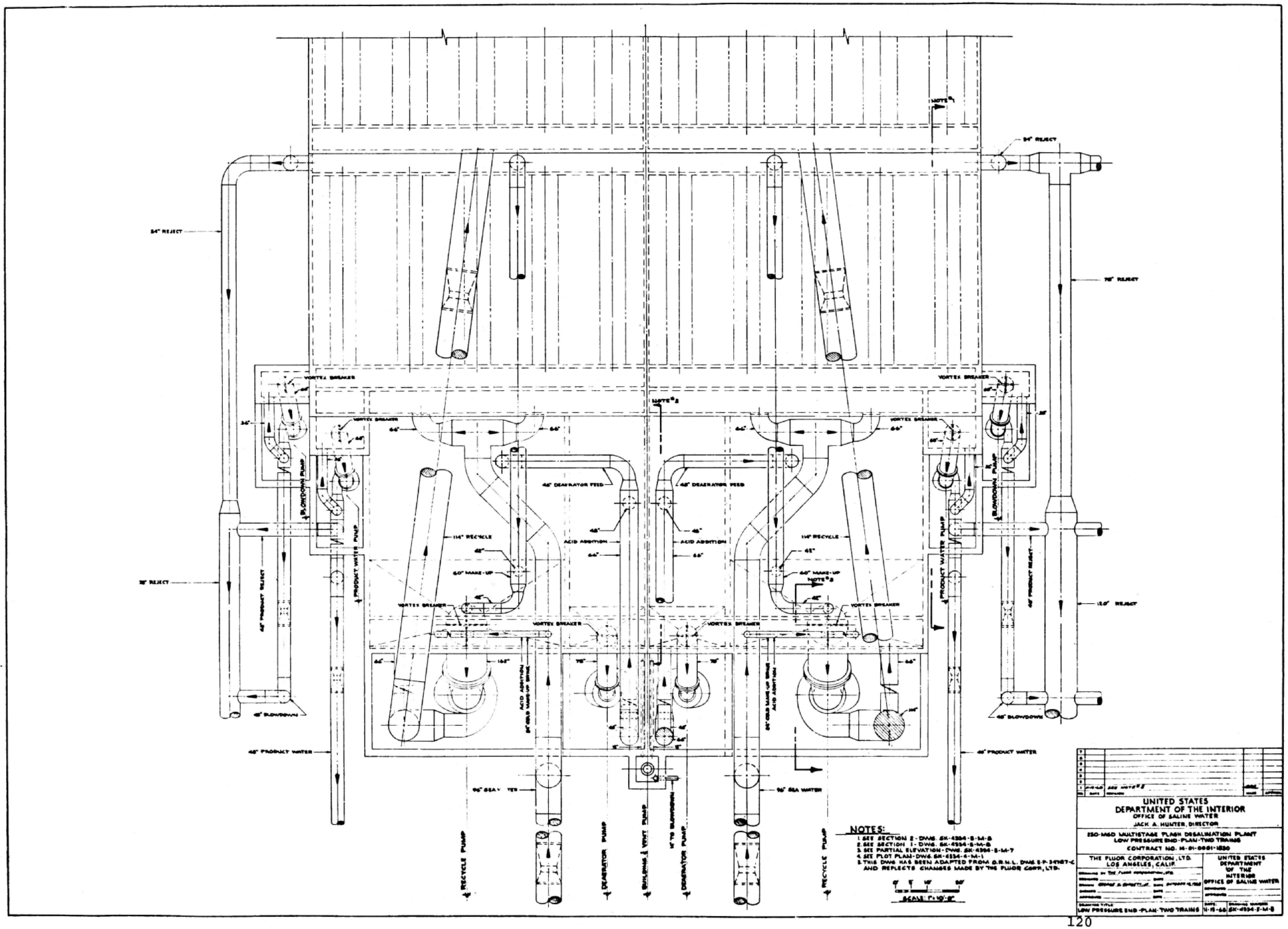
APPROVED

DRAWING TITLE: CHEMICAL FLOW DIAGRAM
DATE: 11-12-68
DRAWING NUMBER: SK-4334-4-M-4



NOTES:
1. SEE SECTION 2 - DWG. SK-4334-5-M-8
2. SEE SECTION 1 - DWG. SK-4334-5-M-6
3. SEE PARTIAL ELEVATION - DWG. SK-4334-5-M-7
4. SEE PLOT PLAN - DWG. SK-4334-4-M-1
5. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-P-34767-C AND REFLECTS CHANGES MADE BY THE FLUOR CORP., LTD.

SCALE: 1" = 10'-0"

1	2-15-68	SEE NOTE #5
NO.	DATE	REVISION

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JACK A. HUNTER, DIRECTOR

250-MGD MULTISTAGE FLASH DESALINATION PLANT
LOW PRESSURE END-PLAN-TWO TRAINS
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

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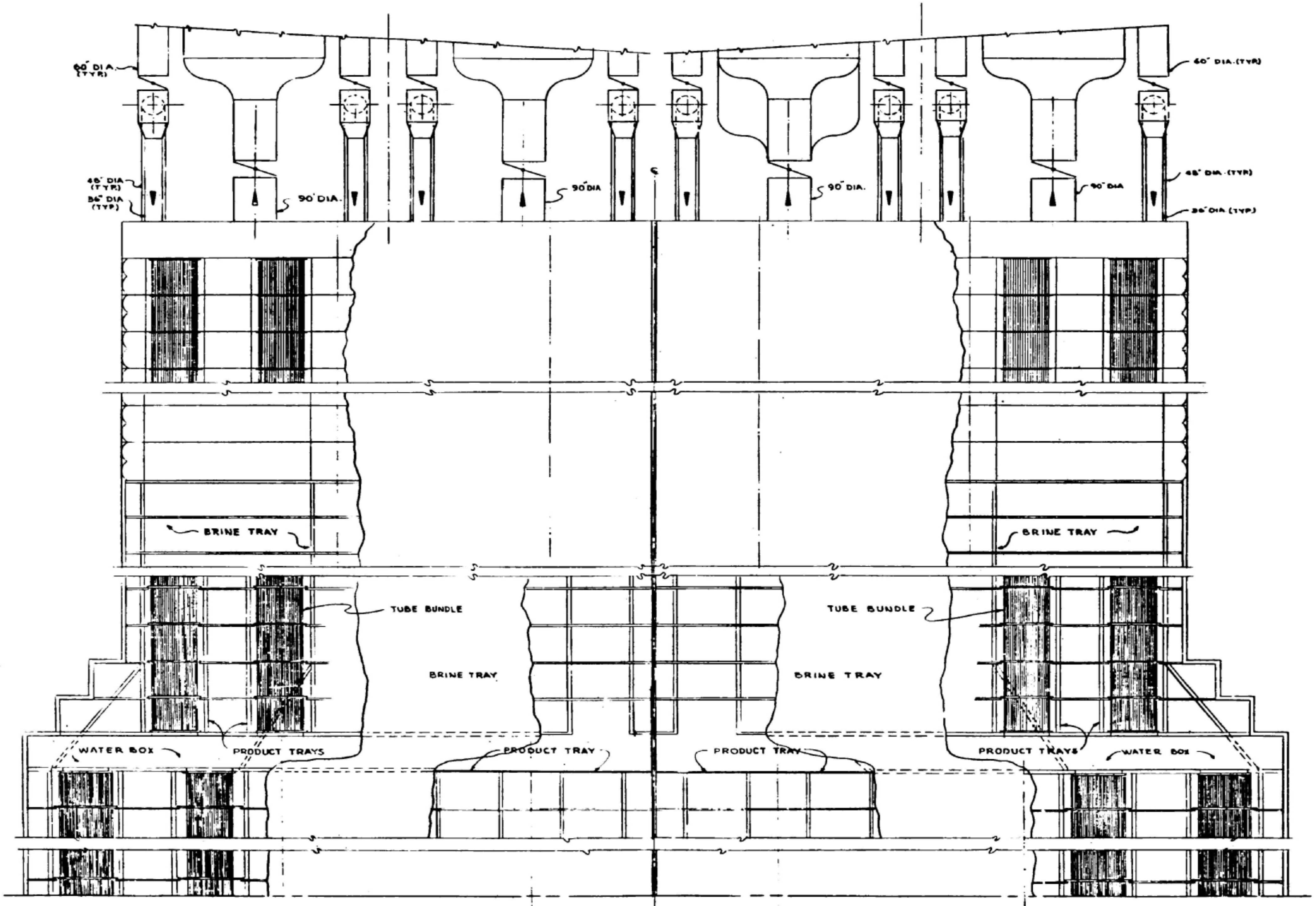
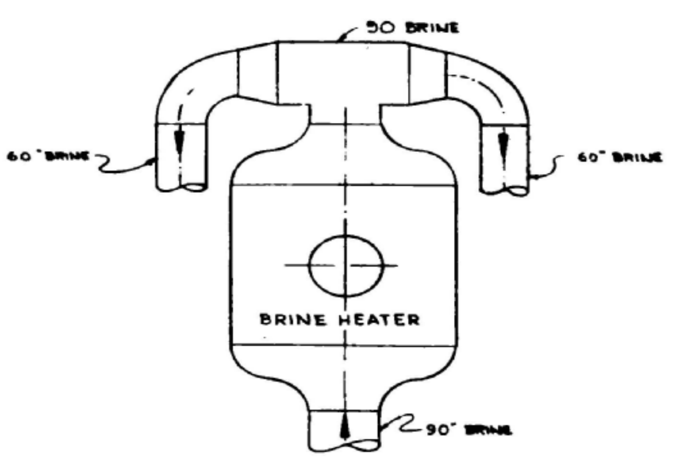
DRAWING TITLE: LOW PRESSURE END-PLAN-TWO TRAINS
DATE: 11-15-66
DRAWING NUMBER: SK-4334-5-M-8





BRINE HEATER PIPING PLAN

NOTES:

1. SEE PLOT PLAN - DWG. SK-4334-4-M-1
2. SEE LONGITUDINAL SECTION - DWG. SK-4334-5-M-7
3. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG E-P-34787-D BY THE FLUOR CORPORATION, LTD.

0' 5' 10' 20'

SCALE: 1/8" = 1'-0"

1 SEE NOTE #3

UNITED STATES
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250-MGD MULTISTAGE FLASH DESALINATION PLANT
HIGH PRESSURE END-PLAN-TWO TRAINS
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD
LOS ANGELES, CALIF.

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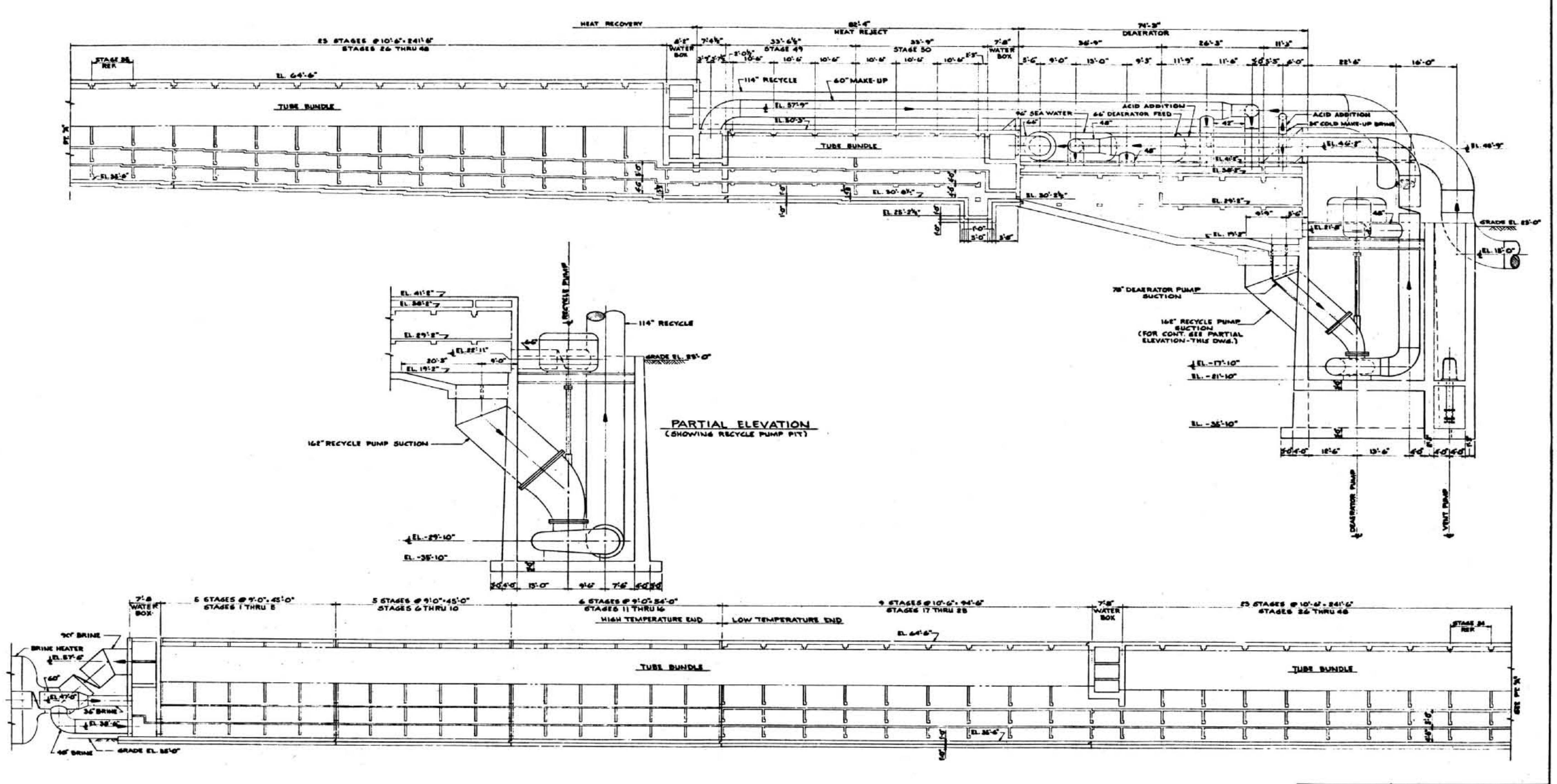
HIGH PRESSURE END-PLAN-TWO TRAINS
11 13 68
SK-4334-5-M-6



NOTES:

1. SEE PLOT PLAN - DWG. SK-4324-4-M-1
2. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-P-34787-E AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

SCALE: 1" = 10'-0"

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1	11-18-68	SEE NOTE # 2		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

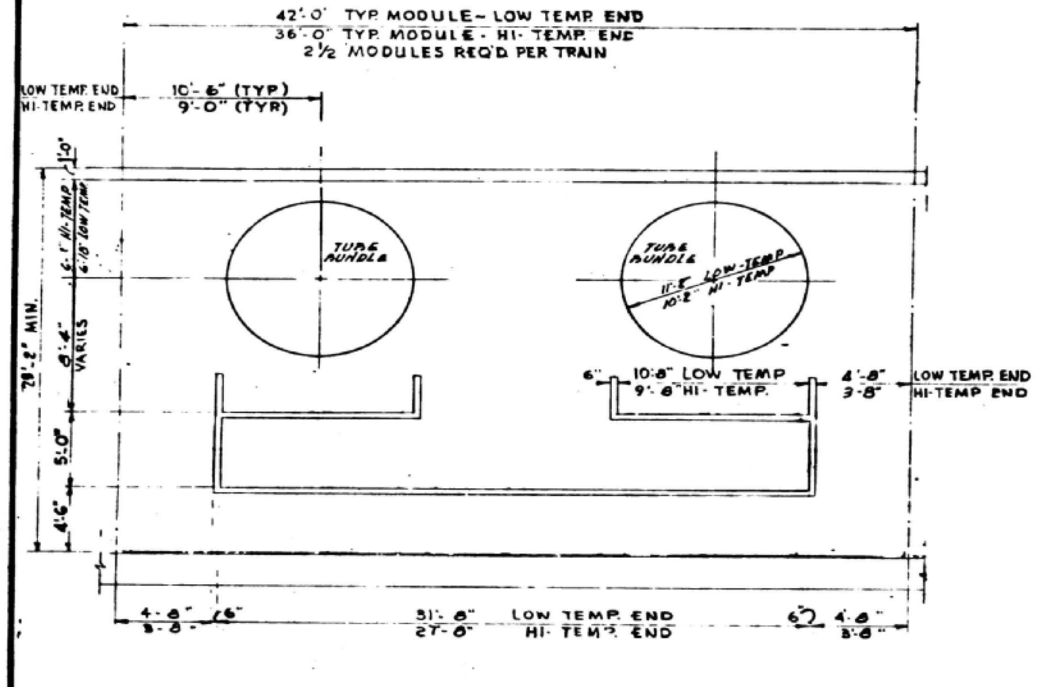
250-MGD MULTISTAGE FLASH DESALINATION PLANT
LONGITUDINAL SECTION
CONTRACT NO. 14-01-0001-1230

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ____ DATE ____
DRAWN GEORGE E. ROBERTS JR. DATE OCTOBER 21, 1968
CHECKED ____ DATE ____
APPROVED ____ DATE ____

UNITED STATES DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
REVIEWED ____
APPROVED ____

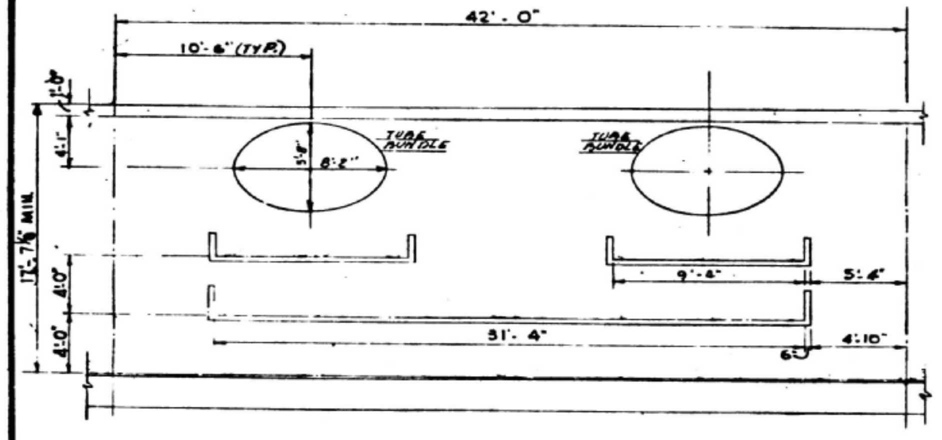
DRAWING TITLE: LONGITUDINAL SECTION
DATE: 11-18-68
DRAWING NUMBER: SK-4324-3-M-7



CROSS SECTION CONC. BLDG.

HEAT RECOVERY AREA

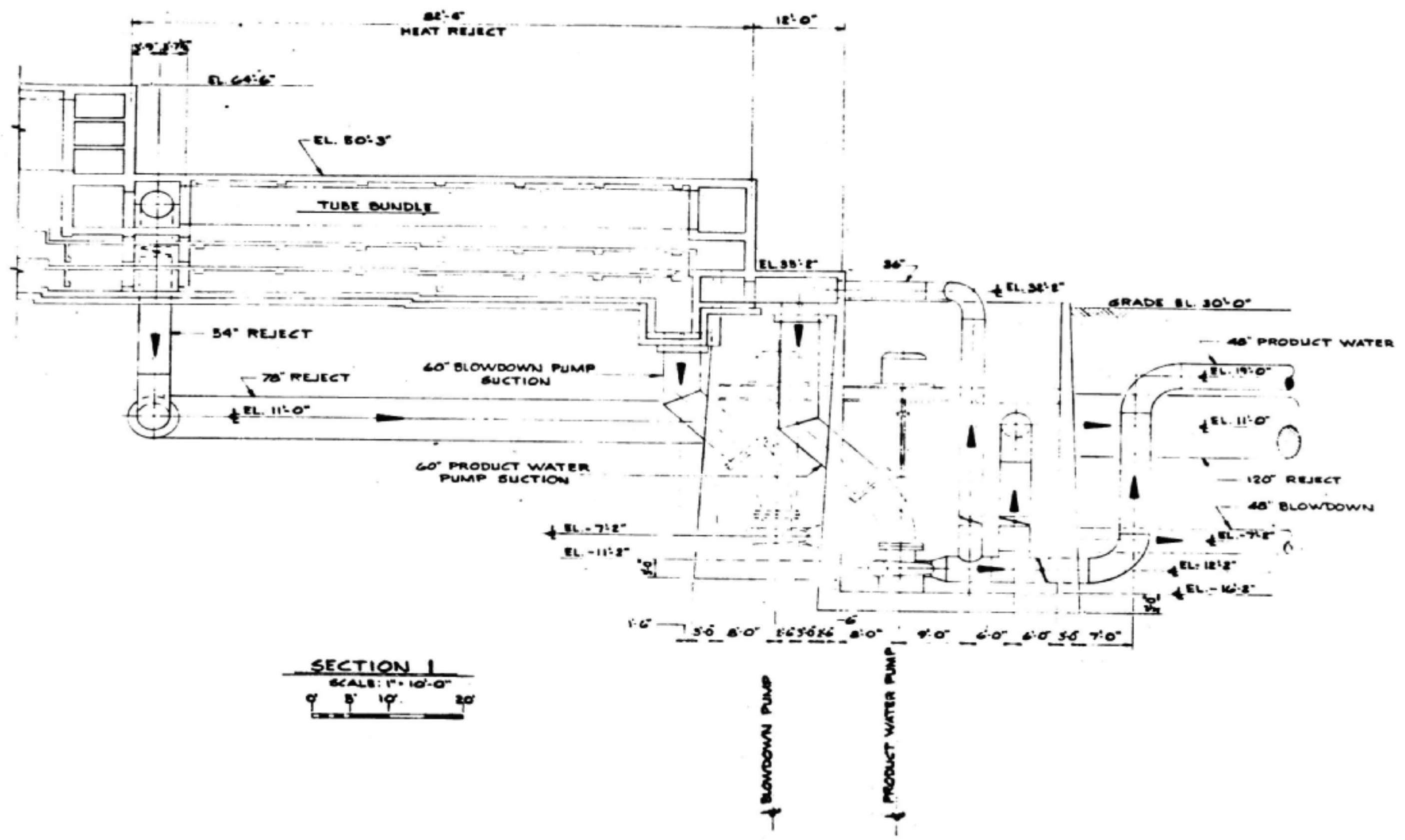
SCALE: ¼" = 1'-0"



CROSS SECTION

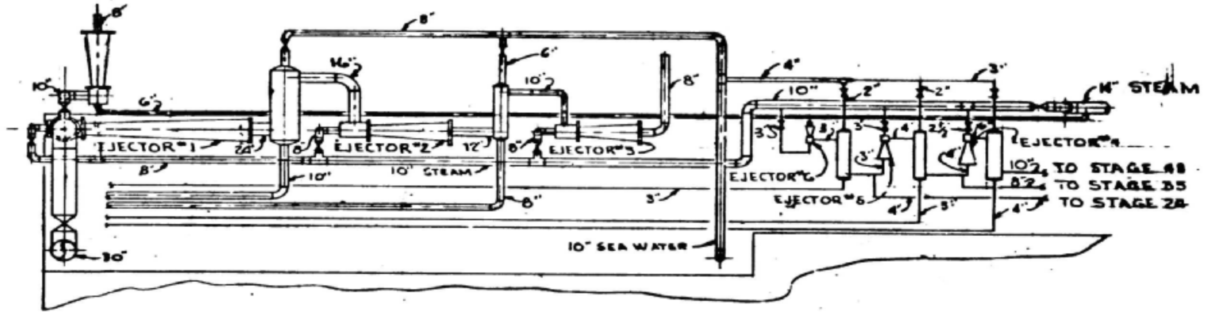
HEAT REJECT AREA

SCALE: ¼" = 1'-0"



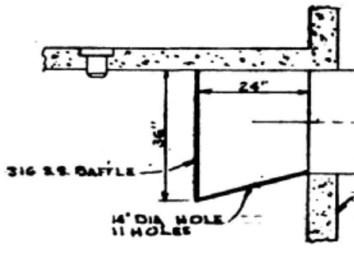
SECTION 1

SCALE: 1" = 10'-0"



SECTION 2

SCALE: ⅛" = 1'-0"



DEAERATOR VENT REMOVABLE DETAIL

NO SCALE

NOTES:

1. SEE PLOT PLAN - DWG. SK-4334-4-M-1
2. SEE LOW PRESS. END - PLAN - DWG. SK-4334-5-M-5
3. THIS DWG. HAS BEEN ADAPTED FROM O.R.N.L. DWG. E-4-34787-F AND REFLECTS CHANGES MADE BY THE FLUOR CORP., LTD.

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1	11-13-68	SEE NOTE # 3		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A HUNTER, DIRECTOR

250-MGD MULTISTAGE FLASH DESALINATION PLANT
DETAILS
CONTRACT NO. 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED DATE
DRAWN GEORGE F. CORBETT JR. DATE OCT. 25, 1968
CHECKED DATE
APPROVED DATE

UNITED STATES
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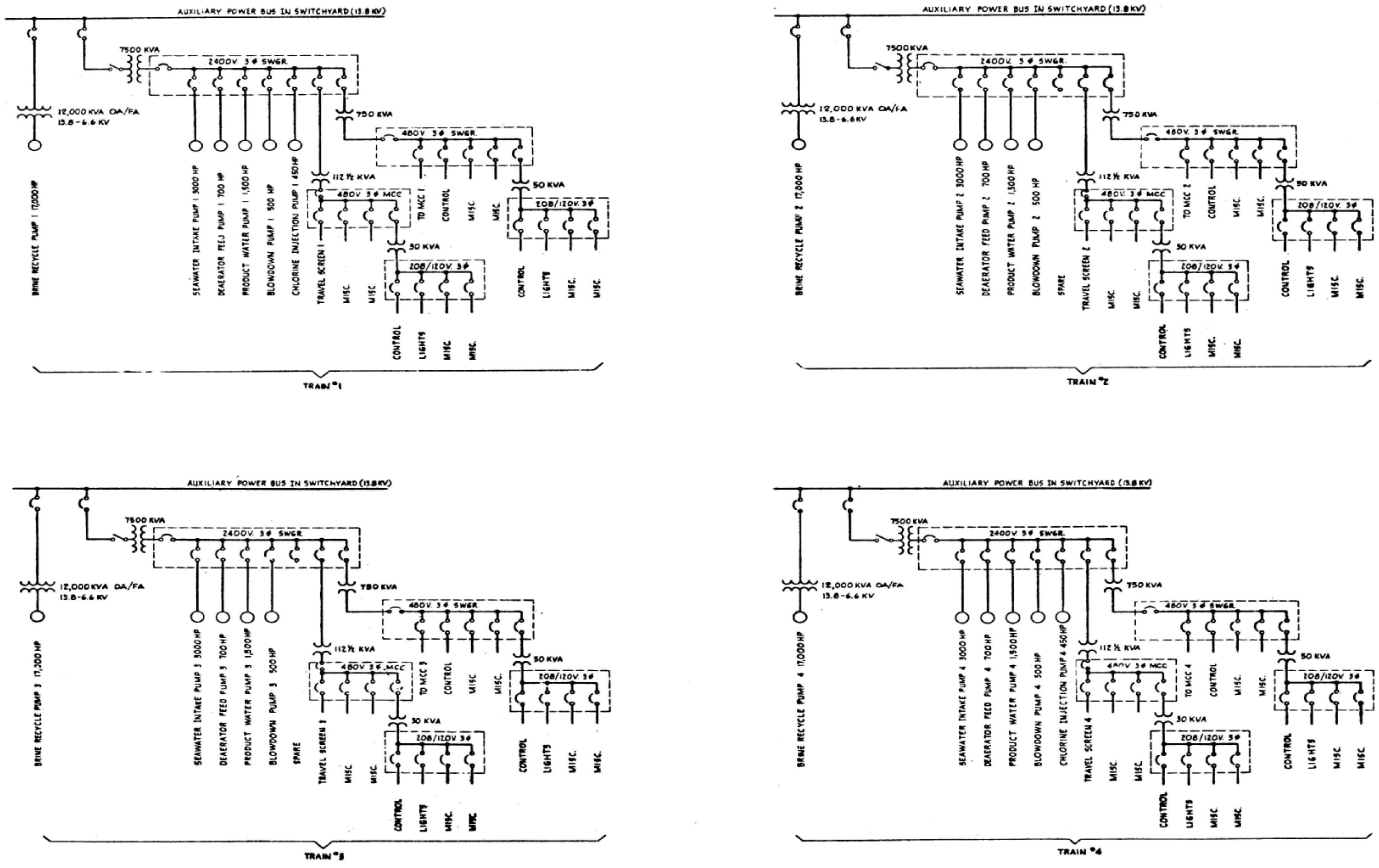
DATE 11-13-68
DRAWING NUMBER SK-4334-5-M-8



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DEPARTMENT OF THE INTERIOR
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JACK A. HUNTER, DIRECTOR

250-MGD MULTISTAGE FLASH DESALINATION PLANT
ELECTRICAL ONE-LINE DIAGRAM
CONTRACT NO. OSW 14-01-0001-1830

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIFORNIA

DRAWING BY
DESIGNED J. HOOPLE DATE
DRAWN P. GRAY DATE
CHECKED DATE
APPROVED DATE
DRAWING TITLE

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REVIEWED
APPROVED
DATE: 10-19-68
DRAWING NUMBER SK-4334-5-M-9

11.0 - TECHNICAL SUMMARY - 2.5 MGD PLANTS

11.1 VTE Plant Description - Process and Physical

Process Description

The desalination process employed in the 2.5 MGD VTE plant is a falling-film, multiple-effect vertical tube evaporative process with 14 heat recovery effects. Accumulating condensate and seawater feed are flashed separately in a single flashing stage for each effect. The plant has a performance ratio of 11.6 pounds of product water for each 1000 Btu of input heating steam. The maximum brine temperature is 258 F. Other temperatures and flow rates of the process stream are shown in the Process Flow Diagram, Drawing 4-003.

Two plant configurations are evaluated in this study - one using conventional smooth tubes for all heat transfer, and one using enhanced-surface tubes. However, the heat and material balances are identical. (The reference source for the process and mechanical design of both plant configurations is given in Section 13.1. Enhanced-surface tubes are described in the latter portion of Section 11.1.)

Seawater is fed to the VTE plants on a once-through basis; thus the brine exposed to the highest evaporating temperature is only slightly concentrated. Seawater at 65 F is chlorinated at the outer end of the intake conduit to control biological growth, and screened to remove debris before being pumped to the plant. More than half of the seawater brought into the plant is used in the heat reject condenser to absorb the latent heat of condensation, and is immediately returned to the sea. Another 5% is diverted to cool the barometric condensers in the air ejector system, and the remainder becomes the seawater feed to the evaporator. The nondeaerated seawater feed pump forces the feed through the product water cooler, where the warm product heats it to 99 F., and then through the feed preheater in Effect 14, where the condensing vapor further heats it to 120 F. Sulfuric acid is added to neutralize its alkalinity, and the feed is then flashed into the combined deaerator-decarbonator, where nearly all of the dissolved oxygen, carbon dioxide, and other inerts are removed. The deaerated feed is then pumped through successive feed preheaters positioned in each effect, arriving at Effect 1 at a temperature of 251 F., where it becomes the feed to the first bundle of vertical falling-film tubes.

The VTE plant receives its heating steam from an outside source, and all condensate from the heating steam is returned to the source. The plant heating steam at 42 psia and 270 F is admitted to the shell-side of the Effect 1 falling-film bundle. The steam condenses on the tubes, releasing its heat of condensation to the preheated, deaerated seawater which is falling as a film on the interior surface of the tubes. This causes the seawater feed to boil violently, so that approximately 5% is vaporized as it falls through the vertical tubes. The mixture of seawater and newly-formed steam flows from the bottom of the heater tube bundle into the lower section of the Effect 1 evaporator, where the seawater disengages from the steam and collects in the sump. The slightly-concentrated brine is then flashed forward to the sump of Effect 2, while the steam is directed to the shell side of the Effect 2 vertical tube bundle and feed preheater tube bundle. Knitted wire mesh entrainment separators are provided to remove entrained droplets of brine from the steam flow. In Effect 2, the vapor condensing on the outside of the vertical tubes performs the same function as the heating steam did in Effect 1, boiling more brine on the inside of the tubes, and producing additional steam to be passed on to Effect 3. This process continues in the same manner through the plant to Effect 14.

Feedwater flowing forward from the first effect brine sump to the second is exposed to the lower pressure found in the second effect, and part of it will flash to vapor. To provide the falling-film portion of the evaporation process in the second effect, brine is pumped from the Effect 2 sump to the top of the vertical tube bundle in Effect 2. There it forms a boiling liquid film which gravitates through the tubes and returns to the Effect 2 sump.

These essential processes are repeated in each effect through the plant, with each effect operating at a progressively lower temperature and pressure. The steam that is formed in the last (14th) effect is condensed at a temperature of 110 F. in the heat reject surface condenser. Seawater, circulating in the tubes, removes the latent heat and rejects it to the sea. The brine remaining in the sump of the final effect is pumped to waste. Condensate from the heat reject condenser is combined with the condensate which has accumulated through Effects 2 through 14 to form the product stream, still at a temperature of 125 F. This sensible heat is recovered and the product water cooled to 79 F by passing it through the product cooler, where the released heat warms the incoming seawater feed to 99 F.

In all effects (except the first) the falling-film tubes are fed by a pump which withdraws brine from the brine sump and feeds it to the top of the vertical bundle. Special distributors (slotted circular weirs) distribute the brine to the tubes, through which it returns by gravity to the sump. The brine is driven forward through the plant by the decreasing pressure gradient, with the flow rate controlled in most cases by properly sized orifices between effects. Improved control over the forward flow of brine through the plant is accomplished by pumping the brine forward to Effects 5, 9, 12, 13 and 14. In each of these cases the pump output is regulated by a level controller in the suction sump. In the effects in which the feed is pumped forward, flashing occurs in a small chamber adjacent to the top of the vertical tube bundle. The feed then overflows to the top of the vertical tube bundle and is distributed to the tubes. Since the pumped feed flow rate is greater than the optimum circulation rate through the vertical falling-film tubes, an overflow weir and return line is provided to bypass excess brine down to the brine tray in the same effect.

Continuous venting of all effects is necessary to remove noncondensable gases. Effects above atmospheric pressure are vented directly to the atmosphere through suitable throttling valves. Effects operating at subatmospheric pressures are vented through barometric condensers to steam-jet air ejectors.

Physical Plant

The 2.5 MGD Vertical Tube Evaporator plant consists of a series of 14 effects, all but the first of which are contained in a single modular vessel. (Effect 1, to which the plant heating steam is supplied, is in a separate vessel.) Two design variations are considered - one using smooth heat-transfer tubes, and one using tubes with enhanced surfaces. Drawing SR-A shows a perspective view of the 2.5 MGD VTE plant, and Drawing SR-B is a cutaway view showing the internal construction of the module. These drawing are specific for the VTE plant with enhanced tubes; however, the smooth-tube plant is similar except for tube construction and somewhat different vessel proportions.

The modular evaporator vessel containing Effects 2 through 14 has a rectangular cross-section with semi-circular bottom. Approximate outside dimensions of the module for both conventional and enhanced plants are 14 feet wide and 120 feet long. Vessel overall height is approximately 34 feet for the conventional plant and $22\frac{1}{2}$ feet for the enhanced plant. Arrangement of the VTE plants on the site is shown in Drawing 4-002 for the smooth tube case and Drawing 4-001 for the enhanced plant.

Effects in the principal evaporator vessel are separated from each other by bulkheads, with appropriate conduits provided to transfer vapor, brine and condensate from effect to effect without the necessity of external piping. Each effect contains a bundle of vertical falling-film tubes, and a bundle of feed water preheater tubes, as well as trays for containing liquid brine and condensate. The feed preheaters are two-pass tube bundles which in each effect heat the feed regeneratively inside the tubes while condensing water vapor on the outside. The falling-film tubes accommodate a recirculating flow of feed brine pumped from and returning to the brine sump in each effect. (For a complete description of all tubes in the VTE plants, refer to the Equipment List in Section 17.)

Feed preheaters in Effects 2 through 14 are shop-assembled and set into the evaporator module during its final assembly. The smooth-tube preheaters and heat reject condensers use smooth 3/4 inch tubes, 18 to 22 feet long; enhanced tube preheaters and heat reject condensers employ nominal 1-inch corrugated tubes 10 to 14 feet long. The smooth-tube product water cooler uses two exchangers, each containing 3/4-inch tubes 26 feet long; with enhanced tubes, a single exchanger is used containing 1-inch tubes 20 feet long. The product water cooler for both plants, and the Effect 14 feet preheater for the smooth tube plant only, are located outside the modular vessel; all other preheater bundles and the heat rejection bundle are built into the vessel.

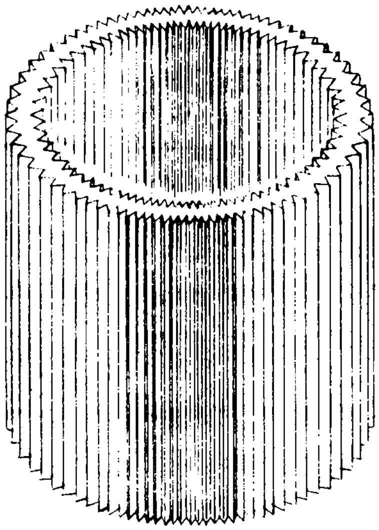
The seawater feed is raised nearly to its final temperature in the last preheater bundle, in Effect 2. From there it flows to the vertical falling-film tubes in Effect 1, which is a separate vessel. Heating steam is admitted to the outside of the tubes, evaporating part of the seawater feed and constituting the heat input to the plant. Details of the plant arrangement are found in the Mechanical Flow Diagram, Drawing 4-004, and process details in Drawing 4-003. Drawing 4-005 is a Chemical Flow Diagram, showing the control and addition of chemical additives, and Drawing 4-006 is an Electrical One-Line Diagram for the VTE plants.

As was mentioned earlier, two designs of VTE plants are reviewed in this study. In the first design, all heat-transfer elements are conventional smooth-surface tubes; in the second, enhanced-surface tubes are provided throughout - tubes whose walls are corrugated or fluted to improve heat-transfer rates. A brief discussion of enhanced tubes is appropriate at this point.

Although many variations exist, for the purposes of this study two general types of tube enhancement are recognized - one for vertical falling-film tubes and one for liquid-filled tubes. For falling-film tubes, the enhancement is double-fluting, with configuration similar to the tube section shown in Figure 11.1.1. The grooves or flutes represented in this sketch are about 1/8 inch apart, crest to crest, with moderately sharp tops and bottoms. The fluting is parallel to the tube axis, or may spiral slightly, but the spiral angle is always small. In vertical tube operation, heat is transferred from the condensing vapor on the outside of the tubes to the boiling liquid film on the inside. Surface tension causes the gravitating liquid on both sides to collect in the grooves, leaving the flute crests exposed.

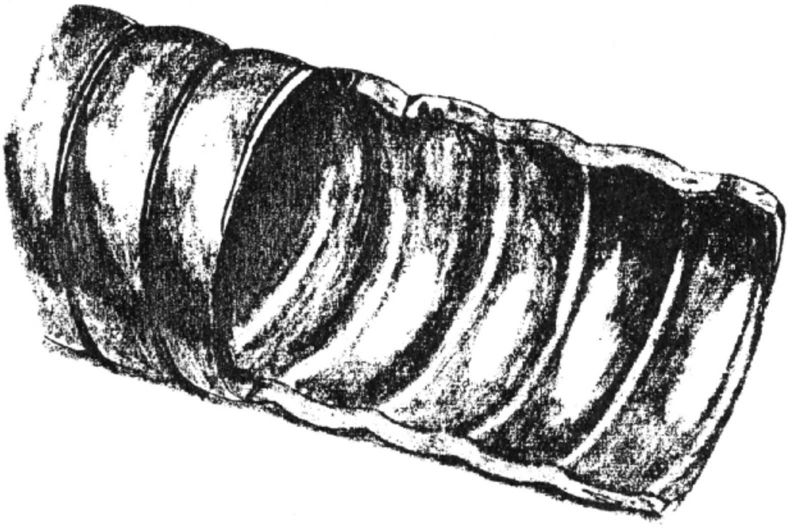
For liquid-filled tubes, enhancement takes the form of corrugations similar to those shown in Figure 11.1.2. These corrugations generate turbulence in the flowing liquid inside the tube, and thus promote heat transfer from the boundary layer to the bulk fluid. The outside of the tubes may be in vapor, as with the feed preheater and heat rejection condenser tubes, or in liquid, as in the product water coolers. In contrast to the fluting in the vertical tubes, corrugations are oriented nearly at right angles to the direction of liquid flow, so that they present the maximum surface roughness to the flowing stream.

The overall designs of the VTE plants using smooth tubes and using enhanced tubes are identical except for the differing configurations of the tubes, and related changes. In general, the enhanced tube design allows the use of shorter tubes; consequently, the evaporator and exchanger vessels are also shorter. For example, the smooth falling-film tubes are 24 feet long, while their fluted counterparts are but 14 feet long. Another difference between the plants is in the pumping requirements. In the case of the corrugated tubes, the higher friction losses experienced by the tube-side liquid usually requires a moderate increase in pumping power.



DOUBLE-FLUTED
ENHANCED SURFACE TUBING

Figure 11.1.1



CORRUGATED ENHANCED SURFACE TUBING

Figure 11.1.2

11.1 VTE Plant Description - Process and Physical (Cont'd.)

The proper distribution of the feed to the vertical falling-film tubes in each effect is accomplished by means of patented flow distributors which are inserted into the top of each individual tube. For the reference plant each flow distributor is a slotted circular weir so proportioned that a head of one to two inches of water is necessary to pass the required flow. This head requirement is sufficient to insure a reasonably uniform distribution of feed to all tubes across the tube bundle. The slots in the circular weir are so shaped that they inpart a tangential swirl to the feed flow entering each tube, thus helping to establish a uniform distribution of the falling-film over the inner surfaces of the vertical tubes.

Noncondensable gases are removed from each effect by appropriate vents. Effects operating at pressures below atmospheric are vented to steam-driven two-stage air ejectors. A barometric precondenser and inter-condenser reduces the load of condensable vapors to the ejectors. A complete spare system of ejectors and condensers is installed to insure continuity of operation.

The deaerator and decarbonator are combined into a single vertical vessel 13'-6" in diameter and 26 feet high, which operates at 26 inches Hg vacuum. (Basis for this size is discussed in the following Study Procedure Section.) Deaerated feed flows by gravity from the deaerator-decarbonator to the vertical can-type deaerated feed pump.

Spares are provided for all pumps to minimize the incidence of plant shutdown for pump repair. Installed spares are provided for the seawater intake, raw seawater feed, deaerated seawater feed, heat reject distillate, product, acid, caustic, chlorine, and condensate return. In addition, one installed spare is provided for each two falling-film feed pumps and a spare is shared between the Effect 14 feed pump and the blowdown pump.

The tubing for both the smooth and enhanced tubes is 90-10 copper-nickel. The smooth-tube plant utilizes only seamless tubing; in the enhanced plant, welded tubes are used for the double-fluted tubes, and seamless for the corrugated enhanced-surface tubes. Tube sheets and channels of the preheaters and the heat reject condenser are solid copper-nickel or copper-nickel-clad over carbon steel base metal. All return heads are solid copper-nickel. In the falling-film tube bundles, the tube sheets are copper-nickel-clad over carbon steel, and water boxes are monel-clad or solid monel on the first five effects, and glass-reinforced polyester on the balance.

The modular evaporator vessel consists of an externally reinforced carbon steel shell with double wall top section, designed so that it provides suitable steam passages and includes flash chambers for recovering heat from the product concentrate in each stage. All inner carbon steel plates in contact with seawater include a corrosion allowance in their design.

Knitted 316 stainless steel entrainment separators 4 inches thick are provided between the flashing liquids and the condensing tubes in the evaporator vessel. These separators are removable through the manways provided in each effect.

The combined deaerator-decarbonator is carbon steel with a shop-applied internal epoxy coating, and in addition, is provided with a 1/4 inch corrosion allowance. The seawater inlet nozzle is of 316 S.S., packing is polypropylene (Dow "Mas Pac") and the packing support plate is glass-reinforced epoxy.

The steam jet ejectors are built of 18-8 stainless steel, with the precondenser and intercondensers of rubber-lined steel or fiberglass.

In the reference design extensive use is made of fiberglass piping, including the following: seawater feed from the supply piping to the deaerator-decarbonator; heat reject cooling water; brine blowdown; deaerated feed from the deaerator through Effect 4; and effect pump piping from Effects 4 through 14. In the three highest temperature effects, 316 S.S. piping is used. The seawater intake line is of reinforced concrete. With minor exceptions, the remainder of the piping in the plant is of carbon steel.

The VTE evaporator is insulated for personnel safety and economy where fluid temperature exceeds 150 F. Evaporator insulation is of semirigid glass fiber panels fitted with aluminum covering, or of granules installed between the double walls of the evaporator vessel. Preformed or block-type insulation is used on other vessel surfaces and on pipes. All except the granule-filled top section has 0.016 inch aluminum covering.

11.2 MSF Plant Description - Process and Physical

Process Description

The MSF desalination process described in this study of 2.5 MGD plants is a conventional multistage, single-effect flash evaporation process using recirculating brine flow. The reference source for the process and mechanical design evaluated in this portion of the study is given in Section 13.1. In this reference, the designer has provided a series of 11 process designs covering a spectrum of possible operating conditions, with the purpose of providing a universal plant design. Of the 11 designs given, 4 were for plants using polyphosphate treatment of the seawater feed, and were limited to a maximum brine temperature of 190 F. The remaining 7 plants, including the one chosen for this comparative study, used acid treatment of the feed, and were designed for a maximum brine temperature of 250 F. The basic plant configuration and module construction was similar for all of the 250 F plants, but the number of stages, operating temperatures and pressures in each stage, and performance ratio varied among the designs. Fluor has selected the Universal Plant Design No. 4 as being the one which most nearly matches the design conditions and performance ratio of the two small VTE plants. The plant contains 39 heat recovery stages and three heat rejection stages. Its performance ratio is 11.5 pounds of product for each 1000 Btu of heating steam, based on its nominal production capability of 2.5 million gallons per day. Temperatures, flow rates, and concentrations of the various process streams are shown in the Process Flow Diagram, Drawing 4-012.

Cold seawater at 65 F is pumped to the MSF plant by the seawater intake pumps as a combined feed and cooling stream. To control biological growth throughout the inlet system, it is chlorinated at the fish cap where the seawater enters the intake conduit. After screening to remove debris, a minor part of the seawater flow is diverted to cool the barometric condensers, while the major portion is pumped through the heat reject module to absorb the latent heat from the final flash stages. Nearly 75% of the warmed seawater leaving the heat reject module at 82 F is returned directly to the sea, while the remainder becomes the seawater make-up feed to the evaporator plant. Sulfuric acid is added to the feed to neutralize the alkalinity, and it is then sprayed into the combined deaerator-decarbonator. Under the joint influence of the very low pressure maintained in the deaerator and the stripping steam injected in countercurrent flow, the carbon dioxide, dissolved oxygen, and other inerts are removed to very low levels. If they are needed, caustic and antifoamer are added to the deaerated feed to adjust pH and prevent excessive foaming. The treated make-up is then added to the recycling brine by allowing it to flow by gravity into the suction of the recycle pump. (See Drawing 4-005 for the Chemical Flow Diagram.) The new seawater feed makes up 29% of the brine circulation stream, and the recycle brine from the last heat reject stage, which is twice as concentrated as natural seawater, constitutes the remaining 71%. To control the recycle brine concentration, a portion of the brine stream from the last stage is diverted to blowdown before the new feed is added to the recycle stream.

11.2 MSF Plant Description - Process and Physical (Cont d.)

The brine circulation stream is discharged from the recycle pump through the preheater tubes of each stage of the evaporator, acquiring heat from the condensing vapor on the way. Emerging from the evaporator, the circulating brine enters the brine heater, where it is heated by externally-supplied stream to its final temperature of 250 F, establishing its flashing potential. From there it flows through a pressure control valve to the flash chamber in the first stage of the evaporator, where a portion of the brine flashes to steam. The remainder flows through a flow-controlling orifice into the slightly lower pressure region of Stage 2, where additional flashing occurs. This process continues through the entire plant, with the brine flowing into regions of progressively lower temperatures and pressures in each successive stage. After leaving the final heat rejection stage, the remaining brine is at a temperature of 82 F.

The steam which flashes from the surface of the flowing brine stream in each evaporator stage passes through entrainment separators and is condensed on the outside of the preheater tubes through which the recycle brine is passing. This condensate, or product water, collects in a tray under the preheater tube bundles. Then, like the brine stream, it flows through flow-controlling orifices from stage to stage, dissipating its sensible heat by reflashing, until it finally emerges from the last heat-rejection stage into the suction of the product water pumps. Vapor flashed from the product stream recondenses on the preheater tubes, transferring its sensible heat to the recycle brine, and recovering the condensate. The temperature of the condensate stream has been reduced to 79 F when it leaves the final heat rejection stage; no product water cooler is necessary.

11.2 MSF Plant Description - Process and Physical

Physical Plant Description

The 2.5 MGD Universal MSF plant whose design is evaluated in this study is a modular plant assembled from a number of identical or near-identical components or modules. (The reference source of the process and mechanical design is given in Section 13.1). The typical recovery module in the MSF plant is a box-like structure approximately 90 feet long, 8½ feet wide, and 12 feet high, with flat sides and bottom and a domed top, and containing 8 evaporator stages. Four such modules connected together, plus a slightly shorter 7-stage module, plus a 3-stage heat rejection module, combine to form the 43-stage evaporator under comparison in this study. Drawings 4334-FC-A, FC-B, and FC-C show the high-temperature, low-temperature and heat rejection modules, respectively.

Modules are fabricated of carbon steel, using standard structural shapes and steel plate. The flat sides and bottom are reinforced with external steel ribs to resist the internal and external pressures. By keeping the overall width below 10'-0", the modules can be shop-assembled and transported to the site.

The arrangement of the units is shown in the Plot Plan, Drawing 4-011. Excluding the seawater intake and outlet structure, the entire water plant is placed on a plot 120' x 272'. The modules are connected together by appropriate piping to convey the recirculating brine feed, the flashing brine stream, and the condensate stream. The flashing brine stream is carried in two parallel pipes to avoid problems in distributing the brine flow laterally across the module width, as it flows from one module to the next. Expansion joints are provided in all pipes between modules to accommodate thermal expansion and contraction.

Each module is divided into stages by bulkheads, with each stage containing channels for the flashing brine and the condensate and knitted mesh demisters to strip droplets of brine from the vapor enroute to the condenser tubes. Properly sized orifices between stages regulate the flow of flashing brine and product from stage to stage. The orifices are installed in liquid-leg U-tubes at the high-pressure end of the plant to provide sufficient submergence to prevent blowing the liquid seals. The condenser tubes extend in continuous lengths through all the stages in each module, so that only two water boxes and tube sheets are needed for each module.

The heat rejection module has the same basic cross-sectional size and shape as the heat recovery modules, but is only 63 feet long and contains three stages. Construction is basically the same, and the flashing brine and product channels are continuations of their counterparts in the heat recovery modules. The condenser coils, however, are supplied with a cooling water stream separate from the recirculating brine stream in the heat recovery modules.

The brine heater is a separate vessel in which the recirculating brine from the first stage preheater is brought to its final temperature by the externally supplied heating steam. The carbon steel brine heater is 46 inches in diameter, with tubes 15'-6" long.

All heat exchange tubes throughout the plant are of 90-10 copper-nickel construction; tube sheets are of solid copper-nickel or copper-nickel clad over carbon steel; water boxes are copper-nickel for temperatures above 180 F, and carbon steel for lower temperatures. Tubing specifications are detailed in the MSF Plant Equipment List, Section 18.1.

All pumps in the MSF plant are driven with electric motors, and those handling water near its flashing point are vertical-type set in pits to avoid cavitation problems. All pumps, except the brine recycle pumps, are provided with an installed spare to minimize the probability of plant shutdown because of the need for pump maintenance. The two brine recycle pumps are designed to operate in parallel, with each pump capable of providing 55 percent of the required brine recirculation flow at the design head. Thus, if one pump were shut down, the other could continue to operate the plant at a reduced throughput.

The reference MSF plant design provided for a separate deaerator and decarbonator. To make the MSF design comparable to the VTE, Fluor combined the two separate units into a single deaerator-decarbonator vessel 15'-4" in diameter and 26 feet long, with spray inlet nozzles and "Mas Pac" polypropylene packing. The vessel is maintained at 26" Hg vacuum and provided with a flow of stripping steam to remove dissolved oxygen and carbon dioxide from the makeup feed. A two-stage steam jet air ejector system with barometric condensers is provided to remove noncondensable gases from the evaporator vessels and the deaerator-decarbonator. Arrangement of the mechanical equipment, piping, and instrumentation is shown in the Mechanical Flow Diagram, Drawing 4-013. The Chemical Flow Systems and the Electrical Diagrams are shown in Drawings 4-005 and 4-014, respectively.

11.3 Study Procedure

The source material furnished to Fluor by OSW for plant comparison consisted of a report in proposal form from Stearns-Roger Corporation covering the design and costs of two 2.5 MGD VTE Desalination Plants, one with smooth tubes and one with enhanced tubes; and Volumes I, II-I, II-II, III, and IV of a Report Manual for a 2.5 MGD MSF Universal Desalting Plant. Both designs covered principally on-site equipment.

Additions Made by Fluor to All Plants

In order to obtain complete costs, the following off-plot items were added to all three plants:

1. A 1000-foot long submarine intake line, an intake-outfall structure, and seawater intake pumps were added as part of the plant equipment necessary for an open coast location.
2. Facilities were added to chlorinate all seawater entering the plant, to control biological growth.
3. Pumps were added to return the heating steam condensate to its source.
4. Buildings, roads, etc. were added as shown on the plot plan and noted on the Equipment Lists.

Changes Made by Fluor to the VTE Plants

One process change was made to the VTE plants; the sulfuric acid dosage rate to the make-up feed was reduced from 135 ppm to 120 ppm to put consumption on the same basis as the MSF plant.

Several on-site physical changes and additions were made to the VTE plants to place them on a basis comparable to the MSF plant. The principal change was to increase the diameter of the deaerator-decarbonator from 5 feet to 13.5 feet, to provide adequate capacity for removal of inert gases. The size was based on the same criteria used in the design of the deaerator-decarbonator for the MSF plant, and verified by conventional design practice in other plants with which Fluor is familiar.

Other on-site physical changes to the VTE plants included the addition of a caustic mixing tank, and the addition of several pumps to obtain the same reliability in the VTE plant as in the MSF plant. These additions are noted in the Equipment Lists in Section 17.

Changes Made by Fluor to the MSF Plant

The MSF plant design selected by Fluor to compare with the VTE plants was one of a group of designs supplied to cover a wide range of operating conditions and requirements. This particular selection (Universal Plant Design No. 4) was made because its conditions most nearly corresponded with those of the VTE plant. It was still necessary, however, to make adjustments to bring the MSF plant to the same bases as the VTE plants. This was done in all cases by changing the MSF process design to correspond with or be comparable to the VTE process design. The process changes made to the MSF plant design are:

1. The assumed seawater temperature, which had been 85 F, was set at 65 F. This corresponds to an average seawater temperature in Southern California.

2. The product water temperature, which had been 95 F, was reduced to 79 F to correspond to the lower temperature of the cooling water.

3. The brine concentration ratio, which had been 1.735, was increased to 2.0.

4. The fouling factor in the heat recovery stages, which had been .0003, was increased to .0005.

5. The fouling factor in the heat rejection stages, which had been .0005, was increased to .0007.

6. The heating steam condensing temperature, which had been 265 F, was raised to 267 F.

Using this input, Fluor made a computer run to determine the new design for the MSF plant. This updated computer run is reproduced in the Appendix of this report.

11.3 Study Procedure (Cont'd.)

In addition, the following physical changes were made to the MSF plant:

> In the Universal Plant Design No. 4, the deaerator and decarbonator are separate vessels. Fluor combined these into a single vessel to correspond with the VTE design, with size and cost of the deaerator-carbonator on each plant in proportion to the relative flow rates through the two vessels. (Enlargement of the VTE deaerator-decarbonator is discussed elsewhere in this section.)
>
> The surface-type ejector condensers specified in the Universal Plant Design No. 4 were changed to barometric type similar to that specified in the VTE plant.

11.0 - TECHNICAL SUMMARY - 2.5 MGD PLANTS

11.4 - CAPITAL COST SUMMARY

	VTE Plant Smooth Tubes	VTE Plant Enhanced Tubes	MSF Plant Smooth Tubes
Developed site cost:			
Land (for water plant)	$ 160,000	$ 160,000	$ 200,000
Site development and offsite facilities	1,028,500	1,028,500	1,080,900
Subtotal, Developed site cost	$1,188,500	$1,188,500	$1,280,900
Desalination plant cost (erected):			
Tube bundles)			$ 622,300(2)
Evaporator shells)	$1,589,938(1)	$1,412,031(1)	1,322,500
Other plant equipment	1,483,662	1,440,069	1,177,700
Subtotal, Desalination plant cost	$3,073,600(3)	$2,852,100(3)	$3,122,500
Engineering design, procurement, inspection, etc.	$ 256,000	$ 256,000	$ 256,000
Interest during construction	$ 169,400	$ 161,100	$ 174,700
GRAND TOTAL ERECTED COST - 1968 DOLLARS	$4,687,500	$4,457,700	$4,834,100

(1) Breakdown not available
(2) Includes cost of separate brine heaters
(3) See Section 15.1 for breakdown

11.5 PRODUCT WATER COST SUMMARY - 2.5 MGD PLANTS

	VTE Plant Smooth Tubes	VTE Plant Enhanced Tubes	MSF Plant Smooth Tubes
Total Capital Cost - 1968	$4,687,500	$4,457,700	$4,834,100
- Escalated to 1970 (1)	$4,900,000	$4,680,000	$5,060,000
Annual Cost, Dollars			
Capital charges (2) -includes interest, amortization, interim replacement and insurance	$ 307,000	$ 293,000	$ 317,000
Utilities (3)			
Steam	298,730	298,730	307,460
Electricity	43,600	52,800	56,700
Materials and Supplies (3)			
Chemicals (4)	37,720	37,720	55,760
Misc. Maintenance Supplies	25,000	25,000	25,000
Labor, including overhead (3)			
Operation	78,000	78,000	78,000
Maintenance	48,100	48,100	48,100
Total Annual Cost, 1968	$ 838,150	$ 833,350	$ 888,020
Annual Net Water Production, 1000 Gallons (5)	817,000	817,000	819,000
Water cost per 1000 gallons - 1968	$1.03	$1.02	$1.08
Water cost per 1000 gallons - Escalated to 1970 (1)	$1.08	$1.07	$1.14

(1) 2.4% escalation/yr
(2) For fixed charges see Section 13.2
(3) For breakdown see Section 15.0
(4) Includes continuous chlorination of seawater
(5) VTE net production is less because of more in-plant usage.

12.0 - DEVELOPMENT POTENTIALS - 2.5 MGD PLANTS

As was the case with the large (250 MGD) desalination plants, there are several areas with the 2.5 MGD plants where potential savings could probably be realized with suitable study and development. These major areas are listed and discussed in the following paragraphs.

Substitution of Seawater Wells for Submarine Seawater Intake Lines

Although seawater intakes located in deep water on sheltered inlets or tidal estuaries are relatively simple to construct, intake structures along open shores and beaches are generally complicated and expensive. They have to extend for relatively long distances from shore so the intake will be in water deep enough to avoid interfering with shipping and be reasonably free of suspended sand and silt. To protect the pipe from storms and erosion, it must be placed in a trench in the ocean floor and covered - an expensive procedure. In fact, the submarine seawater intake systems for the 2.5 MGD plants sited in Southern California have proven to be one of the more costly portions of the whole plant structure. The submarine type of intake was chosen for this small-plant study in spite of its high cost because it is a proven method for this area. Many of the power generation stations along the Southern California coast obtain their condenser cooling water in this manner, and have found that the submarine line does provide a reliable source of fairly clean seawater. One disadvantage is the tendency of the submarine line to collect marine growth, such as mussels, barnacles, and seaweed. In the power plant conduits, marine growth is minimized or eliminated by chlorination or by intermittent heat-shocking of the entire intake line.

Seawater wells are being successfully used in some areas as an alternative to the submarine intake line. Where the underground strata is a permeable material such as coral, drilled wells can provide an adequate supply of filtered seawater for power plant cooling and for desalting plant feed water. The water from such wells is constant in temperature and is completely free from sand, silt, and marine life. Moreover, the cost of drilling seawater wells is many times less than that of building a submarine intake line. It has been suggested that even where the subsurface stratum is not very permeable, several vertical gravel-packed wells, or a Ranney well with gravel-packed horizontal bores radiating from a central vertical bore, could produce sufficient clean seawater at a cost less than that of the submarine line. A seawater collector of the latter type is successfully operating at Ventura, California.

For small desalination plants located on open shores, there is a good possibility that seawater wells could provide an inexpensive method of obtaining cool, filtered seawater devoid of marine life and needing no chlorination or screening. Because submarine intake systems constitute a significant fraction of the capital cost of the 2.5 MGD plants considered in this study, seawater wells could make a significant reduction in the capital cost of such plants.

Increased Use of Plastics

The reference VTE plant designs specify plastic (fiberglass reinforced epoxy or polyester) pipe for most of the seawater and brine piping, whereas the reference MSF plant design specified cement-lined carbon steel or extra strong carbon steel or 90-10 Cu-Ni pipe for these streams. In addition, the VTE reference design uses plastic for 9 of the 14 water box covers over the falling-film elements.

At the present time, plastic pipe is obtainable up to 30 inches in diameter, but experience is limited in the use of plastic pipe larger than about 18 inches. Moreover, in all sizes the plastic materials must be carefully selected to conform to their pressure and temperature limitations. Because there is still so little experience in the installation of plastic pipe, installers must be thoroughly trained and supervised in order to avoid costly rework.

Fluor believes, however, that as experience is gained in the manufacture and installation of plastic pipe, significant first cost and maintenance savings are possible through the greater use of plastics, especially in the case of MSF plants.

Longer Tubes for MSF Plants

At present, heat exchange tubes up to about 100 feet long are available. They can be shipped or barged in straight lengths to the site for field installation, or they can be shop-installed into evaporators, which are then shipped to the site.

The use of even longer tube lengths would eliminate a few tube sheets and water boxes, plus the piping which now interconnects a greater number of shorter evaporators. For very large water plants it is conceivable that tubes of any length can economically be either fabricated in the field or shipped in rolls and then straightened in the field. For small plants (in the 2.5 to 5 MGD range), this means of obtaining longer tubes would not be expected to result in a cost saving. However, it is probable that there are, currently, several tube mills and many potential plant sites so located that straight tube lengths or shop-tubed evaporators up to 150 feet long could be shipped. This would result in a small but significant saving for an MSF plant.

Use of Enhanced Tubes for MSF Plant

There is currently a great deal of interest and activity in the development and testing of enhanced surface tubes designed to improve heat transfer between liquid and vapor phases, such as is found in the tubes in MSF desalination plants. In the portion of this study dealing with the large (250 MGD) desalination plants, it was shown that the use of enhanced-surface tubes in the MSF plant would be potentially advantageous over the use of smooth tubes (Sec. 4.0). Presumably this same advantage would apply to a lesser extent in the small MSF plants; however, this aspect was not investigated in the current project.

In the study of the large MSF plant, the prices and performance of the spirally-corrugated tube of a single manufacturer (Wolverine Tube) were evaluated. It is known that somewhat different configurations are under study by Oak Ridge National Laboratories, by Olin Brass, and perhaps by others. It is anticipated that the next few years may see the development of improved performance and reduced manufacturing costs of enhanced surface tubes for such applications, which should be reflected in reduced capital costs of MSF plants.

Use of Turbine Drives for Large Pumps

The ground rules for this study stipulated the use of electric motor drives for all major pumps. This implies a dual-purpose plant, since electric motor drives on large pumps usually show an advantage only where high-pressure steam is already being used to generate electricity on-site. For single-purpose plants, it is generally more economical to drive the large pumps with high pressure steam turbines, using the turbine exhaust for feed water heating. It is expected that steam turbine drives on major pumps could reduce operating costs on a single-purpose plant, and their use would lead to lower water costs, particularly with the MSF plant.

Increased Maximum Brine Temperatures

For any single-purpose water evaporation plant, the use of higher maximum brine temperatures offers a potential for increasing the performance ratio and thus lowering product water cost. A recent study by Bechtel Corporation for OSW (R&D Progress Report No. 175) found 350 F to be the optimum brine heater temperature for large MSF plants. At this brine temperature, the use of additional flash stages would allow the plant to produce more product with a given thermal input. Similar savings could be expected in VTE plants by increasing the number of stages and effects.

In order for a plant to operate at such elevated temperatures on seawater feed, a practical and inexpensive way must be developed to eliminate the formation of scale on heat transfer surfaces. Even with acid treatment, temperatures much above 260 F cannot be achieved without the risk of scaling. Calcium sulfate scale, which appears above 250 F, is not inhibited by acid treatment of the feed, nor can it usually be removed by anything except mechanical means.

A promising method of scale elimination has recently been developed by the W. R. Grace Company, which removes a major portion of the calcium ion in the seawater feed by precipitating it as calcium carbonate. It is called the lime-magnesium carbonate (LMC) process. Since the calcium is precipitated as calcium carbonate, the process also removes bicarbonate and carbonate ions, and eliminates the necessity for acid treatment of the feed.

This LMC pretreatment process is currently under test at the OSW West Coast Test Facility in Chula Vista, where it is treating the feed to the Clair Engle desalination plant. Early reports indicate that the plant is performing well. If the LMC water pretreatment method should prove to be effective and economical, two-fold savings would result. The significant cost of acid addition would be eliminated, and higher brine temperatures would allow overall plant efficiency to be improved.

13.0 - BASES FOR COST ESTIMATES - 2.5 MGD PLANTS

13.1 Bases for Capital Cost Estimate - 2.5 MGD Plants

General Comments

The basic purpose of the estimates of the VTE and MSF 2.5 MGD plants is to compare the capital costs and the water costs for these two types of plants. Both estimates are based on A&E type designs, in sufficient detail for obtaining lump sum proposals. In the following paragraphs specific portions of the capital cost estimate are discussed, with comments, where appropriate, on the assumptions and method of approach to each.

Scope

The capital cost estimate for the 2.5 MGD desalination plant assumes a single purpose plant and includes only the water plant. The heating steam source is assumed to be a boiler plant adjacent to the water plant. The cost of the boiler plant is not included in the capital costs of the water plants. Its cost would be the same for either type of water plant.

The following procedure was used for estimating the capital costs of the 2.5 MGD plants. The quoted plant selling price given in the source report was accepted as being a correct estimate of the cost of the VTE plant as defined in the report. To this selling price Fluor added: (a) 5% price escalation; (b) the estimated cost of facilities shown on the plot plans which are outside the quoted plant; (c) the cost of added or changed equipment within the quoted plant; and (d) owner's costs.

For the MSF plant the capital costs were estimated completely by Fluor. Equipment prices were based on quotes or in-house information. Foundations, piping, electrical, instrumentation, etc. were estimated and material take-offs made from the flow sheets and drawings provided in the reference design.

Source for Process and Mechanical Designs

For the 2.5 MGD conventional (smooth-tube) and enhanced-tube VTE plants, the basis for design is a report in proposal form submitted to Union Carbide Corporation by Stearns-Roger Corporation. This report is entitled "2,500,000 GPD Multiple Effect Falling Film Desalination Plant," Project No. B-35298, and is dated September 30, 1968, with an addendum dated November 1968. For the 2.5 MGD MSF plant the design basis is the "Report on Design of a 2.5 Million Gallon per Day Universal Desalting Plant," prepared for the Department of the Interior, Office of Saline Water, by Burns and Roe, Inc. This report is dated June 1967.

Site Preparation

The plants are assumed to be located on a Southern California coastal site, with a 200-ft. wide beach rising to an elevation of 35 ft. at the base of the coastal cliff. At the cliff the terrain is assumed to rise 50 ft. to a level plateau at 85 ft. elevation, which extends inland beyond the site limits. The prepared site is to be at elevation 35 ft. An allowable soil bearing pressure of 3500 psf is assumed.

A major expense in site preparation is excavation and grading. For the VTE plant, 71,000 cubic yards must be removed; for the MSF plant, because of its greater area, the figure is 84,000 cubic yards. It is assumed that this excavated material could be used as fill on a location adjacent to the plant site.

Buildings

The cost of a control building, switchgear building and a small shop is included in the cost of each plant.

Owner's Costs

The following owner's costs are included in the capital costs of both the VTE and MSF plants.

a. Cost of land occupied by Water Plant - assumed at $100,000 per acre.

b. A&E costs, permits, etc.

c. Owner organizational costs.

d. Interest during construction (includes bond financing costs).

e. Startup costs - labor, chemicals, etc.

Product Water Treatment

For both the VTE and the MSF plants the product water is assumed to be delivered at the plant boundary under a pressure of 10 psi. No capital costs are included in this estimate for product water treatment or storage.

13.1 Bases for Capital Cost Estimate - 2.5 MGD Plants (Cont'd.)

Price Level

For the MSF plant, labor and equipment pricing is based on 4th quarter 1968 prices, then escalated to 1970 level based on an 18-month engineering-construction schedule. The VTE plant prices are assumed to be also based on 4th quarter 1968 prices. The reference quotation is subject to 5% escalation to bring it to the same time frame as the MSF plant, and this has been added. The facilities added by Fluor are escalated by Fluor on the same basis as for the MSF plant. Annual escalation from 1968 to 1970 is assumed to be at the same rate as the average annual escalation from 1958 to 1968 in Southern California. Escalation is estimated to have averaged 4.2% annually for labor and 2.1% for material. It should be noted that escalation rates during the last five years are much higher than the ten-year average.

Labor Availability

Except for some shift work and overtime by concrete workers and riggers, a 40-hour work week is assumed. Travel and subsistence allowances to the site are included.

Equipment Pricing

Only U. S. manufacturers were contacted for equipment priced by Fluor.

Spare Parts and Shop Tools

The cost of spare parts and shop tools is not included in the capital costs.

Taxes

It is assumed the owner will be tax exempt and, therefore, the California State sales tax of 5% on materials is not included.

Form of Estimate

The breakdown is presented in essentially the form and detail shown in Appendix F of the 1965 Saline Water Conversion Report.

13.2 Bases for Product Water Cost - 2.5 MGD Plants

Escalation

It is assumed that the plant could be operational in mid-1970 if started in early 1969. Product water costs are estimated on the basis of the purchasing power of 1968 dollars, and operational costs are then escalated to 1970, using the average annual escalation experienced from 1958 to 1968. Escalation is estimated at 4.2% annually for labor and 2.1% for material. It should be noted that escalation rates of the last five years have been much higher than for the ten-year period.

Cost of Money

Municipal bond financing is assumed. Bond interest rate is taken as 4.25%.

Cost of Bond Financing and Interest During Construction

Underwriters and bond counsel fees and interest during construction are included in the capital costs.

Repayment Period

Investment costs are amortized over a 30-year period corresponding to the estimated life of the desalination plants. The annual amortization factor of 1.71% is based on a sinking fund repayment method over a 30-year period at 4.25% interest.

Interim Replacement

Both the VTE and the MSF plants are expected to have a useful life of 30 years; however, a 0.35% factor is included for replacement of portions of the plants not expected to last the full 30 years. The 90-10 Cu-Ni tubing of each of the plants is assumed to have a 30-year life.

Fixed Charges on New Plant Costs

The total annual fixed charge is based on the following percentages of capital investment:

a.	Cost of money	4.25%
b.	Bond amortization factor (30-year basis)	1.71%
c.	Plant replacement factor	None
d.	Plant interim replacement factor	0.35%
e.	Tube interim replacement factor	None
f.	Property damage insurance	.25%
g.	Taxes	None
		6.56%

13.2 Bases for Product Water Cost - 2.5 MGD Plants (Cont'd.)

Energy Costs

Energy Costs used in estimating water costs were specified by OSW and are:

	VTE Plant	MSF Plant
Steam supplied at plant boundary:		
150 psig - ¢/10^6 Btu	50	50
42 psia - ¢/10^6 Btu	50	-
40 psia - ¢/10^6 Btu	-	50
Electric power - 4160 V. at plant boundary - ¢/Kwhr	0.85	0.85

Chemical Costs (delivered to site)

	Price, 100% Basis	VTE Plant	MSF Plant
Sulfuric acid (93%)	$/ton	30.00	30.00
Caustic soda - 50% solution	$/ton	150.00	150.00
Chlorine - 100%	$/ton	130.00	130.00
Anti-foam solution - 100%	$/lb	.40	.40

Maintenance Materials and Supplies

The annual cost of plant maintenance materials and supplies is estimated at 0.6% of direct capital cost.

Insurance

The annual insurance premium on the desalination plant is estimated to be 0.25% of capital cost.

Taxes

It is assumed that the owner will be a tax-exempt municipal or governmental agency, and that no city, country, state or federal tax or tax equivalent payments are applicable.

Load Factor

It is assumed the plants will be operating at full design load (2.5 MGD) all of the time that they are on stream.

13.2 Bases for Product Water Cost - 2.5 MGD Plants (Cont'd.)

On-Stream Factor

For a single purpose plant, it is assumed that the plant will be available or on-stream 90% of the time. It is assumed to be shut down for maintenance, repairs, power plant outages, etc., the remaining 10% of the time.

Average Production Rate

Since the maximum daily gross capacity of each plant is 2.5 MGD, the yearly average capacity is 2.25 MGD (90% of 2.5). The net capacity is the gross capacity less plant useage for bearing cooling, glands, flushing, etc.

Product Water Pumping Requirements

Product water is delivered to the plant boundary at 10 psig and 90 F. No other pumping, passivation, or handling charges are included, since conveyance pipeline and storage facilities are not considered plant costs.

Operation and Maintenance Labor

Operation and maintenance labor costs are based on a single staff and a single control room for both steam and water plants. Personnel and estimated cost are shown in Section 15.3.

Owner's Administration and General Costs

These costs are estimated at 30% of operation and maintenance labor costs. The 30% includes payroll burdens of 20% (vacations, sick leave, State Disability Insurance, Federal Insurance Compensation Act, and Unemployment Compensation Disability Benefits).

Interest on Working Capital

Interest on working capital is included in the Administration and General portion of operating costs.

14.0 - SITE - 2.5 MGD PLANTS

For the purposes of this comparative study, all of the small (2.5 MGD) plants are assumed to be sited at the same hypothetical Southern California coastal location as was assumed for the large plants. The beach area is 200 feet wide, rising gradually from the breaker line to an elevation of 35 feet as the base of the coastal cliff. At the cliff the terrain rises abruptly to 85 feet elevation, and is assumed to then extend inland for an indefinite distance at 85 feet above MLLW.

The site will be excavated to an elevation of 35 feet for placement of the evaporation plant, access roads, and service and storage facilities. Typical soil in this region is readily excavated, yet is competent to provide good foundation support. An allowable soil bearing pressure of 3500 psf is used, and cut banks are assumed to be stable at an angle of 45°.

Land transportation facilities are conveniently available to the site. U. S. Highway 101 and the Santa Fe railroad both parallel the coastline in this general area, and overland access to the site presents no problems. No dock or harbor facilities are presently available in this area to accommodate water transport. However, water shipment of large items could be accomplished with the use of beaching-type craft and provision of the necessary unloading equipment.

The intake structure containing the seawater pumps and traveling screens is located at approximately the original breaker line, and the nearest portion of the plant proper about 225 feet inland from this. A buried intake pipe extends seaward 1000 feet to the seawater intake caisson and fish cap. This will be a 39-inch reinforced concrete line for the VTE plants, and a 42-inch line for the MSF plant. The top of the fish cap will be at least 15 feet below MLLW to avoid navigation hazards, and well above the ocean floor to avoid entraining silt with the feed stream. Reject water from the evaporation plant will be piped to a point adjacent the seawater pumps and released into the surf through an open channel.

This study is limited to consideration of the facilities required for the water plant, and does not include any site allowance for boiler plant, water storage, or any other related facilities. The water plant site plans are shown on Drawing 002 for the smooth-tube VTE plant, Drawing 001 for the enhanced surface tube VTE plant, and Drawing 011 for the MSF plant. Each plant will require a plot about 125 feet deep. The VTE plants are approximately 215 feet wide, while the MSF plant needs 275 feet.

15.0 - TABLES - 2.5 MGD PLANTS

15.1 Capital Cost Breakdown

		VTE Plant Smooth Tubes	VTE Plant Enhanced Tubes	MSF Plant Smooth Tubes
I.	Land	$ 160,000	$ 160,000	$ 200,000
II.	Site Development and Offsite Facilities			
	1. Mass excavation	45,700	45,700	53,300
	2. Roads, surfacing, etc.	8,000	8,000	8,400
	3. Buildings	28,700	28,700	37,400
	4. Submarines pipelines	550,000	550,000	560,700
	5. Seawater intake and outfall structures	124,100	124,100	124,100
	6. Screens, seawater pumps for intake structure	196,500	196,500	221,500
	7. Chlorination system (incls. pumps)	49,100	49,100	49,100
	8. Utilities (service water, service air, sewers)	26,400	26,400	26,400
	Subtotal - Section II	$1,028,500	$1,028,500	$1,080,900
III.	Conversion Plant			
	1. Evaporators			
	a. Bundles			601,300
	b. Shells			1,322,500
	2. Brine heater			21,000
	3. Noncondensable removal equipment			20,800
	4. Pumps and motor drivers			
	a. Blowdown			14,800
	b. Brine recycle			91,000
	c. Product water			13,600
	d. Condensate			6,300
	5. Make-up Pretreatment Systems			
	a. Chemical feed systems (incl. pumps, tanks and piping)			52,100
	b. Deaerator-decarbonator			69,300
	6. Excavation, foundations and miscellaneous steel			255,200
	7. Piping			
	a. Seawater and brine			223,000
	b. Product water			18,100
	c. Steam and condensate			8,700
	d. Noncondensables			41,100
	8. Electrical			145,300
	9. Instrumentation			
	a. Instruments, controls and control panel			121,200
	b. Instrument air system (compress., receiv., driers, pipings, etc.)			18,100
	10. Insulation			61,300
	11. Painting			17,800
	12. Spare Parts	None	None	None
	* VTE conversion plants estimated by others	*2,698,100	*2,476,600	
	** Additions to VTE plants estimated by Fluor	375,500	375,500	
	Subtotal - Section III	$3,073,600	$2,852,100	$3,122,500
IV.	Engineering, Design, Procurement, Construction Management and Inspection, Owner Organization Costs, and Owner Startup Costs	256,000	256.000	256,000
V.	Interest During Construction	$ 169,400	$ 161,100	$ 174,700
	GRAND TOTAL - 1968 DOLLARS	$4,687,500	$4,457,700	$4,834,100

* These are Stearns-Roger estimated selling prices plus their stated maximum escalation of 5%. See "A Report in Proposal Form" prepared by Stearns-Roger for Union Carbide dated September 30, 1968.

** For breakdown, see Section 15.4

15.0 - TABLES - 2.5 MGD PLANTS

15.2 Product Water Cost Breakdown

1968 Production Costs

		VTE Plant		MSF Plant
		Smooth Tubes	Enhanced Tubes	Smooth Tubes
Daily Production	MGD	2.5	2.5	2.5
On Stream Factor	%	90	90	90
Gross Production	MGY	822	822	822
Prod. Water Usage in Plant	MGY	5	5	3
Net Production	MGY	817	817	819
Steam - Saturated				
Heating Steam	lbs/hr x 10^3	80.2	80.2	80.9
	Btu/hr x 10^6	74.7	74.7	75.6
	¢/Btu x 10^6	50	50	50
	$/hr	37.3	37.3	37.8
	$/day	896	896	910
	$/yr	$294,000	$294,000	$298,000
Ejector Steam	lbs/hr x 10^3	1.0	1.0	2.0
	Btu/hr x 10^6	1.2	1.2	2.4
	¢/Btu x 10^6	50	50	50
	$/hr	.60	.60	1.20
	$/day	14.40	14.40	28.80
	$/yr	$ 4730	$ 4730	$ 9460
Subtotal - Steam	$/yr	$298,730	$298,730	$307,460
	¢/1000 gals	36.6	36.6	37.5
Power	kw	650	785	845
	¢/kwh	0.85	0.85	0.85
	$/hr	5.52	6.70	7.20
	$/day	133	161	173
Subtotal - Power	$/yr	$ 43,600	$ 52,800	$ 56,700
	¢/1000 gals	5.3	6.5	7.0
Subtotal - Energy	$/yr	$353,330	$362,530	$364,160
	¢/1000 gals	41.9	43.1	44.5

15.2 Product Water Cost Breakdown (Cont'd.)

1968 Production Costs (Cont'd.)

		VTE Plant		MSF Plant
		Smooth Tubes	Enhanced Tubes	Smooth Tubes
Chemicals				
Acid - 66° Be (93%)	tons/day	2.2	2.2	2.7
	$/ton	30	30	30
	$/day	66	66	81
	$/yr	$ 21,700	$ 21,700	$ 26,600
Caustic - 50% Solution	tons/day	.10	.10	.12
	$/ton	50	50	50
	$/day	5	5	6
	$/yr	$ 1,640	$ 1,640	$ 1,960
Chlorine - 100%	tons/day	.26	.26	.37
	$/ton	130	130	130
	$/day	34	34	48
	$/yr	$ 11,100	$ 11,100	$ 15,700
Miscellaneous Chemicals				
Anti-foam	$/day	None	None	25
Ferrous sulfate	$/day	10	10	10
	$/yr	$ 3,280	$ 3,280	$ 11,500
Subtotal - Chemicals	$/yr	$ 37,720	$ 37,720	$ 55,760
	¢/1000 gals	4.6	4.6	6.8
Miscellaneous Maintenance Materials				
Charts, rags, gaskets, lube oil, paint, fittings & other supplies				
Subtotal - Misc. Material	$/yr	$ 25,000	$ 25,000	$ 25,000
	¢/1000 gals	3.1	3.1	3.1
Operating & Maintenance Labor				
Operation	$/yr	50,000	50,000	50,000
Maintenance	$/yr	31,000	31,000	31,000
Supervision	$/yr	16,000	16,000	16,000
Administration & General	30%	29,100	29,100	29,100
Subtotal - O&M	$/yr	$126,100	$126,100	$126,100
	¢/1000 gals	15.5	15.5	15.5
Grand Total - Water	$/yr	$542,150	$551,350	$571,020
Production Costs[1]	¢/1000 gals	65.1	66.3	69.9

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[1] Excluding fixed charges on capital cost

15.3 Operating and Maintenance Cost Estimate for a 2.5 MGD Single Purpose VTE or MSF Plant[1]

	Duty Requirement	Personnel Required	1968 Annual Rate So. Calif.	Annual Cost
Plant Superintendent	5 days - 8 hrs.	1	$16,000	$16,000
Operators	7 days - 24 hrs. (1 per shift)	4½	10,000	45,000
Plant Chemist	5 days - 4 hrs.	½	10,000	5,000
Maintenance Technicians	5 days - 16 hrs.	2	12,000	24,000
Janitor	5 days - 8 hrs.	1	7,000	7,000
		10		$97,000
Administration and General, including payroll burdens and fringe benefits - 30%				= $ 29,100
				$126,100

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[1] Personnel would also operate and maintain the steam generation plant, but the entire cost is charged to the water plant, since it is a single-purpose plant.

15.0 - TABLES - 2.5 MGD PLANTS

15.4 Cost Breakdown of Additions to VTE Plants[1]

1.	Pumps		
	a. Nondeaerated seawater feed	P-1A & B	$ 40,500
	b. H. R. distillate pump spare	P-41B	1,000
	c. Condensate return	P-53A & B	8,100
	d. Spare for P-24 and 25	P-245	5,200
2.	Larger deaerator		28,200
3.	Caustic mixing tank with agitator		4,200
4.	Larger instrument air compressors and system		10,700
5.	Excavation, backfill and foundations for above		31,200
6.	Additional piping and supports		121,900
7.	Additional electrical		90,700
8.	Additional instrumentation		28,100
9.	Additional insulation		1,200
10.	Additional painting		4,500
			$375,500

These additions, made to both VTE plants, were considered necessary by Fluor to insure proper plant operability and reliability.

16.0 - 2.5 MGD DESIGN - VTE AND MSF PLANTS

16.1 Seawater Intake and Outlet

The hypothetical Southern California site chosen for location of the 2.5 MGD plants is typically along an unprotected shoreline, with shallow water extending some distance from the shore. The type of water inlet structure commonly used by power plants in this area is a submerged pipeline extending a considerable distance into the ocean. The water entrance must be in deep enough water so that it can be well above the ocean floor to prevent drawing in sand and silt during storms, and still far enough below the water surface to present no hazard to navigation. It is assumed in this case that this will require about 1000 feet of inlet line beyond the surf.

The intake structure will be located near the surf line, and will include traveling screens to remove debris from the water, screen cleaning equipment, and the seawater intake pumps. The discharge line, returning concentrated, warm brine to the sea, is an open channel releasing the brine into the surf. Associated with the intake line is a small conduit carrying heavily chlorinated seawater to be released in the mouth of the inlet pipe.

This inlet structure and submerged pipeline is an expensive construction project, and there may be other methods of obtaining clean seawater that would be less costly. However, this is a tried and proven method, and for this comparative study it was assumed that all these 2.5 MGD plants would use this type of inlet.

16.2 Chemical Systems

In common with the 250 MGD plants, the small VTE and MSF plants require the addition of chemicals to the system to inhibit biological growth in the plant conduits, prevent the deposition of scale, prevent corrosion, and eliminate foaming. Chemical flows for both plants are in Drawing 005.

Chlorine addition is required to prevent the growth of marine life within the plant structure. The chlorine must be added at the extreme outer end of the inlet pipe, to keep this pipe from becoming fouled with marine growth.

Chlorine is purchased as a liquefied, compressed gas, and must be dissolved in the water in which it will be used. If usage is large, a heat exchanger must be provided to vaporize the liquid chlorine. For plants of this size, however, it is feasible to utilize ambient heat to vaporize the chlorine as it is required. A one-ton cylinder will provide several hundred pounds of gas per day without any special heating means. By manifolding 5 one-ton cylinders together, sufficient gaseous chlorine can be produced to continuously treat the seawater inlet stream with 10 ppm of chlorine, if that rate should be required.

Methods of metering and dissolving the chlorine into the seawater require certain procedures and precautions. Chlorine is soluble in water to large concentrations, but requires time and large contact surface to dissolve. Dry chlorine gas is not corrosive, nor is dissolved chlorine in low concentrations; however, wet chlorine gas and water with high concentrations of dissolved chlorine are quite agressive to most metals. Chlorine gas from the tanks is passed through a pressure reducer and then aspirated into a mixing jet, where it is blended with water to form a solution of approximate 0.1% chlorine. This is then pumped to the end of the submerged intake pipe and released at the inlet of the conduit. In this manner marine growth can be controlled throughout the cold end of the plant. It is the experience of some operators that only intermittent chlorination is required - perhaps a half-hour to an hour once a day. Others find continuous chlorination to be more effective. The equipment has been sized to be capable of continuous chlorination. Steel pipe is used to carry the dry chlorine gas, and fiberglass reinforced plastic pipe for carrying the chlorine solution out to the end of the intake line. Hastelloy B is the best material for the difficult environment of the ejector.

Sulfuric acid is used to treat the make-up feed going to the deaerator-decarbonators. It breaks down the bicarbonate content of the seawater into carbon dioxide and water, preventing the deposits of calcium carbonate and magnesium hydroxide on heat transfer surfaces. The acid is injected with a metering pump into the warmed make-up feed leading to the deaerator-decarbonator, the amount being controlled by measuring the pH of the stream. If the pH of the make-up stream is too low after leaving the deaerator, it may be necessary to add caustic to raise the pH to prevent metal corrosion in the system. A caustic addition system is provided, which is quite similar to the acid system, with the caustic injected by a proportioning pump.

Under some circumstances it has been found necessary in MSF plants to add a small amount of antifoaming agent to the recirculating feed to prevent excessive build-up of froth and foam. A proportioning pump and storage facility has been provided in the MSF plant only, to add antifoamer if it is necessary. It has not been found necessary to use antifoamer in VTE plants.

16.3 Electrical

The initial electrical design of the reference VTE plants called for 480-volt power to be provided at the plot boundary as the sole source of electrical power. Since the VTE plants contain several motors in the 200 to 500 hp category, Fluor changed the plant supply voltage to 4160 volts - a more practical and economical voltage for motors of this size. This also corresponds to the electrical supply provided in the reference Universal MSF Plant. Further details of the electrical distribution system may be found in the Electrical One-Line Diagrams - Drawing 4-006 for the VTE plant and Drawing 4-014 for the MSF.

16.4 Instrumentation

General

Except where noted, the instrumentation recommended in this report for both VTE and MSF plants is essentially the same as that proposed by the reference designs. Changes have been made where, in Fluor's opinion, they are needed to improve plant operability, to reduce cost, or to place the instrumentation of the two plants on a comparable basis. Changes made are discussed and reasons are given.

A review of the instrumentation of the 2.5 MGD VTE and MSF plants shows them both capable of adequate process control; however, there is a basic difference in concept between the two designs. In the MSF plant, the designer has placed major indicating and control instruments in the central control room. All normal plant operation and surveillance will be accomplished from the control room, with only certain initial startup and final shutdown operations requiring local manual control. In contrast, the VTE plant designer has the VTE control room serving principally as a monitoring station. Excepting a few major control loops, the VTE controls and corresponding indicating points are in the field. Suitable control can be achieved with either method, but more operators will be required when controls are installed on local panel boards. To place both plants on an equal basis, Fluor has modified the VTE design by moving all field-mounted controllers to the control room. Most thermometers have been replaced by thermocouples connected to a multipoint temperature indicator on the control room panel board.

In contrast to the VTE plant, the MSF plant designer has proposed a very high level of instrumentation. Instruments which Fluor feels are unnecessary have been eliminated in the interests of economy. These include some of the temperature indicators, gage glasses, and conductivity analyzers.

Materials of Construction

Material of construction have not been specified in the reference designs for the wetted parts of most instruments. Fluor recommends the following materials for instruments exposed to the various plant fluids and the instrumentation was priced on this basis:

a. For wetted parts exposed to brine and seawater: monel

b. For product water and noncondensable gases: 316 stainless steel

c. For steam, condensate, and miscellaneous services: carbon steel

Instrumentation Diagrams

Instrumentation for each plant is shown on the Mechanical Flow Diagrams - Drawing 044 for the VTE and 013 for the MSF plant.

Temperature Instruments

Standard pneumatic transmitters are specified for control loops. Thermocouple temperature points are recorded on a potentiometer-type strip chart multipoint recorder, or indicated on a multipoint indicator, using selector switches for point selection.

Thermocouples and Thermometers

On the VTE plant, Fluor has added thermocouples at the brine pumps, preheaters, and brine stages to provide needed temperature indication from these points in the control room. On the MSF plant, thermometers had been provided on each stage vent crossover line. Fluor has eliminated these, leaving only one thermometer per module on the vent lines.

Pressure Instruments

Standard force-balance pressure transmitters are specified, using standard materials except where process conditions require stainless steel or monel for corrosion protection. Fluor added a board-mounted pressure indicator with field transmitter to the seawater inlet on the VTE design. A board-mounted pressure indicator and field transmitter were added to the deaerator on the MSF plant.

Differential Pressure and Flow Transmitters

Standard force-balance type D/p cells are specified, using suitable materials for corrosion protection as described above. On the MSF plant, the differential pressure control across the brine heater outlet control valve has been changed from board-mounted to field-mounted override control. Fluor believes that board-mounted control is not necessary for this service.

Orifice Plates and Flow Tubes

On the MSF plant, Fluor has changed flow nozzles to monel orifice plates for all brine water service except for the seawater supply and brine recycle, where plastic flow nozzles of the insert type are specified. Stainless steel orifice plates instead of flow nozzles are used on all other fluids of the MSF plant. In the VTE design, Fluor has added an orifice plate and transmitter in the line feeding 150 lb. steam to the ejectors. This makes the two designs comparable in this respect.

Liquid Levels

For brine and seawater service, Fluor recommends the use of flange-mounted force-balance type D/p cells with stainless steel flanges and monel diaphragms. Fluor believes this type of cell is superior to the external float type instrument for corrosive service. The mounting is nearly flush, no stagnant areas are created, and the number of wetted parts is minimized. Since fewer corrosion-resistant parts are necessary, significant cost savings can be realized. For less corrosive service, such as product water and condensate, external float type cells are provided.

For comparability of instrumentation, Fluor has moved to the control room all field mounted level controllers in the reference VTE plant. In the MSF plant the level control override for the first stage was changed from control room panel mounted to field mounted.

Control Valves

On brine service, control valves are to be wafer type butterfly valves if four inches in diameter or larger, and globe valves if smaller than four inches. Materials of construction will vary with the temperature of the fluid. Butterfly valves above 180 F. will have Ni-resist body and disk, and 316 SS shaft, with metal seats (no liner); below 180 F., cast iron bodies, Ni-resist discs, 316 SS shafts, and Buna N rubber lining. Globe valves in brine service are bronze with stainless steel trim.

For condensate, product water, noncondensible gases and stripping steam, control valves are to be wafer type butterfly valves for 4-inch size and larger, with cast iron bodies, Ni-resist discs, 316 SS shafts, and Buna N rubber lining. For sizes smaller than 4-inch, globe valves will be used. Valves 2-inch and smaller will be bronze with stainless steel trim, while 2½ and 3-inch valves will have iron bodies with bronze trim.

For turbine bleed steam service, all control valves will be globe type. Two-inch and smaller valves will be 600-lb. class forged steel with plug-type stellite discs and seats; larger valves are 150-lb. class carbon steel with stainless steel trim.

Gage Glasses

Standard materials are specified on all gage glasses except those in brine and seawater services, for which copper-nickel alloy with monel trim valves is specified. On the VTE design, Fluor added gage glasses to all of the evaporator stages. This will allow the water levels to be monitored at the effect pump suctions. On the MSF design, gage glasses on each product water stage were eliminated, leaving only two product water gage glasses per module.

Relief Valves

Relief valves are standard material and specified as shown on the P&I diagram. They are provided on the discharge side of the positive displacement additive pumps, and on the inlet steam line of each plant. The relief valve on the MSF brine stream at the brine heater was deleted.

Switches, Alarms, and Solenoid Valves

Dual function pneumatic switches with adjustable contacts are specified for alarm and shutdown. Switches are mounted behind the control panel.

Annunciator alarm panels are solid state with backlighted nameplates and with Test and Acknowledge buttons. Switch contacts open to sound alarm. Each panel is provided with 20% spare annunciator points.

Panel Instruments

Recorders and recorder-controllers are miniature pneumatic type. Adjustments and servicing can be performed from the front of the panel. Indicators are vertical scale ribbon type.

Control Panel

The control panel is a standard vertical standing type with semigraphic diagram of the plant process.

Analyzers

Conductivity analyzers are provided only on the final product water streams. Other analyzers on the MSF plant were deleted as being not essential for plant operation. Analyzers are provided by the manufacturer as package units.

Sheet 1 of 4

17.0 - 2.5 MGD VTE PLANT EQUIPMENT LIST AND DRAWING INDEX

17.1.1 - EQUIPMENT LIST
FOR
2.5 MGD VTE PLANT - SMOOTH TUBES

E-1 First Effect Evaporator - 9' x 40' high with 1-3/4" O.D. .049" wall smooth 90-10 Cu-Ni tubes, 24' long.

314 HX - Preheater - 2-pass with 3/4"O.D. .049" wall smooth 90-10 Cu-Ni tubes, 22' long.

M-1 Module - Containing 12 preheaters as follows:

302 HX	- 2-pass preheater with 3/4"	O.D. .035" wall	smooth 90-10 Cu-Ni tubes	18'	long
303 HX	do.	do.	do.	18'	do.
304 HX	do.	do.	do.	18'	do.
305 HX	do.	do.	do.	20'	do.
306 HX	do.	do.	do.	20'	do.
307 HX	do.	do.	do.	20'	do.
308 HX	do.	do.	do.	20'	do.
309 HX	do.	do.	do.	20'	do.
310 HX	do.	do.	do.	22'	do.
311 HX	do.	do.	do.	22'	do.
312 HX	do.	do.	do.	22'	do.
313 HX	do.	do.	do.	22'	do.

and 13 effect tube bundles as follows:

E-2	Second Effect	tube bundle with 2"	O.D. .049" wall	smooth 90-10 Cu-Ni tubes	24' long
E-3	Third	do.	do.	do.	do.
E-4	Fourth	do.	do.	do.	do.
E-5	Fifth	do.	do.	do.	do.
E-6	Sixth	do.	do.	do.	do.
E-7	Seventh	do.	do.	do.	do.
E-8	Eighth	do.	do.	do.	do.
E-9	Ninth	do.	do.	do.	do.
E-10	Tenth	do.	do.	do.	do.
E-11	Eleventh	do.	do.	do.	do.
E-12	Twelfth	do.	do.	do.	do.

17.1.1 - EQUIPMENT LIST FOR 2.5 MGD VTE PLANT - SMOOTH TUBES (Cont'd.)

M-1 Module (Cont'd.)

E-13 Thirteenth Effect tube bundle with 2" O.D. .049" wall smooth 90-10 Cu - Ni tubes 24' long
E-14 Fourteenth do. 2-1/2" O.D. x .049 wall smooth 90-10 Cu - Ni tubes 24' long

and --

E-15 Heat Rejection Condenser with 3/4" O.D. 0.049" wall smooth 90-10 Cu - Ni tubes

Heat Transfer Surfaces - Preheaters 302-314 HX = 47,266 Sq. Ft.
Evaporator Effects E-1 thru E-14 = 162,046 Sq. Ft.
Heat Rejection 3,540 Sq. Ft.

Tube Sheets and Channels - 90-10 Cu - Ni or Cu - Ni - Clad, Min. thickness of cladding - 20% of total

Water Boxes, return heads - 90-10 Cu - Ni or fiberglass

E-16 Product Cooler

2 shell and tube exchangers - 24"** O.D. x 31'-4" long with 3/4" O.D. 0.049" wall smooth 90-10 Cu - Ni tubes 26' long

V-1 Deaerator-Decarbonator

13'-6" I.D. x 26'-0" T-T Vert. w/Dow "Mas Pac" packing

Pumps and Drivers

		Type	GPM	Head ft.	Material	Elec. Motor Speed, RPM
*P-1A & B	Raw Seawater Feed	Horiz.	4000	55	All 316 S.S.	1150
P-2A & B	Deaer. Seawater Feed	Vert-Can	3200	261	do.	1780
P-12	Falling Film Feed	Horiz.	1800	35	do.	1150
P-13	do.	do.	1800	35	do.	do.
P-123	do. (spare)	do.	1800	35	do.	do
P-14	do.	do.	1800	35	do.	do.
P-15	do.	do.	2500	35	do.	do.
P-145	do. (spare)	do.	2500	35	do.	do.
P-16	do.	do.	2100	35	do.	do.

*Not included in price of plant in reference VTE proposal **Dimensions are approximate.

17.[illegible].1 - EQUIPMENT LIST FOR 2.5 MGD VTE PLANT - SMOOTH TUBES (Cont'd.)

OSW Contract 14-01-0001-1830
Fluor Contract 4334
MSF and VTE Comparative Study

Sheet 3 of 4

Pumps and Drivers (Cont'd.)

		Type	GPM	Head ft.	Material	Elec. Motor Speed, RPM
P-17	Falling Film Feed	Horiz.	1800	35	All 316 S.S.	1150
P-167	do. (spare)	do.	2100	35	do.	do.
P-18	do.	do.	1800	35	do.	do.
P-19	do.	do.	1800	35	do.	do.
P-189	do. (spare)	do.	1800	35	do.	do.
P-20	do.	do.	2100	35	do.	do.
P-21	do.	do.	2100	35	do.	do.
P-201	do. (spare)	do.	2100	35	do.	do.
P-22	do.	do.	1800	35	do.	do.
P-23	do.	do.	1800	35	do.	do.
P-223	do. (spare)	do.	1800	35	do.	do.
P-24	do.	do.	1800	35	do.	do.
P-25	Blowdown	do.	1100	55	do.	do.
*P-245	Spare for 24 & 25	do.	1800	35	do.	do.
P-41A	Heat Reject Distillate	do.	120	12	C.I. case, 316 S.S. trim	do.
**P-41B	HR Distillate (spare)	do.	120	12	do.	do.
P-42A & B	Product	do.	2080	85	do.	do.
P-50A & B	Acid	Horiz. Prop.	0.25	55	316 S.S. trim	1750
P-51A & B	Caustic	do.	0.1	250	do.	do.
**P-52A & B	Seawater Intake	Vert.	8250	66	All 316 S.S.	1150
**P-53A & B	Condensate Return	Vert.	215	100	C.I. case, 316 S.S. trim	1750
**P-54A & B	Chlorine	Horiz.	100	100	Monel	do.
**P-55A & B	Screen Cleaning	do.	88	200	All 316 S.S.	do.

Compressors

*C-1	Instrument Air Compressor - 100 scfm at 80 psig nonlubricated, motor-driven w/aftercooler and receiver tank
*C-2	Service Air Compressor - 100 scfm at 100 psig, motor-driven w/aftercooler and receiver tank

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*Not included in price of plant in reference VTE proposal

**Added by Fluor

17.[illegible].1 - EQUIPMENT LIST FOR 2.5 MGD VTE PLANT - SMOOTH TUBES (Cont'd.)

Tanks

TK-1	Acid Storage	- 8'Ø x 14'-0" T-T
TK-2	Caustic Storage	- 4'Ø x 11' T-T
TK-3	Condensate Drum	- 2'Ø x 9'-3" Vert.
TK-4	Caustic Mix Tank with Agitator	- Open Tank 5'Ø x 5'high

Miscellaneous Equipment

Set 1A & B 2-Stage Ejector and Intercondenser, and installed spare. Each set contains:

One Barometric Precondenser and two Barometric Intercondensers - Fiberglass or C.I. or rubber-lined. Ejectors have S.S. nozzles and C.S. chest.

**Instrument Air Drier - 100 scfm with prefilter and afterfilter

**Trash Bar w/traveling rake

**Traveling Screen - 3/8" S.S. mesh

**Chlorination System - Ejector, metering system, pressure reducing valve.

**Communication System

Buildings and Structures

Control House and Control Board
Motor Control Center
Seawater Intake Structure

Warehouse Spares

None

**Added by Fluor

17.0 - 2.5 MGD VTE PLANT EQUIPMENT LIST AND DRAWING INDEX

17 1.2 - EQUIPMENT LIST FOR 2.5 MGD VTE PLANT - ENHANCED TUBES

E-1 First Effect Evaporator - 8'Ø x 30 ft. high with 2" OD. 0.049" wall double-fluted 90-10 Cu—Ni tubes, 14' long

M-1 Module - Containing 13 preheaters as follows:

302 HX	- 2-pass preheater with 1" O.D. x	0.042" wall spirally grooved	90-10 Cu -Ni tubes	10'	long
303 HX	do.	do.	do.	10'	do.
304 HX	do.	do.	do.	10'	do.
305 HX	do.	do.	do.	10'	do.
306 HX	do.	do.	do.	12'	do.
307 HX	do.	do.	do.	12'	do.
308 HX	do.	do.	do.	12'	do.
309 HX	do.	do.	do.	12'	do.
310 HX	do.	do.	do.	12'	do.
311 HX	do.	do.	do.	12'	do.
312 HX	do.	do.	do.	12'	do.
313 HX	do.	do.	do.	12'	do.
314 HX	do.	do.	do.	14'	do.

and 13 effect tube bundles as follows:

E-2	Second Effect	tube bundle witn 2" O.D.	0.049" wall double-fluted	90-10 Cu -Ni tubes	14' long
E-3	Third	do.	do.	do.	do.
E-4	Fourth	do.	do.	do.	do.
E-5	Fifth	do.	do.	do.	do.
E-6	Sixth	do.	do.	do.	do.
E-7	Seventh	do.	do.	do.	do.
E-8	Eighth	do.	do.	do.	do.
E-9	Ninth	do.	do.	do.	do.
E-10	Tenth	do.	do.	do.	do.

17.1.2 - **EQUIPMENT LIST FOR 2.5 MGD VTE PLANT - ENHANCED TUBES** (Cont'd.)

OSW Contract 14-01-0001-1830
Fluor Contract 4334
MSF and VTE Comparative Study

Sheet 2 of 4

M-1 Module (Cont'd.)

E-11 Eleventh Effect tube bundle with 2" O.D. 0.049" wall double-fluted 90-10 Cu -Ni tubes 14' long
E-12 Twelfth do. do. do. do.
E-13 Thirteenth do. do. do. do.
E-14 Fourteenth do. 3" O.D. x 0.049" wall double-fluted 90-10 Cu -Ni tubes 14' long

and --

E-15 Heat Rejection Condenser with 1" O.D. x 0.049" wall enhanced surface 90-10 Cu -Ni tubes

Heat Transfer Surfaces - Preheaters 302-314 HX = 31,155 Sq. Ft.
Evaporator Effects E-1 thru E-14 = 78,598 Sq. Ft.
Heat Rejection = 2,818 Sq. Ft.

Tube Sheets and Channels - 90-10 Cu-Ni or Cu -Ni - clad, min. thickness of cladding - 20% of total.

Water Boxes, return heads - 90-10 Cu-Ni or fiberglass

E-16 Product Cooler

1 shell and tube exchanger - 36"** O.D. x 23'-6" long with 1" O.D. .049" wall enhanced surface 90-10 Cu -Ni tubes 20' long.

V-1 Deaerator-Decarbonator

13'-6" I.D. x 26'-0" T-T Vert. w/Dow "Mas Pac" packing.

Pumps and Drivers

		Type	GPM	Head ft.	Material	Elec. Motor Speed, RPM
*P-1A & B	Non-deaer. Seawater Feed	Horiz.	4000	55	All 316 S.S.	1150
P-2A & B	Deaer. Seawater Feed	Vert-Can	3200	380	do.	1780
P-12	Falling Film Feed	Horiz.	1800	45-55	do.	1150
P-13	do.	do.	1800	45-55	do.	do.
P-123	do. (spare)	do.	1800	45-55	do.	do.
P-14	do.	do.	1800	45-55	do.	do.

*Not included in price of plant in reference VTE proposal

**Dimensions are approximate.

17.1.2 - EQUIPMENT LIST FOR 2.5 MGD VTE PLANT - ENHANCED TUBES (Cont'd.)

Sheet 3 of 4

Pumps and Drivers (Cont'd.)

		Type	GPM	Head ft.	Material	Elec. Motor Speed, RPM
P-15	Falling Film Feed	Horiz.	2500	45	All 316 S.S.	1150
P-145	do. (spare)	do.	2500	45	do.	do.
P-16	do.	do.	2100	45	do.	do.
P-17	do.	do.	1800	45-55	do.	do.
P-167	do. (spare)	do.	2100	45	do.	do.
P-18	do.	do.	1800	45-55	do.	do.
P-19	do.	do.	1800	45-55	do.	do.
P-189	do. (spare)	do.	1800	45-55	do.	do.
P-20	do.	do.	2100	45	do.	do.
P-21	do.	do.	2100	45	do.	do.
P-201	do. (spare)	do.	2100	45	do.	do.
P-22	do.	do.	1800	45-55	do.	do.
P-23	do.	do.	1800	45-55	do.	do.
P-223	do. (spare)	do.	1800	45-55	do.	do.
P-24	do.	do.	1800	45-55	do.	do.
P-25	Blowdown	do.	1100	55	do.	do.
P-245	Spare for 24 & 25	do.	1800	45-55	do.	do.
P-41A	Heat Reject Distillate	do.	120	12	C.I. case,316 SS trim	do.
**P-41B	Heat Reject Distil. (spare)	do.	120	12	do.	do.
P-42A & B	Product	do.	2080	85	do.	do.
P-50A & B	Acid	Horiz. Prop.	0.25	55	316 S.S.	1750
P-51A & B	Caustic	do.	0.1	375	do.	do.
**P-52A & B	Seawater Intake	Vert.	8250	66	All 316 S.S.	1150
**P-53A & B	Condensate Return	Vert.	215	100	C.I. case, 316 SS trim	1750
**P-54A & B	Chlorine	Horiz.	100	100	All monel	do.
**P-55A & B	Screen Cleaning	do.	88	200	All 316 S.S.	do.

**Added by Fluor

17.1.2 - EQUIPMENT LIST FOR 2.5 MGD VTE PLANT - ENHANCED TUBES (Cont'd.)

Sheet 4 of 4

Compressors

*C-1	Instrument Air Compressor - 100 scfm - 80 psig nonlubricated, motor-driven w/aftercooler and receiver tank.
*C-2	Service Air Compressor - 100 scfm - 100 psig, motor-driven w/aftercooler and receiver tank.

Tanks

TK-1	Acid Storage	- 8'Ø x 14'-0" T-T
TK-2	Caustic Storage	- 4'Ø x 11'-0" T-T
TK-3	Condensate Drum	- 2'Ø x 9'-3" Vertical
**TK-4	Caustic Mix Tank with Agitator	- Open Tank 5'Ø x 5' high

Miscellaneous Equipment

Set 1A & B 2-Stage Ejector and Intercondenser, and installed spare. Each set contains:

One Barometric Precondenser and two Barometric Intercondensers - Fiberglass or C.I. or rubber-lined. Ejectors have S.S. nozzles and C.S. chest.

**Instrument Air Drier - 100 scfm with prefilter and afterfilter.

**Trash Bar w/traveling rake

**Traveling Screen - 3/8" S.S. mesh

**Chlorination System - Ejector, metering system, pressure reducing valve.

**Communications System

Buildings and Structures

Control House and Control Board
Motor Control Center
Seawater Intake Structure

Warehouse Spares

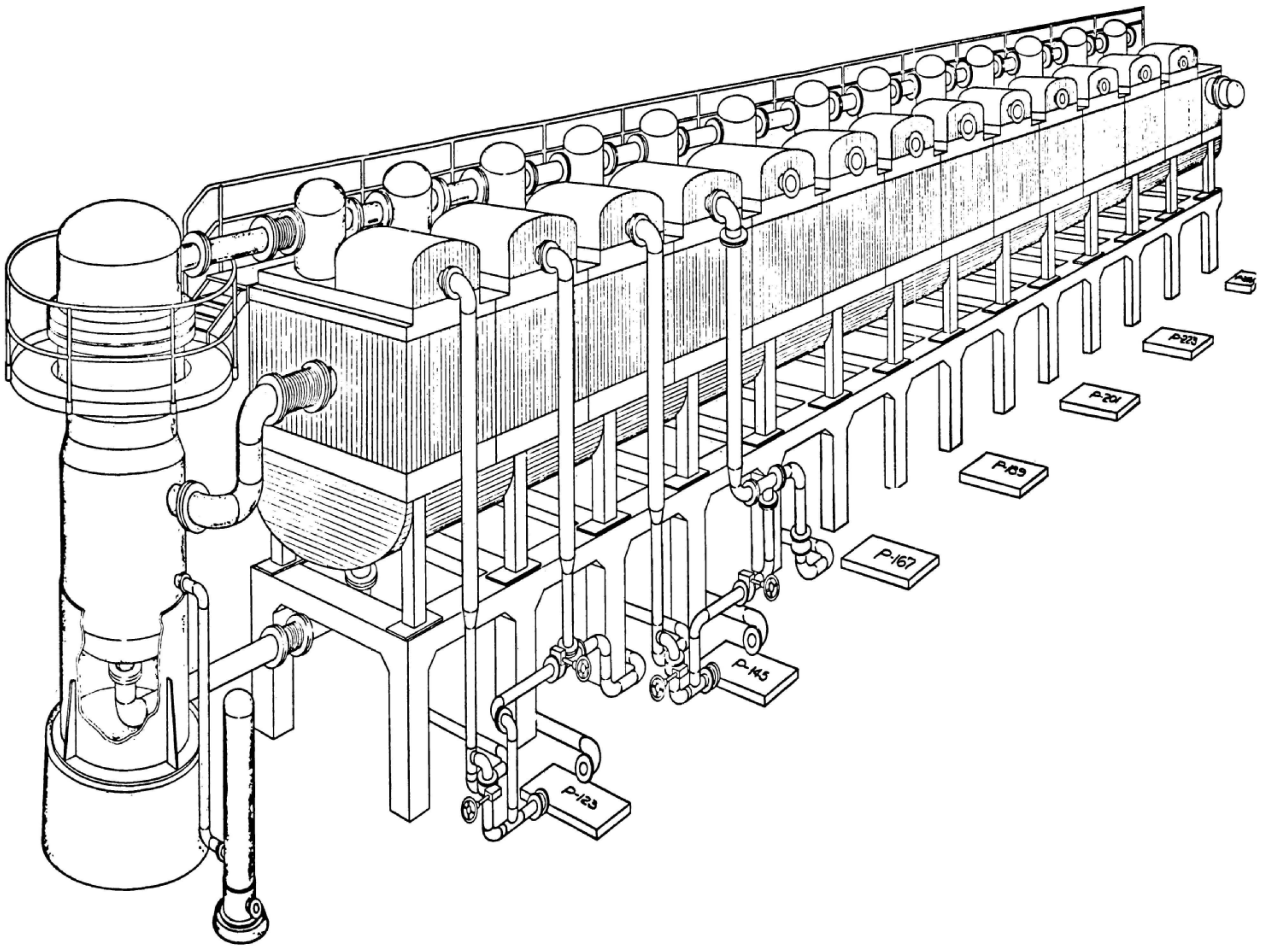
None

*Not included in price of plant in reference VTE proposal
**Added by Fluor

17.0 - 2.5 MGD VTE PLANT EQUIPMENT LIST AND DRAWING INDEX

17.2 Drawing Index

Drawing Number	Title
4334-SR-A	Perspective of VTE Plant
SR-B	Cutaway of VTE Plant
4-001	Enhanced VTE Plot Plan
4-002	Smooth Tube VTE Plot Plan
4-003	Process Flow Diagram
4-004	Mechanical Flow Diagram
4-005	Chemical Flow Diagram
4-006	Electrical One-Line Diagram



NOTES:

1. EXCEPT FOR DIFFERENCES IN VESSEL PROPORTIONS, THIS VIEW OF THE ENHANCED TUBE PLANT ALSO REPRESENTS THE SMOOTH TUBE PLANT.
2. THIS DRAWING HAS BEEN ADAPTED FROM STEARNS-ROGER DRAWING 21923-1 BY THE FLUOR CORPORATION, LTD.

NO.	DATE	REVISION	MADE	APPROV.
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UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

PERSPECTIVE OF 2.5 M.G.D. ENHANCED
TUBE V.T.E. PLANT

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ____ DATE ____
DRAWN GEORGE CORBETT, JR. DATE 1-9-69
CHECKED ____ DATE ____
APPROVED ____ DATE ____

UNITED STATES
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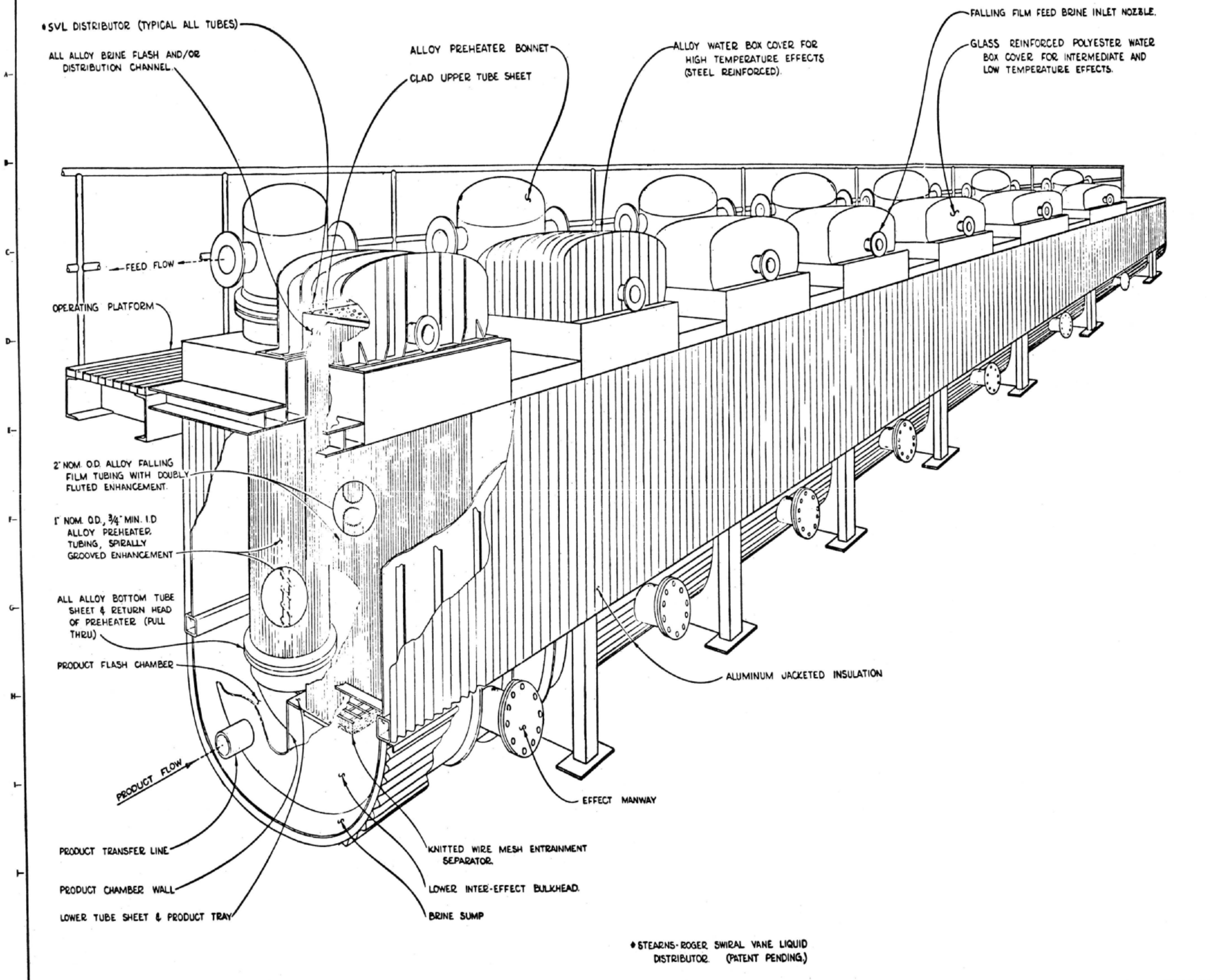
DRAWING TITLE: PERSPECTIVE OF VTE PLANT
DATE: 1-9-69
DRAWING NUMBER: 4334-SR-A



NOTES:

1. EXCEPT FOR DIFFERENCES IN TUBES AND IN VESSEL PROPORTIONS, THIS CUTAWAY VIEW OF THE ENHANCED TUBE VTE PLANT ALSO REPRESENTS THE SMOOTH TUBE PLANT.
2. THIS DRAWING HAS BEEN ADAPTED FROM STEARNS-ROGER DRAWING 21923-4 BY THE FLUOR CORPORATION, LTD.

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DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

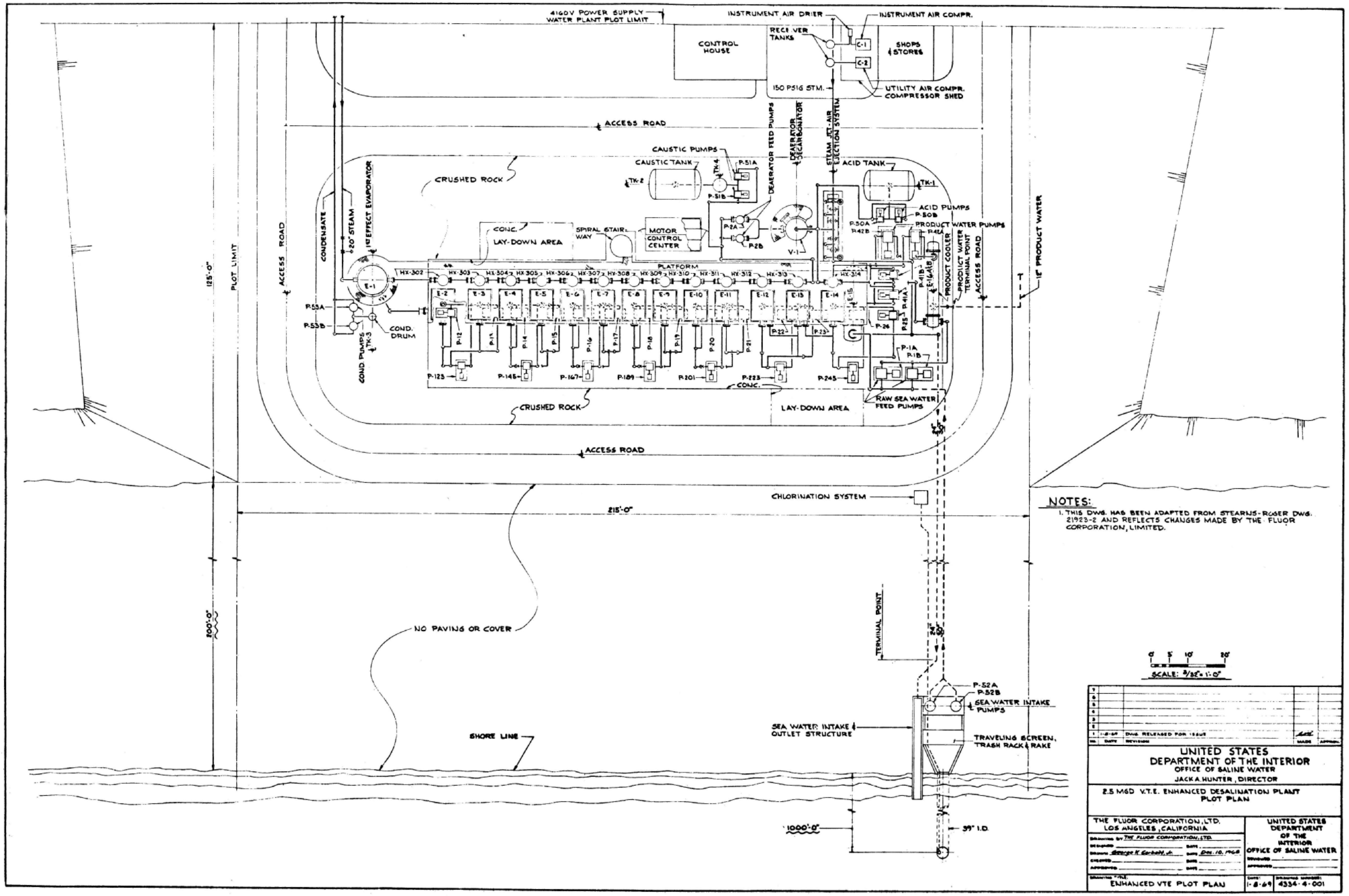
CUTAWAY DRAWING OF 2.5 MGD
ENHANCED TUBE VTE PLANT

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ________ DATE ________
DRAWN GEORGE K. CORBETT, JR. DATE 1-10-69
CHECKED ________ DATE ________
APPROVED ________ DATE ________

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ________
APPROVED ________

DRAWING TITLE:
CUTAWAY OF VTE PLANT
DATE: 1-10-69
DRAWING NUMBER: 4334-SR-B



NOTES:

1. THIS DWG. HAS BEEN ADAPTED FROM STEARNS-ROGER DWG. 21923-2 AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LIMITED.

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JACK A. HUNTER, DIRECTOR

2.5 MGD V.T.E. ENHANCED DESALINATION PLANT
PLOT PLAN

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIFORNIA

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ______ DATE ______
DRAWN George K Corbett, Jr. DATE Dec. 10, 1968
CHECKED ______ DATE ______
APPROVED ______ DATE ______

UNITED STATES
DEPARTMENT
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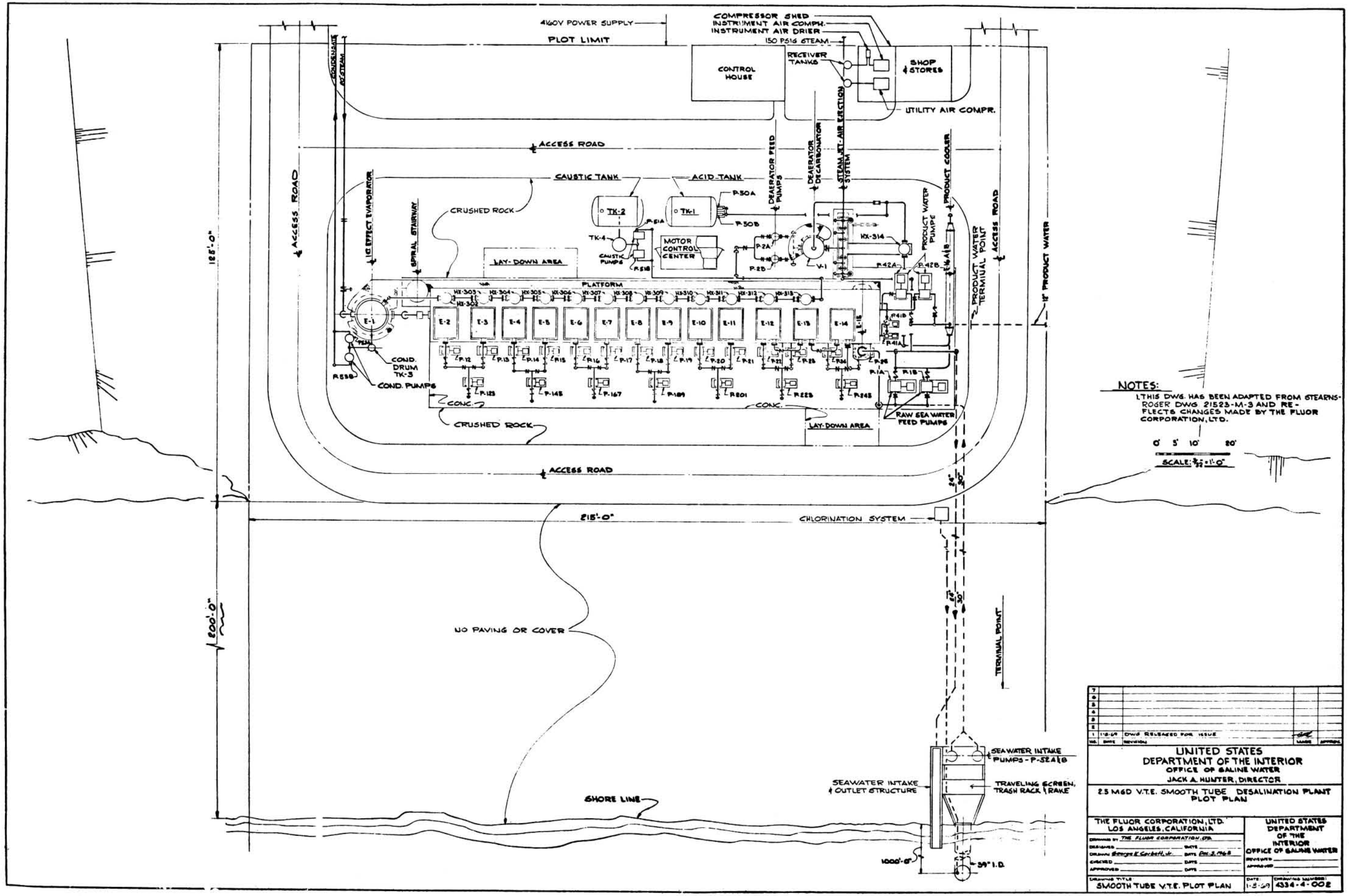
OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

DRAWING TITLE: ENHANCED VTE PLOT PLAN
DATE: 1-8-69
DRAWING NUMBER: 4334-4-001



NOTES:

1. THIS DWG. HAS BEEN ADAPTED FROM STEARNS-ROGER DWG 21523-M-3 AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

0' 5' 10' 20'

SCALE: $\frac{3}{32}$" = 1'-0"

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1	1-8-69	DWG RELEASED FOR ISSUE		

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

2.5 MGD V.T.E. SMOOTH TUBE DESALINATION PLANT
PLOT PLAN

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIFORNIA

DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ______ DATE ______
DRAWN George K Corbett, Jr. DATE Dec. 3, 1968
CHECKED ______ DATE ______
APPROVED ______ DATE ______

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DRAWING TITLE: SMOOTH TUBE V.T.E. PLOT PLAN
DATE: 1-8-69
DRAWING NUMBER: 4334-4-002

LEFT SECTION { PROCESS FLOW DIAGRAM AND MATERIAL BALANCE 2.5 MGD VTE PLANT WITH ENHANCED OR SMOOTH TUBES

RIGHT SECTION { PROCESS FLOW DIAGRAM AND MATERIAL BALANCE 2.5 MGD VTE PLANT WITH ENHANCED OR SMOOTH TUBES

LEGEND

SYMBOL	DESCRIPTION	UNITS
W	MASS FLOW RATE	POUNDS PER HOUR
t	TEMPERATURE	°F
P	PRESSURE	PSIA
Ø	CONCENTRATION	WEIGHT PERCENT TOTAL DISSOLVED SOLIDS
SUBSCRIPT		
S	STEAM	
P	EXTRACTED VAPOR OR PRODUCT	
C	CONDENSATE	
B	BRINE	
SWF	SEA WATER FEED	
V	VENT VAPOR	
CW	COOLING WATER	
CWR	COOLING WATER RETURN	

MATERIAL BALANCE

INLET

HEATING STEAM	83,000 LB/HR
COOLING WATER & SEA WATER FEED	3,720,000 LB/HR
HIGH PRESSURE STEAM	1,000 LB/HR
TOTAL	3,804,000 LB/HR

OUTLET

CONDENSATE RETURN	83,000 LB/HR
COOLING WATER RETURN FROM HRC	2,100,000 LB/HR
COOLING WATER RETURN FROM STEAM JETS	203,320 LB/HR
BRINE DISCHARGE	498,620 LB/HR
VENT TO ATMOSPHERE	800 LB/HR
PRODUCT TO DISTRIBUTION	916,260 LB/HR
	3,804,000 LB/HR

NOTES

THIS DWG. HAS BEEN ADAPTED FROM STEARNS-ROGERS DWG. 21523-M-2 BY THE FLUOR CORPORATION, LTD.

NO.	DATE	REVISION	BY	APPV.
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JACK A. HUNTER, DIRECTOR

PROCESS FLOW DIAGRAM AND MATERIAL BALANCE
2.5 MGD VTE PLANT WITH
ENHANCED OR SMOOTH TUBES

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DWG. BY THE FLUOR CORPORATION, LTD.
DESIGN ______ DATE ______
DWG. ROY WILLIAMS DATE 1-13-69
CHK'D ______ DATE ______
APPV. ______ DATE ______

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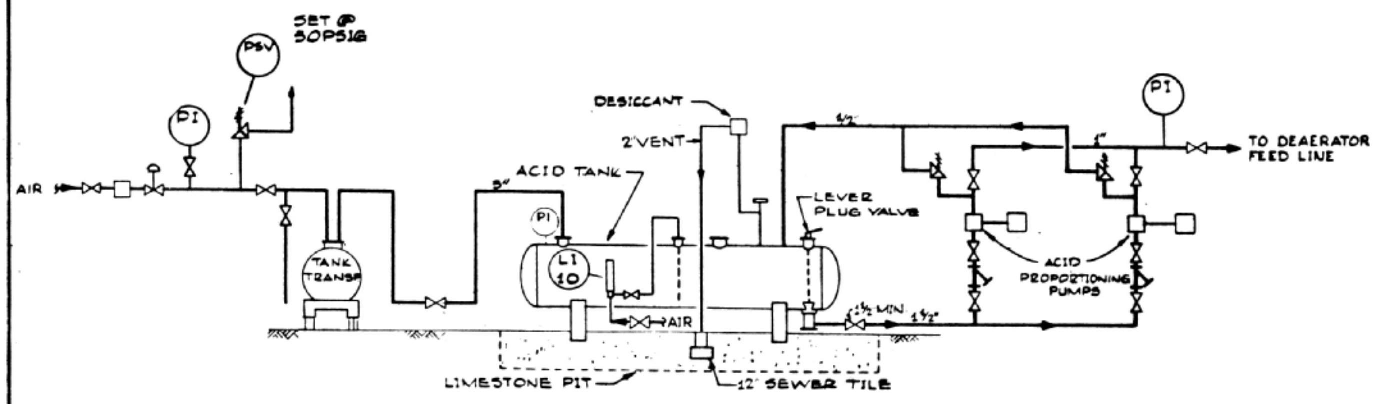
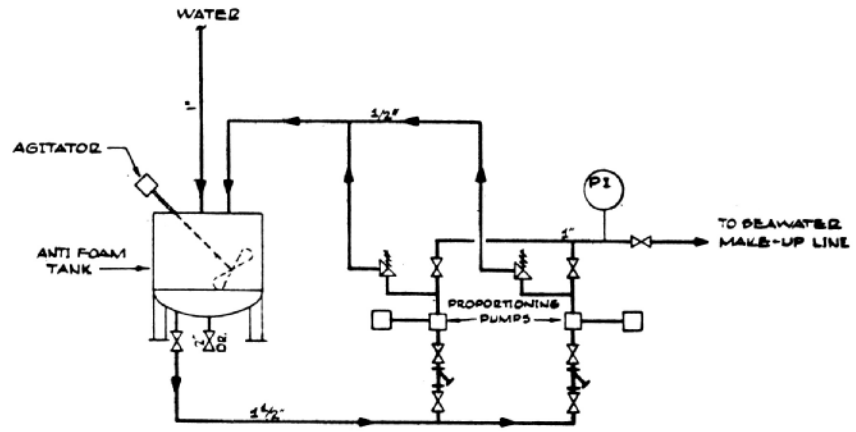
DRAWING TITLE
PROCESS FLOW DIAGRAM

DATE:

DRAWING NUMBER
4334-4-003



ACID SYSTEM
VTE & MSF



ANTI FOAM SYSTEM
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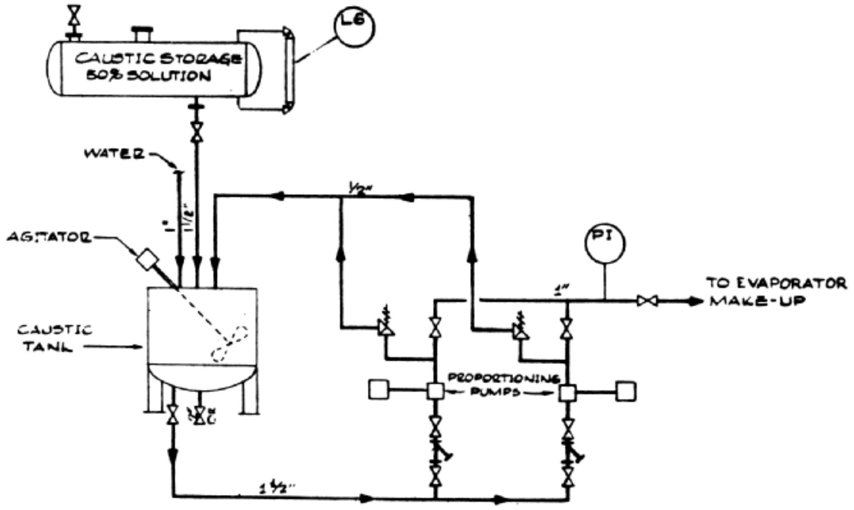
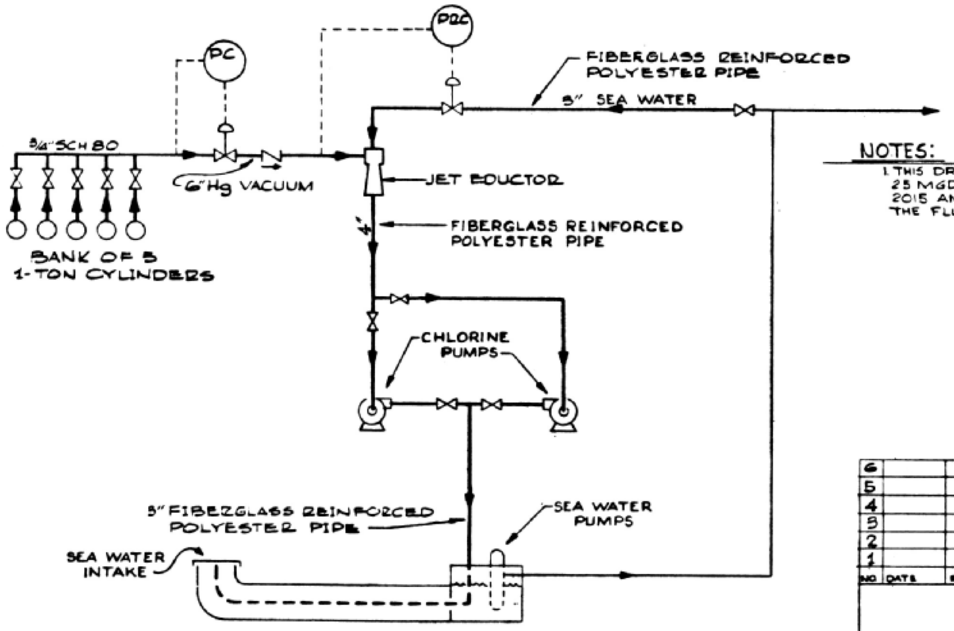


CAUSTIC SYSTEM
VTE & MSF



CHLORINATION SYSTEM
VTE & MSF

NOTES:

1. THIS DRAWING HAS BEEN ADAPTED FROM 2.5 MGD UNIVERSAL PLANT DRAWING 2015 AND REFLECT CHANGES MADE BY THE FLUOR CORPORATION, LTD.

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UNITED STATES
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JACK A. HUNTER, DIRECTOR

2.5 MGD VTE & MSF DESALINATION PLANTS
P&I FLOW DIAGRAMS-CHEMICAL SYSTEMS

THE FLUOR CORPORATION LTD.
LOS ANGELES, CALIF.

DRAWN BY THE FLUOR CORPORATION LTD.
DESIGNED ______ DATE ______
DRAWN SELBY ______ DATE 12/12/68
CHECKED ______ DATE ______
APPROVED ______ DATE ______

UNITED STATES
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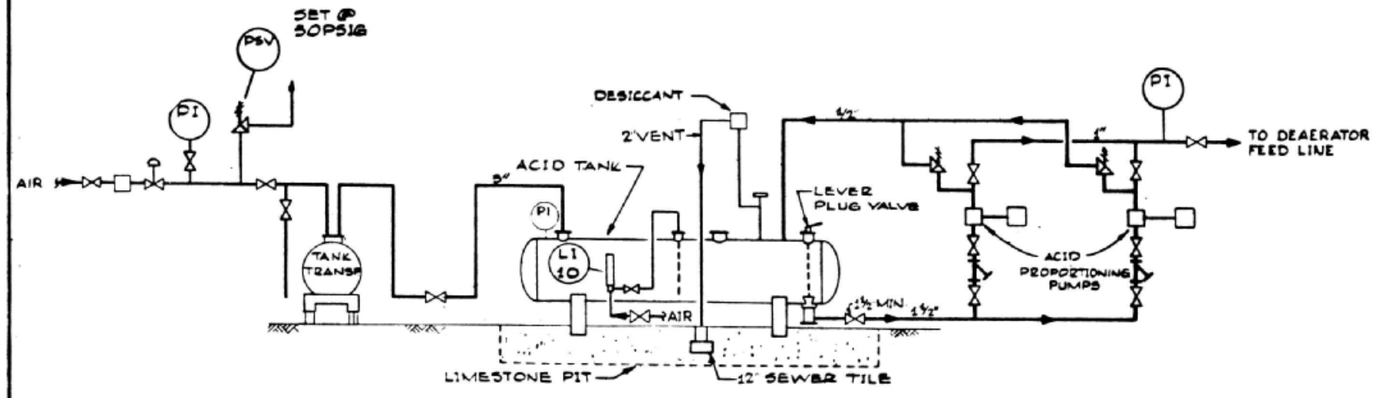
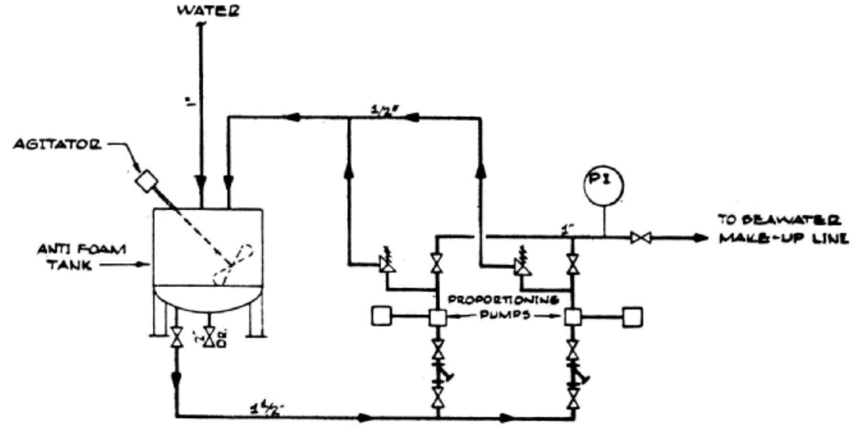
REVIEWED ______
APPROVED ______

DRAWING TITLE:
CHEMICAL FLOW DIAGRAM

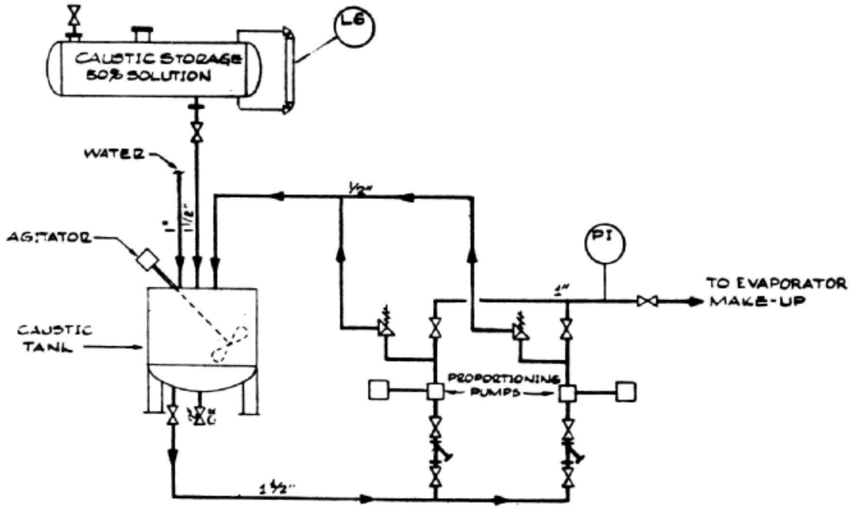
DATE:
DRAWING NO:
4554-4-008



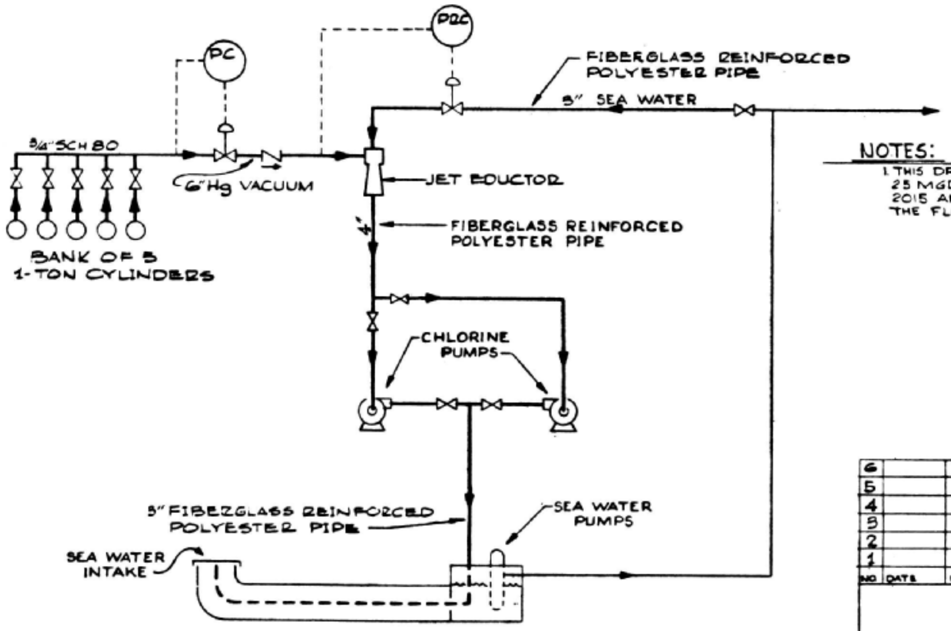
ACID SYSTEM
VTE & MSF



ANTI FOAM SYSTEM
(MSF ONLY)



CAUSTIC SYSTEM
VTE & MSF



CHLORINATION SYSTEM
VTE & MSF

NOTES:

1. THIS DRAWING HAS BEEN ADAPTED FROM 25 MGD UNIVERSAL PLANT DRAWING 2015 AND REFLECT CHANGES MADE BY THE FLUOR CORPORATION, LTD.

NO	DATE	REVISION	MADE	APPROV
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DEPARTMENT OF INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

2.5 MGD VTE & MSF DESALINATION PLANTS
P&I FLOW DIAGRAMS-CHEMICAL SYSTEMS

THE FLUOR CORPORATION LTD.
LOS ANGELES, CALIF.

DRAWN BY THE FLUOR CORPORATION LTD.
DESIGNED ______ DATE ______
DRAWN [illegible] DATE [illegible]
CHECKED ______ DATE ______
APPROVED ______ DATE ______

UNITED STATES
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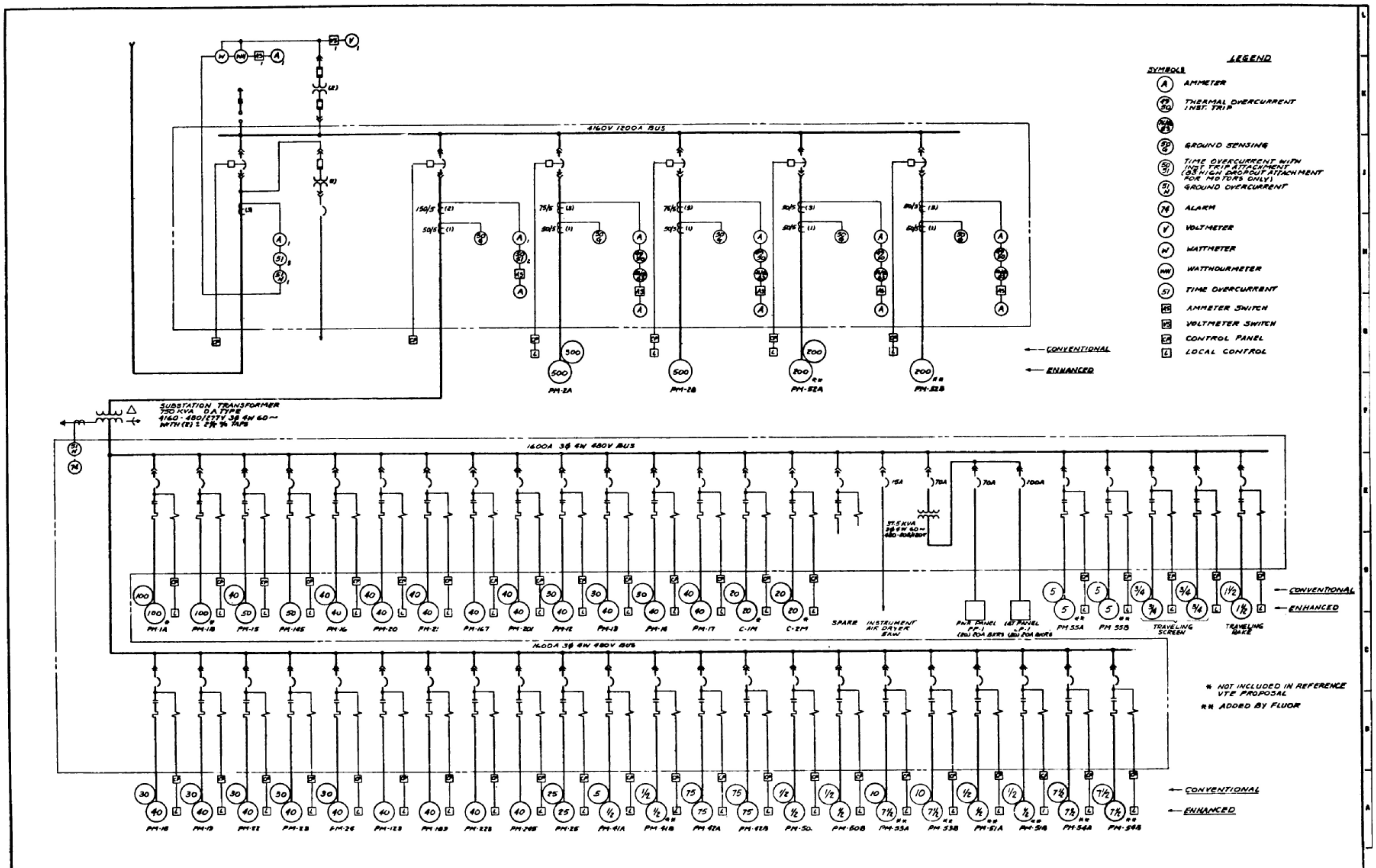
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

DRAWING TITLE:
CHEMICAL FLOW DIAGRAM

DATE:
DRAWING NO:
4554-4-005



Note

THIS DRAWING WAS ADAPTED FROM STEVENS-ROGERS DWG. 81523-E1-R0, REFLECTS CHANGES MADE THE FLUOR CORPORATION, LTD.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

ELECTRICAL ONE-LINE DIAGRAM
5 MGD VTE PLANT
ENHANCED OR SMOOTH TUBES

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.
DWG. BY THE FLUOR CORPORATION, LTD.
DESIGN
DWG. ROY WILLIAMS DATE 1-8-69
CHK'D DATE
APP. DATE

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APPROVED

DRAWING TITLE ELECTRICAL ONE-LINE DIAGRAM
DATE: 1-15-69
DRAWING NUMBER 1854-4-006

18.0 - 2.5 MGD MSF PLANT EQUIPMENT LIST AND DRAWING INDEX

OSW Contract 14-01-0001-1830
Fluor Contract 4334
MSF and VTE Comparative Study

Sheet 1 of 3

18.1 - EQUIPMENT LIST FOR 2.5 MGD MSF PLANT - SMOOTH TUBES

Flash Evaporator Modules

M-1	Heat Recovery Module - 8'-6" x 12' high x	90' long	- 8 stages	- Tubes 3/4" O.D. x .035" wall	90-10 Cu-Ni
M-2	do.	do.	90' long	- 8 stages	do.	do.
M-3	do.	do.	90' long	- 8 stages	do.	do.
M-4	do.	do.	90' long	- 8 stages	do.	do.
M-5	do.	do.	79' long	- 7 stages	do.	do.
M-6	Heat Rejection Module - 8'-6" x 12' high x	63' long	- 3 stages	- Tubes 3/4" O.D. x .035" wall	90-10 Cu-Ni

Tube Sheets - 90-10 Cu-Ni or Clad

Water Box - 90-10 Cu-Ni above 180 F

Water Box - Carbon steel below 180 F

E-1 **Brine Heater** - 46" dia. x 16'-6" T-T, tubes 3/4" O.D. x .035" wall 90-10 Cu-Ni, - 15'-6" long

TK-1 **Deaerator-Decarbonator** - 15'-4" dia. x 26'-0" T-T vertical with Dow "Mas Pac" packing

Pumps and Drivers

		Type	GPM	Head ft.	Material	Elec. Motor Speed, RPM
P-1A & B	Brine Recycle (50% Cap.)	Vert.	6300	203	All 316 S.S.	1150
P-2A *P-2B	Blowdown) Blowdown)	Vert.	2000	61	do.	1150
P-3A & B	Product	Horiz.	2080	85	C.I. case, 316 S.S. trim	1150
P-4A & B	Acid	Horiz. Prop.	0.25	21	316 S.S.	1750
P-5A & B	Anti-foam	Do.	0.1	100	316 S.S.	1750
P-6A & B	Caustic	Do.	0.1	155	316 S.S.	1750

*Added by Fluor

18.1 - EQUIPMENT LIST FOR 2.5 MGD MSF PLANT - SMOOTH TUBES (Cont'd.)

Sheet 2 of 3

Pumps and Drivers (Cont'd.)

		Type	GPM	Head ft.	Material	Elec. Motor Speed, RPM
*P-8A & B	Seawater Intake	Vert.	12,000	66	All 316 S.S.	870
*P-9A & B	Condensate Return	Vert.	208	100	C.I. Case, 316 S.S. trim	1750
*P-10A & B	Chlorine	Horiz.	100	100	All monel	1750
*P-11A & B	Screen Cleaning	Horiz.	88	200	All 316 S.S.	1750

Compressors

C-1 Instrument Air Compressor
Motor-driven w/aftercooler E-3 and receiver Tk-8
100 scfm at 80 psig - nonlubricated

C-2 Service Air Comp.
Motor-driven w/aftercooler E-4 and receiver Tk-9
100 scfm at 100 psig

Tanks

TK-4 Anti-foam Tank with Agitator A-1 - Open Tank 5'Ø x 5' high
TK-5 Caustic Storage Tank - 4' O.D. x 10' T.T. horizontal
TK-6 Acid Storage - 9' O.D. x 14' T.T. horizontal
TK-7 Caustic Mixing Tank with Agitator A-2 - Open Tank 5'Ø x 5' high

Miscellaneous Equipment

EJ-1 One two-stage steam jet air ejector with inter-and aftercondensers

EJ-2 Hogging Ejector

*Added by Fluor

18.1 - EQUIPMENT LIST FOR 2.5 MGD MSF PLANT - SMOOTH TUBES (Cont'd.)

OSW Contract 14-01-0001-1830
Fluor Contract 4334
MSF and VTE Comparative Study

Sheet 3 of 3

Miscellaneous Equipment (Cont'd.)

E-2	Vent Condenser
TK-3	Instrument Air Drier - 100 scfm, with prefilter and afterfilter
	*Trash Bar w/traveling rake
	*Traveling Screen - 1/2" S.S. mesh
	*Chlorination System - Ejector, metering system, pressure reducing valve.
	*Communication System

Buildings and Structures

Control Building and Control Board
Switchgear Building
Seawater Intake Structure

Warehouse Spares

None

*Added by Fluor

18.0 - 2.5 MGD MSF PLANT EQUIPMENT LIST AND DRAWING INDEX

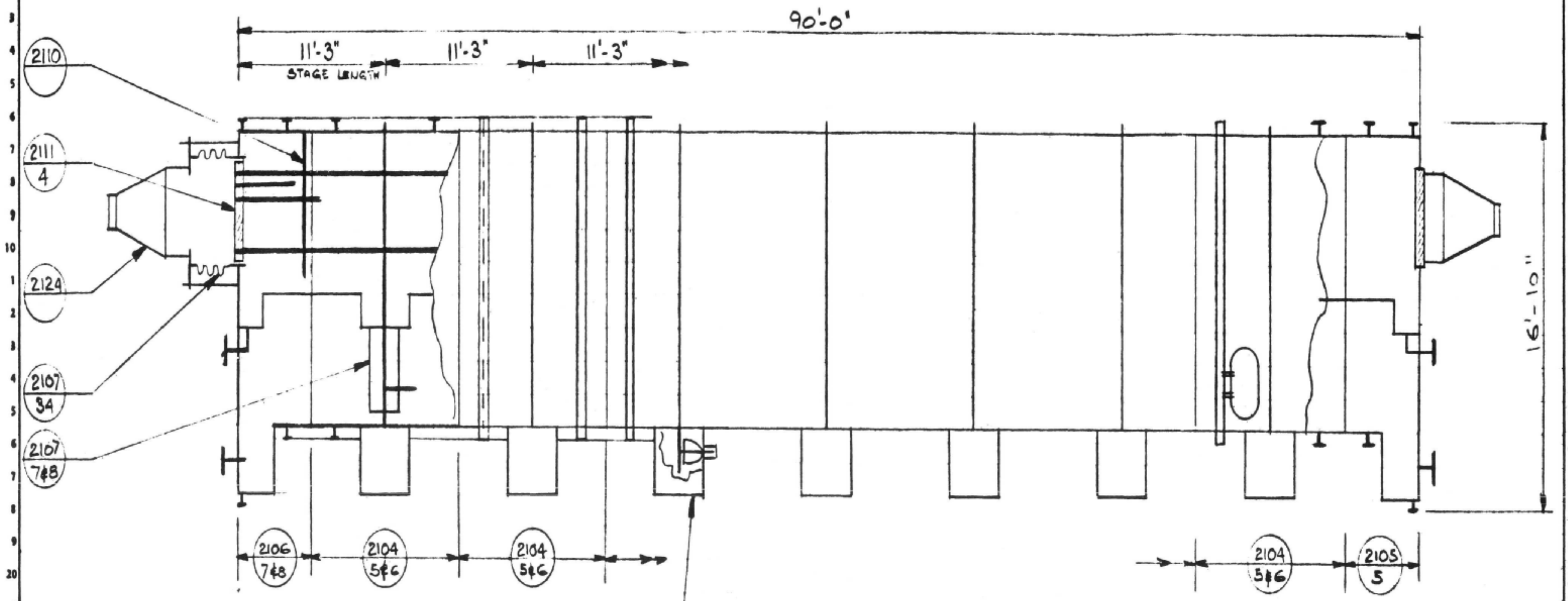
18.2 Drawing Index

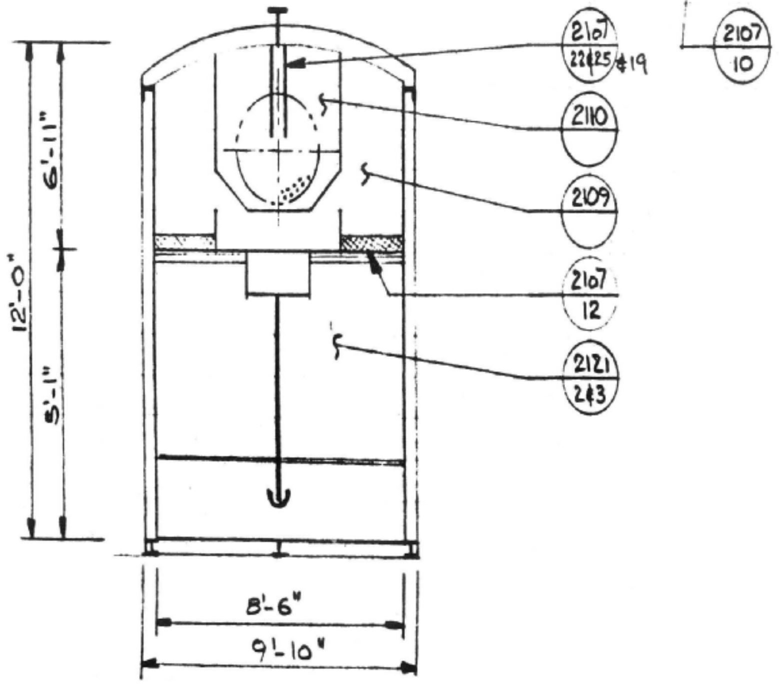
Drawing Number	Title
4334-FC-A	High Temperature MSF Module
FC-B	Low Temperature MSF Module
FC-C	Heat Rejection MSF Module
4-011	MSF Plot Plan
4-012	Process Flow Diagram
4-013	Mechanical Flow Diagram
4-005	Chemical Systems
4-014	MSF Electrical One-Line Diagram

ENGINEERING-CONSTRUCTION DIVISION
FORM E-052 REV. 12-66

CALCULATIONS and SKETCHES
THE FLUOR CORPORATION LTD.

SHEET NO. ______
DATE ______
BY ______ CHK'D ______
JOB NO. ______





ESTIMATED WEIGHT

	M1	M2
ERECTION	315,200#	315,200#
TEST	385 200#	885 200#
OPER.	429,600#	429,600#

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UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

HIGH TEMPERATURE MSF MODULE
2.5 MGD MSF DESALINATION PLANT

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.
DWG. BY THE FLUOR CORPORATION, LTD.
DESIGN ______ DATE ______
DWG. ROY WILLIAMS DATE 1-13-69
CHK'D ______ DATE ______
APPV. ______ DATE ______

UNITED STATES
DEPARTMENT
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OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

DRAWING TITLE HIGH TEMPERATURE MSF MODULE
DATE: 1-13-69
DRAWING NUMBER 4334-FC-A

CALCULATIONS and SKETCHES
THE FLUOR CORPORATION LTD.

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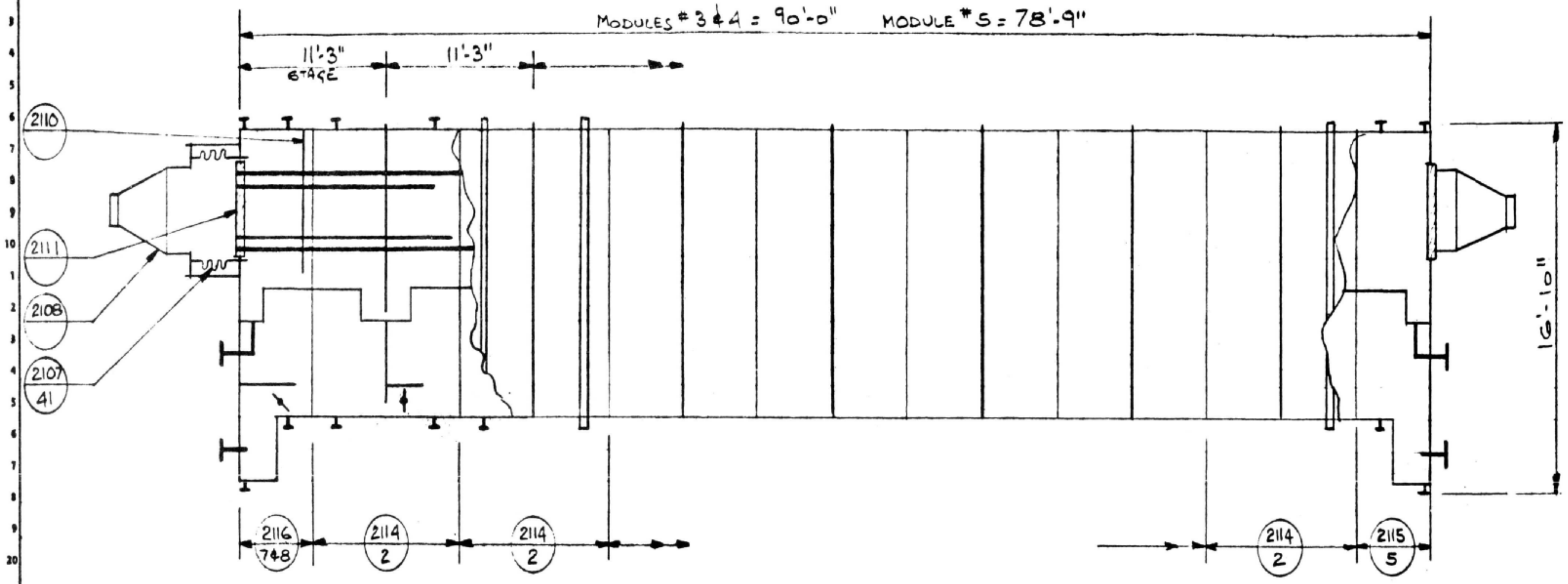
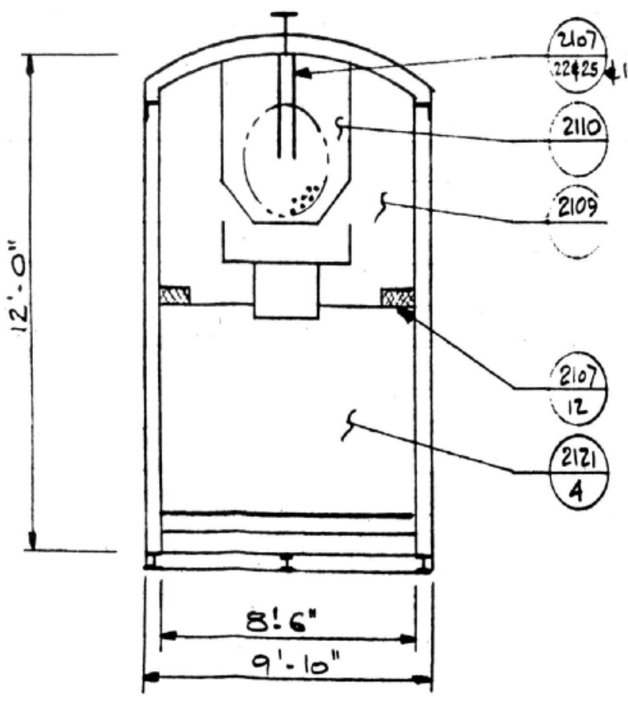
BY CHK'D
JOB NO.





NOTE MODULE # 5 IS COMPOSED OF 7 STAGES ONLY

ESTIMATED WEIGHT

	M3	M4	M5
ERECT	306,000#	306,000#	270,500#
TEST	876,000#	876,000#	767,000#
OPER	420,300#	420,300#	370,000#

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JACK A. HUNTER, DIRECTOR

LOW TEMPERATURE MSF MODULE
2.5 MGD MSF DESALINATION PLANT

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.
DWG. BY THE FLUOR CORPORATION, LTD.
DESIGN ______ DATE ______
DWG. Roy Williams DATE 1-13-69
CHK'D ______ DATE ______
APPV. ______ DATE ______

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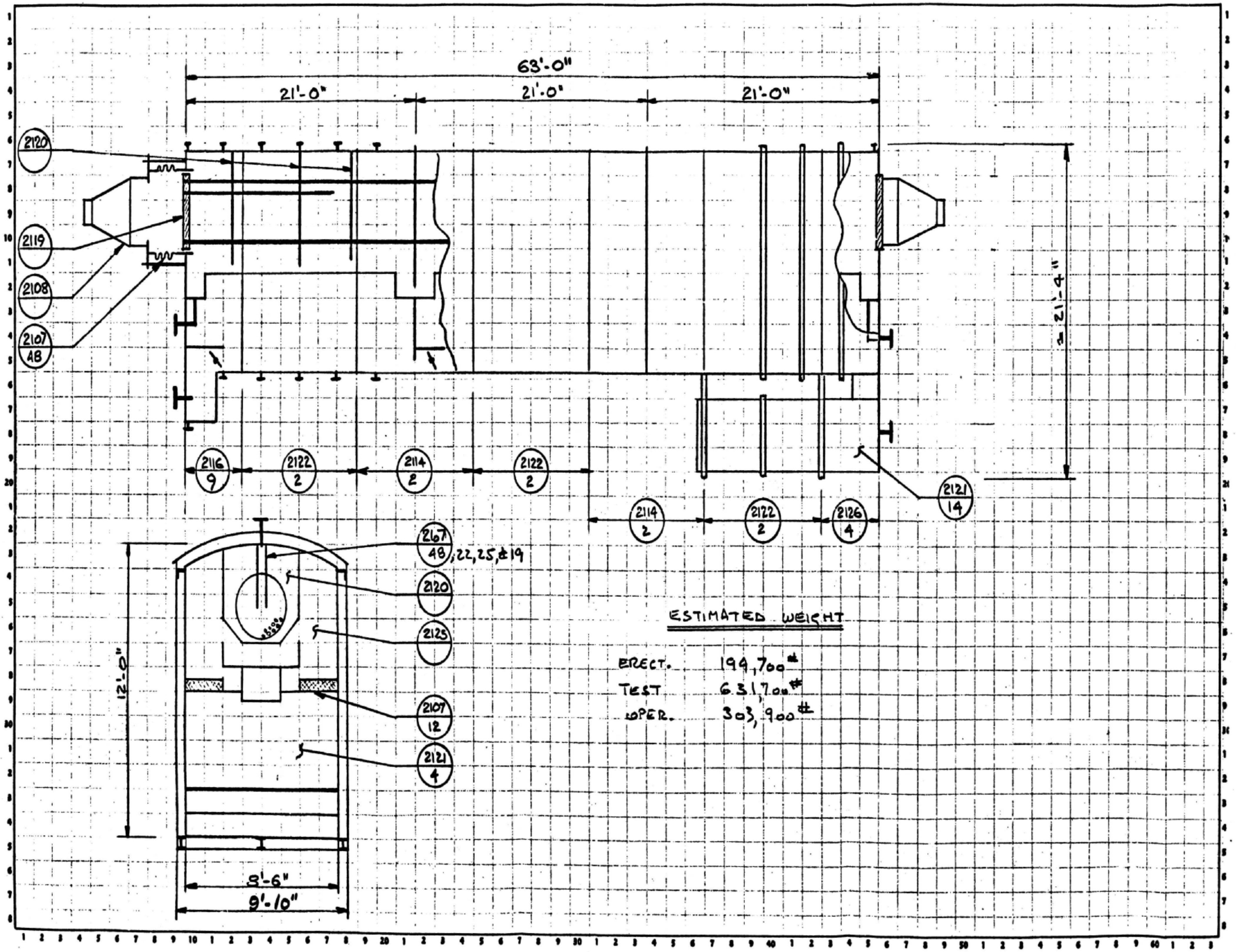
DRAWING TITLE
LOW TEMPERATURE MSF MODULE
DATE: 1-13-69
DRAWING NUMBER 1334-FC-B

CALCULATIONS and SKETCHES
THE FLUOR CORPORATION LTD.

SHEET NO. ____
DATE ____
BY ____ CHK'D ____
JOB NO. ____

ENGINEERING-CONSTRUCTION DIVISION
Form E-052 REV. 12-66



ESTIMATED WEIGHT

ERECT. 199,700#
TEST 631,700#
OPER. 303,900#

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JACK A. HUNTER, DIRECTOR

HEAT REJECTION MSF MODULE
2.5 MGD MSF DESALINATION PLANT

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

DWG. BY THE FLUOR CORPORATION, LTD.
DESIGN ____ DATE ____
DWG. ROY WILLIAMS DATE 1-13-69
CHK'D ____ DATE ____
APPV. ____ DATE ____

UNITED STATES
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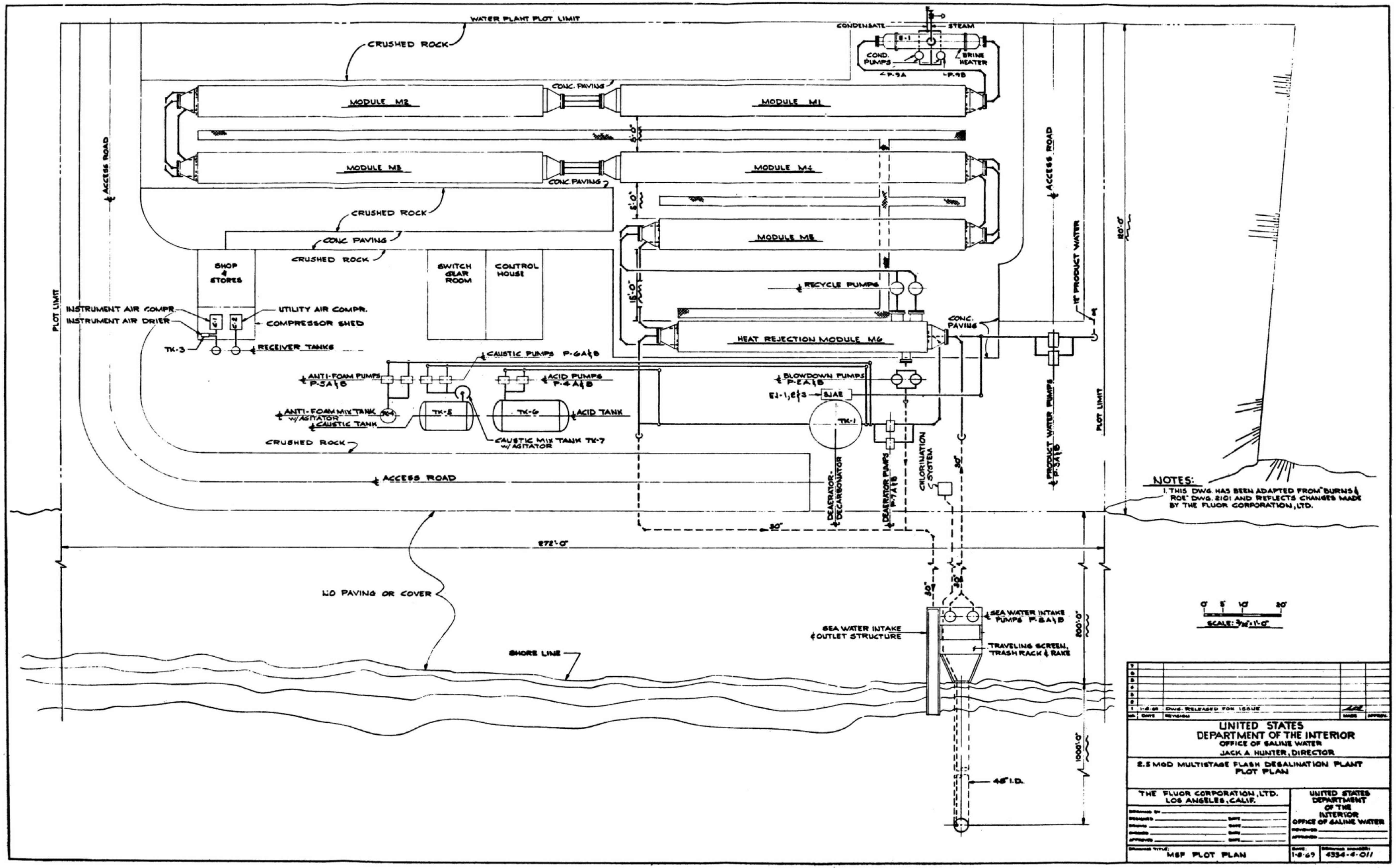
OFFICE OF SALINE WATER
REVIEWED ____
APPROVED ____

DRAWING TITLE HEAT REJECTION MSF MODULE
DATE: 1-13-69
DRAWING NUMBER 4334-FC-C



NOTES:

1. THIS DWG. HAS BEEN ADAPTED FROM "BURNS & ROE" DWG. 2101 AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

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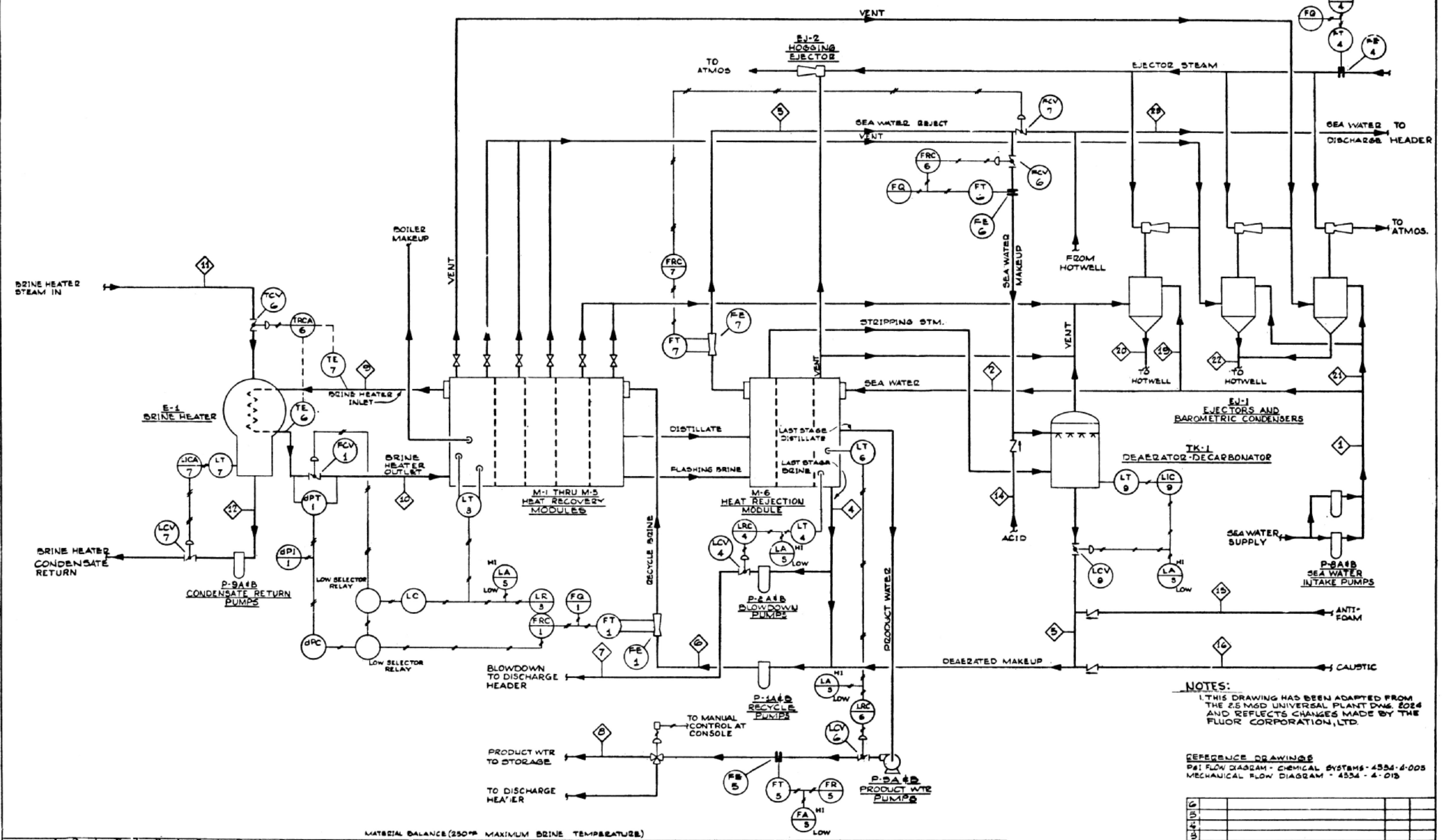
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

2.5 MGD MULTISTAGE FLASH DESALINATION PLANT
PLOT PLAN

THE FLUOR CORPORATION, LTD.
LOS ANGELES, CALIF.

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER

DRAWING TITLE: MSF PLOT PLAN
DATE: 1-8-69
DRAWING NUMBER: 4334-4-011



NOTES:

1. THIS DRAWING HAS BEEN ADAPTED FROM THE 2.5 MGD UNIVERSAL PLANT DWG. 2024 AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

REFERENCE DRAWINGS

P&I FLOW DIAGRAM - CHEMICAL SYSTEMS - 4334-4-005
MECHANICAL FLOW DIAGRAM - 4334 - 4 - 013

MATERIAL BALANCE (250°F MAXIMUM BRINE TEMPERATURE)

	⟨1⟩ SEAWATER SUPPLY	⟨2⟩ COOLANT SEAWATER TO EVAPORATOR	⟨3⟩ SEAWATER REJECT	⟨4⟩ LAST STAGE BRINE	⟨5⟩ DEAERATED MAKEUP	⟨6⟩ RECYCLE BRINE	⟨7⟩ BLOWDOWN	⟨8⟩ PRODUCT WATER TO STORAGE	⟨9⟩ BRINE HEATER INLET	⟨10⟩ BRINE HEATER OUTLET	⟨11⟩ BRINE HEATER STEAM	⟨12⟩ BRINE HEATER CONDENSATE
FLOW LB/HR × 10³	5148	4628	4628	5030	1780	5915	864.6	863.4	5915	5915	80.87	80.87
FLOW GPM	10,000	9050	9060	9630	3400	11,400	1650	1750	11,900	12,000	—	175
TEMP °F	65	65	82	82	82	82	82	78	237.7	250	267	267
DISSOLVED SOLIDS PPM	55,000	55,000	55,000	70,000	55,000	58,700	70,000	25MAX	58,700	58,700	—	2MAX
SPECIFIC GRAVITY	1.028	1.028	1.021	1.047	1.021	1.040	1.047	1.00	0.992	0.986	—	0.988

	⟨13⟩ EJECTOR STEAM	⟨14⟩ ACID H_2SO_4	⟨15⟩ ANTI-FOAM	⟨16⟩ CAUSTIC	⟨17⟩ NON CONDENSABLES	⟨18⟩ DECARBONATED VENT CO_2	⟨19⟩ SEAWATER TO VENT CONDENSER	⟨20⟩ SEAWATER FROM VENT CONDENSER	⟨21⟩ SEAWATER TO SJAE	⟨22⟩ SEAWATER FROM SJAE	⟨23⟩ SEAWATER DISCHARGE
FLOW LB/HR × 10³	*2000	0.208	0-0.005	0-0.005	225	*.20	330	330	167	167	3418
FLOW GPM							685	687	326	328	6700
TEMP °F					210	95	65	87	65	93	82
DISSOLVED SOLIDS PPM							55,000	55,000	55,000	55,000	55,000
SPECIFIC GRAVITY		1.83					1.028	1.021	1.028	1.02	1.02

* ESTIMATED

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UNITED STATES
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OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

PROCESS FLOW DIAGRAM
2.5 MGD MULTISTAGE FLASH (MSF) PLANT

THE FLUOR CORPORATION LTD.
LOS ANGELES, CALIF.
DRAWING BY THE FLUOR CORP. LTD.
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DRAWN DELBY DATE 12/20/68
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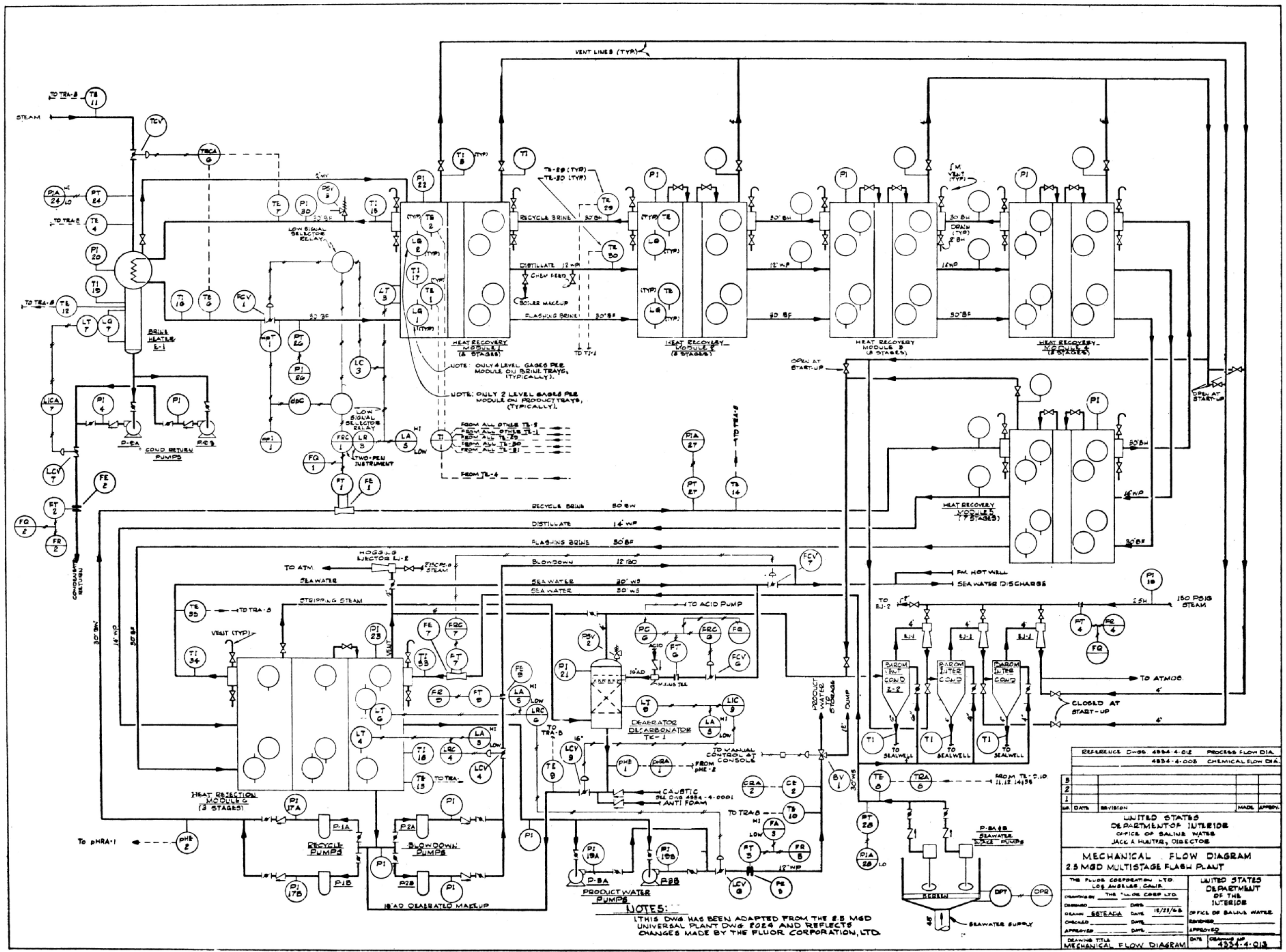
DRAWING NO. 4334-4-012



NOTES:

1. THIS DWG HAS BEEN ADAPTED FROM THE 2.5 MGD UNIVERSAL PLANT DWG 2024 AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

REFERENCE DWGS 4334-4-012 PROCESS FLOW DIA.
4334-4-008 CHEMICAL FLOW DIA.

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JACK A. HUNTER, DIRECTOR

MECHANICAL FLOW DIAGRAM
2.5 MGD MULTISTAGE FLASH PLANT

THE FLUOR CORPORATION LTD.
LOS ANGELES, CALIF.
DRAWING BY THE FLUOR CORP LTD.
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DRAWN ESTRADA DATE 12/23/66
CHECKED ______ DATE ______
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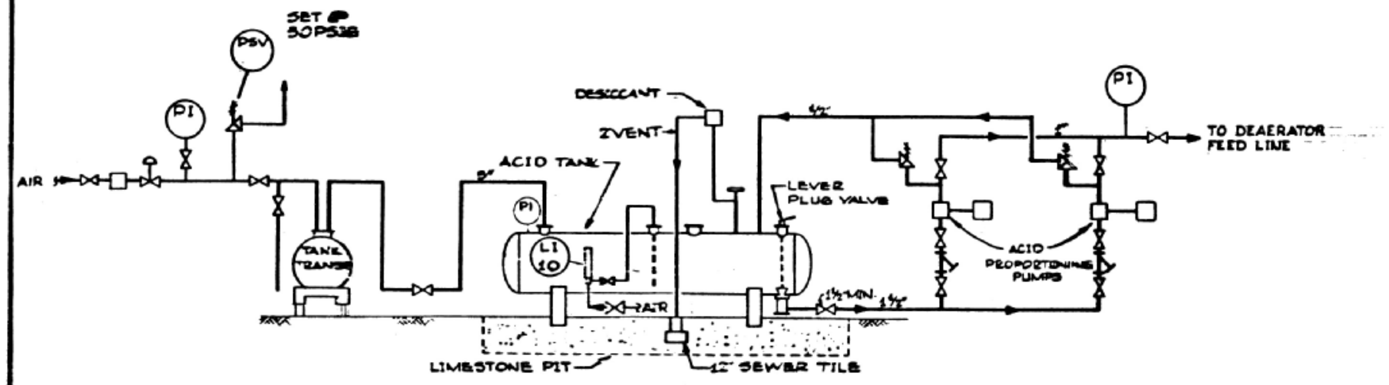
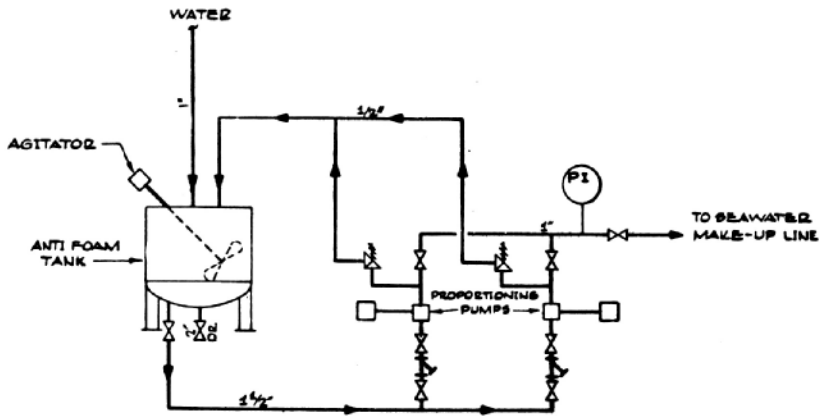
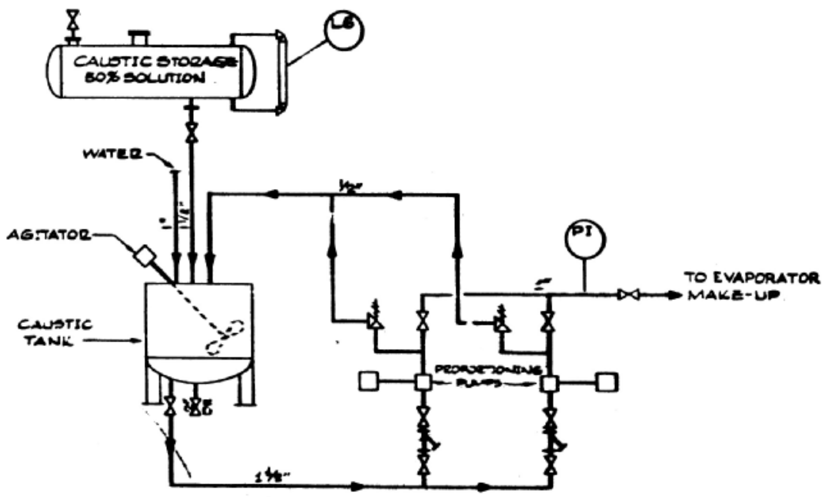
DRAWING TITLE
MECHANICAL FLOW DIAGRAM
DATE
DRAWING NO.
4334-4-013



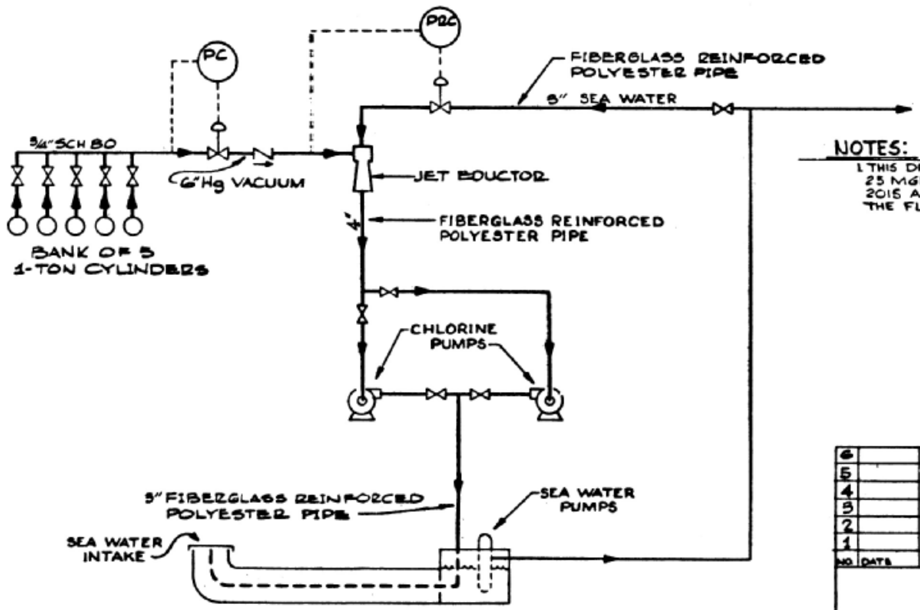
ACID SYSTEM
VTE & MSF



ANTI FOAM SYSTEM
(MSF ONLY)



CAUSTIC SYSTEM
VTE & MSF



CHLORINATION SYSTEM
VTE & MSF

NOTES:

1. THIS DRAWING HAS BEEN ADAPTED FROM 25 MGD UNIVERSAL PLANT DRAWING 2015 AND REFLECT CHANGES MADE BY THE FLUOR CORPORATION, LTD.

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OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

2.5 MGD VTE & MSF DESALINATION PLANTS
P&I FLOW DIAGRAMS - CHEMICAL SYSTEMS

THE FLUOR CORPORATION LTD.
LOS ANGELES, CALIF.

DRAWN BY THE FLUOR CORPORATION LTD.
DESIGNED ______ DATE ______
DRAWN [illegible] DATE [illegible]
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APPROVED ______ DATE ______

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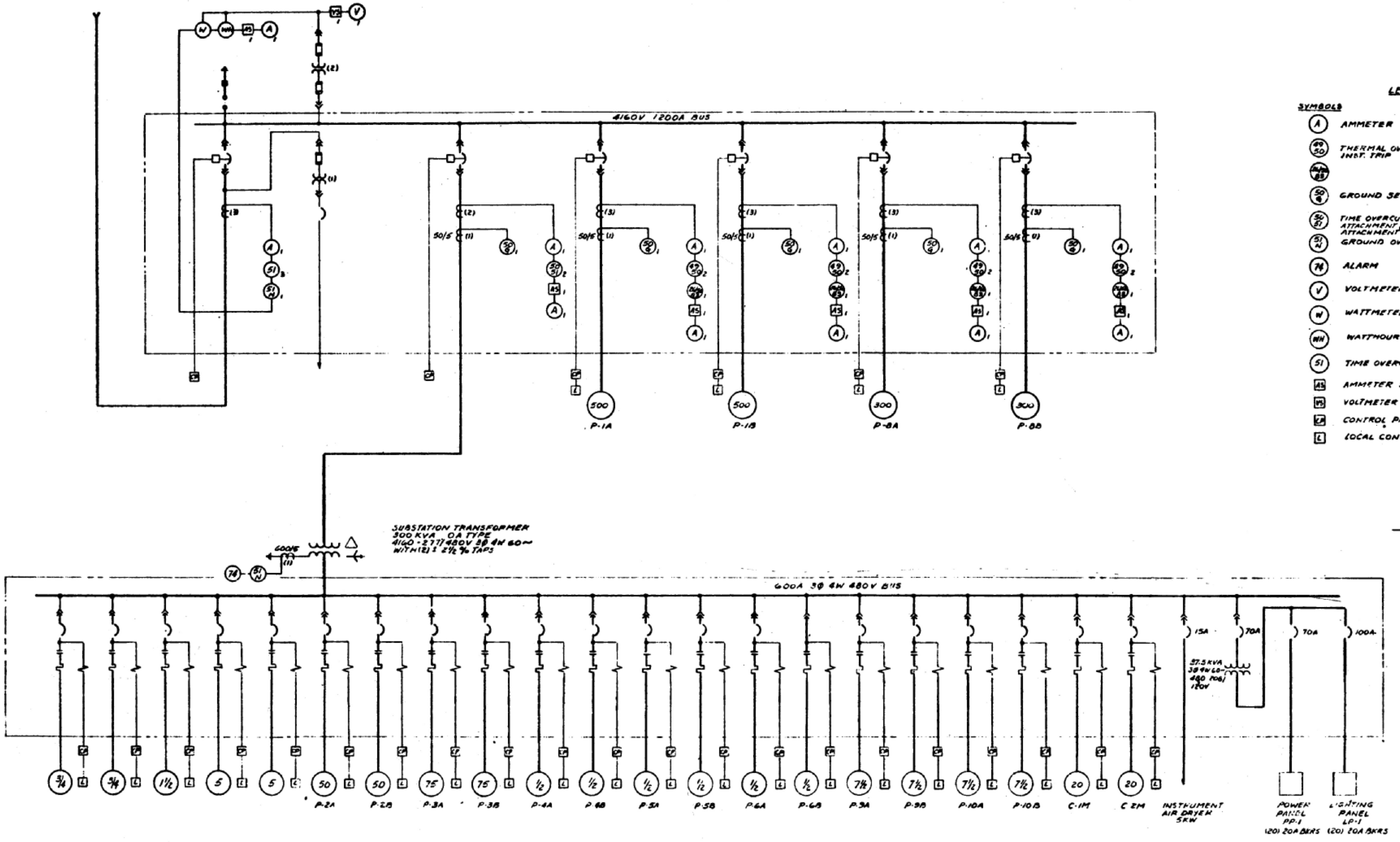
DRAWING TITLE
CHEMICAL FLOW DIAGRAM
SHEET
DRAWING NO.
4334-4-003



LEGEND

SYMBOLS

A	AMMETER
49/50	THERMAL OVERCURRENT WITH INST. TRIP
83	
50/G	GROUND SENSING
50/51	TIME OVERCURRENT WITH INST TRIP ATTACHMENT (83 HIGH DROPOUT ATTACHMENT FOR MTRS ONLY)
51/N	GROUND OVERCURRENT
74	ALARM
V	VOLTMETER
W	WATTMETER
WH	WATTHOURMETER
51	TIME OVERCURRENT
AS	AMMETER SWITCH
VS	VOLTMETER SWITCH
CP	CONTROL PANEL
L	LOCAL CONTROL

NOTES:

1. THIS DRAWING HAS BEEN ADAPTED FROM STEARNS-ROGER DRAWING 21523-E1-RO AND REFLECTS CHANGES MADE BY THE FLUOR CORPORATION, LTD.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR

ELECTRICAL ONE-LINE DIAGRAM
2.5 MGD MSF PLANT

THE FLUOR CORPORATION, LTD
LOS ANGELES, CALIF.

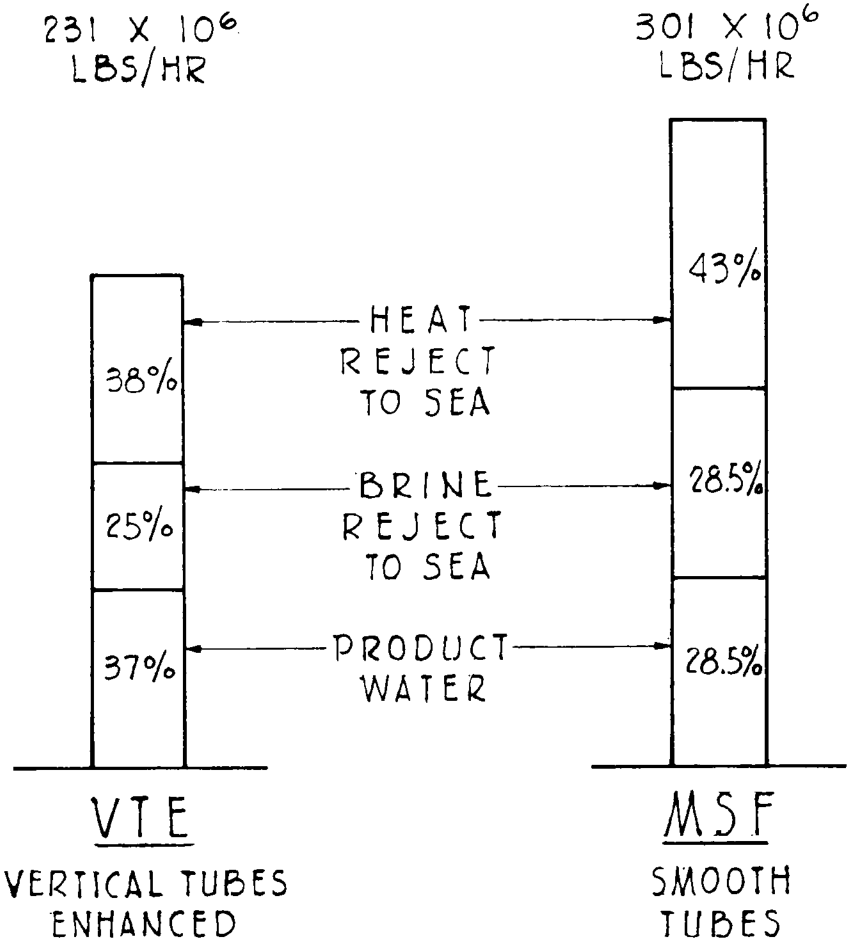
DRAWING BY THE FLUOR CORPORATION, LTD.
DESIGNED ______ DATE ______
DRAWN GEORGE K. CORBETT, JR. DATE 1-10-69
CHECKED ______ DATE ______
APPROVED ______ DATE ______

UNITED STATES
DEPARTMENT
OF THE
INTERIOR
OFFICE OF SALINE WATER
REVIEWED ______
APPROVED ______

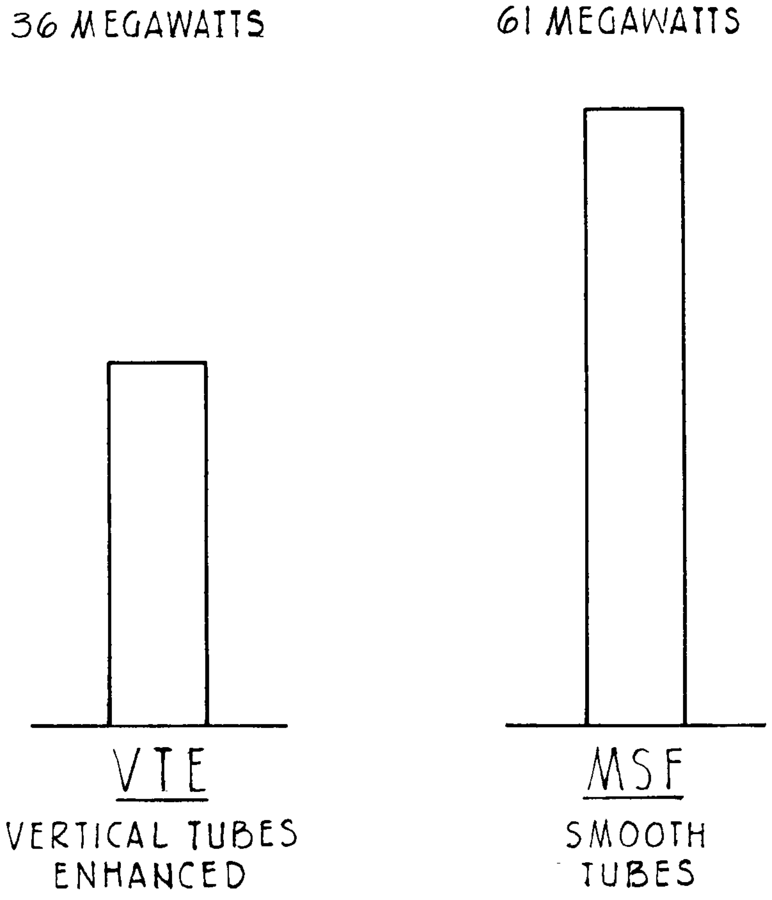
DRAWING TITLE: MSF ELECTRICAL ONE-LINE DIAGRAM
DATE: 1-10-69
DRAWING NUMBER: 4334-4-014

LARGE (250MGD) PLANTS

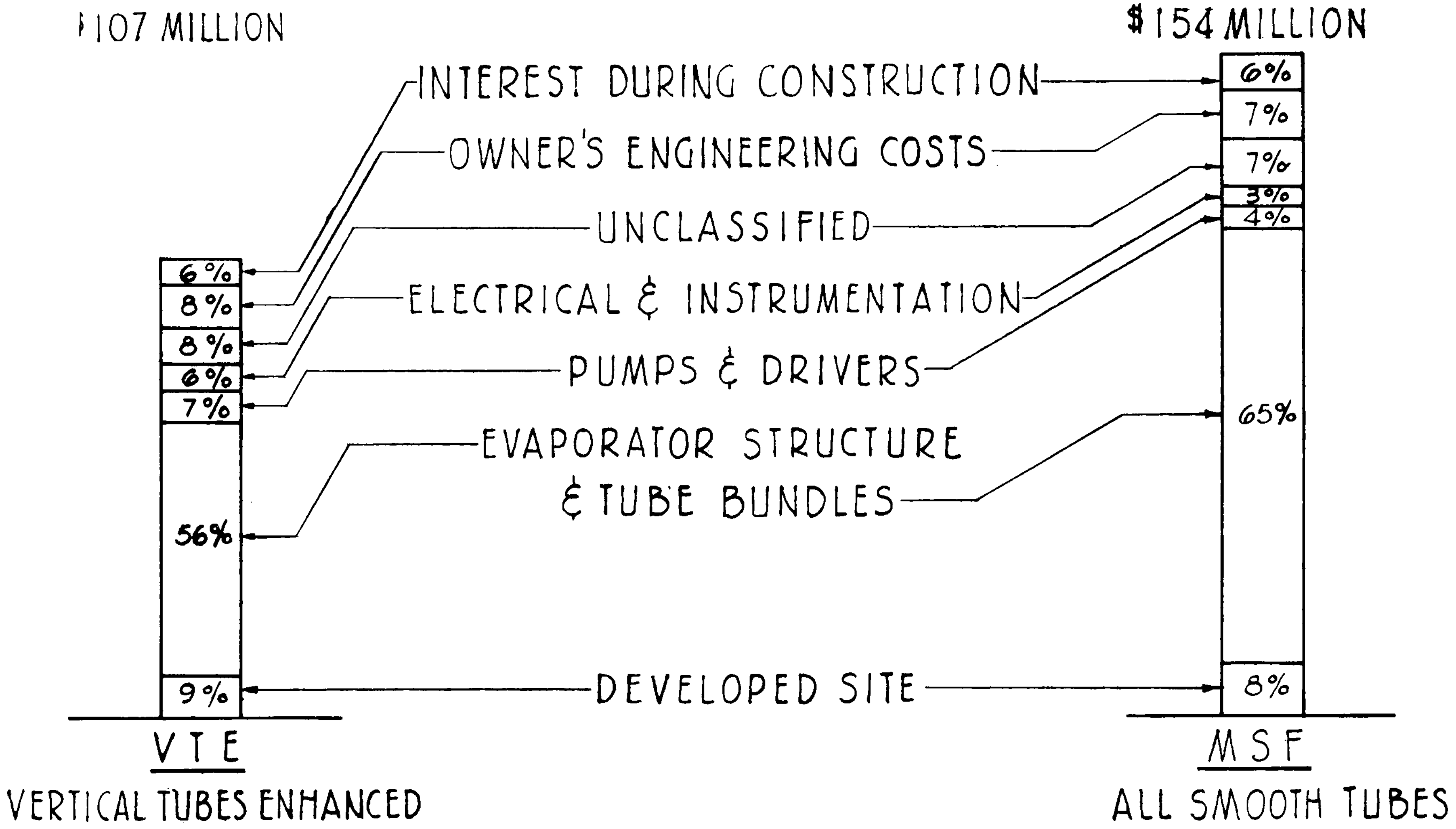
SEAWATER INTAKE FLOWS



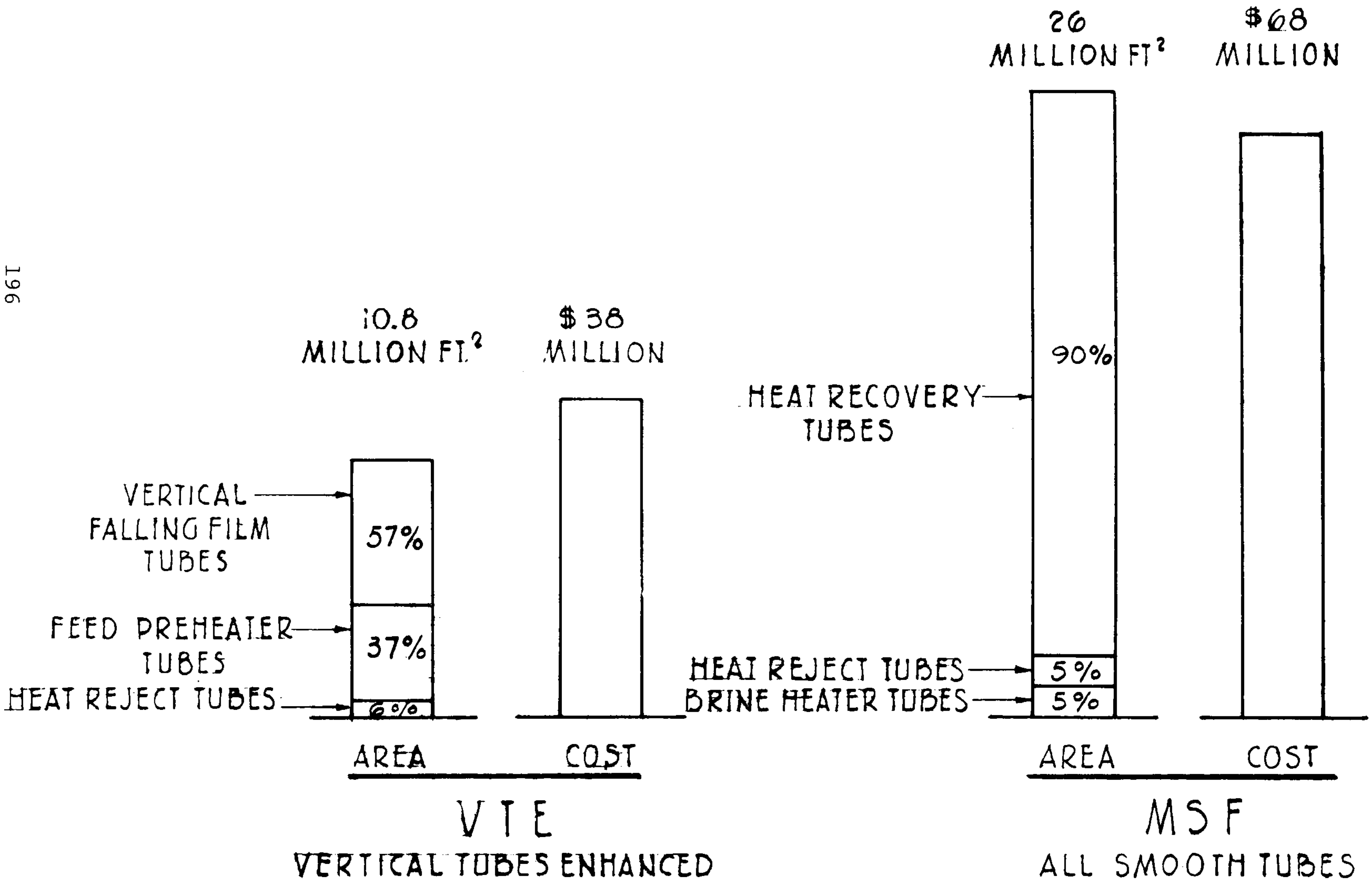
PUMPING POWER REQUIREMENTS



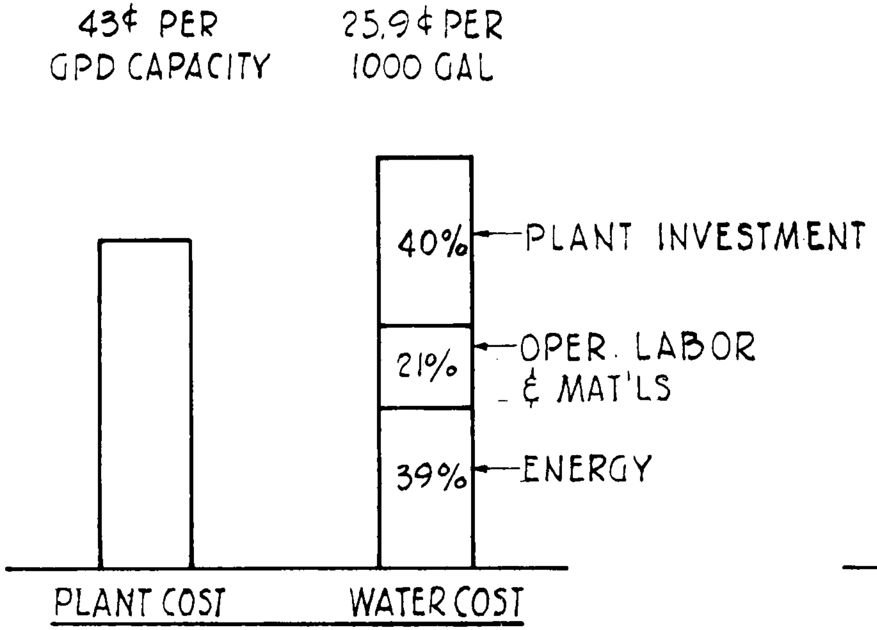
CAPITAL COSTS
LARGE (250MGD) PLANTS



HEAT TRANSFER AREAS AND COSTS LARGE (250 MGD) PLANTS

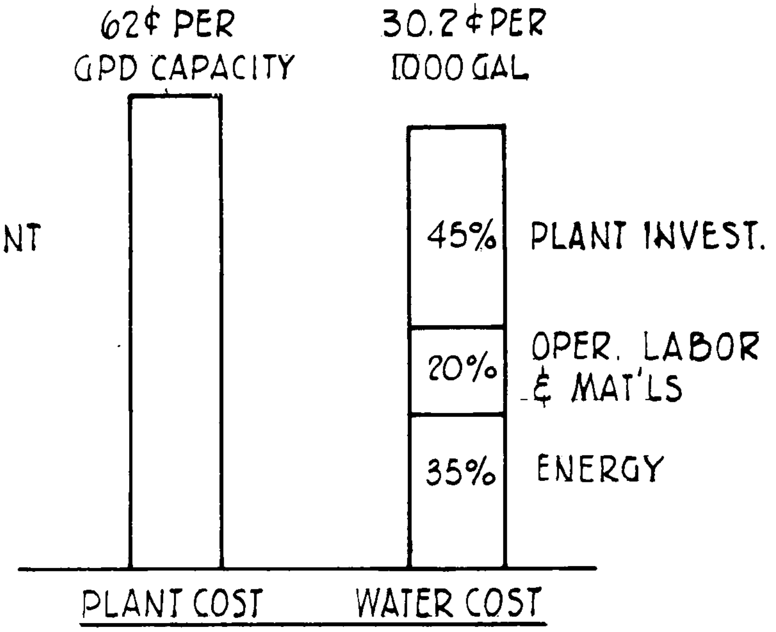


CAPITAL AND WATER COSTS
LARGE (250MGD) PLANTS



VTE

ENHANCED VERTICAL TUBES

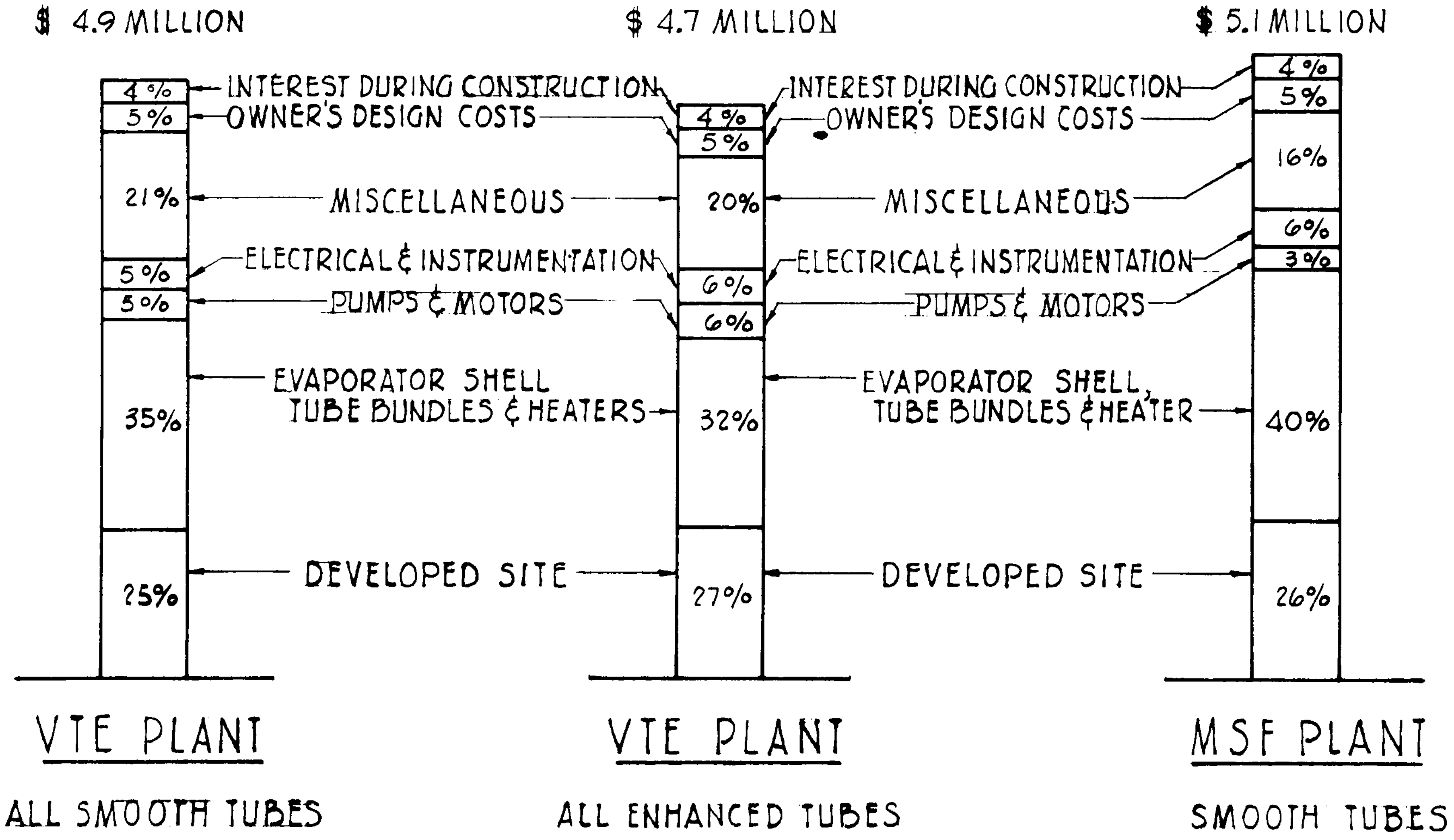


MSF

SMOOTH TUBES

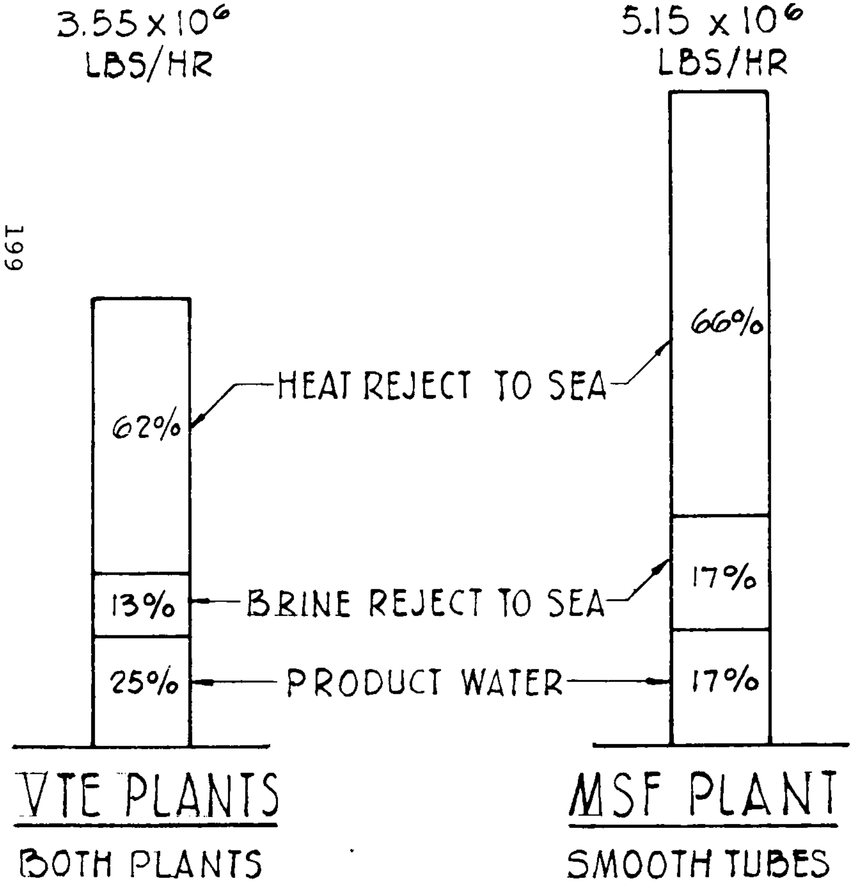
BASIS FOR COST —
- DUAL PURPOSE PLANTS
- STEAM AT 11.2-12¢/10^6 BTU.
- 30 YEAR PLANT LIFE ASSUMED.
- INTEREST AT 4.25%
- COSTS ESCALATED TO 1970.

CAPITAL COSTS
SMALL (2.5 MGD) PLANTS

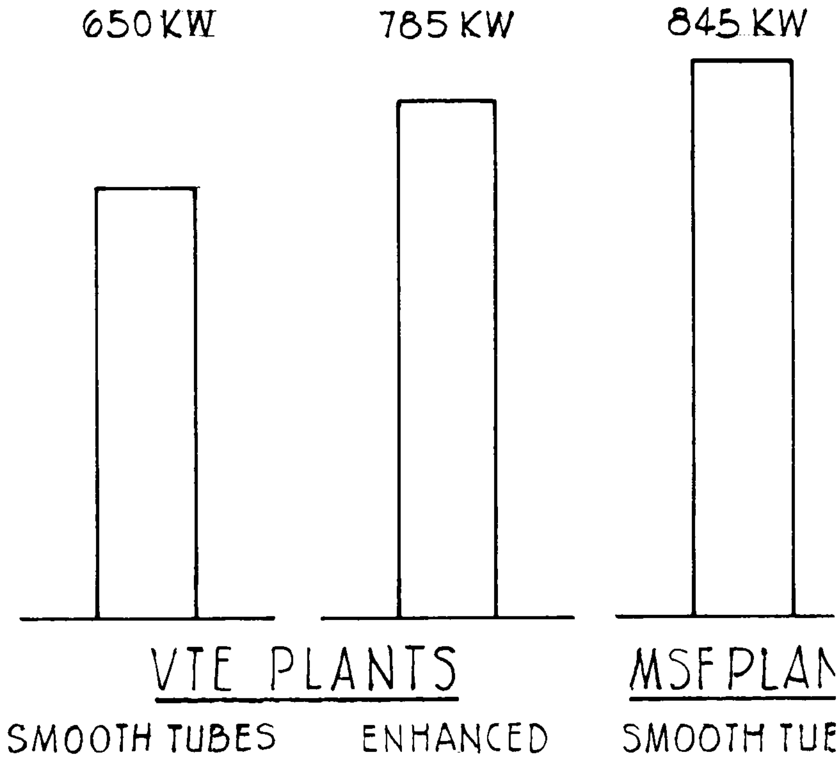


SMALL (2.5MGD) PLANTS

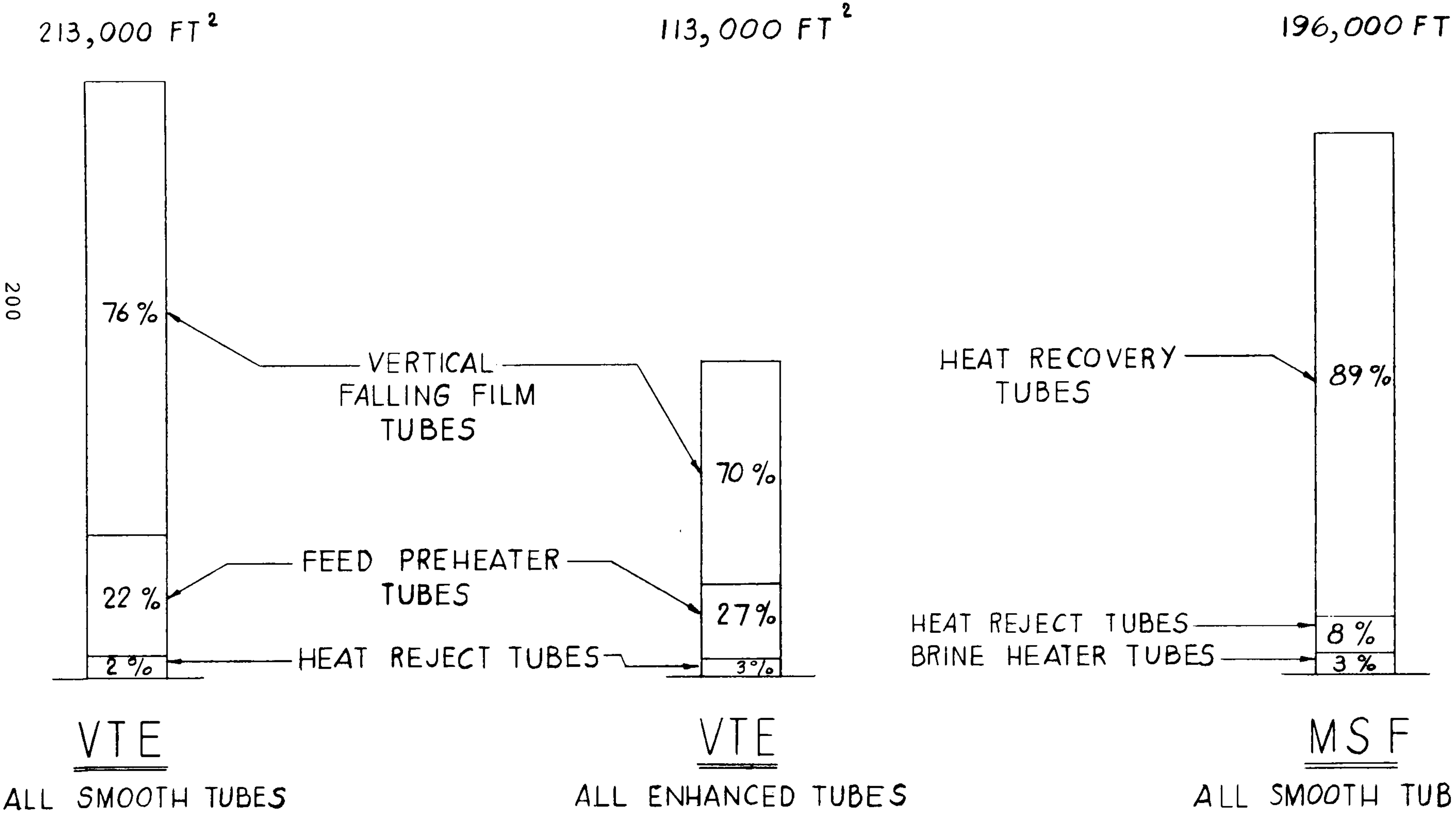
SEAWATER INTAKE FLOWS



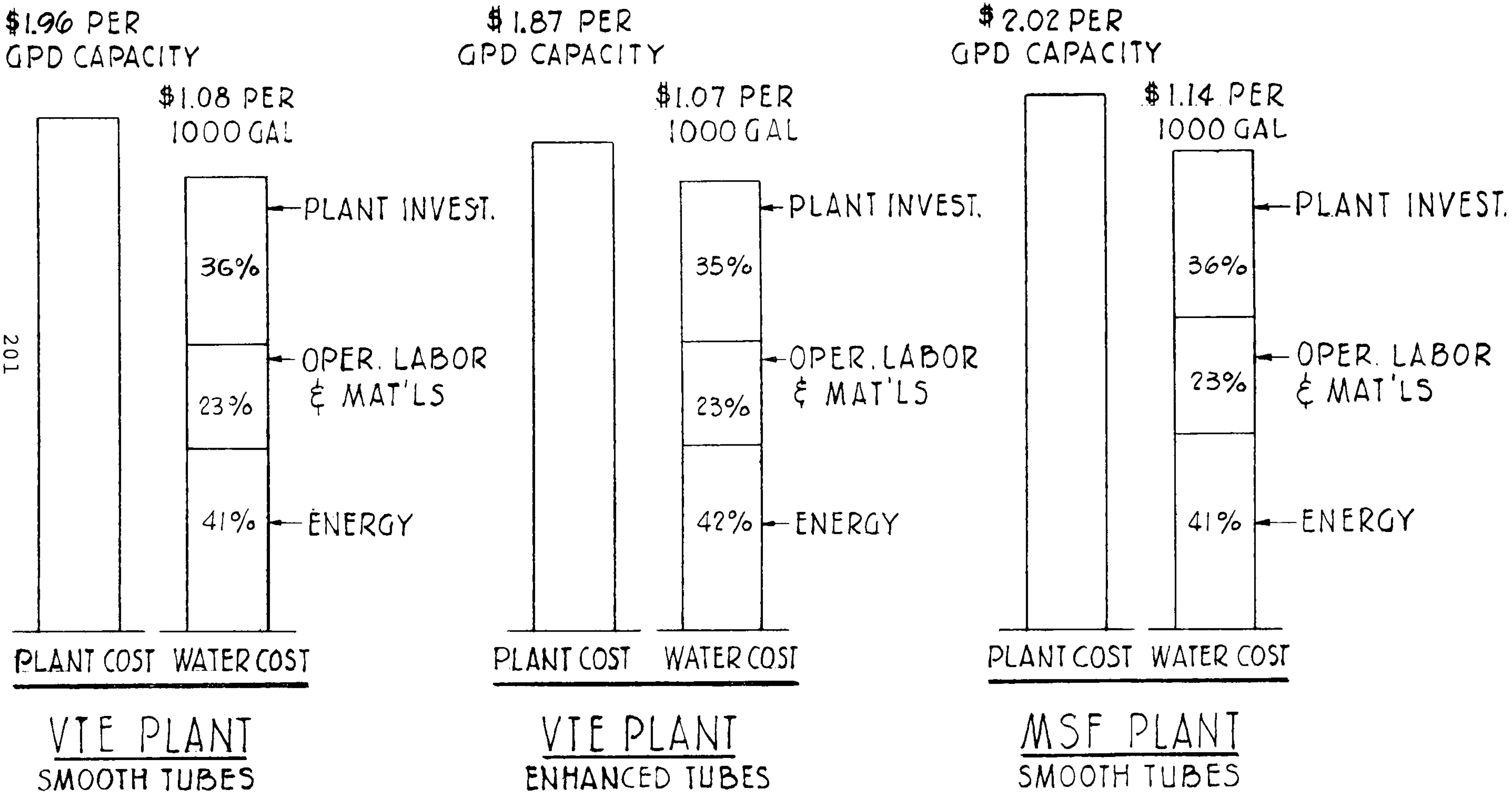
PUMPING POWER REQUIREMENTS



HEAT TRANSFER AREAS
SMALL (2.5 MGD) PLANTS



CAPITAL AND WATER COSTS
SMALL (2.5MGD) PLANTS



BASIS FOR COST —

- SINGLE PURPOSE PLANTS
- STEAM AT 50¢/10^6 BTU.
- 30 YEAR PLANT LIFE ASSUMED.
- INTEREST AT 4.25 %.
- COSTS ESCALATED TO 1970.

19.2 - 250 MGD VTE COMPUTER PRINTOUT

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    REF CASE 311A  CURRENT TECHNOLOGY  8/20/68  CDA 194                                       PAGE 1
 I  SUMMARY OF PLANT DATA

    GENERAL                                              PERFORMANCE RATIOS
        PLANT CAPACITY, MGD              250.00              OVERALL                       12.8930
        SEA WATER CONCENTRATION         0.03360              VTE                           15.2691
        PRODUCT CONCENTRATION          0.000025              PHTR%ACTUAL<                   7.3740
        DEAERATED FEED CONC.            0.03360              MSF %CONVENTIONAL<            11.0867
        CONCENTRATION RATIO              2.5000
        NUMBER OF EFFECTS                    15
        NO STAGES IN PREHEATER               50

    TEMPERATURES - DEG F                                   FLOWS, LBS/HR
        STEAM                           267.186              TOTAL STEAM              0.716506D 07
        MAXIMUM BRINE                   260.000              VE STEAM                 0.500583D 07
        FINAL EFFECT                    112.000              PHTR STEAM               0.215923D 07
        BLOWDOWN                         92.820              TOTAL PRODUCT            0.862575D 08
        PRODUCT                          91.167              VE PRODUCT               0.713691D 08
        DEAERATED FEED                   77.000              PHTR PRODUCT             0.148670D 08
        OCEAN                            65.000              BLOWDOWN                 0.574622D 08
                                                             SEA INTAKE               0.230727D 09
        CONDENSER APPROACH                5.000              CONDENSER REJECT         0.818165D 08
                                                             TUBE VELOCITY, FPS              4.520

II DESCRIPTION OF PHYSICAL PLANT

    PLANT DIMENSIONS, FT
        OVERALL VE LENGTH               374.658              OVERALL HEIGHT                 33.000
        OVERALL PHTR LENGTH             374.608              VE HEIGHT                      21.500
        MIN WIDTH %1ST EFFECT<          270.721              PHTR HEIGHT                    11.500
        MAX WIDTH %LAST EFFECT<         430.335              VE SHELL VOLUME, FT3     0.248123D 07
        NO OF TRAINS                          4              PHTR SHELL VOLUME, FT3   0.144578E 07
        TOTAL NO OF MODULES                   4

    TUBING DESCRIPTION
                                           VE                    PREHEATER               CONDENSER
        OUTSIDE DIA, INCHES               3.000                      0.750                   1.000
        WALL THICKNESS, INCHES                                       0.035                   0.049
        K,BTU/HR FT2 F                  125.000                     26.000                  26.000
        FOULING RESISTANCE              0.0                        0.00050                 0.00070
        FLOODING FACTOR                                             19.000                  19.000
        NO OF TUBES                     611311.                     58017.                  27716.
        TUBE LENGTH FT                   10.000                    350.868                  88.626
        SURFACE AREA, FT2        0.611311030 07            0.399693140 07          0.643081000 06
        AVG OVERALL UBAR               1455.658                    574.817                 394.748
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19.2 - 250 MGD VTE COMPUTER PRINTOUT

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    REF CASE 311A  CURRENT TECHNOLOGY  8/20/68  CDA 194                                            PAGE 2

 III HEAD REQUIREMENTS, FT                                  PUMPING POWER REQUIREMENTS, MW

          SEA WATER DELIVERY           66.226                   INTAKE PUMPS                 6.5421
          PREHEATER FEED              162.236                   PHTR FEED PUMPS              9.9828
          PRODUCT DELIVERY            108.575                   PRODUCT PUMPS                4.0098
          BLOWDOWN DISCHARGE           40.000                   BLOWDOWN PUMPS               0.9841
          DEAERATOR BOOSTER            12.247                   BOOSTER PUMPS                0.2851
                                                                EFFECT PUMPS                14.0817
                                                                TOTAL                       35.8857

 IV SUBSIDIARY SECTIONS
                                    BRINE HEATER       CONDENSER                   DEAERATOR

          LMDT, F                      13.045            18.412    TEMP IN-HOT, F                97.000
          H INSIDE, B/HR FT2 F        2067.90           1021.95    TEMP IN-COLD, F               65.000
          H OUTSIDE, B/HR FT2 F       2648.65           1714.87    TEMP OUT, F                   77.000
          OVERALL U, B/HR-FT2-F        654.160           394.748   TEMP TO EJECT, F              66.000
          HEAT RATE, BTU/HR         0.201614D 10     0.457409D 10  FLOW IN-HOT, LB/HR   0.543808D 08
          FOULING RESISTANCE           0.00050           0.00070   FLOW IN-COLD, LB/HR  0.893559D 08
          SURFACE AREA, FT2         0.236260D 06     0.643081D 06  FLOW OUT, LB/HR      0.143720D 09
          NO OF TUBES                  58017.            27716.    VAPOR TO EJECT       0.169600D 05
          TUBE LENGTH, FT              20.740            88.626    INERTS, LB/HR        0.175625D 05
          TEMP-COOLANT EXIT, F                          103.717
          TUBE FLOW                 0.143720D 09     0.126734D 09
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19.2 - 250 MGD VTE COMPUTER PRINTOUT

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REF CASE 311A  CURRENT TECHNOLOGY  8/20/68  CDA 194                                                       PAGE 3
                                                       VTE EFFECT DATA     ORVE-3P
-------------------------------------------------------------------------------------------------------------------------------
                                                                                 ACTUAL          TUBE                          PLANT
 NO   UBAR       WT           CB        TB       HB       T         EV          AREA %FT2<      NUMBER     DELTA-T     ALPHA    WIDTH
 --   -----      --           --        --       --       -         --          ----------      ------     -------     -----    -----
                                       245.73
  1   1837.4  0.1437D 09   0.03360   260.00   213.28   267.19   0.5022D 07   0.3540D 06   0.3540D 05     7.19     1.4065   270.7212
  2   1789.1  0.5351D 08   0.03506   251.44   204.51   258.50   0.4938D 07   0.3699D 06   0.3699D 05     7.06     1.5426   282.2256
  3   1735.3  0.3719D 08   0.03662   242.79   195.62   249.81   0.4907D 07   0.3836D 06   0.3836D 05     7.02     1.7162   293.8511
  4   1688.7  0.3853D 08   0.03829   233.98   186.63   240.98   0.4877D 07   0.3955D 06   0.3955D 05     7.00     1.8225   304.8703
  5   1640.4  0.3976D 08   0.04010   225.05   177.50   232.07   0.4847D 07   0.4060D 06   0.4060D 05     7.02     1.9319   315.6802
  6   1590.5  0.4088D 08   0.04207   215.96   168.20   223.03   0.4817D 07   0.4154D 06   0.4154D 05     7.07     2.0443   326.5186
  7   1538.8  0.4190D 08   0.04421   206.65   158.68   213.82   0.4788D 07   0.4235D 06   0.4235D 05     7.17     2.1597   337.5457
  8   1485.0  0.4278D 08   0.04655   197.08   148.88   204.40   0.4758D 07   0.4301D 06   0.4301D 05     7.32     2.2784   348.8261
  9   1428.7  0.4348D 08   0.04913   187.19   138.73   194.72   0.4728D 07   0.4348D 06   0.4348D 05     7.52     2.4008   360.3378
 10   1369.4  0.4395D 08   0.05198   176.89   128.13   184.70   0.4698D 07   0.4370D 06   0.4370D 05     7.81     2.5273   371.9857
 11   1306.0  0.4410D 08   0.05515   166.06   116.93   174.27   0.4667D 07   0.4359D 06   0.4359D 05     8.21     2.6583   383.6254
 12   1237.0  0.4382D 08   0.05870   154.54   104.90   163.32   0.4634D 07   0.4305D 06   0.4305D 05     8.78     2.7944   395.1093
 13   1159.9  0.4299D 08   0.06272   142.05    91.65   151.66   0.4600D 07   0.4196D 06   0.4196D 05     9.60     2.9362   406.3844
 14   1070.1  0.4147D 08   0.06731   128.16    76.44   139.03   0.4563D 07   0.4018D 06   0.4018D 05    10.87     3.0838   417.7217
 15    958.5  0.3907D 08   0.07266   112.00    75.96   124.98   0.4523D 07   0.3756D 06   0.3756D 05    12.98     3.2363   430.3347
                                                         109.10

 UBAR   #EFFECT UBAR, BTU/HR-FT2-DEG F        WT#BRINE FLOW TO TUBES,LBS/HR               CB#WT FR SALT ENTERING TUBES
 TB     #BRINE TEMP OF WB, DEG F              HB#BRINE ENTHALPY OF WB,BTU/LB              T #SATURATED VAPOR TEMP, DEG F
 EV#STEAM FLOW FROM EFFECT, LBS/HR            Q #EVAPORATOR HEAT RATE, BTU/HR             ALPHA # BPE & VE BUNDLE LOSS, F
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                                        COST SUMMARY PAGE

              COMPONENTS                   COST-$/YR      COST-$/KGAL      COST-$ DIRECT
              ----------                   ---------      -----------      -------------

      EFFECT TUBES & SHEETS              0.11358842D 07  0.13831157D-01  0.16136114D 08
      PHTR TUBES & SHEETS                0.55509242D 06  0.67591139D-02  0.78855178D 07
      VE & PHTR SHELL                    0.76932888D 06  0.93677762D-02  0.10928913D 08
      PUMPS AND MOTORS                   0.53704273D 06  0.65393309D-02  0.76291080D 07
      SEA-WATER INTAKE                   0.32606057D 06  0.39702949D-02  0.46319430D 07
      VALVES AND PIPING                  0.27470068D 06  0.33449083D-02  0.39023360D 07
      CHEMICAL CAPITAL                   0.17230067D 06  0.20980287D-02  0.24476644D 07
      INSTRUMENTS                        0.21458062D 06  0.26128529D-02  0.30482839D 07
      ELECTRICAL                         0.12024304D 06  0.14641461D-02  0.17081455D 07
      DEAERATOR                          0.96726089D 05  0.11777907D-02  0.13740690D 07
      CONDENSER                          0.12849048D 06  0.15645715D-02  0.18253068D 07
      BRINE HEATER                       0.50487017D 05  0.61475799D-03  0.71720718D 06
      SITE, BLDGS, CRANES                0.66727628D 05  0.81251270D-03  0.94791764D 06  COST-$DIR&IND      $/GPD
                                                                                         -------------      -----
           TOTAL CAPITAL                 0.44476650D 07  0.54157242D-01  0.63182490D 08  0.76683835D 08  0.30673534D 00

           RETUBING                      0.44261401D 06  0.53895169D-02

      HEAT                               0.31152772D 07  0.37933365D-01
      CHEMICAL                           0.96184247D 06  0.11711934D-01
      POWER                              0.56584511D 06  0.68900480D-02
      OPERATING                          0.66005362D 06  0.80371837D-02
      MAINT & SUPPLIES                   0.46010275E 06  0.56024678E-02
      EJECTOR STEAM                      0.66595005D 05  0.81089819D-03

           TOTAL OPERATING               0.58297161D 07  0.70985897D-01

             TOTAL %CAP&RETUBE&OPER<     0.10719995D 08  0.13053266D 00
      COST FACTORS
           HEAT %$/MMBTU<       0.05906        PLANT LIFE, YRS          30.00000         LOAD FACTOR                0.90000
           POWER %$/KWH<        0.00200        VTE TUBE LIFE, YRS       15.00000         VTE RETUBING CHGE RATE     0.03211
           ANN CHARGE RATE      0.05800        PHTR TUBE LIFE, YRS      30.00000         PHTR RETUBING CHGE RATE    0.0
           INTEREST RATE        0.04000        CNDNSR TUBE LIFE, YRS    30.00000         CNDNSR RETUBING CHGE RATE  0.0
           HIGHER COST FACTOR   1.21369

      MISC. TOTAL UNIT COSTS
           $/CU.FT. SHELL         2.7830       $/SQ.FT. VE AREA           2.6396         $/SQ.FT. PHTR AREA  1.9509

                                        SUBMARINE LINES USED IN SEA INTAKE COST.
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STAGE  NF       FLOW            RHO          TV2     TS1     TS2     T1      T2     DTPDP          SUBMERG

  1     3   0.1325249D 09   0.2852762D 01  255.25  260.00  257.15  242.85  245.73  0.609147D-02  0.795393D 00
  2     0   0.0             0.2852762D 01  252.39  257.15  254.29  239.97  242.85  0.646441D-02  0.811097D 00
  3     0   0.0             0.2852762D 01  249.52  254.29  251.44  237.09  239.97  0.686492D-02  0.827154D 00
  4     3   0.1264360D 09   0.2884695D 01  246.60  251.44  248.56  234.18  237.09  0.730442D-02  0.828919D 00
  5     0   0.0             0.2884695D 01  243.71  248.56  245.67  231.26  234.18  0.777342D-02  0.845672D 00
  6     0   0.0             0.2884695D 01  240.81  245.67  242.79  228.35  231.26  0.827877D-02  0.862815D 00
  7     3   0.1204230D 09   0.2934719D 01  237.84  242.79  239.85  225.39  228.35  0.883875D-02  0.863574D 00
  8     0   0.0             0.2934719D 01  234.89  239.85  236.92  222.43  225.39  0.943880D-02  0.881625D 00
  9     0   0.0             0.2934719D 01  231.95  236.92  233.98  219.46  222.43  0.100881D-01  0.900115D 00
 10     3   0.1144892D 09   0.2976377D 01  228.93  233.98  231.01  216.46  219.46  0.108091D-01  0.903023D 00
 11     0   0.0             0.2976377D 01  225.94  231.01  228.03  213.45  216.46  0.115843D-01  0.922477D 00
 12     0   0.0             0.2976377D 01  222.95  228.03  225.05  210.45  213.45  0.124266D-01  0.942424D 00
 13     3   0.1086295D 09   0.3032028D 01  219.87  225.05  222.02  207.38  210.45  0.133707D-01  0.944395D 00
 14     0   0.0             0.3032028D 01  216.83  222.02  218.99  204.32  207.38  0.143907D-01  0.965522D 00
 15     0   0.0             0.3032028D 01  213.78  218.99  215.96  201.26  204.32  0.155049D-01  0.987208D 00
 16     3   0.1028401D 09   0.3102230D 01  210.63  215.96  212.86  198.13  201.26  0.167661D-01  0.987961D 00
 17     0   0.0             0.3102230D 01  207.52  212.86  209.75  195.00  198.13  0.181369D-01  0.101107D 01
 18     0   0.0             0.3102230D 01  204.40  209.75  206.65  191.86  195.00  0.196437D-01  0.103483D 01
 19     3   0.9711707D 08   0.3189264D 01  201.16  206.65  203.46  188.64  191.86  0.213684D-01  0.103374D 01
 20     0   0.0             0.3189264D 01  197.95  203.46  200.27  185.42  188.64  0.232571D-01  0.105922D 01
 21     0   0.0             0.3189264D 01  194.74  200.27  197.08  182.20  185.42  0.253486D-01  0.108544D 01
 22     3   0.9145685D 08   0.3297415D 01  191.40  197.08  193.79  178.87  182.20  0.277743D-01  0.108136D 01
 23     0   0.0             0.3297415D 01  188.08  193.79  190.49  175.55  178.87  0.304558D-01  0.110967D 01
 24     0   0.0             0.3297415D 01  184.76  190.49  187.19  172.22  175.55  0.334526D-01  0.113885D 01
 25     3   0.8585525D 08   0.3433645D 01  181.27  187.19  183.76  168.75  172.22  0.369834D-01  0.112976D 01
 26     0   0.0             0.3433645D 01  177.81  183.76  180.32  165.28  168.75  0.409349D-01  0.116149D 01
 27     0   0.0             0.3433645D 01  174.35  180.32  176.89  161.81  165.28  0.454012D-01  0.119425D 01
 28     3   0.8030730D 08   0.3608989D 01  170.70  176.89  173.28  158.17  161.81  0.507688D-01  0.117652D 01
 29     0   0.0             0.3608989D 01  167.06  173.28  169.67  154.53  158.17  0.568742D-01  0.121242D 01
 30     0   0.0             0.3608989D 01  163.42  169.67  166.06  150.88  154.53  0.638777D-01  0.124953D 01
 31     3   0.7480651D 08   0.3841455D 01  159.53  166.06  162.22  147.00  150.88  0.725112D-01  0.121654D 01
 32     0   0.0             0.3841455D 01  155.65  162.22  158.38  143.12  147.00  0.825545D-01  0.125749D 01
 33     0   0.0             0.3841455D 01  151.77  158.38  154.54  139.25  143.12  0.943075D-01  0.129988D 01
 34     4   0.6934364D 08   0.3121778D 01  148.36  154.54  151.42  136.09  139.25  0.106300D 00  0.149752D 01
 35     0   0.0             0.3121778D 01  145.20  151.42  148.30  132.94  136.09  0.119080D 00  0.153660D 01
 36     0   0.0             0.3121778D 01  142.04  148.30  145.17  129.79  132.94  0.133745D 00  0.157688D 01
 37     0   0.0             0.3121778D 01  138.87  145.17  142.05  126.64  129.79  0.150631D 00  0.161838D 01
 38     4   0.6390388D 08   0.3473986D 01  135.34  142.05  138.58  123.13  126.64  0.172480D 00  0.156176D 01
 39     0   0.0             0.3473986D 01  131.81  138.58  135.10  119.62  123.13  0.198278D 00  0.160862D 01
 40     0   0.0             0.3473986D 01  128.27  135.10  131.63  116.11  119.62  0.228857D 00  0.165690D 01
 41     0   0.0             0.3473986D 01  124.73  131.63  128.16  112.61  116.11  0.265297D 00  0.170656D 01
 42     4   0.5845745D 08   0.4039052D 01  120.69  128.16  124.12  108.53  112.61  0.315549D 00  0.156339D 01
 43     0   0.0             0.4039052D 01  116.55  124.12  120.08  104.45  108.53  0.379283D 00  0.161831D 01
 44     0   0.0             0.4039052D 01  112.39  120.08  116.04  100.37  104.45  0.459305D 00  0.167402D 01
 45     0   0.0             0.4039052D 01  108.21  116.04  112.00   96.29  100.37  0.560833D 00  0.172998D 01
 46     5   0.0             0.3836000D 01  103.91  112.00  108.16   92.44   96.29  0.694294D 00  0.182758D 01
 47     0   0.0             0.3836000D 01   99.89  108.16  104.33   88.58   92.44  0.855137D 00  0.187786D 01
 48     0   0.0             0.3836000D 01   95.84  104.33  100.49   84.72   88.58  0.106336D 01  0.189888D 01
 49     0   0.0             0.3836000D 01   91.74  100.49   96.66   80.86   84.72  0.133884D 01  0.190562D 01
 50     0   0.0             0.3836000D 01   87.75   96.66   92.82   77.00   80.86  0.150000D 01  0.192242D 01
```

STAGE	N	CT	C1	C2	QN	UBAR	HI	HO	OM	AS	LS	ALPHA
1	3	0.03360	0.03475	0.03485	0.40301188D 09	656.72	2025.85	2773.72	10.89	0.563315D 05	4.945	0.189845D 01
2	0	0.03360	0.0	0.03496	0.40301188D 09	654.56	2011.04	2765.90	10.91	0.564220D 05	4.953	0.190781D 01
3	0	0.03360	0.0	0.03506	0.40301188D 09	652.35	1996.06	2757.82	10.93	0.565195D 05	4.962	0.191757D 01
4	3	0.03360	0.03629	0.03640	0.40666724D 09	650.25	1980.80	2752.70	10.90	0.573514D 05	5.035	0.195378D 01
5	0	0.03360	0.0	0.03651	0.40666724D 09	647.92	1965.30	2743.98	10.92	0.574637D 05	5.044	0.196399D 01
6	0	0.03360	0.0	0.03662	0.40666724D 09	645.53	1949.64	2735.01	10.94	0.575838D 05	5.055	0.197464D 01
7	3	0.03360	0.03795	0.03806	0.41278899D 09	643.29	1933.65	2729.67	10.90	0.588518D 05	5.166	0.201218D 01
8	0	0.03360	0.0	0.03818	0.41278899D 09	640.76	1917.39	2719.98	10.92	0.589906D 05	5.178	0.202345D 01
9	0	0.03360	0.0	0.03829	0.41278899D 09	638.18	1900.95	2710.03	10.94	0.591382D 05	5.191	0.203522D 01
10	3	0.03360	0.03974	0.03986	0.41782964D 09	635.73	1884.23	2703.61	10.90	0.602925D 05	5.293	0.207758D 01
11	0	0.03360	0.0	0.03998	0.41782964D 09	633.00	1867.24	2692.95	10.92	0.604609D 05	5.308	0.209006D 01
12	0	0.03360	0.0	0.04010	0.41782964D 09	630.21	1850.10	2682.03	10.93	0.606394D 05	5.323	0.210311D 01
13	3	0.03360	0.04169	0.04181	0.42482830D 09	627.58	1832.61	2675.17	10.89	0.621747D 05	5.458	0.214754D 01
14	0	0.03360	0.0	0.04194	0.42482830D 09	624.63	1814.84	2663.47	10.90	0.623793D 05	5.476	0.216150D 01
15	0	0.03360	0.0	0.04207	0.42482830D 09	621.62	1796.91	2651.53	10.92	0.625956D 05	5.495	0.217612D 01
16	3	0.03360	0.04380	0.04394	0.43385946D 09	618.78	1778.59	2644.13	10.86	0.645484D 05	5.666	0.222275D 01
17	0	0.03360	0.0	0.04407	0.43385946D 09	615.58	1759.95	2631.32	10.88	0.647980D 05	5.688	0.223853D 01
18	0	0.03360	0.0	0.04421	0.43385946D 09	612.31	1741.17	2618.26	10.89	0.650614D 05	5.711	0.225509D 01
19	3	0.03360	0.04612	0.04626	0.44523934D 09	609.24	1721.93	2610.28	10.82	0.675168D 05	5.927	0.230383D 01
20	0	0.03360	0.0	0.04641	0.44523934D 09	605.75	1702.34	2596.25	10.84	0.678235D 05	5.954	0.232187D 01
21	0	0.03360	0.0	0.04655	0.44523934D 09	602.20	1682.60	2581.96	10.85	0.681473D 05	5.982	0.234087D 01
22	3	0.03360	0.04866	0.04882	0.45956231D 09	598.86	1662.35	2573.36	10.77	0.712516D 05	6.255	0.239123D 01
23	0	0.03360	0.0	0.04897	0.45956231D 09	595.05	1641.67	2557.97	10.78	0.716334D 05	6.288	0.241216D 01
24	0	0.03360	0.0	0.04913	0.45956231D 09	591.17	1620.87	2542.33	10.79	0.720367D 05	6.324	0.243429D 01
25	3	0.03360	0.05146	0.05164	0.47779306D 09	587.50	1599.44	2533.08	10.70	0.760257D 05	6.674	0.248515D 01
26	0	0.03360	0.0	0.05181	0.47779306D 09	583.31	1577.53	2515.15	10.71	0.765098D 05	6.716	0.250987D 01
27	0	0.03360	0.0	0.05198	0.47779306D 09	579.04	1555.49	2498.98	10.71	0.770222D 05	6.761	0.253614D 01
28	3	0.03360	0.05458	0.05477	0.50145899D 09	575.00	1532.70	2489.03	10.60	0.822761D 05	7.223	0.258518D 01
29	0	0.03360	0.0	0.05496	0.50145899D 09	570.34	1509.31	2470.31	10.60	0.829068D 05	7.278	0.261507D 01
30	0	0.03360	0.0	0.05515	0.50145899D 09	565.61	1485.81	2451.36	10.61	0.835771D 05	7.337	0.264710D 01
31	3	0.03360	0.05807	0.05828	0.53304876D 09	561.10	1461.36	2440.67	10.47	0.907363D 05	7.965	0.268972D 01
32	0	0.03360	0.0	0.05849	0.53304876D 09	555.86	1436.15	2419.81	10.47	0.915915D 05	8.040	0.272713D 01
33	0	0.03360	0.0	0.05870	0.53304876D 09	550.54	1410.84	2398.75	10.47	0.925068D 05	8.121	0.276773D 01
34	4	0.03360	0.06199	0.06217	0.43266554D 09	545.12	1387.94	2369.51	10.62	0.747703D 05	6.564	0.305443D 01
35	0	0.03360	0.0	0.06235	0.43266554D 09	540.67	1367.27	2352.34	10.61	0.754561D 05	6.624	0.309462D 01
36	0	0.03360	0.0	0.06254	0.43266554D 09	536.16	1346.55	2335.09	10.59	0.761841D 05	6.688	0.313790D 01
37	0	0.03360	0.0	0.06272	0.43266554D 09	531.60	1325.81	2317.78	10.58	0.769583D 05	6.756	0.318464D 01
38	4	0.03360	0.06646	0.06667	0.48096456D 09	527.31	1303.73	2311.34	10.36	0.880291D 05	7.728	0.323436D 01
39	0	0.03360	0.0	0.06689	0.48096456D 09	522.09	1280.58	2291.78	10.34	0.891281D 05	7.824	0.329321D 01
40	0	0.03360	0.0	0.06710	0.48096456D 09	516.80	1257.42	2272.28	10.30	0.903167D 05	7.928	0.335827D 01
41	0	0.03360	0.0	0.06731	0.48096456D 09	511.44	1234.25	2252.90	10.27	0.916082D 05	8.042	0.343060D 01
42	4	0.03360	0.07161	0.07187	0.55865776D 09	506.29	1209.02	2246.58	9.98	0.110550D 06	9.705	0.343001D 01
43	0	0.03360	0.0	0.07213	0.55865776D 09	499.90	1182.09	2224.22	9.92	0.112676D 06	9.891	0.353149D 01
44	0	0.03360	0.0	0.07239	0.55865776D 09	493.44	1155.17	2202.48	9.84	0.115084D 06	10.103	0.365008D 01
45	0	0.03360	0.0	0.07266	0.55865776D 09	486.93	1128.29	2181.65	9.74	0.117851D 06	10.346	0.379046D 01
46	5	0.03360	0.0	0.08288	0.52895969D 09	481.12	1102.04	2174.42	9.42	0.116752D 06	10.249	0.425014D 01
47	0	0.03360	0.0	0.08316	0.52879604D 09	474.98	1076.68	2158.88	9.24	0.120465D 06	10.575	0.444229D 01
48	0	0.03360	0.0	0.08344	0.52864136D 09	458.78	1051.38	2144.06	9.05	0.124607D 06	10.939	0.465259D 01
49	0	0.03360	0.0	0.08372	0.52858023D 09	462.62	1026.11	2132.36	8.81	0.129739D 06	11.389	0.491590D 01
50	0	0.03360	0.0	0.08400	0.52827576D 09	456.04	1001.01	2113.26	8.67	0.133593D 06	11.727	0.507497D 01

```
         AM
       0.1000D 01  0.1045D 01  0.1084D 01  0.1117D 01  0.1147D 01  0.1173D 01  0.1195D 01  0.1215D 01  0.1228D 01  0.1235D 01
       0.1231D 01  0.1216D 01  0.1185D 01  0.1135D 01  0.1061D 01
         TUBE LENGTH
       0.1000D 02  0.1000D 02  0.1000D 02  0.1000D 02  0.1000D 02  0.1000D 02  0.1000D 02  0.1000D 02  0.1000D 02  0.1000D 02
       0.1000D 02  0.1000D 02  0.1000D 02  0.1000D 02  0.1000D 02
T#  0.99996650D 02
T#  0.98606497D 02
T#  0.97437016D 02
T#  0.96324180D 02
M   1
M   0  0.93220348D 02  0.10910269D 03
M   1  0.10528744D 03  0.10910269D 03
M   2  0.10813091D 03  0.10910269D 03
M   3  0.10910269D 03  0.10910269D 03
M   2
M   1
M   0  0.11181931D 03  0.10910269D 03
M   1  0.10984696D 03  0.10910269D 03
M   2  0.10930446D 03  0.10910269D 03
M   3  0.10910269D 03  0.10910269D 03
M   2
M   1
M   0  0.10875907D 03  0.10910269D 03
M   1  0.10901015D 03  0.10910269D 03
M   2  0.10907774D 03  0.10910269D 03
M   3  0.10910269D 03  0.10910269D 03
M   2
M   1
M   0  0.10911544D 03  0.10910269D 03
M   1  0.10910613D 03  0.10910269D 03
M   2
M   0  0.58436021D 08  0.62203721D 08
M   1
M   0  0.10264530D 03  0.10910269D 03
M   1  0.10741777D 03  0.10910269D 03
M   2  0.10865223D 03  0.10910269D 03
M   3  0.10910269D 03  0.10910269D 03
M   2
M   1  0.58436021D 08  0.58720134D 08
M   1
M   0  0.10864127D 03  0.10910269D 03
M   1  0.10897854D 03  0.10910269D 03
M   2  0.10906923D 03  0.10910269D 03
M   3  0.10910269D 03  0.10910269D 03
M   2
M   2  0.58436021D 08  0.58457445D 08
TCF  0.33600000D-01  0.20794763D 03  0.22197592D 03  0.23161419D 10  0.14371969D 09  0.65902362D 10  0.46740943D 10
TCF  0.46740943D 10  0.51027576D 10  0.33616439D 10  0.64482595D 10  0.44866917D 02
 0.16534221D 03  0.65560011D 05  0.19000000D 02  0.14138644D 01
 0.16534221D 03  0.65560011D 05  0.19000000D 02  0.14138644D 01
 0.13898383D 03  0.31320183D 05  0.19000000D 02  0.14138644D 01
 0.15250194D 03  0.60468700D 05  0.19000000D 02  0.14138644D 01
 0.15250194D 03  0.60468700D 05  0.19000000D 02  0.14138644D 01
 0.12819051D 03  0.28887896D 05  0.19000000D 02  0.14138644D 01
 0.14901106D 03  0.59084529D 05  0.19000000D 02  0.14138644D 01
```

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   0.14901106D 03  0.59084529D 05  0.19000000D 02  0.14138644D 01
   0.12525614D 03  0.23224631D 05  0.19000000D 02  0.14138644D 01
   0.14598945D 03  0.57846776D 05  0.19000000D 02  0.14138644D 01
   0.14588945D 03  0.57846776D 05  0.19000000D 02  0.14138644D 01
   0.12263217D 03  0.27635315D 05  0.19000000D 02  0.14138644D 01
   0.14653082D 03  0.58101086D 05  0.19000000D 02  0.14138644D 01
   0.14653082D 03  0.58101086D 05  0.19000000D 02  0.14138644D 01
   0.12317129D 03  0.27756808D 05  0.19000000D 02  0.14138644D 01
   0.14631716D 03  0.58016367D 05  0.19000000D 02  0.14138644D 01
   0.14631716D 03  0.58016367D 05  0.19000000D 02  0.14138644D 01
   0.12299169D 03  0.27716335D 05  0.19000000D 02  0.14138644D 01

 TCF  0.33600000D-01  0.20794763D 03  0.22197592D 03  0.20161419D 10  0.14371969D 09  0.66902362D 10  0.46740943D 10

 TCF  0.46740943D 10  0.51027576D 10  0.33616439D 10  0.64482595D 10  0.44866917D 02
   0.14631798D 03  0.58016692D 05  0.19000000D 02  0.14138644D 01
   0.14631798D 03  0.58016692D 05  0.19000000D 02  0.14138644D 01
   0.12299238D 03  0.27716490D 05  0.19000000D 02  0.14138644D 01

 TCF  0.24573164D 03  0.26000000D 03  0.80159982D 01  0.32888889D 01  0.12673427D 09  0.46740943D 10  0.70345941D 02

 TCF  0.33464881D 02  0.65000000D 02  0.33603965D-01  0.10371688D 03  0.81816530D 08  0.44917741D 08  0.23072709D 09

 TCF  0.89355883D 08  0.51739087D 07  0.57462205D 08  0.86257488D 08
```

19.2 - 250 MGD VTE COMPUTER PRINTOUT

```
REF CASE 311A  CURRENT TECHNOLOGY  8/20/68  CDA 194
             CASE NO.       G            TRAINS      AMODJ       N           EVAP STAGE  REJ STAGES  NO. ITER       FLAG
CARD 1       0.1000D 01  0.2500D 09  0.4000D 01  0.4000D 01  0.1500D 02  0.4500D 02  0.5045D 01  0.0         0.1000D 01
             TS          TBRINE      TK          TBB         TOO         TO          DEL TC      CR
CARD 2       0.2674D 03  0.2600D 03  0.1120D 03  0.9282D 02  0.7700D 02  0.6500D 02  0.5000D 01  0.2500D 01
             EFF.        ELEC        HEAT        CHARGE      RATE INT    WPL         HD          HBL            HPR
CARD 3       0.8800D 00  0.2000D-02  0.6000D-01  0.5800D-01  0.4000D-01  0.3000D 02  0.3500D 02  0.4000D 02  0.0
             DOV         SURFF       VTUBLN      DO          WALL E      DOC         WALLC       S
CARD 4  0.3000D 01  0.1273D 01  0.1000D 02  0.7500D 00  0.3500D-01  0.1000D 01  0.4900D-01  0.1900D 02
                                 BIKT        BKTC        TBLIFV      TBLIFP      TBLIFC      AIV         AIE         AIC
CARD 5       0.1250D 03  0.2600D 02  0.2600D 02  0.1500D 02  0.3000D 02  0.3000D 02  0.1718D 01  0.1206D 01  0.1562D 01
             CO          CPP         CAP F       FOUL V      FOUL PH     FOUL C
CARD 6       0.3360D-01  0.2500D-04  0.9000D 00  0.0         0.5000D-03  0.7000D-03  0.0         0.0
```

D.3 - 250 MGD MSF COMPUTER PRINTOUT

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        UPDATE MSF 250 MDG CURRENT TECHNOLOGY I-24-68 DEPTH*15 FOLL*.C005                  PAGE 1

  I  SUMMARY OF PLANT DATA

     GENERAL                                                 PERFORMANCE RATIOS
          PLANT CAPACITY, MGD                  250.00            INPUT                            12.8450
          SEA WATER CONCENTRATION             0.03360            CALC                             12.8431
          PRODUCT CONCENTRATION              0.000025            RECOVER RATIO P                   0.1381
          DEAERATED FEED CONC.                0.03360            REJECT/EVAP TUBE Q                0.4326
          CONCENTRATION RATIO                  2.0000
          NO OF STAGES, EVAP                       48
          NO STAGES IN REJECT                       2

     TEMPERATURES - DEG F                                     FLOWS, LBS/HR
          STEAM                               254.200            TOTAL STEAM                0.712355E 07
          MAXIMUM BRINE                       250.000            TUBE FLOW, EVAP            0.624547E 09
          FINAL EFFECT                        103.447            TUBE FLOW,REJ              0.270154E 09
          BLOWDOWN                             91.800            TOTAL PRODUCT              0.862575E 08
          PRODUCT                              90.023            RECYCLE FLOW               0.452096E 09
          DEAERATED FEED                       91.123            EJECTOR SYSTEM             0.620823E 07
          OCEAN                                65.000            BLOWDOWN                   0.861933E 08
                                                                 SEA INTAKE                 0.304274E 09
          BRINE INTO HEATER                   238.761            SEAWATER RETURN            0.125594E 09

  II DESCRIPTION OF PHYSICAL PLANT

     PLANT DIMENSIONS, FT
          OVERALL LENGTH                      574.975            OVERALL HEIGHT                    18.800
          NO OF LEVELS                          2.000            FREEBOARD                          2.700
          PLANT WIDTH                         474.580            HEIGHT OFLEVEL                     6.700
          TOTAL NO OF MODULES                      10            EV SHELL VOLUME, FT3       0.171316E 08
          NO OF TRAINS                              4            REJ  SHELL VOLUME, FT3     0.252684E 07

     TUBING DESCRIPTION
                                                   BH                 EVAPORATOR                   REJECT
          OUTSIDE DIA, INCHES                   0.750                      0.750                    0.750
          WALL THICKNESS, INCHES                0.035                      0.035                    0.049
          K,BTU/HR FT2 F                       26.000                     26.000                   26.000
          FOULING RESISTANCE                  0.00050                    0.00050                  0.00070
          FLOODING FACTOR                      19.000                     19.000                   19.000
          NO OF TUBES                         249197.                    247970.                  101953.
          TUBE LENGTH FT                       24.140                    480.032                   70.803
          SURFACE AREA, FT2             0.11811857E 07             0.23372154E 08           0.14173621E 07
          TUBE VELOCITY                          4.50                       4.50                     5.00
          AVE OVERALL UBAR                     658.52                     578.68                   424.32
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19.3 - 250 MGD MSF COMPUTER PRINTOUT

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         UPDATE MSF 250 MDG CURRENT TECHNOLOGY 1-24-68 DEPTH#15 FOLL#.0005                  PAGE 2

III HEAD REQUIREMENTS, FT                                   PUMPING POWER REQUIREMENTS, MW

          SEA WATER DELIVERY                  66.285          INTAKE PUMPS                   8.8360
          RECYCLE                            188.561          RECYCLE PUMP                  51.5932
          PRODUCT DELIVERY                   106.758          PRODUCT PUMPS                  4.0343
          BLOWDOWN DISCHARGE                  40.000          BLOWDOWN PUMPS                 1.5105
          DEAERATOR BOOSTER                   23.800          BOOSTER PUMPS                  1.8628
                                                              BLOWERS                        3.2212
                                                              TOTAL                         71.0580

IV SUBSIDIARY SECTIONS
                                  BRINE HEATER                                   DEAERATOR

          LMDT, F                              8.633            TEMP IN-HOT, F               91.586
          H INSIDE, B/HR FT2 F               1947.43            TEMP IN-COLD, F              65.000
          H OUTSIDE, B/HR FT2 F              2990.13            TEMP OUT, F                  91.123
          OVERALL U, B/HR-FT2-F               658.521           TEMP TO EJECT, F             70.000
          HEAT RATE, BTU/HR              0.671536E 10           FLOW IN-HOT, LB/HR   0.144561E 09
          FOULING RESISTANCE                 0.00050            FLOW IN-COLD, LB/HR  0.279115E 08
          SURFACE AREA, FT2              0.118119E 07           FLOW OUT, LB/HR      0.173025E 09
          NO OF TUBES                        249197.            VAPOR TO EJECT       0.948267E 04
          TUBE LENGTH, FT                     24.140            INERTS, LB/HR        0.215590E 05
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19.5 - 250 MGD MSF COMPUTER PRINTOUT

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UPDATE MSF 250 MDG CURRENT TECHNOLOGY 1-24-68 DEPTH#15 FOLL#.C005               PAGE 3

                                                      COST SUMMARY PAGE

           COMPONENTS                        COST-$/YR       COST-$/KGAL      COST-$ DIRECT
           ----------                        ---------       -----------      -------------

      EVAP AREA                            0.35873467E 07   0.43681543E-01   0.49579033E 08
      VE + PHTR SHELL                      0.13020926E 07   0.15855009E-01   0.17995611E 08
      PUMPS AND MOTORS                     0.66643371E 06   0.81148703E-02   0.92104672E 07
      SEA-WATER INTAKE                     0.30866049E 06   0.37584231E-02   0.42658516E 07
      VALVES AND PIPING                    0.35809860E 06   0.43604092E-02   0.49491125E 07
      CHEMICAL CAPITAL                     0.15258561E 06   0.18579679E-02   0.21088140E 07
      INSTRUMENTS                          0.13521028E 06   0.16463962E-02   0.18686778E 07
      ELECTRICAL                           0.15274424E 06   0.18598994E-02   0.21110063E 07
      DEAERATOR                            0.10666779E 06   0.12988468E-02   0.14742054E 07
      BRINE HEATER                         0.24174910E 06   0.29436725E-02   0.33411008E 07
      SITE, BLDGS, CRANES                  0.36807443E 05   0.44818805E-03   0.50869837E 06   COST-$DIR+IND      $/GPD
                                                                                              -------------      -----
           TOTAL CAPITAL                   0.70483962E 07   0.85825223E-01   0.97412572E 08   0.11747327E 09   0.46989308E 00

           RETUBING                        0.               0.

      HEAT                                 0.52943098E 07   0.64466483E-01
      CHEMICAL                             0.11316091E 07   0.13779107E-01
      POWER                                0.56022124E 06   0.68215678E-02
      OPERATING                            0.73505394E 06   0.89504275E-02
      MAINT + SUPPLIES                     0.70483962E 06   0.85825222E-02

           TOTAL OPERATING                 0.84260335E 07   0.10260011E 00

              TOTAL (CAP+RETUBE+OPER)      0.15474429E 08   0.18842532E 00


      COST FACTORS
           HEAT ($/MMBTU)       0.10000        PLANT LIFE, YRS          30.00000       LOAD FACTOR                   0.90000
           POWER ($/KWH)        0.00100        EVAP TUBE LIFE, YRS      30.00000       EVAP RETUBING CHGE RATE       0.
           ANN CHARGE RATE      0.06000        REJT TUBE LIFE, YRS      30.00000       REJ  RETUBING CHGE RATE       0.
           INTEREST RATE        0.04000        BR HTR TUBE LIFE, YRS    30.00000       BR HTR RETUBING CHGE RATE     0.00000
           HIGHER COST FACTOR   1.20594

      MISC. TOTAL UNIT COSTS
           $/CU.FT. SHELL         0.0286       $/SQ.FT. VE AREA           2.0000       $/SQ.FT. PHTR AREA  2.0000

                                               CHANNEL USED IN SEA INTAKE COST.
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UPDATE MSF 250 MDG CURRENT TECHNOLOGY 1-24-68 DEPTH#15 FOUL#.0005

STAGE    AREA DM          DPTDM            CTDM             CPROD            WIDDM            SUB              TPROD
  1   0.41053965E 02  0.16616837E-01  0.33218384E-01  0.35998630E-05  0.52995844E 01  0.77944571E 00  0.24505069E 03
  2   0.41719313E 02  0.16758498E-01  0.35232544E-01  0.38519031E-05  0.53644850E 01  0.80083035E 00  0.24200753E 03
  3   0.42353928E 02  0.16896277E-01  0.37132263E-01  0.38251289E-05  0.54249175E 01  0.82297476E 00  0.23896449E 03
  4   0.43011806E 02  0.17035442E-01  0.39184570E-01  0.37350703E-05  0.54863837E 01  0.84570765E 00  0.23592131E 03
  5   0.43693861E 02  0.17176033E-01  0.41328430E-01  0.36244704E-05  0.55489244E 01  0.86905374E 00  0.23287803E 03
  6   0.44401367E 02  0.17318022E-01  0.43640137E-01  0.35073074E-05  0.56123456E 01  0.89300250E 00  0.22983457E 03
  7   0.45135141E 02  0.17461528E-01  0.46157837E-01  0.33893319E-05  0.56769131E 01  0.91761327E 00  0.22679093E 03
  8   0.45896667E 02  0.17606491E-01  0.48799978E-01  0.32732456E-05  0.57423237E 01  0.94286159E 00  0.22374716E 03
  9   0.46686869E 02  0.17753010E-01  0.51605225E-01  0.31603878E-05  0.58087963E 01  0.96880247E 00  0.22070321E 03
 10   0.47507210E 02  0.17901073E-01  0.54603577E-01  0.30514360E-05  0.58761585E 01  0.99543323E 00  0.21765908E 03
 11   0.48358920E 02  0.18050758E-01  0.57838440E-01  0.29467085E-05  0.59445373E 01  0.10227950E 01  0.21461471E 03
 12   0.49243596E 02  0.18202179E-01  0.61271657E-01  0.28463187E-05  0.60141990E 01  0.10509456E 01  0.21157013E 03
 13   0.50162229E 02  0.18355423E-01  0.64956665E-01  0.27502615E-05  0.60853259E 01  0.10799393E 01  0.20852530E 03
 14   0.51117078E 02  0.18510326E-01  0.68870544E-01  0.26584743E-05  0.61571802E 01  0.11096984E 01  0.20548025E 03
 15   0.52406523E 02  0.18499655E-01  0.72471619E-01  0.25761982E-05  0.62657457E 01  0.11403168E 01  0.20243549E 03
 16   0.53902605E 02  0.18405669E-01  0.75935364E-01  0.25042372E-05  0.63941649E 01  0.11717421E 01  0.19939087E 03
 17   0.55463144E 02  0.18311936E-01  0.79612732E-01  0.24407315E-05  0.65254332E 01  0.12040639E 01  0.19634603E 03
 18   0.57089637E 02  0.18219335E-01  0.83557129E-01  0.23842107E-05  0.66587824E 01  0.12372403E 01  0.19330091E 03
 19   0.58787481E 02  0.18126971E-01  0.87692261E-01  0.23335353E-05  0.67951161E 01  0.12713844E 01  0.19025560E 03
 20   0.60557467E 02  0.18036345E-01  0.92140198E-01  0.22877589E-05  0.69330099E 01  0.13063931E 01  0.15720997E 03
 21   0.62406031E 02  0.17946062E-01  0.96862793E-01  0.22461471E-05  0.70738841E 01  0.13424376E 01  0.18416406E 03
 22   0.64333400E 02  0.17858024E-01  0.10186005E 00  0.22080573E-05  0.72158362E 01  0.13793745E 01  0.18111786E 03
 23   0.66347384E 02  0.17770597E-01  0.10723877E 00  0.21729937E-05  0.73605705E 01  0.14173984E 01  0.17807126E 03
 24   0.68446930E 02  0.17686177E-01  0.11296844E 00  0.21404962E-05  0.75055550E 01  0.14563203E 01  0.17502431E 03
 25   0.70642500E 02  0.17602376E-01  0.11912537E 00  0.21102250E-05  0.76533574E 01  0.14964110E 01  0.17197693E 03
 26   0.72930078E 02  0.17522793E-01  0.12570190E 00  0.20818287E-05  0.77999918E 01  0.15373596E 01  0.16892910E 03
 27   0.75323996E 02  0.17443297E-01  0.13275909E 00  0.20550709E-05  0.79493684E 01  0.15795558E 01  0.16588080E 03
 28   0.77816909E 02  0.17370421E-01  0.14035034E 00  0.20296733E-05  0.80960184E 01  0.16225675E 01  0.16283194E 03
 29   0.80426782E 02  0.17297948E-01  0.14850616E 00  0.20054680E-05  0.82449889E 01  0.16668815E 01  0.15978250E 03
 30   0.83159160E 02  0.17226885E-01  0.15722656E 00  0.19823052E-05  0.83958549E 01  0.17125843E 01  0.15673249E 03
 31   0.86029653E 02  0.17154556E-01  0.16658020E 00  0.19600926E-05  0.85519615E 01  0.17599636E 01  0.15368183E 03
 32   0.88980046E 02  0.17100827E-01  0.17687225E 00  0.19384883E-05  0.86885336E 01  0.18068117E 01  0.15063021E 03
 33   0.92072904E 02  0.17048746E-01  0.18791199E 00  0.19174190E-05  0.88262486E 01  0.18550582E 01  0.14757784E 03
 34   0.95274808E 02  0.17009301E-01  0.19995117E 00  0.18966940E-05  0.89509296E 01  0.19035433E 01  0.14452444E 03
 35   0.98631760E 02  0.16971542E-01  0.21296692E 00  0.18762777E-05  0.90763986E 01  0.19534919E 01  0.14147006E 03
 36   0.10209353E 03  0.16950927E-01  0.22725677E 00  0.18559829E-05  0.91822232E 01  0.20031933E 01  0.13841438E 03
 37   0.10572436E 03  0.16932251E-01  0.24275970E 00  0.18358069E-05  0.92881430E 01  0.20543765E 01  0.13535748E 03
 38   0.10944545E 03  0.16937190E-01  0.25988770E 00  0.18155583E-05  0.93650002E 01  0.21045163E 01  0.13229894E 03
 39   0.11334942E 03  0.16944327E-01  0.27854919E 00  0.17952688E-05  0.94412673E 01  0.21561136E 01  0.12923884E 03
 40   0.11731300E 03  0.16984364E-01  0.29934692E 00  0.17755500E-05  0.94753146E 01  0.22054026E 01  0.12617659E 03
 41   0.12147232E 03  0.17027067E-01  0.32209015E 00  0.17575175E-05  0.95080453E 01  0.22560140E 01  0.12311237E 03
 42   0.12563302E 03  0.17116724E-01  0.34724698E 00  0.17408213E-05  0.94797010E 01  0.23022112E 01  0.12004511E 03
 43   0.12999764E 03  0.17210011E-01  0.37607574E 00  0.17253730E-05  0.94494197E 01  0.23493901E 01  0.11697538E 03
 44   0.13426170E 03  0.17371864E-01  0.40861511E 00  0.17107323E-05  0.93315890E 01  0.23858888E 01  0.11390130E 03
 45   0.13872997E 03  0.17539587E-01  0.44456482E 00  0.16968319E-05  0.92115643E 01  0.24279497E 01  0.11082360E 03
 46   0.14291967E 03  0.17811265E-01  0.47696136E 00  0.16831029E-05  0.89663774E 01  0.24529305E 01  0.10773982E 03
 47   0.15095411E 03  0.17173395E-01  0.50686646E 00  0.16695100E-05  0.89363246E 01  0.24761504E 01  0.10467832E 03
 48   0.16339591E 03  0.15760111E-01  0.50250244E 00  0.16554981E-05  0.90067936E 01  0.24412372E 01  0.10164107E 03
 49   0.35398000E 03  0.13912240E-01  0.49765015E 00  0.16240249E-05  0.86138751E 01  0.43684147E 00  0.95841657E 02
      [illegible]     [illegible]     0.51206207E 00  0.16170889E-05  0.11565320E 02  0.10470915E 01  0.90022882E 02
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UPDATE MSF 250 MGD CURRENT TECHNOLOGY.1-24-68 DEPTH*15 POOL*.GOOD

STAGE     WV               WS2              WP2            TV2     TS1     TS2     T1      T2     BRINE CFM     PROD CFM

  1  0.19277770E 07  0.62261935E 09  0.19277770E 07  244.26  250.00  246.95  235.70  238.76  0.465936E 05  0.
  2  0.19162753E 07  0.62070307E 09  0.38440524E 07  241.20  246.95  243.89  232.63  235.70  0.487546E 06  0.114956E 04
  3  0.19046900E 07  0.61879818E 09  0.57489423E 07  238.13  243.89  240.84  229.57  232.63  0.510431E 06  0.242361E 04
  4  0.18936117E 07  0.61690456E 09  0.76425541E 07  235.07  240.84  237.79  226.50  229.57  0.534675E 06  0.383461E 04
  5  0.18824488E 07  0.61502210E 09  0.95250029E 07  232.00  237.79  234.73  223.44  226.50  0.560375E 06  0.539581E 04
  6  0.18713920E 07  0.61315070E 09  0.11396395E 08  228.93  234.73  231.68  220.37  223.44  0.587628E 06  0.712268E 04
  7  0.18604435E 07  0.61129026E 09  0.13256838E 08  225.86  231.68  228.63  217.31  220.37  0.616544E 06  0.903119E 04
  8  0.18495979E 07  0.60944066E 09  0.15106436E 08  222.79  228.63  225.58  214.24  217.31  0.647240E 06  0.111397E 05
  9  0.18388571E 07  0.60760179E 09  0.16945293E 08  219.72  225.58  222.52  211.18  214.24  0.679842E 06  0.134678E 05
 10  0.18282161E 07  0.60577357E 09  0.18773509E 08  216.65  222.52  219.47  208.12  211.18  0.714487E 06  0.160385E 05
 11  0.18176793E 07  0.60395589E 09  0.20591138E 08  213.58  219.47  216.42  205.05  208.12  0.751325E 06  0.185750E 05
 12  0.18072369E 07  0.60214865E 09  0.22398425E 08  210.50  216.42  213.36  201.99  205.05  0.790511E 06  0.220065E 05
 13  0.17968945E 07  0.60035175E 09  0.24195320E 08  207.43  213.36  210.31  198.92  201.99  0.832223E 06  0.254600E 05
 14  0.17866436E 07  0.59856510E 09  0.25981963E 08  204.35  210.31  207.26  195.86  198.92  0.876644E 06  0.292707E 05
 15  0.17764894E 07  0.59678861E 09  0.27758453E 08  201.27  207.26  204.20  192.80  195.86  0.923980E 06  0.334657E 05
 16  0.17664319E 07  0.59502218E 09  0.29524884E 08  198.19  204.20  201.15  189.73  192.80  0.974455E 06  0.380972E 05
 17  0.17564593E 07  0.59326571E 09  0.31281343E 08  195.12  201.15  198.10  186.67  189.73  0.102830E 07  0.432058E 05
 18  0.17465821E 07  0.59151913E 09  0.33027926E 08  192.03  198.10  195.04  183.60  186.67  0.105579E 07  0.488470E 05
 19  0.17367896E 07  0.58978234E 09  0.34764715E 08  188.95  195.04  191.99  180.54  183.60  0.114719E 07  0.550639E 05
 20  0.17270910E 07  0.58805524E 09  0.36491806E 08  185.87  191.99  188.94  177.48  180.54  0.121282E 07  0.619334E 05
 21  0.17174701E 07  0.58633777E 09  0.38209276E 08  182.78  188.94  185.89  174.41  177.48  0.125302E 07  0.695062E 05
 22  0.17079395E 07  0.58462982E 09  0.39917215E 08  179.70  185.89  182.83  171.35  174.41  0.135814E 07  0.778767E 05
 23  0.16984932E 07  0.58293133E 09  0.41615708E 08  176.61  182.83  179.78  168.28  171.35  0.143861E 07  0.871109E 05
 24  0.16891281E 07  0.58124219E 09  0.43304936E 08  173.52  179.78  176.73  165.22  168.28  0.152483E 07  0.973267E 05
 25  0.16798441E 07  0.57956234E 09  0.44984680E 08  170.43  176.73  173.67  162.16  165.22  0.161731E 07  0.108601E 06
 26  0.16706400E 07  0.57789170E 09  0.46655320E 08  167.33  173.67  170.62  159.09  162.16  0.171656E 07  0.121085E 06
 27  0.16615138E 07  0.57623018E 09  0.48316434E 08  164.24  170.62  167.57  156.03  159.09  0.182315E 07  0.134874E 06
 28  0.16524677E 07  0.57457770E 09  0.49969301E 08  161.14  167.57  164.51  152.96  156.03  0.193772E 07  0.150161E 06
 29  0.16434987E 07  0.57293420E 09  0.51612799E 08  158.04  164.51  161.46  149.90  152.96  0.206096E 07  0.167059E 06
 30  0.16346074E 07  0.57129959E 09  0.53247406E 08  154.94  161.46  158.41  146.82  149.90  0.219363E 07  0.185862E 06
 31  0.16257892E 07  0.56967380E 09  0.54873195E 08  151.83  158.41  155.35  143.76  146.82  0.233656E 07  0.206647E 06
 32  0.16170475E 07  0.56805675E 09  0.56490242E 08  148.72  155.35  152.30  140.69  143.76  0.249069E 07  0.229648E 06
 33  0.16083774E 07  0.56644837E 09  0.58098619E 08  145.61  152.30  149.25  137.63  140.69  0.265703E 07  0.255206E 06
 34  0.15997762E 07  0.56484858E 09  0.59698395E 08  142.50  149.25  146.20  134.56  137.63  0.283670E 07  0.283650E 06
 35  0.15912499E 07  0.56325733E 09  0.61289445E 08  139.39  146.20  143.14  131.50  134.56  0.303096E 07  0.315231E 06
 36  0.15827907E 07  0.56167454E 09  0.62872435E 08  136.27  143.14  140.09  128.43  131.50  0.324118E 07  0.350393E 06
 37  0.15744037E 07  0.56010013E 09  0.64446539E 08  133.15  140.09  137.04  125.36  128.43  0.346891E 07  0.389538E 06
 38  0.15660789E 07  0.55853405E 09  0.66012917E 08  130.03  137.04  133.98  122.29  125.36  0.371583E 07  0.433084E 06
 39  0.15578299E 07  0.55697622E 09  0.67570747E 08  126.90  133.98  130.93  119.23  122.29  0.398387E 07  0.481774E 06
 40  0.15496411E 07  0.55542657E 09  0.69120388E 08  123.78  130.93  127.88  116.16  119.23  0.427513E 07  0.535800E 06
 41  0.15415210E 07  0.55388504E 09  0.70661908E 08  120.65  127.88  124.82  113.09  116.16  0.459198E 07  0.596566E 06
 42  0.15334614E 07  0.55235158E 09  0.72195369E 08  117.52  124.82  121.77  110.02  113.09  0.493705E 07  0.663600E 06
 43  0.15254666E 07  0.55082610E 09  0.73720835E 08  114.38  121.77  118.72  106.95  110.02  0.531335E 07  0.739658E 06
 44  0.15175301E 07  0.54930857E 09  0.75238365E 08  111.26  118.72  115.66  103.88  106.95  0.572418E 07  0.822650E 06
 45  0.15096564E 07  0.54779890E 09  0.76749021E 08  108.13  115.66  112.61  100.80  103.88  0.617334E 07  0.918065E 06
 46  0.15018350E 07  0.54629706E 09  0.78249856E 08  105.01  112.61  109.56   97.73  100.80  0.666503E 07  0.101975E 07
 47  0.14940580E 07  0.54480300E 09  0.79743913E 08  101.91  109.56  106.51   94.66   97.73  0.720402E 07  0.112839E 07
 48  0.14862830E 07  0.54331671E 09  0.81230196E 08   98.91  106.51  103.45   91.59   94.66  0.779554E 07  0.121964E 07
 49  0.28141698E 07  0.54050254E 09  0.84044365E 06   95.14  103.45   97.63   78.42   91.59  0.173905E 08  0.174435E 07
 50  0.22131899E 07  0.53771501E 09  0.86257554E 08   88.50   97.63   91.80   65.00   78.42  0.161920E 06  0.389650E 07
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      UPDATE MSF 250 MDG CURRENT TECHNOLOGY 1-24-68 DEPTH#15 FOUL#.0005

STAGE  TTD      CT      C1      C2          GN          UBAR     HI      HO        DM        AS          LS       W-W SF
   1  5.5047 0.05786 0.05786 0.05804  0.18286154E 10  663.51 1921.65 3170.49    6.92  0.398087E 06   8.176  0.100000E 01
   2  5.5011 0.05786 0.05804 0.05822  0.18275638E 10  661.14 1906.73 3161.37    6.92  0.399412E 06   8.203  0.995327E 00
   3  5.5002 0.05786 0.05822 0.05840  0.18265168E 10  658.70 1891.59 3151.68    6.92  0.400717E 06   8.230  0.990683E 00
   4  5.4984 0.05786 0.05840 0.05858  0.18254654E 10  656.21 1876.25 3141.75    6.92  0.402116E 06   8.259  0.986066E 00
   5  5.4958 0.05786 0.05858 0.05876  0.18244208E 10  653.66 1860.71 3131.55    6.92  0.403608E 06   8.290  0.981476E 00
   6  5.4922 0.05786 0.05876 0.05894  0.18233773E 10  651.05 1844.97 3121.11    6.91  0.405206E 06   8.322  0.976913E 00
   7  5.4877 0.05786 0.05894 0.05912  0.18223374E 10  648.39 1829.04 3110.44    6.91  0.406909E 06   8.357  0.972375E 00
   8  5.4822 0.05786 0.05912 0.05930  0.18212989E 10  645.67 1812.93 3099.53    6.90  0.408723E 06   8.395  0.967864E 00
   9  5.4758 0.05786 0.05930 0.05948  0.18202662E 10  642.90 1796.62 3088.37    6.89  0.410647E 06   8.434  0.963377E 00
  10  5.4682 0.05786 0.05948 0.05965  0.18192384E 10  640.07 1780.14 3077.01    6.89  0.412695E 06   8.476  0.958914E 00
  11  5.4596 0.05786 0.05965 0.05983  0.18182155E 10  637.18 1763.48 3065.42    6.88  0.414863E 06   8.521  0.954474E 00
  12  5.4496 0.05786 0.05983 0.06001  0.18172022E 10  634.23 1746.64 3053.64    6.87  0.417173E 06   8.568  0.950058E 00
  13  5.4385 0.05786 0.06001 0.06019  0.18161924E 10  631.23 1729.63 3041.65    6.86  0.419616E 06   8.618  0.945663E 00
  14  5.4261 0.05786 0.06019 0.06037  0.18151901E 10  628.17 1712.46 3029.47    6.84  0.422206E 06   8.672  0.941291E 00
  15  5.4130 0.05786 0.06037 0.06055  0.18141773E 10  625.05 1695.13 3017.01    6.83  0.424901E 06   8.727  0.936939E 00
  16  5.3989 0.05786 0.06055 0.06073  0.18131849E 10  621.87 1677.65 3004.33    6.82  0.427741E 06   8.785  0.932607E 00
  17  5.3836 0.05786 0.06073 0.06091  0.18121976E 10  618.63 1660.01 2991.45    6.80  0.430730E 06   8.847  0.928296E 00
  18  5.3667 0.05786 0.06091 0.06109  0.18112336E 10  615.34 1642.22 2978.42    6.78  0.433901E 06   8.912  0.924003E 00
  19  5.3487 0.05786 0.06109 0.06127  0.18102639E 10  611.98 1624.29 2965.18    6.77  0.437229E 06   8.980  0.919729E 00
  20  5.3290 0.05786 0.06127 0.06145  0.18093259E 10  608.57 1606.22 2951.82    6.75  0.440761E 06   9.053  0.915473E 00
  21  5.3080 0.05786 0.06145 0.06163  0.18083759E 10  605.09 1588.02 2938.27    6.72  0.444458E 06   9.129  0.911233E 00
  22  5.2852 0.05786 0.06163 0.06181  0.18074586E 10  601.56 1569.69 2924.60    6.70  0.448396E 06   9.209  0.113376E 01
  23  5.2609 0.05786 0.06181 0.06199  0.18065393E 10  597.97 1551.24 2910.76    6.68  0.452523E 06   9.294  0.112850E 01
  24  5.2348 0.05786 0.06199 0.06217  0.18056538E 10  594.32 1532.66 2896.84    6.65  0.456899E 06   9.384  0.112326E 01
  25  5.2071 0.05786 0.06217 0.06235  0.18047598E 10  590.61 1513.97 2882.76    6.62  0.461476E 06   9.478  0.111804E 01
  26  5.1825 0.05786 0.06235 0.06253  0.18039026E 10  586.84 1495.18 2868.61    6.59  0.466369E 06   9.579  0.111283E 01
  27  5.1510 0.05786 0.06253 0.06271  0.18030377E 10  583.02 1476.28 2854.32    6.56  0.471487E 06   9.684  0.110764E 01
  28  5.1173 0.05786 0.06271 0.06289  0.18022190E 10  579.13 1457.28 2839.99    6.53  0.476922E 06   9.795  0.110246E 01
  29  5.0819 0.05786 0.06289 0.06307  0.18013895E 10  575.18 1438.18 2825.54    6.49  0.482631E 06   9.913  0.109730E 01
  30  5.0434 0.05786 0.06307 0.06325  0.18006472E 10  571.15 1418.97 2810.49    6.46  0.488407E 06  10.031  0.109215E 01
  31  5.0144 0.05786 0.06325 0.06344  0.17998705E 10  567.05 1399.67 2795.18    6.42  0.494392E 06  10.154  0.108701E 01
  32  4.9714 0.05786 0.06344 0.06362  0.17990772E 10  562.93 1380.33 2780.72    6.38  0.501195E 06  10.294  0.108188E 01
  33  4.9266 0.05786 0.06362 0.06380  0.17983234E 10  558.75 1360.93 2766.17    6.33  0.508361E 06  10.441  0.107676E 01
  34  4.8793 0.05786 0.06380 0.06398  0.17976198E 10  554.51 1341.45 2751.61    6.28  0.515958E 06  10.597  0.107164E 01
  35  4.8300 0.05786 0.06398 0.06416  0.17969159E 10  550.21 1321.91 2737.00    6.23  0.523961E 06  10.761  0.106654E 01
  36  4.7784 0.05786 0.06416 0.06434  0.17962443E 10  545.85 1302.32 2722.37    6.18  0.532425E 06  10.935  0.106143E 01
  37  4.7246 0.05786 0.06434 0.06452  0.17955919E 10  541.43 1282.68 2707.71    6.13  0.541365E 06  11.119  0.105633E 01
  38  4.6690 0.05786 0.06452 0.06470  0.17949210E 10  536.95 1262.99 2692.98    6.07  0.550751E 06  11.312  0.105123E 01
  39  4.6112 0.05786 0.06470 0.06488  0.17943283E 10  532.40 1243.26 2678.25    6.01  0.560705E 06  11.516  0.104612E 01
  40  4.5527 0.05786 0.06488 0.06506  0.17936266E 10  527.79 1223.51 2663.30    5.95  0.571029E 06  11.728  0.104102E 01
  41  4.4917 0.05786 0.06506 0.06524  0.17930683E 10  523.11 1203.72 2648.40    5.89  0.582027E 06  11.954  0.103591E 01
  42  4.4323 0.05786 0.06524 0.06542  0.17922713E 10  518.36 1183.92 2632.98    5.83  0.593179E 06  12.183  0.103080E 01
  43  4.3703 0.05786 0.06542 0.06561  0.17917634E 10  513.55 1164.10 2617.64    5.77  0.605128E 06  12.428  0.102568E 01
  44  4.3137 0.05786 0.06561 0.06579  0.17907179E 10  508.63 1144.29 2601.26    5.71  0.616760E 06  12.667  0.102056E 01
  45  4.2545 0.05786 0.06579 0.06597  0.17902739E 10  503.66 1124.46 2584.97    5.65  0.629338E 06  12.926  0.101542E 01
  46  4.2042 0.05786 0.06597 0.06615  0.17886426E 10  498.55 1104.66 2566.60    5.60  0.640521E 06  13.155  0.101028E 01
  47  4.1874 0.05786 0.06615 0.06633  0.17860107E 10  493.25 1084.89 2544.73    5.58  0.649058E 06  13.331  0.100514E 01
  48  4.2537 0.05786 0.06633 0.06651  0.17780526E 10  487.47 1065.24 2511.02    5.65  0.646143E 06  13.271  0.100000E 01
  49  3.5470 0.03360 0.06651 0.06686  0.32311441E 10  437.15 1183.98 2233.73    8.50  0.869988E 06  43.459  0.997272E 00
  50 10.0874 0.03360 0.06686 0.06721  0.34966962E 10  403.89 1091.29 1806.57   15.85  0.546123E 06  27.281  0.992107E 00
```

```
UPDATE MSF 250 MDG CURRENT TECHNOLOGY 1-24-68 DEPTH#15 FOUL#.0005

CASE        3.   RP  12.84500   CR   2.00000   P  -0.        Q  -0.        TB    91.80000   N  50.   ROE  -0.

SUBMERGENCE BASED ON AMF DATA AS USED IN DRVE CODE

THE CALCULATION OF NO DEAERATORS HAS BEEN OPTIONED FOR THIS CASE

UNDRFLOW AT 62360 IN MQ

UNDRFLOW AT 71440 IN MQ

UNDRFLOW AT 62360 IN MQ

UNDRFLOW AT 71440 IN MQ

UNDRFLOW AT 62360 IN MQ
 0.62564153E 03  0.24807370E 06  0.19000000E 02  0.14138646E 01
 0.23407078E 03  0.10095434E 06  0.19000000E 02  0.14138646E 01
 0.62873651E 03  0.24930089E 06  0.19000000E 02  0.14138646E 01
 0.62531329E 03  0.24794355E 06  0.19000000E 02  0.14138646E 01
 0.23691424E 03  0.10218072E 06  0.19000000E 02  0.14138646E 01
 0.62840829E 03  0.24917075E 06  0.19000000E 02  0.14138646E 01
 0.62538042E 03  0.24797016E 06  0.19000000E 02  0.14138646E 01
 0.23638731E 03  0.10195346E 06  0.19000000E 02  0.14138646E 01
 0.62847542E 03  0.24919737E 06  0.19000000E 02  0.14138646E 01

PLANT WIDTH #   0.47458040E 03   UNIT WIDTH #   0.11864510E 03
ADJ TRAYWD  #   0.26687250E 02.  PROD TRAY  #   0.53432376E 01

     2  0.14076627E 07  0.65772848E 07  0.66442613E 06  0.23217655E 07  0.14143567E 06  0.18379012E 06

     2  0.39888646E 06  0.16410040E 06  0.10805848E 07  0.89412020E 06  0.70999998E 03  0.60216059E 06

     2  0.11974837E 07  0.26871355E 07  0.17995611E 08

   301  0.66284739E 02  0.18856118E 03  0.10675824E 03  0.23799999E 02  0.35000000E 02  0.11284739E 02

   301  0.18799999E 02  0.25000000E 02  0.66896172E 02  0.60331012E 02  0.30340027E 01  0.66758242E 02

   302  0.88359607E 01  0.51593220E 02  0.15104584E 01  0.40343489E 01  0.18628468E 01  0.32211648E 01

   302  0.16243614E 02  0.51593220E 02  0.71057999E 02  0.30427415E 09  0.                0.62082293E 07
OPEN CHANNEL USED    ANNUAL COSTS ARE    0.38726034E 06   VS  0.39683241E 06

OPEN CHANNEL USED    ANNUAL COSTS ARE    0.38366049E 06   VS  0.39225759E 06
```

19.7 - 250 MGD MSF COMPUTER PRINTOUT

```
UPDATE MSF 250 MDG CURRENT TECHNOLOGY 1-24-68 DEPTH#15 FOUL#.0005

            CASE NO.    G           RP          P           Q           CR          ROE         ROER        FLAG D
  CARD 1    0.3000E 01  0.2500E 09  0.1285E 02 -0.         -0.          0.2000E 01 -0.         -0.          0.1000E 01
            TS          THF         TB          TO          TP          TA          CD          CP
  CARD 2    0.2542E 03  0.2500E 03  0.9180E 02  0.6500E 02 -0.          0.8000E 02  0.3360E-01  0.2500E-04
            MODU        ALEV        UNIT        TOTALE      TOTAL R     FREEBD      TRAYDP      CL          SPL
  CARD 3    0.1000E 02  0.2000E 01  0.4000E 01  0.4800E 02  0.2000E 01  0.2700E 01  0.4000E 01  0.4000E 01  0.1200E 02
            EFF%        ELEC        HEAT        CHARGE      RATE INT    WPL         CAPF        SUB FLAG
  CARD 4    0.8600E 00  0.1000E-02  0.1000E 00  0.6000E-01  0.4000E-01  0.3000E 02  0.9000E 00  0.1000E 01  0.1000E 01
            DOH         WALLH       DOE         WALL E      DOR         WALLR       A3          SMA1        SMA2
  CARD 5    0.7500E 00  0.3500E-01  0.7500E 00  0.3500E-01  0.7500E 00  0.4900E-01  0.2000E 01  0.2000E 01  0.2000E 01
            BIKTH       BIKTE       BIKTR       CSLTBH      CSLTBP      CSLTBR      SF1         S0100       SI100
  CARD 6    0.2400E 02  0.2600E 02  0.2600E 02  0.3000E 02  0.3000E 02  0.3000E 02  0.1000E 01  0.1000E 01  0.1000E 01
            RH          RE          RR          SH          SE          SR          VH          VE          VR
  CARD 7    0.5000E-03  0.5000E-03  0.7000E-03  0.1900E 02  0.1900E 02  0.1900E 02  0.4500E 01  0.4500E 01  0.5000E 01
            HD          HH          HBL         HPR         FFHL        SSF1        SSF         TREYA       TRAYB
  CARD 8    0.3500E 02  0.2500E 02  0.4000E 02  0.9200E 02 -0.         -0.          0.1000E 01  0.8000E 06  0.1000E 07
            CPSTB       FACID       ACACID      DPLIM                               XSOD        NNN         LLL
  CARD 9    0.1500E 02  0.2674E 01 -0.1222E-01  0.1470E 02 -0.         -0.          0.1300E 01           2           2
```

- 5. MGD MSF COMPUTER PRINTOUT Page 2

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     UPDATE MSF 250 MDG CURRENT TECHNOLOGY 1-24-68 DEPTH#15 FOUL#.0005

 ONE LEVEL OF ONE MODULE
         VAPOR VEL    TRAY FLOW     TRAY WIDTH   RES TIME                      DELP         DELP
 STAGE    FT/SEC       LB/HR FT        FT          SEC          PV          AVAILABLE    REQUIRED         A            ALPHA  DTPD

   1    9.291495   0.100000E 07   31.227357    1.678415 0.26957E 02 0.14393E 01 0.81190E 00 0.95792E 01    2.683 0.82
   2    9.698374   0.995327E 06   31.277117    1.725586 0.25518E 02 0.13763E 01 0.80570E 00 0.97585E 01    2.695 0.84
   3   10.108258   0.990683E 06   31.327042    1.742230 0.24142E 02 0.13154E 01 0.79956E 00 0.99438E 01    2.708 0.87
   4   10.549475   0.986066E 06   31.377131    1.759413 0.22826E 02 0.12565E 01 0.79350E 00 0.10136E 02    2.721 0.89
   5   11.013376   0.981476E 06   31.427394    1.777139 0.21570E 02 0.11996E 01 0.78751E 00 0.10334E 02    2.736 0.92
   6   11.500925   0.976913E 06   31.477844    1.795473 0.20370E 02 0.11446E 01 0.78159E 00 0.10540E 02    2.751 0.95
   7   12.013562   0.972375E 06   31.528494    1.814427 0.19225E 02 0.10915E 01 0.77574E 00 0.10753E 02    2.767 0.98
   8   12.552641   0.967864E 06   31.579357    1.834030 0.18134E 02 0.10402E 01 0.76996E 00 0.10973E 02    2.784 1.00
   9   13.119771   0.963377E 06   31.630447    1.854299 0.17094E 02 0.99081E 00 0.76425E 00 0.11202E 02    2.802 1.03
  10   13.716238   0.958914E 06   31.681777    1.875300 0.16103E 02 0.94315E 00 0.75860E 00 0.11439E 02    2.820 1.06
  11   14.343944   0.954474E 06   31.733363    1.897039 0.15160E 02 0.89729E 00 0.75301E 00 0.11685E 02    2.840 1.10
  12   15.004021   0.950058E 06   31.785220    1.919623 0.14262E 02 0.85308E 00 0.74750E 00 0.11940E 02    2.861 1.13
  13   15.698826   0.945663E 06   31.837365    1.943030 0.13409E 02 0.81057E 00 0.74204E 00 0.12204E 02    2.884 1.16
  14   16.429936   0.941291E 06   31.889817    1.967339 0.12599E 02 0.76950E 00 0.73665E 00 0.12480E 02    2.907 1.20
  15   17.201482   0.936939E 06   31.942591    1.992357 0.11829E 02 0.73016E 00 0.73132E 00 0.12766E 02    2.931 1.24
  16   18.014380   0.932607E 06   31.995703    2.018295 0.11099E 02 0.69238E 00 0.72605E 00 0.13062E 02    2.956 1.27
  17   18.871043   0.928296E 06   32.049170    2.045186 0.10407E 02 0.65620E 00 0.72083E 00 0.13369E 02    2.982 1.31
  18   19.772863   0.924003E 06   32.103010    2.073211 0.97506E 01 0.62141E 00 0.71568E 00 0.13689E 02    3.010 1.35
  19   20.723871   0.919729E 06   32.157247    2.102265 0.91292E 01 0.58816E 00 0.71059E 00 0.14021E 02    3.039 1.39
  20   21.725070   0.915473E 06   32.211899    2.132602 0.85410E 01 0.55624E 00 0.70555E 00 0.14366E 02    3.069 1.43
  21   22.781104   0.911233E 06   32.266994    2.164094 0.79848E 01 0.52576E 00 0.70057E 00 0.14725E 02    3.101 1.48
  22   23.893303   0.907010E 06   32.322551    2.196996 0.74590E 01 0.49654E 00 0.69565E 00 0.15098E 02    3.135 1.52
  23   25.066581   0.902803E 06   32.378599    2.231221 0.69625E 01 0.46870E 00 0.69078E 00 0.15486E 02    3.170 1.57
  24   26.302110   0.898610E 06   32.435163    2.267050 0.64938E 01 0.44203E 00 0.68596E 00 0.15891E 02    3.207 1.62
  25   27.605944   0.894431E 06   32.492275    2.304356 0.60517E 01 0.41666E 00 0.68120E 00 0.16311E 02    3.246 1.67
  26   28.979217   0.890266E 06   32.549961    2.343461 0.56351E 01 0.39240E 00 0.67649E 00 0.16749E 02    3.287 1.72
  27   30.428754   0.886113E 06   32.608255    2.384233 0.52427E 01 0.36936E 00 0.67183E 00 0.17204E 02    3.329 1.78
  28   31.955219   0.881971E 06   32.667190    2.427071 0.48733E 01 0.34735E 00 0.66722E 00 0.17680E 02    3.374 1.83
  29   33.566905   0.877840E 06   32.726804    2.471795 0.45260E 01 0.32655E 00 0.66266E 00 0.18172E 02    3.421 1.89
  30   35.285965   0.873718E 06   32.787132    2.517306 0.41994E 01 0.30666E 00 0.65815E 00 0.18689E 02    3.472 1.95
  31   37.109700   0.869606E 06   32.848181    2.564393 0.38928E 01 0.28770E 00 0.65369E 00 0.19229E 02    3.524 2.02
  32   38.996709   0.865503E 06   32.909979    2.616409 0.36051E 01 0.26974E 00 0.64928E 00 0.19792E 02    3.578 2.08
  33   40.989095   0.861407E 06   32.972627    2.670924 0.33353E 01 0.25275E 00 0.64492E 00 0.20378E 02    3.635 2.15
  34   43.088780   0.857315E 06   33.036171    2.728372 0.30826E 01 0.23660E 00 0.64060E 00 0.20991E 02    3.694 2.22
  35   45.306513   0.853228E 06   33.100665    2.788671 0.28460E 01 0.22131E 00 0.63633E 00 0.21632E 02    3.755 2.30
  36   47.646572   0.849145E 06   33.166159    2.852169 0.26247E 01 0.20681E 00 0.63211E 00 0.22303E 02    3.820 2.37
  37   50.117674   0.845063E 06   33.232710    2.919004 0.24179E 01 0.19304E 00 0.62793E 00 0.23009E 02    3.887 2.45
  38   52.733333   0.840982E 06   33.300380    2.989074 0.22248E 01 0.18005E 00 0.62380E 00 0.23746E 02    3.956 2.53
  39   55.493956   0.836900E 06   33.369222    3.063121 0.20448E 01 0.16765E 00 0.61971E 00 0.24528E 02    4.028 2.62
  40   58.432596   0.832817E 06   33.439309    3.140089 0.18771E 01 0.15601E 00 0.61566E 00 0.25343E 02    4.102 2.70
  41   61.532769   0.828731E 06   33.510686    3.221775 0.17211E 01 0.14478E 00 0.61165E 00 0.26222E 02    4.178 2.79
  42   64.846359   0.824640E 06   33.583438    3.305252 0.15764E 01 0.13435E 00 0.60769E 00 0.27133E 02    4.254 2.88
  43   68.381506   0.820545E 06   33.657584    3.394305 0.14420E 01 0.12412E 00 0.60377E 00 0.28138E 02    4.333 2.97
  44   72.229663   0.816444E 06   33.733224    3.482514 0.13179E 01 0.11474E 00 0.59989E 00 0.29171E 02    4.408 3.05
  45   76.285903   0.812339E 06   33.810318    3.577277 0.12031E 01 0.10530E 00 0.59605E 00 0.30354E 02    4.486 3.14
  46   80.874380   0.808226E 06   33.888983    3.664875 0.10978E 01 0.96018E-01 0.59225E 00 0.31686E 02    4.552 3.22
  47   86.275822   0.804110E 06   33.969047    3.737699 0.10018E 01 0.85526E-01 0.58849E 00 0.33466E 02    4.594 3.27
  48   93.741134   0.800000E 06   34.050178    3.742694 0.91630E 00 0.97032E-01 0.58477E 00 0.31320E 02    4.545 3.24
  49   62.380457   0.797818E 06   34.050178   12.591806 0.81927E 00 0.14459E 00 0.58109E 00 0.25567E 02    2.489 1.20
  50   93.086899   0.793685E 06   34.050178    7.910161 0.67468E 00 0.                       0.57417E 00 0.             3.303 2.04
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UPDATE MSF 250 MDG CURRENT TECHNOLOGY 1-24-68 DEPTH#15 FOUL#.0005

TUBE BUNDLE IN EVAPORATOR SECTION

     TUBE OD, INCHES      0.750000E 00    NO OF TUBES/BNDLE  0.619859E 04
     VERT ROWS            0.690000E 02    HORIZ ROWS          0.900000E 02    S/D RATIO            0.130000E 01
     BUNDLE HT, FT        0.484715E 01    BUNDLE WIDTH, FT    0.729375E 01    BUNDLE WIDTH + 3     0.102937E 02

TUBE BUNDLE IN REJECT SECTION

     TUBE OD, INCHES      0.750000E 00    NO OF TUBES/BNDLE  0.255452E 04
     VERT ROWS            0.730000E 02    HORIZ ROWS          0.350000E 02    S/D RATIO            0.130000E 01
     BUNDLE HT, FT        0.512860E 01    BUNDLE WIDTH, FT    0.282500E 01    BUNDLE WIDTH + 3     0.582500E 01
 I      DPINIT            DTINIT            DPCLR             DTCLR             DTCMD
   1  0.14123838E-02   0.28152466E-02   0.22063255E-02   0.44021606E-02   0.72174072E-02
   2  0.14633352E-02   0.30746460E-02   0.22891760E-02   0.48103333E-02   0.78849792E-02
   3  0.15142866E-02   0.33340454E-02   0.23720264E-02   0.52185059E-02   0.85525513E-02
   4  0.15636589E-02   0.36087036E-02   0.24529696E-02   0.56648254E-02   0.92735291E-02
   5  0.16130313E-02   0.38833618E-02   0.25339127E-02   0.61111450E-02   0.99945068E-02
   6  0.16656398E-02   0.42152405E-02   0.26206970E-02   0.66413879E-02   0.10856628E-01
   7  0.17182484E-02   0.45471191E-02   0.27074814E-02   0.71716309E-02   0.11718750E-01
   8  0.17742153E-02   0.49285889E-02   0.28005838E-02   0.78086853E-02   0.12737274E-01
   9  0.18301822E-02   0.53100586E-02   0.28936863E-02   0.84457397E-02   0.13755798E-01
  10  0.18896465E-02   0.57716370E-02   0.29920936E-02   0.91819763E-02   0.14953613E-01
  11  0.19491109E-02   0.62332153E-02   0.30905008E-02   0.99182129E-02   0.16151428E-01
  12  0.20126528E-02   0.67901611E-02   0.31974316E-02   0.10826111E-01   0.17616272E-01
  13  0.20761947E-02   0.73471069E-02   0.33043623E-02   0.11734009E-01   0.19081116E-01
  14  0.21436452E-02   0.80032349E-02   0.34186840E-02   0.12798309E-01   0.20801544E-01
  15  0.22110958E-02   0.86593628E-02   0.35330057E-02   0.13862610E-01   0.22521973E-01
  16  0.22823336E-02   0.94566345E-02   0.36545396E-02   0.15155792E-01   0.24612427E-01
  17  0.23535714E-02   0.10253906E-01   0.37760735E-02   0.16448975E-01   0.26702881E-01
  18  0.24286114E-02   0.11192322E-01   0.39052963E-02   0.17997742E-01   0.29190063E-01
  19  0.25036516E-02   0.12130737E-01   0.40345192E-02   0.19546509E-01   0.31677246E-01
  20  0.25822989E-02   0.13256073E-01   0.41705966E-02   0.21411896E-01   0.34667969E-01
  21  0.26609461E-02   0.14381409E-01   0.43066740E-02   0.23277283E-01   0.37658691E-01
  22  0.27429109E-02   0.15727997E-01   0.44497848E-02   0.25520325E-01   0.41248322E-01
  23  0.28248758E-02   0.17074585E-01   0.45928955E-02   0.27763367E-01   0.44837952E-01
  24  0.29096626E-02   0.18692017E-01   0.47429204E-02   0.30475616E-01   0.49167633E-01
  25  0.29944494E-02   0.20309448E-01   0.48929453E-02   0.33187866E-01   0.53497314E-01
  26  0.30812141E-02   0.22232056E-01   0.50474405E-02   0.36453247E-01   0.58685303E-01
  27  0.31679788E-02   0.24154663E-01   0.52019358E-02   0.39718628E-01   0.63873291E-01
  28  0.32556152E-02   0.26459740E-01   0.53602457E-02   0.43636322E-01   0.70095062E-01
  29  0.33432517E-02   0.28762817E-01   0.55185556E-02   0.47554016E-01   0.76316833E-01
  30  0.34352930E-02   0.31551361E-01   0.56853592E-02   0.52307129E-01   0.83858490E-01
  31  0.35273344E-02   0.34339905E-01   0.58521628E-02   0.57060242E-01   0.91400146E-01
  32  0.36102658E-02   0.37578583E-01   0.60060620E-02   0.62629700E-01   0.10020828E 00
  33  0.36931971E-02   0.40817261E-01   0.61599612E-02   0.68199158E-01   0.10901642E 00
  34  0.37693384E-02   0.44624329E-01   0.63040107E-02   0.74752808E-01   0.11937714E 00
  35  0.38454796E-02   0.48431396E-01   0.64480603E-02   0.81306458E-01   0.12973785E 00
  36  0.39101489E-02   0.52825928E-01   0.65738261E-02   0.88966370E-01   0.14179230E 00
  37  0.39748182E-02   0.57220459E-01   0.66995919E-02   0.96626282E-01   0.15384674E 00
  38  0.40213888E-02   0.62198639E-01   0.67929924E-02   0.10530472E 00   0.16750336E 00
  39  0.40679594E-02   0.67176819E-01   0.68863928E-02   0.11398315E 00   0.18115997E 00
  40  0.40874172E-02   0.72647095E-01   0.69300607E-02   0.12347412E 00   0.19612122E 00
  41  0.41068749E-02   0.78117371E-01   0.69737285E-02   0.13296509E 00   0.21108246E 00
  42  0.40867893E-02   0.83778381E-01   0.69421157E-02   0.14268112E 00   0.22645950E 00
  43  0.40667037E-02   0.89439392E-01   0.69105029E-02   0.15239716E 00   0.24183655E 00
  44  0.39905959E-02   0.94707489E-01   0.67832693E-02   0.16145706E 00   0.25616455E 00
  45  0.39144881E-02   0.99975586E-01   0.66560358E-02   0.17051697E 00   0.27049255E 00
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46  0.37597264E-02  0.10364914E 00  0.63944906E-02  0.17687988E 0C  0.28052902E 00
47  0.36049647E-02  0.10732269E 00  0.61329454E-02  0.18324280E 0C  0.29056549E 00
48  0.33668207E-02  0.10828400E 00  0.57284236E-02  0.18492889E 0C  0.29321289E 00
49  0.31362785E-02  0.11316681E 00  0.42787641E-02  0.15495300E 0C  0.26811981E 00
50  0.47818904E-02  0.20186615E 00  0.65278783E-02  0.27737427E 0C  0.47924042E 00
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19.4 - 2.5 MGD MSF COMPUTER PRINTOUT

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                          THE FLUOR CORPORATION, LTD.

      CUSTOMER  OFFICE OF SALINE H2O                              CONTRACT 4334     PAGE NO. 1

      LOCATION  WASHINGTON DC                                     DATE      1.-18-68

      RUN NO.    2                                                BY        PAH

TOTAL NUMBER OF EFFECTS  1                         TOTAL NUMBER OF STAGES     42

TOTAL PRODUCTION        865 MLB/HR.    2.49 MMGPD  MAXIMUM BRINE TEMPERATURE 250.0 F

SEA WATER TEMPERATURE   65.0 F                     SEA WATER CONCENTRATION     3.500 WT. PCT

SEA WATER MAKEUP       1730 MLB/HR                 EXCESS SEA WATER          2898 MLB/HR

   EFFECT  NUMBER   PRODUCTION   RECYCLE     BLOWDOWN   BLOWDOWN   INITIAL    RECYCLE BRINE
     NO.  OF STAGES   MLB/HR   BRINE,MLB/HR  MLB/HR      TEMP,F  STAGE TTD,F  CONC.,WT. PCT
      1      42         865        4185         865      82.00     6.623         7.000
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19.4 - 2.5 MGD MSF COMPUTER PRINTOUT

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                                                                                           RUN NO. 2        PAGE NO.

EFFECT STAGE   FLASHING    DISTILLATE  PRODUCTION   RECYCLE      BOILING POINT  PRESSURE  FLASHING BRINE, VAPOR
 NO.    NO.  BRINE,MLB/HR   MLB/HR      MLB/HR   BRINE,MLB/HR  ELEV., DEG F.    PSIA    CONC.,WT. PCT    CF/S
  1      1       5889         26         25.6       4185          2.466       26.466        6.002          110
         2       5864         51         25.3       4185          2.475       24.494        6.028          117
         3       5839         76         25.0       4185          2.483       22.649        6.054          124
         4       5814        101         24.8       4185          2.491       20.925        6.080          132
         5       5790        125         24.5       4185          2.499       19.314        6.106          141
         6       5765        149         24.2       4185          2.507       17.812        6.131          151
         7       5742        173         23.9       4185          2.515       16.412        6.157          161
         8       5718        197         23.7       4185          2.522       15.108        6.182          172
         9       5694        220         23.4       4185          2.529       13.895        6.208          184
        10       5671        243         23.1       4185          2.536       12.708        6.233          196
        11       5649        266         22.9       4185          2.543       11.722        6.258          210
        12       5626        289         22.6       4185          2.549       10.752        6.283          225
        13       5604        311         22.3       4185          2.556        9.854        6.308          242
        14       5581        333         22.1       4185          2.562        9.022        6.333          259
        15       5560        355         21.8       4185          2.568        8.254        6.358          279
        16       5538        377         21.6       4185          2.573        7.544        6.383          300
        17       5517        398         21.3       4185          2.579        6.889        6.407          322
        18       5496        419         21.0       4185          2.584        6.285        6.432          347
        19       5475        440         20.8       4185          2.589        5.730        6.456          374
        20       5454        460         20.5       4185          2.594        5.219        6.481          403
        21       5434        481         20.3       4185          2.599        4.749        6.505          435
        22       5414        501         20.0       4185          2.603        4.318        6.529          469
        23       5394        520         19.8       4185          2.607        3.923        6.553          507
        24       5375        540         19.5       4185          2.611        3.561        6.577          548
        25       5356        559         19.3       4185          2.615        3.230        6.600          593
        26       5337        578         19.0       4185          2.619        2.927        6.624          642
        27       5318        597         18.8       4185          2.623        2.651        6.647          695
        28       5299        616         18.5       4185          2.626        2.399        6.671          754
        29       5281        634         18.3       4185          2.629        2.169        6.694          817
        30       5263        652         18.0       4185          2.632        1.960        6.717          887
        31       5245        670         17.8       4185          2.635        1.770        6.739          963
        32       5228        687         17.6       4185          2.638        1.597        6.762         1046
        33       5210        705         17.3       4185          2.640        1.440        6.785         1137
        34       5193        722         17.1       4185          2.642        1.298        6.807         1237
        35       5176        739         16.8       4185          2.645        1.169        6.829         1345
        36       5160        755         16.6       4185          2.647        1.052        6.851         1464
        37       5143        771         16.4       4185          2.648         .946        6.873         1594
        38       5127        788         16.1       4185          2.650         .851        6.894         1737
        39       5111        803         15.9       4185          2.651         .765        6.916         1892
                                     HEAT REJECTION SECTION
                                        FRESH SEA WATER
        40       5092        823         19.3       4628          2.653         .669        6.942         2606
        41       5072        843         20.5       4628          2.655         .579        6.970         3175
        42       5050        865         21.7       4628          2.656         .495        7.000         3897
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19.4 - 2.5 MGD MSF COMPUTER PRINTOUT

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                                                                                                RUN NO. 2        PAGE NO.  3

                                                                                           RECYCLE BRINE       SEA WATER MAKEUP
EFFECT STAGE   FLASHING    DISTILLATE    TTD    RECYCLE-MAKEUP  LMTD   HEAT TRANSFER  OVERALL U   AREA   OVERALL U     AREA
 NO.    NO.   BRINE TEMP,F  TEMP,F        F     BRINES TEMP, F   F        MBTU/HR     BTU/FT2/F/HR FT2  BTU/FT2/F/HR  FT2
  1      1      245.70      243.24      6.622      236.62      8.596      24320      629.44      4495     0.00            0
         2      241.41      238.94      6.626      232.31      8.597      24226      626.93      4495     0.00            0
         3      237.13      234.65      6.636      228.01      8.602      24141      624.30      4495     0.00            0
         4      232.86      230.37      6.647      223.73      8.609      24053      621.56      4495     0.00            0
         5      228.61      226.11      6.658      219.45      8.615      23963      618.73      4495     0.00            0
         6      224.36      221.86      6.671      215.18      8.623      23870      615.80      4495     0.00            0
         7      220.13      217.62      6.684      210.93      8.630      23775      612.77      4496     0.00            0
         8      215.92      213.39      6.698      206.70      8.639      23677      609.65      4496     0.00            0
         9      211.72      209.19      6.713      202.47      8.648      23577      606.43      4496     0.00            0
        10      207.53      204.99      6.729      198.26      8.657      23474      603.10      4496     0.00            0
        11      203.36      200.82      6.746      194.07      8.667      23368      599.68      4496     0.00            0
        12      199.21      196.66      6.763      189.89      8.678      23260      596.17      4496     0.00            0
        13      195.07      192.51      6.782      185.73      8.689      23149      592.56      4496     0.00            0
        14      190.95      188.39      6.801      181.59      8.701      23035      588.84      4496     0.00            0
        15      186.85      184.28      6.821      177.46      8.714      22919      585.04      4496     0.00            0
        16      182.77      180.20      6.841      173.36      8.726      22800      581.13      4496     0.00            0
        17      178.71      176.13      6.863      169.27      8.740      22678      577.14      4496     0.00            0
        18      174.67      172.08      6.885      165.20      8.754      22553      573.04      4496     0.00            0
        19      170.65      168.06      6.908      161.15      8.769      22426      568.85      4496     0.00            0
        20      166.65      164.06      6.933      157.12      8.784      22295      564.57      4496     0.00            0
        21      162.67      160.07      6.957      153.12      8.800      22162      560.20      4496     0.00            0
        22      158.72      156.12      6.983      149.13      8.816      22026      555.73      4496     0.00            0
        23      154.79      152.18      7.016      145.17      8.833      21886      551.17      4496     0.00            0
        24      150.88      148.27      7.037      141.23      8.850      21744      546.52      4496     0.00            0
        25      147.00      144.39      7.065      137.32      8.868      21599      541.78      4496     0.00            0
        26      143.15      140.53      7.094      133.43      8.886      21451      536.96      4495     0.00            0
        27      139.32      136.69      7.124      129.57      8.905      21300      532.05      4495     0.00            0
        28      135.51      132.89      7.155      125.73      8.925      21146      527.05      4495     0.00            0
        29      131.74      129.11      7.186      121.92      8.945      20989      521.96      4495     0.00            0
        30      127.99      125.36      7.219      118.14      8.966      20829      516.82      4495     0.00            0
        31      124.27      121.63      7.252      114.38      8.987      20666      511.59      4495     0.00            0
        32      120.58      117.94      7.286      110.66      9.008      20500      506.28      4495     0.00            0
        33      116.92      114.28      7.321      106.96      9.031      20331      500.90      4495     0.00            0
        34      113.29      110.65      7.356      103.29      9.053      20160      495.45      4495     0.00            0
        35      109.69      107.04      7.392       99.65      9.076      19986      489.93      4494     0.00            0
        36      106.12      103.48      7.429       96.05      9.100      19809      484.35      4494     0.00            0
        37      102.59       99.94      7.467       92.47      9.124      19630      478.71      4494     0.00            0
        38       99.08       96.43      7.506       88.93      9.149      19448      473.02      4494     0.00            0
        39       95.62       92.96      7.546       85.42      9.174      19263      467.27      4494     0.00            0
                                                                                  TOTAL AREA     175317                    0
                                                   HEAT REJECTION SECTION
        40       91.37       88.72      6.777       81.94      9.166      23555        0.00         0   508.33         5056
        41       86.84       84.18      7.521       76.66     10.082      25186        0.00         0   495.04         5046
        42       82.01       79.35      8.336       71.01     11.071      26823        0.00         0   480.95         5038
                                                                                  TOTAL AREA          0                15139

                                                                   TOTAL AREA EFFECT  1      175317                15139

                                                                      GRAND TOTAL AREA       175317                15139
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19.4 - 2.5 MGD MSF COMPUTER PRINTOUT

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                                                                         RUN NO. 2        PAGE NO. 4

                              BRINE HEATER

 STEAM TEMPERATURE,F                                         267.00
TEMPERATURE RISE OF BRINE THROUGH HEATER,F                    13.38
LOG MEAN TEMPERATURE DIFFERENCE                               23.05
OVERALL HEAT TRANSFER COEFFICIENT,BTU/FT2/F/HR               611.58
HEAT REQUIREMENT,MMBTU/HR                                     75.58
AREA REQUIREMENT,SQ.FT.                                     5362
STEAM REQUIREMENT,MLB/HR                                      80.9
STEAM ECONOMY RATIO,LBS PRODUCT/LB STEAM                      10.69

TOTAL NUMBER OF TUBES                                       1765
NUMBER OF TUBE BUNDLES                                         1
LENGTH OF TUBES,FT                                            15.47
OUTSIDE DIAMETER OF TUBES,IN                                    .7500
WALL THICKNESS OF TUBES,IN                                      .0350
THERMAL CONDUCTIVITY,BTU/HR-FT2-F/FT                          26.00
VELOCITY OF RECYCLE BRINE IN TUBES,FT/SEC                      6.000
PRESSURE DROP THROUGH THIS SECTION,PSI                         1.57

                               PUMPS

PUMP EFFICIENCY,PERCENT                                       78.0
MOTOR EFFICIENCY,PERCENT                                      93.0

                       MISC.         TOTAL
                     PRESSURE    DIFFERENTIAL
                     DROP,PSI      HEAD,PSI          BHP
SEA WATER PUMP         16.00         22.05          149.2
MAKEUP PUMP            16.00         72.31          183.4
BLOWDOWN PUMP          16.00         30.20           37.4
PRODUCT PUMP           16.00         45.20           58.5
RECYCLE PUMP
 EFFECT NO.  1         16.00         75.18          449.9

                                           TOTAL    878.3

                            EJECTOR STEAM

EJECTOR STEAM,MLB/HR                                            .85
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19.4 - 2.5 MGD MSF COMPUTER PRINTOUT

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                                                                                  RUN NO. 2        PAGE NO.
S

EFFECT NO.  1                                      HEAT RECOVERY                            HEAT REJECTION
                                              RECYCLE          MAKEUP                 RECYCLE          MAKEUP
 NUMBER OF TUBES PER STAGE                     2052              -0                  *000000            1331
 NUMBER OF TUBE BUNDLES PER STAGE                 1               0                        0               1
 LENGTH OF TUBES, FT                          11.16           11.16                    21.00           21.00
 OUTSIDE DIAMETER OF TUBES, IN                 .750            .750                     .750            .750
 WALL THICKNESS OF TUBES, IN                   .035            .035                     .035            .035
 THERMAL CONDUCTIVITY, BTU/HR-FT2-F/FT         26.0            26.0                     26.0            26.0
 VELOCITY IN TUBES, FT/SEC                    5.000           0.000                    0.000           6.000
 IN-TUBE PRESSURE DROP, PSI                   27.11            0.00                     0.00            6.44
 ENTRANCE AND EXIT LOSSES, PSI                 1.17            0.00                     0.00             .13
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