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ENGINEERING FEASIBILITY AND ECONOMIC STUDY

FOR

DUAL-PURPOSE ELECTRIC POWER-WATER DESALTING PLANT

FOR

ISRAEL

PREPARED FOR

UNITED STATES-ISRAEL JOINT BOARD

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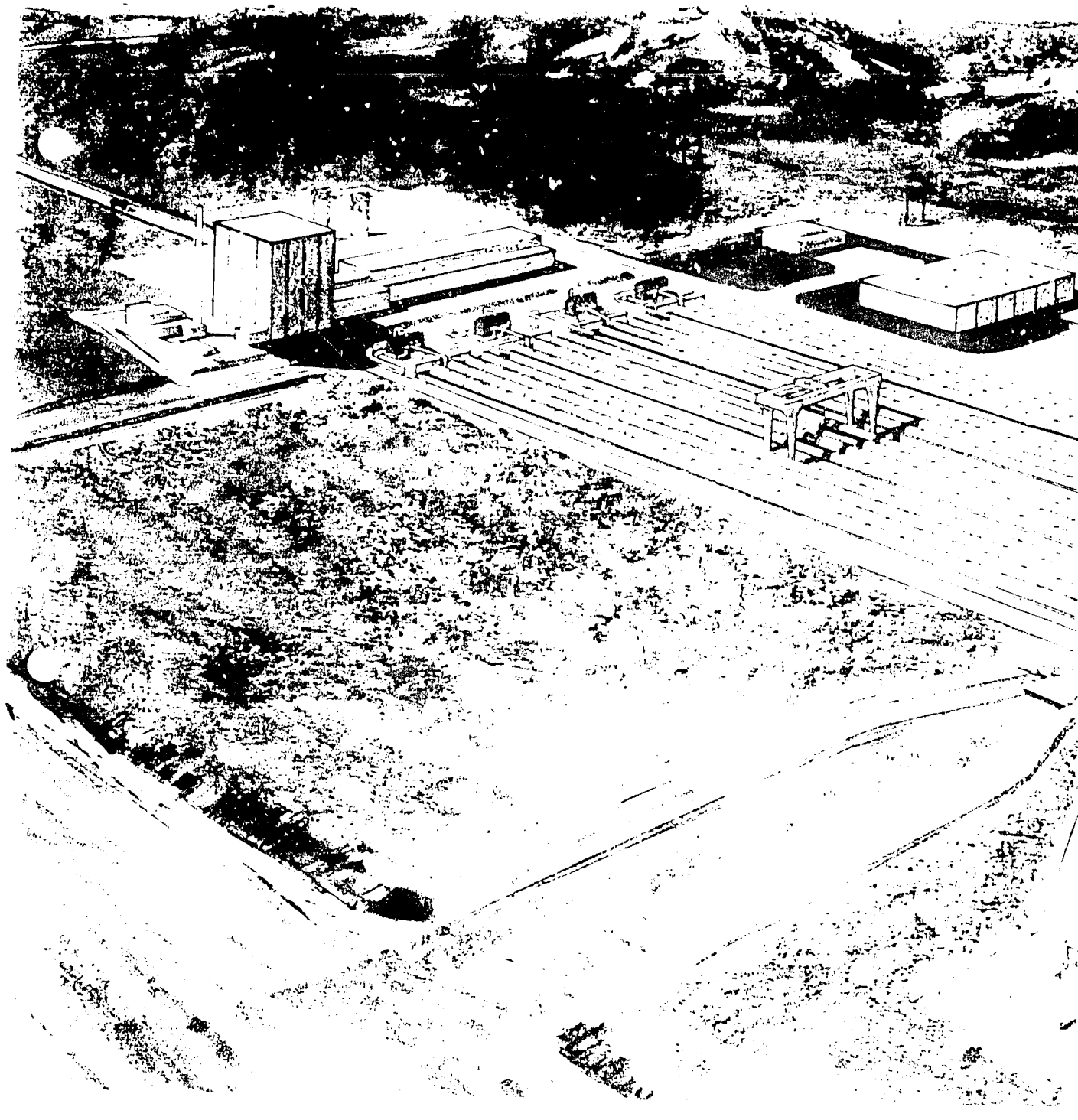

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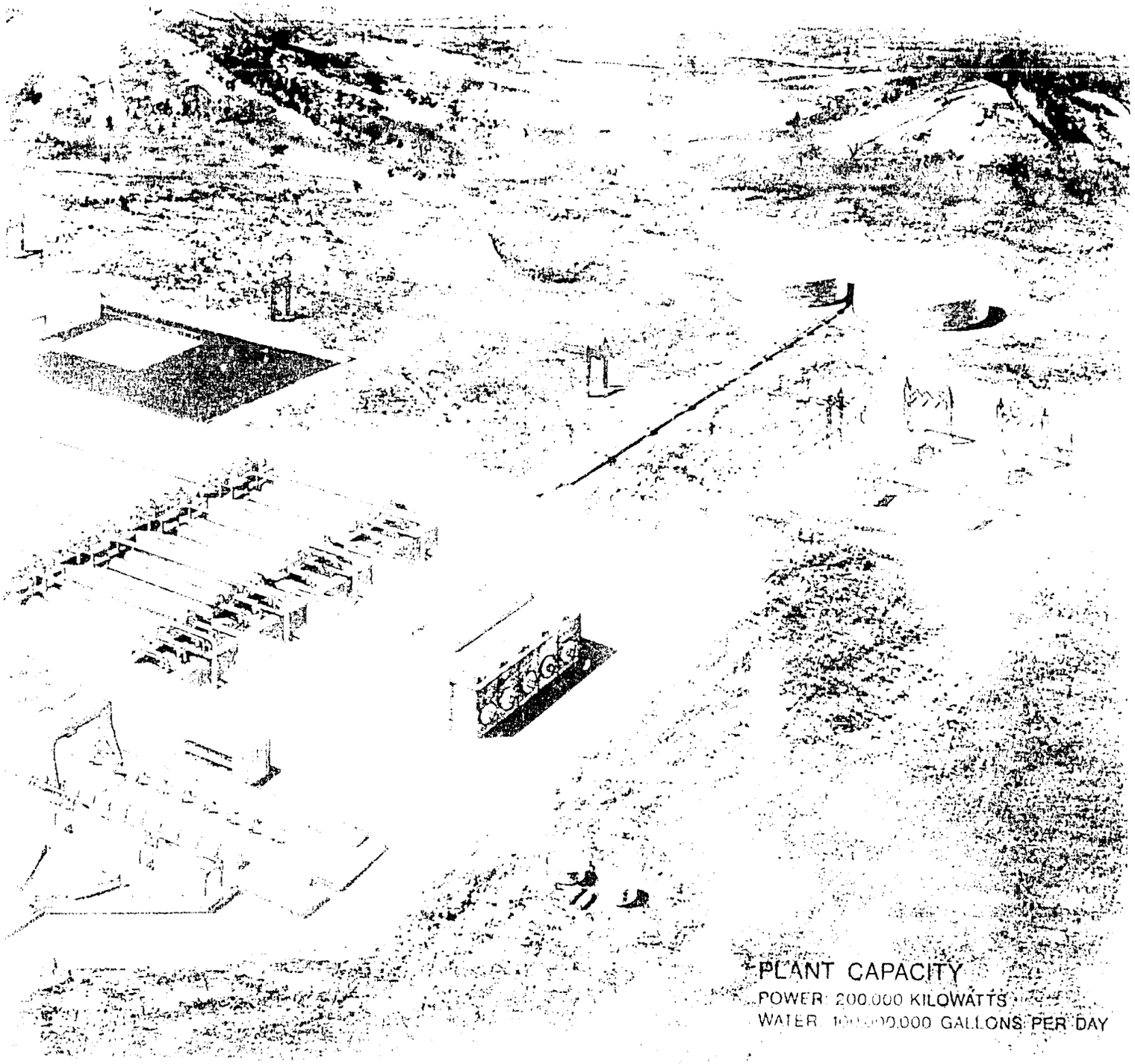

WATER DESALTING PLANT FOR ISRAEL

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I. INTRODUCTION

Israel anticipates a serious water problem by the early 1970's. Action toward solution of this problem was taken when Prime Minister Eshkol and President Johnson signed a Joint Communique on June 2, 1964 calling for cooperation between the United States and Israel in the preparation of a study to determine the feasibility of a large desalting plant to be built in Israel. In October 1964, a Joint Team of experts from Israel (Water Planning for Israel, Ltd. (Tahal); Israel Electric Corporation, Ltd.; Israel Atomic Energy Commission) and from the United States (Department of Interior Water and Power Development Office and Office of Saline Water; and the Atomic Energy Commission) completed a preliminary study on a combination seawater desalting and electric power plant to be built in Israel. The study indicated that a plant of this kind may be technically and economically feasible in Israel. Based on these conclusions, a U.S. - Israel Joint Board recommended Kaiser Engineers and its principal subcontractor, Catalytic Construction Company, for the preparation of a detailed study of the above subject. In December 1964 the U.S. Department of Interior, with the concurrence of the U.S. Atomic Energy Commission and the State of Israel, contracted with the Kaiser/Catalytic team to conduct an engineering feasibility and economic study of a dual-purpose power generation and desalting plant to be located in Israel. The bases for the study were specified as:

- A plant capacity of 175-200 megawatts of salable electricity and 100-150 million cubic meters of water per year.

- A plant ready for initial operation in 1971 and commercial production in 1972.

The study was conducted in two phases.

The first phase, completed in July 1965, was directed toward determining the feasibility of a dual-purpose electric power-water desalting plant ready for commercial operation in Israel by mid-1972 and included:

- Comparisons of various dual-purpose nuclear power and desalting plants using the multi-stage flash evaporation process and selection of one of these plants (hereinafter referred to as the reference plant) for detailed evaluation.

- Comparison of this selected plant with a comparable fossil-fuel dual-purpose plant.

- A recommended development program to confirm certain desalting plant components and design criteria.

The second phase was directed toward preparing a detailed evaluation of the reference plant and to develop information for use in preparing an application to funding agencies. During Phase II the conceptual design was refined and new estimates of the capital cost, annual cost, and the unit cost of water were prepared. In addition, several plant alternatives and factors important in the determination of the total annual cost were examined such as:

- Differences in the desalting plant design and in the cost of water resulting from the selection of either a boiling-water or pressurized-water reactor for the nuclear steam supply.

- Differences in the cost of water resulting from the selection of a concrete instead of a steel reactor containment building.

- Differences in the cost of water resulting from the selection of concrete instead of steel evaporator chambers.

- Review of the plant operating factor.

- Determination of the effect of seasonal seawater temperature on the capital cost and the unit cost of water.

- Determination of the change in the cost of water which would result if potential decreases in the nuclear fuel cycle costs materialize.

The refinement of the estimates of capital cost incorporates the information from preliminary quotations received from vendors of reactors, turbine-generator units, and complete desalting plants, and also of desalting plant components including brine heaters, recovery and reject stage tube bundles, pumps and vacuum system.

This report includes the results of the Phase I work and describes the results of the above Phase II studies including the estimates of capital cost, annual cost, and the unit cost of water.

II. SUMMARY

The results of the Phase I and Phase II work show that a dual-purpose power-water desalting plant in Israel with capacity of 200 megawatts (MWe) salable power and 100 million gallons water per day (MGD) of desalted seawater ready for initial operation in 1971 and full commercial operation by late 1972 is technically feasible, provided, however, that a timely development program such as is recommended herein is undertaken. This schedule is based on starting preliminary design of the plant in May 1966 and starting operation of the development program test modules by January 1968.

The dual-purpose plant upon which the cost estimates reported herein are based (reference plant) consists of a light water nuclear reactor supplying steam to a turbine-generator producing electric power; the 25 psia turbine exhaust steam in turn supplies heat to the brine heaters of the desalting plant wherein this exhaust steam is condensed before returning to the reactor. In the brine heater the turbine exhaust steam furnishes the thermal energy required by the desalting plant for evaporating fresh water from seawater. The concentrated brine resulting from the partial evaporation of seawater is returned to the sea.

Two available sites near Ashdod have been determined to be suitable for nuclear dual-purpose plants. Site 2 which is near Nitzanim is considered the preferred site; a subsurface investigation not yet completed at Site 2 will provide the required data to determine the actual plant location on this site and permit confirmation of the assumed subsurface structure design criteria. The frontispiece and Figure 1 (annotated) depict the layout of the reference plant.

Capital costs have been estimated for the dual-purpose plant. Separate cost studies were prepared by the Israel Electric Corporation and by Tahal to determine the cost of the electrical power and water conveyance facilities beyond the dual-purpose plant boundaries. Water production costs have been estimated for fixed charge rates of 5, 7 and 10 percent of the capital costs of the dual-purpose plant. The foregoing are based on 1965 costs. Unit water production cost estimates for the reference nuclear dual-purpose plant are as follows:

Fixed Charge Rates	Unit Water Costs at Plant Boundary		
	5%	7%	10%
Cents/1,000 Gallons	28.6	43.4	67.0
Cents/Cubic Meter	7.6	11.5	17.7
Agorot/Cubic Meter	22.6	34.4	53.1

The importance of the fixed charge rate on the unit water cost can be noted from the above; a change of one percentage point yields a change of approximately 7 cents per thousand gallons.

Estimates were also made for fossil-fuel plants of comparable size. For all fixed charge rates through 10 percent, the unit cost of water from the reference nuclear dual-purpose plant was less than that from a fossil-fuel dual-purpose plant.

Tables I and II on the following pages show details of the unit and capital costs for the reference plant.

To arrive at unit water costs, a determination was made of the value of the salable power. This value was credited against the total annual cost of the dual-purpose plant, and the difference, divided by the quantity of water produced, yields the unit cost of water. For this study, the Joint Board specified a power credit of 5.3 mills/kwhr, which is the cost of electric power produced in Israel at the prevailing fixed charge rates, and 85 percent plant operating factor, which value Kaiser Engineers has examined and agrees is reasonable for single purpose plants of 175 to 200 MWe salable capacity constructed in Israel in 1965. This value represents Israel Electric Corporation's estimate of the cost, on a 1965 basis, of producing power in a single-purpose (power only) plant designed to operate in the same capacity range as the dual-purpose plant studied herein; i.e., 175-200 megawatts electrical (MWe) salable power.

Based on the conceptual design work performed, it was concluded that either a pressurized water (PWR) or boiling water reactor (BWR) would be technically suitable for the nuclear steam supply. With respect to the reactors, the cost of a PWR would be essentially the same as a BWR; however, the equipment layouts are somewhat different. Typical layouts for both reactor types were prepared and are included in this report. Cost estimates for each were prepared and found to be

TABLE I

ESTIMATES OF UNIT WATER COST AT THE PLANT BOUNDARY-1965 COST BASIS
NUCLEAR DUAL-PURPOSE POWER-WATER DESALTING PLANT

NOMINAL FIXED CHARGE RATE	5%	7%	10%
CAPITAL COST*			
Depreciable Capital - Thousands of Dollars	$170,000	$180,200	$193,000
Nondepreciable Capital	17,000	17,000	17,000
Total Capital Cost	$187,000	$197,200	$210,000
ANNUAL COST - Thousands of Dollars			
Fixed Charges (Depreciable Capital)	$ 8,500	$ 12,610	$ 19,300
Fixed Charges (Nondepreciable Capital)	370	880	1,540
Operating and Maintenance Expenses	3,470	3,470	3,470
Fuel Expense	4,430	4,410	4,390
Total Annual Cost	$ 16,770	$ 21,370	$ 28,700
Power Credit	(7,900)	(7,900)	(7,900)
NET ANNUAL WATER COST	$ 8,870	$ 13,470	$ 20,800
WATER PRODUCTION			
Million Gallons Per Day	100	100	100
Million Gallons Per Year	31,050	31,050	31,050
Million Cubic Meters Per Year	117.5	117.5	117.5
UNIT WATER COST			
Cents Per Thousand Gallons	28.6	43.4	67.0
Cents Per Cubic Meter	7.6	11.5	17.7
Agorot Per Cubic Meter	22.6	34.4	53.1
Dollars Per Acre-Foot	93.1	141.0	218.0

*Excluding electrical transmission and water conveyance facilities.

TABLE II

ESTIMATE OF TOTAL CAPITAL COST - 1965 COST BASIS
NUCLEAR DUAL-PURPOSE POWER-WATER DESALTING PLANT
(Thousands of Dollars)

NOMINAL FIXED CHARGE RATE	5%	7%	10%
DUAL-PURPOSE PLANT			
Depreciable Items			
Power Plant	$ 52,850	$ 52,850	$ 52,850
Desalting Plant	74,540	74,540	74,540
Intake and Outfall	4,950	4,950	4,950
General Plant Facilities	2,440	2,440	2,440
Other Construction Costs	16,980	26,090	37,560
Subtotal	$151,760	$160,870	$172,340
Contingency @ 12%	18,240	19,330	20,660
Total Depreciable Items	$170,000	$180,200	$193,000
Nondepreciable Items			
Land Cost	$ 0	$ 0	$ 0
Working Capital	16,000	16,000	16,000
Subtotal	$ 16,000	$ 16,000	$ 16,000
Contingency @ 6%	1,000	1,000	1,000
Total Nondepreciable Items	$ 17,000	$ 17,000	$ 17,000
TOTAL DUAL-PURPOSE PLANT	$187,000	$197,200	$210,000

NOTE: It is estimated the additional investments required for electrical transmission facilities and water conveyance facilities are $5,000,000 and $25,000,000 respectively.

competitive. The cost estimates appearing in this report are therefore equally applicable to the BWR or PWR reactor plant. The specifications for major equipment could be written on a "performance type" basis, in which event the manufacturers' competition between the alternates mentioned above would be preserved.

The estimates herein are based on a desalting plant of the multi-stage flash evaporation type consisting of four trains of 31 stages each. Each train would have four parallel module streams each with capacity of 6.25 million gallons of product water per day (MGD). The maximum brine temperature would be 220 F and the economy ratio would be 10.3 lb water per 1,000 Btu heat.

The plant concept used as a basis for cost estimates includes engineering assumptions regarding process and equipment performance which represent an extrapolation of the desalting plant current state-of-the-art. Accordingly, there is recommended a development program which must be prosecuted in a timely fashion to make possible the scheduled start-up date, and the proper operating and cost performance of the plant.

Water and Power Background

The water and power needs of Israel are based on recent studies made by Tahal and Israel Electric Corporation. Based on these studies, Tahal forecasts that Israel's water consumption by 1970 will reach 90 percent of the country's potential water resources that could be made available by that time. This critical situation demands that an additional source of fresh water be provided. The increasing salinity of the natural supply aggravates the problem of water shortage. One significant man-made water supply addition is the reclamation of sewage. But this aggravates the salinity problem still further because the effluent from this supply has a higher salinity than the original input water; thus, a supply of fresh water for dilution is mandatory. Even after the successful implementation of plans for conserving and reclaiming water, Israel will need to supplement its annual water supply by about 200 million cubic meters (MCM) by 1980, of which about 120 MCM will be required by the early 1970's. A desalting plant capacity of 100 million gallons per day will produce 118 MCM per year. In 1972, this quantity would represent approximately 8 percent of Israel's total demand. The provision of this high-purity supply will make it possible to reduce the salinity of water supplied to agriculture to the level considered safe for continued healthy crop growth; notably citrus which is a vital export.

Israel Electric's forecast of power demand and energy consumption is based on a detailed analysis of the expected consumption pattern of the main consumer groups in the period of 1970. The forecast concluded that by 1970 the "doubling period" of the maximum demand will be eight years, and the optimum unit size for additional generating units in the beginning of the next decade lies between 175 and 200 MWe net.

State-of-the-Art

Commercial desalting plants are operating successfully in many parts of the world. The process most advanced, and the one most used in commercial operation, is the multi-stage flash evaporation process; there are 10 MSF plants of at least one million-gallons-per-day capacity in operation; the largest unit has a capacity of approximately 1.5 million gallons per day. For scaling-up to the capacity proposed herein, the design of some parts of the process and some of the components must be confirmed in a development program to be discussed later in this summary.

Commercial production of electric power from a nuclear energy heat source is a proven operation in plants almost as large as that required for the reference dual-purpose plant. Other nuclear power plants, already under construction or on order by United States utilities under firm guarantees as to output and costs, are larger than that contemplated herein. These larger plants will be in commercial operation before Israel's dual-purpose plant would be completed. Both the pressurized water (PWR) and boiling water (BWR) nuclear reactor types, which have been considered equal alternates for the Israel plant, are being guaranteed in thermal ratings more than double that required for the Israel plant.

Reference Dual-Purpose Plant

One site under consideration (Site 1) is 10 km north of Ashdod, and the other one (Site 2) is 9 km south of Ashdod, both being on the coast. Approximately 40 acres (160 dunams) are required for the proposed plant. Either of these locations will accommodate several plants of this size, thus ensuring room for expansion With respect to accessibility, subsoil conditions, topography, oceanography, transportation, communications, and availability of construction labor, it is concluded that both sites are equal Particular attention was given to the nuclear hazards

comparison between the two sites; it was concluded that both sites are acceptable, and that, depending on the direction of Ashdod's future expansion, there may be a slight preference for one site over the other. At present writing, the U.S.-Israel Joint Board has stated that Site 2 is preferred.

The conceptual design of the plant was based on certain ground rules, the principal ones being the following:

175-200 megawatts salable power credited @ 5.3 mills/kwhr.
100-150 million cubic meters/yr water output.
Fixed charge rates of 5, 7 and 10 percent.
Estimates for reactor, turbine-generator and major desalting plant equipment of U.S. manufacture.
Plant ready for commercial operation by mid-1972.

A survey was made of all contending U.S. reactor manufacturers to determine those which could supply reactors for commercial operation in 1971 for a plant of this size. Only the manufacturers of the PWR and BWR types indicated that their reactors would be available commercially, and were able to supply operating characteristics and cost data at this time.

Based on a computer optimization, a nuclear plant of about 1,250 megawatts thermal (MWt) with a 250 megawatts electrical (250 MWe) (200 MWe salable) turbine-generator supplying steam at 25 psia to the desalting plant was chosen. Either a pressurized water (PWR) or boiling water reactor (BWR) would be suitable and the cost of water from a desalting plant which is optimized for one reactor type will be within one percent of the cost of water from a desalting plant which is optimized for the other reactor type. Heat balances and arrangement drawings for each are included in this report. In addition to the normal back-pressure turbine exhaust system, a provision is made in each cycle to supply additional steam to the brine heater through a turbine line with pressure-reducing station, thus ensuring continuous water plant operation when the turbine-generator is shut down and providing for maximum use of the desalting plant during the winter when colder sea temperatures will permit more water production. The pressurized or boiling water reactor systems are housed in containment or pressure-suppression type reactor buildings, respectively, which will contain the radioactive products released in the unlikely event of a rupture in the reactor coolant system.

The desalting plant conceptual design was based on the multi-stage flash evaporation process. This design was studied in sufficient detail to enable the determination of a development program to test those items of process and component design requiring validation in time to ensure commercial operation by the scheduled date. The plant on which cost estimates are based consists of 31 stages through which flow several streams: brine in tubes, brine in open channels, flashed vapor, and distillate (product water). Different temperatures and pressures exist in each stage. Because of the need to examine plants over a large range of physical and economic parameters, a computer program was devised to permit the evaluation of several thousand plants in a reasonable time, and to determine the optimum plant--the one with the combination of characteristics yielding the lowest unit water cost. The reference plant consists of four trains each having a capacity of 25 million gallons per day (MGD), and each capable of operating independently of each other. Within each train, there are four module streams operating in parallel, each having a capacity of 6.25 MGD and representing only a four-fold capacity scale-up of existing plants of this kind.

The reference plant cost estimate is based on field-erected steel evaporator structures. Should the development program confirm the suitability of the concrete structure alternate, a reduction in the capital cost of the dual-purpose plant of 3.6 million dollars would be realized. The major equipment (brine heaters, removable evaporator heat exchange bundles, pumps, air ejectors and gantry crane) is shop-fabricated with some field assembly to reduce freight costs and U.S. dollar expense.

Design is arranged so that if the turbine-generator of the power plant is shut down, the desalting plant can continue to operate; conversely, if the desalting plant must be shut down, the turbine-generator can continue to generate power. The optimization program yielded the following plant characteristics for the reference plant conceptual design:

Capacity	100 MGD
Trains	4
Stages	31
Maximum brine temperature	220 F
Economy ratio	10.3 lb water/1,000 Btu heat
Steam pressure at brine heater	25 psia
Tube bundle material (recovery and reject stages)	7/8 in. diameter 20 BWG 90-10 copper-nickel alloy

Tube bundle material (brine heaters)	1 in. diameter 18 BWG 90-10 copper-nickel alloy
Tube bundle material (reject-deaerator stage and air cooling sections in all stages)	7/8 in. diameter 20 BWG stainless steel/90-10 copper-nickel bimetallic
Chlorine consumption	140 metric tons/yr
Sulfuric acid consumption	33,000 metric tons/yr

Preliminary quotations based on performance specifications were requested and obtained from several manufacturers of desalting plants and desalting plant components. The consensus of their responses is that the industry will be in a position to contract, in accordance with the schedule requirements of this project, to supply plants on an erected basis or plant components and equipment. The cost estimates for plants supplied on an erected basis are consistent with the cost estimates contained herein (which are based upon purchase of components and equipment).

After selection of the nuclear dual-purpose plant, a fossil-fuel dual-purpose plant was studied and compared with respect to characteristics and cost. The study showed that the cost of water produced in a nuclear dual-purpose plant was lower than that produced in a fossil-fuel dual-purpose plant for all fixed charge rates through 10 percent when the desalting plant capacity was 100 MGD.

Three important conclusions were derived from the optimization studies, and from the studies of reactor types:

- The fixed charge rate has almost no effect on the selection of the technical specifications for a nuclear or fossil-fuel dual-purpose plant. The plant selected for the 7 percent fixed charge rate case will result in unit water costs, when evaluated at 5 percent and 10 percent fixed charges, no more than 1 percent higher than the water costs obtained from plants optimized for those fixed charge rates. It is therefore possible to proceed with one plant design even though the fixed charge rate may not be settled until a later date.

- The value selected for power credit has no effect on the technical specifications for a dual-purpose plant of a given power and water capacity. The "optimum" plant will still have the same

characteristics and lowest total annual cost when compared to others considered, with or without the power credit. The unit water cost will, of course, change with a change in power credit.

- The desalting plant optimized for one reactor system was found to be essentially the same as that optimized for the other reactor system. Thus the same MWe rating would be required for either a PWR or BWR except for the small difference in nuclear reactor auxiliary power requirements and the selection of the reactor type can be made as a result of competitive bidding with due allowances for normal nuclear power plant BWR-PWR differences and allowances associated with the handling of radioactive steam in the desalting plant brine heaters and steam driven auxiliaries.

Cost Estimates

The capital cost estimates are based on 1965 costs and reflect information received by personal contact in Israel with construction contractors, by detailed discussions with Israel Electric and U. S. equipment manufacturers, and by review of the extensive experience of the firms making this study. It is believed that due allowance has been made for such things as maximum practical use of Israeli products and construction participation; availability in Israel of special skills required for a plant of this nature; and items inadvertently omitted at this conceptual design stage.

The capital cost estimates include, as separate line items, the costs of the electric transmission and water conveyance facilities required to bridge the gap from the dual-purpose plant boundaries to the main Israel distribution systems. These costs have not been reviewed during this study and are included as submitted by the U. S. -Israel Joint Board.

The unit water cost estimates are based on 1965 costs with respect to the capital costs upon which the fixed charges are calculated, and the costs for operating labor, materials and power credit. Fixed charges constitute the major portion of the total annual cost of the dual-purpose plant (Table I); within the fixed charge rate, interest and sinking-fund depreciation (with it's heavy dependence on interest rate) constitute almost the entire fixed charge. For instance, with a fixed charge rate of 7 percent, interest is 4.6 percent and depreciation (30-year sinking fund basis) is 1.6 percent--the two together constituting 90 percent of the total fixed charge.

The major systems of the reference plant described herein were analyzed as to component and combined availability for full-load operation over the life of the plant. It was concluded that the nuclear steam supply would be available to supply steam to the power plant and the desalting plant 90 percent of the time, the turbine-generator would be available 89 percent of the time, and the desalting plant would be producing 85 percent of the time. From an operational point of view, it is not possible to run the power plant at full load during the whole period of its availability and power production is therefore based on an 85 percent plant operating factor. The desalting plant has an availability of 85 percent and since no such restriction applies to water, the desalting plant operating factor is also 85 percent. These plant operating factors are average for the 30-year lifetime of the plant.

Another consideration important to the unit cost of water is the effect of the seasonal seawater temperature variations on plant capacity. The performance of the plant was determined for the various seawater temperatures that could be encountered. It was found that to maintain the average capacity of the desalting plant at the design value, it would be necessary to have sufficient reactor capacity to provide for operating the brine heater at the design temperatures and pressures at all seasons. This will require operating the nuclear steam supply at 1,330 MWt instead of the normal 1,250 MWt. The stretch capability of the nuclear steam supply can accommodate this increase. The cost estimates include the cost of the required reactor and feedwater heater capacity to maintain the average capacity at the desalting plant in spite of seasonal temperature variations.

The present estimates are believed to be quite conservative since they are based on vendors' quotations and on construction experience in Israel. It is prudent, however, to examine the sensitivity of the capital and unit water costs to the major design and cost parameters. For example, one leading reactor manufacturer has recently published predictions of fuel cycle costs for the period of the 1980's and 1990's which are 35 percent lower than those shown in Table I. This decrease in fuel cycle cost would result in a decrease of 4 cents/1,000 gallons in the reference plant unit water costs. The effect on the capital and unit water costs of such variants as lower fuel cost, longer and shorter plant life, and changing other major design parameters is reported in Section XI, Effect of Variants.

The effect on unit costs of the conservative value of 220 F for the maximum brine temperature was studied. Accordingly, the reference plant design was checked for its suitability for 235 F operation and was found adequate. Data now available on scaling properties of seawater at this elevated temperature also seem to be favorable as long as the blowdown concentration ratio does not exceed 2.0. If one optimized the reference plant using a maximum brine temperature of 235 F instead of 220 F, there would be some reduction in the cost of water.

Schedule

In attaining the late 1972 commercial operation date, the dual-purpose plant construction schedule is dependent on these sequential events: start of dual-purpose plant preliminary design by May 1966; ordering the nuclear steam supply by May 1967; start operation of the test modules by January 1968; and "freezing" desalting plant design by June 1968.

It should also be noted that the schedule and cost estimate are based on a steel spherical containment building in the event there is a PWR nuclear steam supply. It is presently estimated that concrete containment design for a PWR would result in a delay of about six months in the completion of the plant. The schedule for the concrete containment may be subject to further slippage due to the critical scheduling of certain equipment items which must be installed at specific times during the concrete containment construction.

Recommended Development Program

One important basis for this study is that the reference dual-purpose plant will be an operating utility rather than a developmental type installation. Therefore either the process and component technology must be proven at the present time, or there must be reasonable assurance that whatever development work will be necessary to "prove out" those features not currently in commercial operation will be successfully concluded by the required date of June 1968 for "freezing" desalting plant design. The study has shown that the only items requiring development are part of the desalting plant. Such things as hydrodynamic and process design to obtain the vapor separation desired; and the acquisition and evaluation of oceanographic and chemical properties information on the Mediterranean seawater to be used in the selected plant comprise the principal items of the recommended development and investigative program.

The testing of a full scale module is now planned by the OSW for the San Diego Saline Water Test Facility. This will provide information on such aspects of flash evaporation design as:

- Tube bundle design.
- Evaporator hydrodynamics.
- Large pumps for recycle service.
- Special mechanical hardware.

The portion of the development program to be accomplished in Israel--the work on site oceanography and seawater chemical properties--appears to have sufficient time for orderly prosecution of the work.

Without the results of the development program the design of the reference plant would have to be more conservative than would otherwise be necessary, thereby resulting in significant capital and operating cost increases as well as longer start-up time.

Conclusion

On the basis of this study, it is concluded that a dual-purpose power-water desalting plant of 200 MWe and 100 MGD capacity for Israel is technically feasible for initial operation in 1971 and full-commercial operation by late 1972. The demand for power and low-salinity water requires a solution such as a dual-purpose plant. The conceptual design on which the cost estimates are based employs certain desalting plant process and component design criteria requiring confirmation in a development program. However, these design criteria are considered to be reasonable extrapolations from currently proven technology. It should be further noted that the scheduled 1971 plant operating date is dependent on (1) the expeditious start of the module testing program and its completion in accordance with the schedule set forth herein, and (2) the starting of preliminary design of the dual-purpose plant by May 1966.

The matter of the economic feasibility of the utilization of the quantity of water to be produced at the cost estimated for the different fixed charge rates will have to be determined.

III. WATER AND POWER RESOURCES AND REQUIREMENTS

A. Israel's Water Needs

Israel's water development is being prosecuted according to a national long-term plan which, from time-to-time, is updated. The most recent review occurred in December 1964 and was incorporated in a report "Israel Water Development Program 1965-80". The information which follows summarizes the water resources and utilization aspects of that report. The water resources of the northern half of Israel are approaching full utilization by means of an integrated system (Figure 2) which makes it possible to optimize the use of all the water resources.

1. Proven Water Resources

Israel's natural and reclaimed water resources that could be made available by 1970 are 1,400 MCM (million cubic meters) per year (1 cubic meter = 264 gallons). By 1980 the resources developed will reach 1,565 MCM per year. Water consumption by 1970 is anticipated to reach close to 90 percent of the country's natural and reclaimed water resources that could be made available by that time.

Over 50 percent of the country's proven resources are represented by groundwater found in two principal geological formations: the coastal non-consolidated sand and sandstone aquifer, and the hilly consolidated limestone and dolomite aquifer. The remaining 50 percent of the proven resources consists of spring flow, perennial and intermittent river flow and reclaimed sewage. The country possesses only one important perennial river--the Jordan.

The intermittent streams, which represent only a small part of the country's water inventory, are covered by short-term records, and "synthetic data" have to be used in evaluating the likely long-term contribution of these streams.

Man-made water resources--mainly reclaimed municipal and industrial wastes--possess the advantage of being reliable from the long-term point of view, not being affected by climatic factors, and of thus adding to the dependability of the overall estimates; their salinity, however, is relatively high.

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2. Salinity Problems

Israel's water salinity problems can be grouped under four headings as follows:

- Salinity problems that existed prior to the implementation of the Jordan Project.
- Salinity problems connected with the implementation of the Jordan Project.
- Salinity problems arising from the reclamation of sewage.
- Salinity problems of a long-range nature due to the creeping accumulation of salt in the country's groundwater.

The problems of the first group relate mainly to some of the country's groundwater and springs whose salinity is much above agricultural tolerance level, and, in some cases, above the tolerance level of municipal supplies. Many of these problems have now been solved by such means as intercepting the flow of springs before the water has a chance to pick up salt on the way to the outlet. Considerable success has been achieved by these means with respect to most major saline springs. Some of the natural brackish waters are now being used in fish ponds, but no success can be claimed yet in finding application for the remaining brackish water. Dilution and desalting by electrodialysis seem to be two other possible solutions for future utilization of these waters.

The second group of salinity problems has arisen with the recent implementation of the Jordan Project. It is significant that the Jordan water entering Lake Tiberias presents no salinity problems, and is, in fact, of very high quality, with a total dissolved solids (TDS) value of only 30 to 40 parts per million (ppm). The water is now drawn from Lake Tiberias (whose volume is about 3.5 million acre-feet), where it becomes heavily contaminated with the saline discharges of springs rising above the lake's shores and in its bottom. In 1965, the lake's water has shown a chloride ion (Cl^-) content up to 360 ppm.

The discharge of the shore springs, representing about one-half of the total discharge of salts into the lake, is now being diverted.

Attempts are also being made to control the discharge of subaqueous saline springs into the lake; however, the geohydrological situation encountered is extremely complicated, and it is still difficult to predict to what extent these saline underwater discharges can be controlled. There is much doubt whether it will be possible to prevent completely the entry of these saline discharges into the lake bottom. In the current development program, it has been assumed that only the saline shore springs will be diverted.

Since the beginning of operation of the Jordan Project, various techniques have been adopted to reduce the salinity of the water supplied by the project to a degree that can be tolerated by citrus. Groundwater is still being overdrawn for use as a diluent. Some exchanges of water with local supplies are also being effected.

The third group of salinity problems arises out of the proposed large-scale reclamation of municipal and industrial sewage. The effluent will have a TDS value which is 200 ppm higher than the original input water. Since this is not a transient phenomenon but a permanent one, adequate permanent measures must be taken to reduce the salinity of the reclaimed water before it is reused. The only solution that can now be seen is a supply of fresh water for dilution in amounts roughly equal to those of the reclaimed sewage, which points to the need for desalted seawater. The volume of reclaimed sewage is anticipated to reach about 90 MCM by 1970 and 140 MCM by 1980; similar quantities of desalted water would be required to lower the salinity of reclaimed sewage to tolerable levels. On the long-term basis, no significant reclamation of sewage is feasible without the provision of desalted seawater. The first large-scale sewage reclamation plant, with capacity to process 75 MCM per year, will be in operation by 1970.

The fourth group of salinity problems is represented by the creeping salinity rise resulting from the almost complete discontinuance of surface and subsurface outflows to the sea. The salt, which can no longer be discharged into the sea, will accumulate in the groundwater. The process has an extremely long time-lag and the effect will not be felt before the 1980's, but will thereafter become gradually more serious.

It thus appears that by the early 1970's all the country's water resources will have come into regular use, and it will thereafter

become necessary to add desalted seawater, both from the standpoint of normal growth requirements, and from the necessity of solving the salinity problems.

3. Demand Projections

a. Municipal Demand

It is assumed that population growth in the 1965-70 period will be at an annual rate of 3.7 percent, and the annual increase of per capita demand will be at a rate of 1 percent. Metering and disincentive water rates may slow the demand growth to some extent. Even at the above moderate growth rates, municipal annual demand will more than double by 1980, from 180 MCM in 1964 to about 400 MCM in 1980.

b. Industrial Demand

The forecast of industrial water consumption was based on the assumption that the prevailing water cost will remain unchanged, although some saving can be achieved by the use of dry processes and air cooling or by the use of sea or brackish water for cooling. The consumption is forecast to increase from 55 MCM in 1964 to 95 MCM in 1970 and to about 220 MCM in 1980.

c. Agricultural Demand

Of the three demand groups, agriculture is the most sensitive to water cost since water represents the most expensive single input to this branch of the economy. A study of the use of water in agriculture shows that water use in some branches of agriculture must be considered "fixed", being indispensable to the national well-being and economy. These include vegetables, fruit, and milk, as well as Israel's present export crops, notably citrus.

A second group of crops, defined as "flexible", comprise field crops (mainly industrial) which can be imported at reasonable cost and can yield only low profits when grown locally. Considerable shifts of water allocations from "flexible" to "fixed" crops are possible, and will be implemented, but there will remain a hard core of "flexible" crops that

cannot, under present circumstances be abolished. For example, the Beit She'an and Hula Valleys grow the only crops that can be grown there, though they are not indispensable. Here, and elsewhere, social and economic considerations prevent the discontinuance of the less profitable "flexible" crops.

Altogether, a very slow growth rate of agricultural water consumption is anticipated, owing to the shortage of water resources and the relatively high cost of water. Thus, between 1964 and 1970, the projected increase is from 995 MCM to 1,050 MCM per year (a growth of only 55 MCM per year over the six-year period). Between 1970 and 1980, agricultural consumption is projected to rise from about 1,050 MCM to only 1,145 MCM per year, assuming water costs do not exceed those of recently developed conventional water resources. Thus, between 1964 and 1980 the total 16-year increase in annual agricultural water supplies will be about 150 MCM. Between 1949 and 1964 the total 15-year increase in annual agricultural water supplies was 780 MCM, an amount five times greater than the 1964-1980 projections. Although the amounts of water added to existing supplies will be relatively small, it is assumed that agricultural production will nevertheless expand significantly as a result of improved overall efficiency.

The anticipated growth of water demand in Israel's municipal, industrial and agricultural sectors is shown in Table III.

4. Resources Development

To supply the requirements of the country's economy, as well as to replace existing overdrafts, and, as governed by prevailing costs, an additional amount of about 700 MCM per year will be needed in the early 1980's out of which about one-fourth will have to be used to discontinue over-exploitation of groundwater in the Coastal Plain while the remainder will be applied to new uses added after 1965.

The relatively small amount of unexploited groundwater still available for development in the north of Israel and in the desert part of the country (about 100 MCM per year) will be fully developed by 1970. Definite provisions have been made for the interception of storm run-off over the next three years; this will yield an additional 65 MCM per year.

Sewage reclamation works will have their major parts constructed between 1966 and 1970. By 1980 sewage reclamation will add about 140 MCM per year.

The Lake Tiberias-Negev Project will reach full capacity in a few years (about 320 MCM per year); the additional amount is approximately 150 MCM per year over present supply.

The Coastal Groundwater Collector--an unprecedented method of gaining water--is now to be constructed on a national scale. So far, a 3 km-run of the collector has been completed as a pilot project, and the section built is operating successfully. A start is now being made on considerable additions to the line, as the scheme is considered basically sound. This source will add about 25 MCM per year between 1965 and 1970, and another 25 MCM per year between 1970 and 1980.

TABLE III

ANTICIPATED WATER REQUIREMENTS IN ISRAEL'S MUNICIPAL, INDUSTRIAL AND AGRICULTURAL SECTORS
Million Cubic Meters (MCM)

Year	Municipal	Industrial	Agricultural	Total
1964	180	55	995	1,230
1970	255	95	1,050	1,400
1980	400	220	1,145	1,765

Reference: Israel Water Development Program 1965-1980 - December 1964

5. Anticipated Water Shortages

Table IV, on the following page, summarizes the requirements, supply, and shortage of water for 1970 and 1980.

TABLE IV

WATER REQUIREMENTS, SUPPLY AND SHORTAGE
Million Cubic Meters

Year	Water Requirements	Water Supply: Natural Resources	Water Supply: Reclaimed Sewage	Water Supply: Total	Shortage
1970	1,400	1,310	90	1,400	-
1980	1,765	1,425	140	1,565	200

From the above it is clear that after 1970 the total water requirements cannot be met from further development of water from natural resources and from reclaimed sewage.

The additional source of water on which the heaviest reliance will have to be placed is desalted seawater, of which about 200 MCM per year will be needed by 1980. Out of this quantity, 120 MCM will be required by the early 1970's.

Concurrent with the emergence of a water shortage will be serious salinity problems as a result of intensive use of all natural water resources and the increased supply of high-salinity reclaimed sewage water. To reduce salinity to acceptable levels, 100 MCM per year of very low salinity water will be required in the early 1970's to blend with the saline water sources.

The provision of this supply, together with the other additions, will make it possible to meet the anticipated needs of water of the Israeli economy and to reduce through dilution the salinity of natural and reclaimed waters to levels acceptable for agriculture. In fact, the implementation of the sewage reclamation projects, which will yield about 140 MCM per year of additional water by 1980, will be conditional on the provision of a similar quantity of desalted seawater.

The following considerations will apply for the determination of the water capacity of the proposed first desalting plant intended to solve Israel's water and salinity problems which will develop during the early 1970's.

The spacing between the proposed and any subsequent dual-purpose plant should be sufficient to allow the accumulation of operating experience on the first plant before orders have to be placed for the second plant.

A plant capacity should be chosen which would make use of significant economies in investment and operating costs resulting from size.

Assuming 1972 as the earliest possible date of operation of a large power-desalting plant, and taking four years as the time required between it and any subsequent plant, the first dual-purpose plant would have to be large enough to meet the water demand growth that will take place between 1970 and 1975, after deducting the quantity that can be derived from natural and reclaimed sources. The dual-purpose plant capacity should also be sufficient to take care of the salinity problems which will appear by 1975; i.e., mainly to provide diluent for about 120 MCM per year of reclaimed water that will be developed over the next ten years.

The final choice of the size of the plant will depend, to a certain extent, on the cost of desalted water. The capacity of 100 MGD chosen in this study constitutes the size that meets the water shortage, and at the same time solves Israel's salinity problems until the mid-1970's.

B. Israel's Power Needs

1. Past Trends

The planning, supply and sale of electric energy in Israel is almost exclusively the responsibility of the Israel Electric Corporation, Ltd. During the first ten years of existence of the State of Israel, the maximum power demand was doubling every 4-1/2 years and since then every 5-3/4 years, reaching 720 megawatts (MW) in 1965. Figure 3 represents Israel Electric's power grid.

2. Forecast of Power Demand

Israel Electric has forecasted that the maximum electric power demand will increase from 720 MW in 1965 to 1,110 MW in 1970 and 1,630 MW in 1975. This forecast is based on detailed analysis

of the expected consumption pattern of the main consumer groups up to 1970 (Table V). The forecast took into consideration the projected population growth based on estimates by the Economic Planning Authority of the Prime Minister's Office; industrial output, which was estimated by the Ministry of Commerce and Industry; and data made available by the water planning authority. This forecast (Table V), based on the foregoing information and extrapolation of previous trends, predicts that by 1970 the doubling period of the maximum demand will be eight years.

3. Generation and Unit Sizes

Electric power for the Israel transmission and distribution network is generated in three thermal power stations using heavy fuel oil. The stations are located at Haifa, Tel Aviv (Reading), and Ashdod. Unit sizes, location, and commissioning time for each unit are given in Table VI. The forecast of generating capacity based on expected demand and reserve requirement is given in Table VII.

Based on the forecasted expansion pattern, reserve requirements, production cost, and operating considerations, Israel Electric has determined that the optimum unit size for additional generating units in the beginning of the next decade lies between 175 and 200 MW net. This expansion pattern is based on detailed studies using accepted criteria for utility growth and reliability requirements.

TABLE V

FORECAST OF MAXIMUM POWER DEMAND

Year	Participation of Main Consumer Groups Maximum Demand - Megawatts				Total Maximum Demand MW	System Load Factor %
	Domestic	Commercial	Industry	Water Pumping		
1963 (Actual)	232	127	87	115	561	63.8
1964 (Actual)	252	145	111	152	660	64.6
1965	272	165	119	164	720	67.2
1966	292	185	133	170	780	67.2
1967	313	209	152	181	855	67.2
1968	334	234	180	187	935	68.4
1969	356	259	199	226	1,040	67.4
1970	375	286	216	233	1,110	68.0
1971*					1,200	67.6
1972					1,295	67.1
1973					1,400	66.5
1974					1,510	65.9
1975					1,630	65.3

*Growth rate predictions for 1971-75 range from 8 to 9 percent annual increase. The more conservative value of 8 percent is used in Table V and Table VII.

TABLE VI

GENERATING UNITS OF THE ISRAEL ELECTRIC CORPORATION, LTD.

Year of Commission	Location	Installed Capacity (Nominal) (MW)	Steam Conditions Pressure (atm.)	Steam Conditions Temperature (°C)
1935	Haifa	6	25	425
1935	Haifa	12	25	425
1936	Haifa	12	25	425
1938	Reading	12	25	425
1938	Reading	12	25	425
1948	Reading	12	25	425
1949	Haifa	30	25	425
1951	Haifa	30	25	425
1953	Reading	50	88	510
1954	Reading	50	88	510
1956	Reading	20	60	482
1957	Reading	20	60	482
1958	Ashdod	50	88	513
1958	Ashdod	50	88	513
1959	Ashdod	50	88	513
1961	Haifa	75	125	535/535
1962	Haifa	75	125	535/535
1963	Ashdod	75	125	535/535
1964	Ashdod	75	125	535/535
1966	Haifa	125	140	538/538
1967	Haifa	125	140	538/538
	TOTAL	966		

TABLE VII

FORECAST OF REQUIRED GENERATING CAPACITY
1965-73

Megawatts

Year	Estimated Maximum Demand	Reserve Required	Generating Capacity Required	Generating Capacities*
1964 (Actual)	660	75	735	740
1965 (Actual)	720	75	795	740
1966	780	140	920	880
1967	855	140	995	1,020
1968	935	140	1,075	1,020
1969	1,040	140	1,180	1,160
1970	1,110	140	1,250	1,300
1971**	1,200	200	1,400	1,500
1972**	1,295	200	1,495	1,700
1973**	1,400	200	1,600	1,700

*After allowance for maximum capability of units.

**Growth rate predictions for 1971-75 range from 8 to 9 percent annual increase. The more conservative value of 8 percent is used in Table VII and Table V.

Reference: (1) Report of United States and Israel Desalting and Power Team, October 1964

(2) Unpublished recent IEC data on reserve required.

IV. STATE-OF-THE-ART

A. Desalting State-of-the-Art

Commercial desalting plants are operating successfully in many locations including the Middle East, the Caribbean, and the United States with a total installed capacity of more than 30 million gallons per day (MGD). The installed capacity has more than doubled during the past five years. Demonstration desalting plants have been built and operated by the U. S. Department of Interior's Office of Saline Water (OSW) at Freeport, Texas; Roswell, New Mexico; Webster, South Dakota; and Pt. Loma, California (subsequently moved to Guantanamo Bay, Cuba) to test the technical and economic feasibility of various desalting processes. Much larger plants are now being studied for southern California, the Florida Keys, New York City and Long Island, and locations in Africa, Central America, and the Near and Far East.

Design of an economical evaporative desalting plant, while based on an ancient process, requires the most advanced metallurgical materials, fluid flow and solution chemistry technology. The process, components, and materials technology which make up the desalting state-of-the-art includes data and experience from the commercial desalting plants and OSW demonstration plants; the substantial body of technical data resulting from OSW-sponsored research and development; and published private industry data.

1. Distillation Process

Many distillation processes are currently under development. While each is based on purification of seawater by boiling and condensation, the arrangement of the brine and product flow paths and the configuration of the heat exchangers take many forms. These are generally cataloged as (1) flash systems where boiling is restricted to zones other than from the heat transfer surface (single stage, multiple stages and multiple-effect) and (2) other systems where the boiling takes place from the heat transfer surface (long-tube-vertical, thin film, etc.).

a. Multi-Stage Flash Process

The process most advanced in its state of development is the multi-stage flash evaporation process (MSF). In the MSF process, brine is heated in tubes under pressure without boiling, and is subsequently flashed in the open spaces of the stage enclosures below the tube bundles. Because boiling does not occur within tubes, there is less tendency to scale on the heat transfer surfaces. Multiple stages are employed to provide counter current heat transfer for good heat recovery. Recirculation of the brine is usually employed to increase the brine concentration of the blowdown with subsequent reduction in blowdown, make-up flows and seawater pretreatment cost.

There are now 10 MSF plants of over 1 MGD capacity each in operation. Nearly all of the recent and proposed commercial plants are of the MSF type. The MSF experience includes desalting plants at Guantanamo Bay, Cuba; Kuwait and Qatar on the Persian Gulf; the Virgin Islands; Shell Oil Company at Curacao; Cardon in Venezuela; Nassau in the Bahamas; Eilat in Israel and many smaller installations.

b. Once-Through vs Recirculation, Multi-Stage Flash Process

One form of the MSF systems uses the once-through rather than recirculation brine flow system. The once-through design offers some advantages in the way of pump simplification, lower concentration ratios and hence lower boiling point elevations and less tendency to scale (with the same pretreatment). Nevertheless, for every fixed charge rate and for every top temperature studied, the once-through process resulted in water costs at least 4 cents per thousand gallons higher than those of the "recirculation process" plants. The study was based on acid costing $27 per long ton, and on a cost of heat transfer surface of $2.50 per sq ft. If the cost of the heat transfer surface increment were less than $2.50 per sq ft, the advantage for recycling would be increased. The results appear to be quite conclusive that the cost of acid would have to be significantly reduced to make the once-through design economical for the reference plant.

c. Multi-Effect, Multi-Stage Flash Process

Compared to single-effect flash processes, the multi-effect, multi-stage flash process (MEMS) permits the use of higher brine temperatures without scaling. As brine temperatures are raised, one must consider that: (1) present experience in distillation plants has been limited to very short runs at a top temperature of 250 F, (2) corrosion rates generally increase, and (3) the higher temperature stages will require enclosures of high pressure design. For comparable cases of brine temperatures of 250 F and below, it was determined that the MSF process yielded lower unit water costs than the MEMS process. The MEMS process thus had increased risk and unproven performance above 250 F when compared with the MSF process.

It is recognized that there is current development work on the utilization of brine temperatures in excess of 250 F which may reduce the risk of the MLMS process. It is doubtful if the results of this work would be available, even if successful, in time to be consistent with the schedule for the reference plant.

d. Long-Tube-Vertical Process

The long-tube-vertical process (LTV) is a multiple-effect distillation process where boiling takes place on the inside of long vertical tubes. In the usual arrangement, the brine flows downward in a thin film on the inside surface of the tubes, is collected at the bottom and pumped to the next effect. The vapor generated by evaporation from this film in one effect flows to the next lower pressure effect and is condensed on the outside of the tubes in this effect. An arrangement involving a rising film has been proposed for plants of relatively low performance ratios. The long-tube-vertical process is the basis for the Freeport, Texas, demonstration plant which is being studied for future dual-purpose applications. No LTV-type commercial plants are in operation, and the process is today less advanced.

e. Thin Film and Spray Film Processes

The "thin" film and "spray" film are other applications of multiple-effect distillation plants. In the "thin" film process

the tubes are disposed vertically and the brine film is made to flow downward in a thin film on the inside tube surface. It differs from the LTV only because of its geometry; i.e., shorter tubes having fluted surfaces.

The "spray" film usually employs horizontal tubes with the brine being sprayed over the outside surface and the vapor condensed inside. Plants of this type have been produced only in very small sizes to date. They are not ready for scaling up to the capacities considered in this report.

2. Process Chosen for Reference Plant

The multi-stage flash (MSF) distillation process was chosen for the reference plant after a review of alternatives which included the multi-effect, multi-stage (MEMS) process, the long-tube-vertical (LTV) and the "thin film" and "spray film" processes. This choice was made because at the present time, the MSF is the only process in use in large commercial plants; it is in a more advanced stage of development than the others; it is well suited to a dual-purpose plant; and no other commercially proven process offers lower cost water.

The largest size of water plant train in operation or under construction using MSF is approximately 1.5 MGD. Based on studies recently made for the OSW, several U.S. manufacturers have indicated that they expect to be in a position to supply trains up to approximately 50 MGD each.

3. Developmental Requirements

Process technology in MSF has progressed to the point where units as large as those recommended in this study can be designed with confidence provided certain component and materials data are obtained in the recommended development program (Section X).

Specific component development is included in the recommended program for determining (1) stage construction and geometry, (2) means for predicting and promoting the disengaging of vapor from the flashing brine stream and (3) means for reducing carry-over of salt to the product water. Material testing of concrete

now in progress at the Bureau of Reclamation in Denver, Colorado, together with successful testing of coatings and liners are required before the concrete stage design can be finalized.

The state-of-the-art of each major MSF component is summarized below:

a. Brine Heater

The brine heater can be designed by using well-established feedwater heater technology, heat transfer coefficients and fouling factors. The arrangement of the heat transfer surface, the proposed geometry, and the fabrication methods are conventional. Tubes of copper-nickel alloy (90 percent Cu - 10 percent Ni) and steel shells are current practice.

b. Evaporator Flash Chambers

The evaporator flash chambers have been built and successfully operated for desalting plant train capacities of approximately 1.5 MGD. The module streams of the reference plant have a capacity of 6.25 MGD, four of which are combined into one train of 25 MGD capacity. The appropriate design values for flashing brine flows, the associated nonequilibrium values, the means for improving the disengaging of the vapor from the flashing brine, and the required demisting of the vapor are all areas of uncertainty. Developmental testing is required to avoid costly over-design or inadequate performance. The proposed development program provides for the required testing to reduce the uncertainties to acceptable values.

c. Evaporator Bundles

The evaporator bundles involve a number of discrete removable tube bundles of 90-10 copper-nickel alloy tubes and Cu-Ni clad tube sheets. Design of heat transfer bundles of this type are considered within the heat transfer industry's current state-of-the-art. However, it is important that a prototype heat transfer bundle be tested for proper venting.

d. Pumps

The pumps for brine recycling, blowdown and product water are similar to condensate pumps. While pumps of this size and for this type of brine service have not been built, considerable design and development work will have been completed and the results made available by the time such pumps are required to meet the construction schedule of the dual-purpose plant.

B. Nuclear State-of-the-Art

The commercial production of electric power from a nuclear energy heat source began in the United States with the start-up of the Pressurized Water Reactor (PWR) facility at Shippingport, Pennsylvania in 1957. Most commercial nuclear power plants in the United States have since utilized the pressurized water or boiling water reactor concepts although some "semiexperimental-commercial" nuclear power plants have been built using other reactor concepts. Since the start-up of the Shippingport plant, reactors have undergone continuous development, so that, at present, nuclear power plants are considered a competitive energy source. Nuclear power plants are being selected by American electrical utilities as being more economical than those using fossil fuels (oil, coal and gas) when the unit cost of fossil fuels is in excess of about 25 cents per million Btu (higher heating value) and the unit size of the generating plants exceeds 300 megawatts electrical (MWe).

1. Types of Power Reactors

The commercial United States power reactors have been either boiling water or pressurized water reactors. Other commercial reactor types such as gas-cooled reactors and heavy water reactors have been very successful in the United Kingdom, Canada, and France, but are not now being offered commercially by United States manufacturers. The reactor types which may be considered for dual-purpose power-water desalting plants are:

a. Pressurized Water Reactors (PWR)

The basic design of all PWR plants is to circulate water under high pressure past fuel elements within the reactor vessel, then through a heat exchanger or steam generator. The pressurized

coolant, having transferred heat to the secondary fluid in the steam generator is pumped back to the reactor. The secondary fluid turns to steam in the steam generator and passes to a turbine of generally conventional design, is condensed and pumped through feed water heaters back to the steam generator.

Since it is imperative to avoid flashing in the primary circuit coolant, the coolant must be at a pressure of 2,000 psi or more. Volume changes in the primary coolant are accommodated by a pressurizer or surge chamber. The pressurizer is essentially a small boiler which uses electric heating elements to maintain a constant primary loop pressure.

The number of heat transfer loops depends on the plant rating. Improvements in heat exchanger and coolant pump design have made a significant increase possible in heat transfer capacity per loop.

Some reactor manufacturers have proposed a two-loop design for the nominal 1,250 MWt required in this dual-purpose plant selected for Israel.

The PWR is inherently a stable reactor because of the physical properties of the coolant: the change in density of water with temperature results in a large negative temperature coefficient of reactivity. The fact that there is no phase change of the coolant and hence no steam voids in the core, makes the reactor control relatively simple. The reactor itself is controlled, either manually or automatically, by the negative temperature coefficient, by inserting neutron-absorbing rods, and by changing the concentration of certain soluble neutron poisons in the coolant. During normal shutdown, decay heat is removed by an auxiliary cooling system.

b. Boiling Water Reactor (BWR)

Fundamentally similar to the PWR in its use of light water as coolant and moderator, the BWR differs primarily in that boiling (i.e., net steam generation) takes place in the reactor itself. A direct cycle can be used. Early fears that radioactive steam would make turbine maintenance difficult have so far proved groundless. Steam temperatures somewhat

higher than those of the PWR are possible at reactor primary system pressures of about 1,000 psi in place of the 2,000 psi required for pressurized water reactors. This reduces the design pressure requirements and the cost of the large high-pressure reactor vessel. Boiling water reactor stability has proved excellent.

The system chosen for new large BWR plants embodies the forced-circulation, direct-cycle concept. Feed water joins circulating water at the top of the core and flows downward in the annulus between the vessel wall and the core. The coolant is then pumped to a plenum chamber at the bottom of the vessel from which it enters the reactor core. Saturated steam which is produced as the coolant passes through the reactor core is separated from the saturated liquid in steam separators and dryers, within the reactor vessel, thus eliminating the need for an external steam drum. Although one major area of BWR development presently centers on the use of integral nuclear superheat, this feature has not yet been adopted for commercial power plants.

Bottom entry control rods are an important feature of new BWR vessels. Space above the core is then free for steam separators and driers. Since scramming by gravity is no longer possible, very reliable mechanical or piston-type control rod drives are essential. The familiar reactor containment sphere can be eliminated by using pressure-suppression containment to condense any steam released and trap fission products in the unlikely event of a primary coolant system rupture.

c. Other Reactor Concepts

Other reactor concepts presently undergoing extensive development in the United States are the high-temperature gas-cooled reactor, the heavy water cooled-organic moderated reactor, and fast breeder reactors. It is doubtful that any of these reactor concepts will achieve commercial availability in time to be selected for the proposed dual-purpose plant in Israel. Other reactor types such as sodium-cooled, graphite-moderated reactors, organic-cooled-and-moderated reactors, pressurized heavy water reactors, and spectral shift reactors, which have an appreciable technological background and operational prototypes are no longer being offered commercially by American reactor manufacturers.

2. Nuclear Power Plant Capacity by 1970

Plants scheduled for operation by 1970 will bring the total U. S. capacity in nuclear power plants to over 7, 000 MWe and will include units as large as 800 MWe. The largest U. S. -built commercial nuclear power plant in operation, "SELNI", has a capacity of 240 MWe and a thermal rating of 825 MWt. The largest U. S. -built plants on order are "Dresden-2" which will have a capacity of 775 MWe, a thermal rating of 2, 350 MWt and a scheduled operation for 1969, and Indian Point-2 (Consolidated Edison Company); which will have a capacity of 873 MWe, and a thermal rating of 2, 758 MWt. Although no nuclear power plants are presently in operation whose reactor thermal rating equals that required for the proposed dual-purpose plant in Israel (1, 250 MWt), at least one water reactor power plant whose power level exceeds this value will be in operation by late 1966, and by 1970 several such plants will be in operation in the United States.

Both pressurized and boiling water nuclear power plants are now being guaranteed in capacities up to 1, 000 MWe, equivalent to a reactor thermal rating of 3, 000 MWt.

3. Vendor Capability

The major United States reactor manufacturers were requested early in 1965 to confirm the commercial availability of light water reactors for operation by 1971 as part of the proposed dual-purpose plant. Vendors were also asked if any other reactor systems might be available in time for the proposed plant.

Although "advanced" power reactor systems (other than boiling and pressurized water) are presently being developed by American manufacturers, cost and performance data for advanced nuclear power plants which could be in operation in Israel by 1971 are not currently available. The nuclear power plant cost and performance estimates included in this report are based on data supplied by several manufacturers for BWR and PWR reactors. At least one manufacturer of an advanced reactor system indicated it might be in a position to quote on the reactor system by the time proposals are invited in 1966.

C. Industry Survey

Preliminary performance specifications were prepared for the major items of equipment in the nuclear power plant and desalting plant, as well as for a complete desalting plant "package". These were sent to several leading manufacturers of desalting plants, desalting plant components and nuclear power plant equipment for preliminary quotations. The consensus of their responses is that the industry will be in a position to contract in 1967 to supply plants and equipment to meet the performance specifications required. The number of vendors responding to the request for preliminary quotations are tabulated below. In several cases where vendors made no response, they indicated a desire to respond when formal quotations were required.

Item	Vendors Contacted	Vendors Responding
Turbine Generator	2	2
PWR	3	3
BWR	2	2
Condenser Tube Bundles	20	3
Brine Heaters	20	5
Condenser Tubes	9	7
Major Pumps	16	6
Evacuation Equipment	9	5
Degassing Tower	3	2
Butterfly Valves	7	3
Check Valves	7	2
Complete Desalting Plants	5	4

The quotations on more conventional equipment such as the nuclear reactor, pumps, valves, condenser tubes and small desalting plant components had relatively little spread between vendors. It is also significant that a normalization of the quotations received from vendors of complete desalting plants showed a relatively small spread in costs; all of the normalized quotations were within 10 percent of the estimated cost of the reference desalting plant.

V. SELECTION OF REFERENCE PLANT

A. Summary

The selection of the reference plant was based on certain ground rules such as the range of salable power from 175 to 200 MWe and product water from 100 to 150 MCM per year (85-127 MGD); the credit for electric power at 5.3 mills/kwhr; fixed charge rates of 5, 7 and 10 percent; and the cost of fossil fuel at $12.85 per metric ton (39,000,000 Btu/mt lower heating value = 33¢ per million Btu) C.I.F., unloaded.

A number of desalting plant design concepts were examined using a wide range of parameters; the examination was in sufficient detail to make engineering and economic evaluations. The extensive parametric study with a computer optimization program revealed that the dual-purpose plant producing 200 MWe net salable power would result in lower cost water than a plant producing any lower salable power. The study further revealed that the unit cost of water is only slightly sensitive to desalting plant capacity within the range studied; therefore, it became possible to select the desalting plant capacity with greater regard for Israel's water needs. The capacity selected for the reference plant is 200 MWe (net salable) electric power and 100 MGD of desalted water.

The plant operating factor was then determined, and this, in turn, fixed the total number of kilowatt-hours of power and cubic meters of water produced annually. Under these conditions, the optimum dual-purpose plant design, i.e., the one that has the lowest unit cost of water, is also the one which has the lowest total annual cost. The value of the power credit (mills/kilowatt-hour) will not affect the selection of the optimum plant, since it represents a fixed revenue credit applied to all plant designs. The optimum plant design is thus, the one having the lowest annual cost (for a given output) exclusive of the fixed or "constant" power credit.

After a conservative value of 220 F was selected for the maximum brine temperature, computer optimizations of alternative dual-purpose plants were analyzed, each optimized for the three fixed charge rates of 5, 7, and 10 percent. It was possible to select plant design parameters optimized for the 7 percent fixed charge

rate as the basis for the reference plant for all three fixed charge rates for the purposes of this study, since the design parameters for the optimized 5 percent, and 10 percent cases were within a few percent of those for the 7 percent case. For the ranges of power and water production studied, the analysis showed that a nuclear-fueled power plant would yield cheaper unit water cost than a fossil-fueled power plant.

B. Study Ground Rules and Basic Data

This study of dual-purpose electric power-water desalting plants being focused on Israel's needs, desalting and nuclear states-of-the-art, and prevailing economic factors, was based on the following:

1. The range of net salable electric power is 175-200 megawatts.

2. The range of the desalting plant capacity is 100-150 million cubic meters (MCM) per year.

3. The dual-purpose plant will be ready for full commercial operation by 1972.

4. Israel will own the nuclear fuel, with appropriate payment for U.S. toll enrichment, reprocessing and credit for plutonium.

5. The credit for salable power is 5.3 mills per kwhr which represents Israel Electric Corporation's estimate of the cost of producing power in the most economical single-purpose plant in the range of the study.

6. The cost of fossil fuel is $12.85 per metric ton, C.I.F. unloaded, (39,000,000 Btu per metric ton, lower heating value).

7. The annual cost for the reference plant will be determined for 5 percent, 7 percent and 10 percent fixed charge rates. These fixed charge rates include interest, 30-year sinking fund depreciation, normal insurance, and costs in lieu of local taxes. They do not include interim replacement, nuclear rider on property insurance, or nuclear liability insurance; all of which are included in operating costs.

8. Neither capital nor annual costs include general Israeli taxes or customs duties.

9. Estimates for the reactor, turbogenerator and major equipment for the desalting plant are to be obtained from U. S. manufacturers.

10. Local Israeli materials and equipment will be used where it is practical to do so.

11. Analysis of Mediterranean seawater is shown in Table VIII which follows.

C. Method of Approach

The method of approach used in conducting the feasibility study of a dual-purpose electric power - water desalting plant in the capacity range of 175 to 200 megawatts of salable electric power and 100 to 150 million cubic meters per year of freshwater involved the following steps:

1. From among the many alternates studied, choose the reference plant which will result in the lowest cost water consistent with the power and water needs of Israel.

2. Determine the engineering and economic feasibility of this dual-purpose plant for Israel, such plant to be ready for start-up in 1971 and for commercial operation by mid-1972.

3. Recommend a development program which will reduce the risk and minimize over-design of the plant.

4. Refine the capital cost, unit water cost and performance estimates of the dual-purpose plant.

Drawings and a detailed description of the reference plant were prepared. Where major alternatives such as selection of a single reactor type have yet to be determined, the alternatives were studied in equal depth.

TABLE VIII

ANALYSIS OF MEDITERRANEAN SEAWATER

	Mediterranean Seawater(1)		Normal Seawater(2)
	ppm	millieq/million	ppm
Fluoride (F^-)	1.5	0.08	1.3
Chloride (Cl^-)	21,200	597.0	19,360.5
Bromide (Br^-)	72*	0.90*	65.9
Sulfate (SO_4^{--})	2,950	60.1	2,701.7
Nitrate (NO_3^-)	0.2	.00	
Bicarbonate (HCO_3^-)	154.6	2.54	142.5
Calcium (Ca^{++})	423	21.2	408.1
Magnesium (Mg^{++})	1,403	115.2	1,297.5
Potassium (K^+)	463	11.9	387.6
Sodium (Na^+)	11,800	512.3	10,767.8
Metasilicic Acid	1.0	0.0	0.02 to 4.0
Others			
Total dissolved solids	38,600		35,174.5
Chlorosity (gm/liter)	21.75		19.862
Alkalinity (mg/liter)	129.8		119.8
Hardness (PPM)	6,830		
Density at 20 C	1.027		1.0248

*Estimated

(1) Mekorot Water Company, Ltd.
(2) Critical Review of Literature on Formation and Prevention of Scale, by W. L. Badger and Associates, Inc. Office of Saline Water, Report No. 25

D. Nuclear Power Plant

1. Survey of Nuclear Reactors

Early in 1965, a study was performed to determine the availability from American manufacturers, of nuclear power reactors within the range of 1,000 to 2,000 MWt which would be proven in utility operation and be available for commercial operation in Israel by 1971. This study was performed through review of the technical literature, discussions with the technical staff of the United States Atomic Energy Commission, and personal contacts with all of the U.S. manufacturers of commercial power reactors. Reactor concepts considered included light water reactors (pressurized and boiling), organic-cooled/D_2O-moderated reactors, sodium-graphite reactors, fast breeders, and high temperature gas-cooled reactors.

Only the manufacturers of pressurized water (PWR) and boiling water (BWR) reactor types indicated that their reactors would be available commercially and were able to supply current and forecasted operating characteristics and cost data. Moreover, the ratio of the power-to-water requirements for this dual-purpose operation is particularly well suited to the steam conditions available from water reactors. Accordingly, further considerations of the nuclear power plant concept were limited to the PWR and BWR designs.

Commercial production of electric power from a nuclear energy heat source is a proven operation in plants using boiling and pressurized water reactors almost as large as that required for the proposed Israel dual-purpose plant. Similar nuclear plants now being constructed or on order by U.S. utilities, under firm guarantees as to output and costs, are larger than the contemplated Israel plant.

2. Consideration of Power Plant Cycles

A study was performed to determine the annual cost of heat supplied to the desalting plant as a function of the quantity of heat supplied, gross power generation, and turbine exhaust pressure. The annual cost of heat supplied to the desalting plant was defined as the difference between the total annual costs (including fixed charges) of the power plant and the annual power credit.

The BWR and PWR reactor operating characteristics as supplied by the manufacturers were used in preparing a number of power plant heat balances. In each cycle the turbine exhaust was condensed in the desalting plant brine heater and returned to the power plant cycle at the saturation temperature.

In addition to the turbine exhaust steam available to the brine heater, provision was made in each cycle to supply steam to the brine heater through a turbine bypass and pressure-reducing station. Such a bypass will be required to operate the water plant when the turbine is not in service or is operating at reduced load, or during other occasions when the desalting plant steam demand exceeds the turbine exhaust flow. By varying the quantity of steam bypassed, it is possible to change the quantity of heat delivered to the water plant independently of the gross power generation and the turbine exhaust pressure. Provision is also made for operating the turbine generator at full power output when the water plant is shut down by supplying raw seawater to the brine heaters through an emergency supply line.

An evaluation of preliminary cost estimates received from water reactor manufacturers indicated no significant differences in nuclear power plant capital, operating and maintenance and fuel cycle costs between pressurized water and boiling water reactors of the same thermal output. Since there was also no significant difference in the required reactor thermal output (MWt) between the two reactor systems for the same gross power generation and heat supplied to the brine heater, the total annual costs of a power plant using one reactor type would also represent the costs using the other reactor type.

3. Selection of Nuclear Plant

A function was developed relating (a) the total annual cost of a nuclear power plant producing 175 to 200 MW salable electric power and the required allowance for electric plant and desalting plant power, (b) various amounts of steam to the desalting plant, and (c) varying turbine exhaust pressures. This function was used in the dual-purpose plant optimizations.

As a result of these optimization studies the nuclear power plant portion of the selected dual-purpose plant was found to consist of a pressurized water or boiling water reactor with a thermal rating of approximately 1,250 MWt supplying steam to a 250 MWe (gross) turbine generator (resulting in 200 MW net salable electric power) supplying turbine exhaust steam to the brine heater.

A preliminary evaluation was prepared on the effect of the choice between a PWR and a BWR on the desalting plant design. As a result of the different steam conditions used in the two reactor concepts, the optimum dual-purpose plant using a BWR would have a desalting plant with a slightly higher economy ratio than one using a PWR However, the steam exhausted from the turbine generator (at a constant net salable power) can be varied sufficiently by changing the final feedwater temperature and/or bypassing steam, so that the desalting plant optimized for one reactor type can be used with the other. Moreover, in such an event the resulting unit water cost will be less than one percent greater than the unit water cost for the optimum desalting plant design for that reactor concept. Consequently, the desalting plant studies, design and development can proceed without concern as to the particular reactor type ultimately selected.

E. Desalting Plant

The selection of the reference desalting plant results from selection of the reference dual-purpose plant.

1. Method of Selecting Reference Dual-Purpose Plant

The determination of the reference plant was accomplished by analysis of computer "optimizations" of alternative dual-purpose plants. Optimization is defined as the determination of the plant which produces the lowest cost water within the ground rules set forth.

To accomplish the optimization, a computer program was prepared. This program was used to calculate the requirements of the principal items of equipment in the desalting plant, calculate the investment costs and operating costs of the desalting plant and calculate the total annual cost of water. The input data used in the program include: an expression which describes the cost of heat supplied from the nuclear power plant to the desalting plant as a function of steam quantity and pressure; the cost of desalting plant materials, components and chemicals; and the factors such as fixed charge rate and interest during construction for developing the total investment cost and annual operating cost of the desalting plant. The number of stages and the terminal temperature difference values are varied in a preset pattern

by the computer which then calculates the total capital cost and the total annual cost of water for each set of values. The computer selects as optimum that design which produces the lowest total annual cost of water.

A procedure was selected for distributing the total annual cost (fixed charges, operating and maintenance costs, and fuel costs) between the electric power plant and the water desalting plant. The cost of heat used as input to the desalting plant computer program was obtained by subtracting the annual gross power (at 5.3 mills/kwhr) from the total annual cost of the power plant (fixed changes, fuel, operating and maintenance costs).

After choosing an optimum plant, the computer prints a set of design data for the plant. The design data include the temperatures, pressure, flows, concentrations and heat transfer coefficients in each stage and in the brine heater. The computer then lists the brine velocity, the tube diameter and thickness, tube length, number of tubes, and total tube weight in each stage and in the brine heater. Also listed are the pressure drops in each section and in the brine heater, as well as the total recycle-brine pump head. The computer printout of design data for the reference plant is shown on pages 61-67.

In the course of determining the reference plant, more than one thousand sets of plant variables were examined. It should be noted that once the optimization program was used to determine the dual-purpose plant yielding the lowest cost water consistent with the water needs of Israel, the detailed estimate of cost for this selected plant was based on preliminary design layouts which included all essential plant components.

A number of nuclear and desalting plant designs were prepared as a basis for engineering and economic evaluations. Sufficient detail was developed to estimate the cost of both the nuclear plant and the desalting plant and to locate areas of uncertainty in the water plant so that an investigational program to test concepts important to the economic design and operation of the plant could be recommended.

2. Bases for Selecting Reference Dual-Purpose Plant

The selection of the reference plant was based on the future water and power needs of Israel, the technical requirements and the cost of meeting these needs by a nuclear fueled dual-purpose plant, and the cost of providing for these needs by an alternate energy source.

a. Determination of the Capacity of the Reference Dual-Purpose Plant

The effect of the dual-purpose plant capacity for both power and desalted water production on the unit cost of water was investigated by means of a parametric study with the computer optimization program previously described. The results of the parametric study indicate that at 200 MWe net salable power, the optimum desalting capacity is different for each fixed charge rate. For example, at 220 F maximum brine temperature the optimum capacities at the three fixed charge rates are:

5 percent	below 85 MGD
7 percent	approximately 85 MGD
10 percent	above 125 MGD

One of the most important findings in this study was: for any given combination of maximum brine temperature and fixed charge rate, the cost of water is only slightly sensitive to water plant capacity. For example, at 7 percent fixed charge rate and 220 F, maximum brine temperature, as the desalting plant capacity was varied from 85 to 125 MGD (approximately 100 to 150 MCM/yr at 85 percent plant operating factor), the maximum variation in unit water cost was about 1.5 cents per 1,000 gallons, or less than 5 percent of the total unit cost of water.

Equivalent studies with only 175 MWe net salable power indicate appreciably higher water costs in every case studied; e.g, for 100 MGD and 7 percent fixed charge rate, the difference in water cost was about 3 cents per 1,000 gallons.

Other criteria for establishing the capacity of the reference plant are the future water and power needs of Israel. As described in Section III, these are based on analysis of existing data and future developments made by Water Planning for Israel, Ltd., (Tahal) and the Israel Electric Corporation.

The forecast of water and power requirements took into consideration: (1) the projected population growth based on estimates by the Economic Planning Authority of the Prime Minister's Office; (2) municipal, industrial and agricultural requirements estimated by the appropriate Israel Ministries; and (3) requirements of low salinity water for blending.

The analysis shows that an additional annual water supply of approximately 120 MCM (100 MGD at 85 percent plant operating factor) of low-salinity water will be needed to meet the requirements of the Israel economy in the early 1970's. This analysis also shows that, to realize the economy of a large-scale plant, a power unit of at least 200 MWe net salable power should be coupled to the desalting plant. The analysis of the Israel power system shows that a unit of 200 MWe net salable power capacity can be accommodated on the system and that the power generated by this unit represents less than two years' growth of the system at time of installation.

Since the Israel power system can accommodate a power unit of 200 MWe (net salable) and this capacity showed a clear advantage over 175 MWe, 200 MWe was selected as the net salable power capacity of the reference plant. For water plant capacity, there was no value within the range of interest that showed a similar clear advantage. Accordingly, Israel's water needs were used as the governing criteria and a plant of 100 MGD (producing about 120 MCM/year at 85 percent plant operating factor) was selected.

b. Determination of the Desalting Plant Technical Requirements

Having selected the capacities of the reference plant at 200 MWe net salable power and 100 MGD water production, it was necessary to establish values for the other desalting plant parameters in order to prepare conceptual designs and cost estimates for the reference plant. For instance, with respect to the maximum brine temperature, the conceptual design is based on a conservative value of 220 F, which was originally believed to be the maximum practical value for the reference plant. A study of the effect of the maximum brine temperature showed a possible advantage in raising this temperature to 235 F. Data presently available on scaling properties of Mediterranean

seawater at this elevated temperature also seem to be favorable as long as the blowdown concentration ratio does not exceed 2.0. The scale forming properties of Mediterranean seawater at 235 F are about the same as normal seawater at 250 F, because of the higher concentration of Mediterranean seawater salts, for equivalent blowdown concentration ratios. The 250 F value is generally considered the maximum "safe" value for MSF plants operating on normal seawater. Whether the plant ultimately constructed in Israel is based on a maximum of 220 F or 235 F will depend upon cost and other data that will be developed prior to finalizing the design.

For the selected capacities and maximum brine temperature, additional computer optimization studies were performed using relatively small incremental steps for the number of stages and terminal temperature differenc . Table IX lists certain parameters, such as terminal temperature difference, number of stages and economy ratios which were determined to be optimum by this procedure.

It will be noted from Table IX that optimum conditions are different for each fixed charge rate. Since the fixed charge rate for the final plant installation cannot be established at this time, and it was desirable to select "one" plant for preliminary design layout and costing, a particular value for the terminal temperature difference and number of stages was selected such that the "off-optimum penalty" for unit water cost will be a minimum over the fixed charge range of 5 to 10 percent. Because the "penalty" for a "one plant" selection, rather than a plant for each of the three fixed charge rates, is so small, it is practical to estimate costs for one plant only.

From an analysis of the various plant variables, it was indicated that for fixed charge rates in the range of 5 percent to about 8.5 percent, the plant having 31 stages and a terminal temperature difference (TTD) of 4.5 F would give the lowest penalty. Considering that the fixed charge rate will most probably be within this range, the reference 100 MGD plant was based on 31 stages, and a TTD of 4.5 F.

TABLE IX

OPTIMUM CONDITIONS FOR A 100 MGD PLANT CAPACITY AT 200 MWe NET SALABLE POWER

Basis:	Power Source	Nuclear
	Maximum Brine Temperature	220 F
	Steam Temperature	240 F
	Net Salable Power	200 MWe
	Desalting Plant Capacity	100 MGD
	Concentration Ratio	2.0
	Tube Velocity	6 fps

FIXED CHARGE RATE, %	5	7	10
Optimum Conditions			
1. TTD, F	4.6	4.5	4.7
2. Number of Stages*	32	31	29
3. Economy Ratio, lb/1,000 Btu Steam	10.4	10.3	9.9

*Includes 3 heat rejection stages.

Since the result showing the optimum plant design to be almost independent of fixed charge rate is unusual for desalting plants, a brief explanation is warranted.

When both desalted water and power output are fixed at the selected values, for a particular brine heater outlet temperature, the optimum desalting plant economy ratio shows but little variation with wide changes in fixed charge rate. This results from the fact that as the economy ratio increases, the capital cost of the desalting plant increases, but the nuclear-boiler cost decreases appreciably.

For any given brine heater outlet temperature, economy ratio and water output, it is possible to vary desalting plant design by changing the number of stages, terminal temperature difference, heat transfer surface and brine velocity in the tubes. However, near the optimum design, changes in any one variable tend to be offset by the resulting changes in others. This, in turn, means that the specific features of a nuclear-fueled dual-purpose plant optimized for one fixed charge rate will not be greatly different from the corresponding features for the optimum plants designed for other fixed charge rates. As a result, for purposes of this study, it is possible to employ a plant optimized for one fixed charge rate at either of the other two fixed charge rates with only a small cost penalty compared to the optimum plant for each rate.

F. Cost of Providing Water From an Alternate Energy Source (Fossil-Fuel Dual-Purpose Plant)

Several fossil-fuel dual-purpose plants were studied and compared with the selected nuclear dual-purpose plant. A dual-purpose plant using a nuclear (light water reactor) steam source well satisfies the power-water ratio established by Israel's power and water needs (175 to 200 MWe and 85 to 125 MGD, respectively). The exhaust steam from a back-pressure turbine furnishes the steam requirements of a desalting plant at reasonable economy ratios (lb product water/1,000 Btu steam used) and currently acceptable maximum brine temperatures. Fossil-fuel power plants using normal steam conditions have much less turbine exhaust than nuclear-fuel plants for the same power output. Consequently, to produce the required

ratio of power and water in a fossil-fuel dual-purpose plant, it is necessary either (1) to use a water plant with a higher economy ratio than that required for a nuclear plant or (2) suffer the economic penalty of bypassed boiler steam.

The study was made for fossil-fuel power plants of 250 MWe gross electrical (approximately 200 MWe net salable power) and 85 and 100 MGD water production for the following three steam cycles:

900 psig at 800 F

1,450 psig at 900 F

2,400 psig at 1,000/1,000 F, reheat

Heat balances were computed, and capital and annual operating cost estimates were prepared for each cycle. The conclusions were:

1. Only the 900 psig, 800 F cycle exhausted sufficient steam to produce 85 to 100 MGD in a water plant with an economy ratio readily attainable under the current state-of-the-art.

2. The cost of water produced in a 100 MGD fossil-fuel dual-purpose plant using this cycle was higher than the cost of water produced in a nuclear-fuel dual-purpose plant at all fixed charge rates studied.

3. Other fossil-fuel cycles would result in still higher unit costs of water.

4. In order to make fossil fuel competitive with nuclear fuel for the proposed plant, a reduction in the cost of fossil fuel would be needed. For a 7 percent fixed charge rate, a reduction in the cost of fossil fuel of 10¢/million Btu from the current cost of approximately 33¢/million Btu would be required to have fossil-fueled and nuclear-fueled plants result in equal unit water costs. The fossil-fuel cost (¢/million Btu) required to result in a unit water cost equal to that of a nuclear-fueled dual-purpose plant decreases as the fixed charge rate decreases; hence, a greater reduction in fossil-fuel cost will be required at 5 percent fixed charges to make it competitive with nuclear fuel.

VI. REFERENCE PLANT

A. Summary

The reference plant is a dual-purpose 200 MWe (salable) nuclear power - 118 MCM/yr (100 MGD) desalting plant. The preferred location is a graded site at Nitzanim, about 9 km south of Ashdod and adjacent to the seashore (Figure 4). The plant consists of a nuclear reactor and turbine generator, four multi-stage flash evaporator trains, and associated structures and equipment arranged as shown in the Dual-Purpose Plant Plot Plan (Figure 5) and Desalting Plant Plot Plan (Figure 6).

The desalting plant flash evaporator trains are each capable of operating independently; each train is further divided into four 6.25 MGD module streams.

The major equipment of the desalting plant includes the evaporator structures, the brine heaters, air ejectors, gantry crane, and the recycle, make-up, product, and blowdown pumps. The evaporator structures consist of the heat recovery stages, heat reject and heat reject-deaerator stages. The structures are field erected, arch-shaped reinforced concrete or steel enclosures within which are located the removable tube bundles, product water trays and flashing brine channel.

The characteristics of the reference desalting plant are as follows:

Capacity	100 MGD
Trains	4
Module streams/train	4
Number of stages	31
Maximum brine temperature	220 F
Economy ratio	10.3 lb water/1,000 Btu heat
Concentration ratio	2.0
Tube materials:	
Brine heater	1 in. diameter, 18 BWG, 90-10 Cu-Ni alloy
1st and 2nd Stages (heat recovery)	7/8 in. diameter, 18 BWG, 90-10 Cu-Ni alloy, except air cooling section which contains 150 - 7/8 in. diameter, 20 BWG, stainless steel/90-10 Cu-Ni bimetallic or equal

3rd thru 28th Stages (heat recovery) and 29th and 30th Stages (heat reject)	7/8 in. diameter, 20 BWG, 90-10 Cu-Ni alloy, except air cooling section which contains 150-7/8 in. diameter, 20 BWG, stainless steel/90-10 Cu-Ni bimetallic or equal
31st Stage (heat reject-deaerator)	7/8 in. diameter, 20 BWG, stainless steel/90-10 Cu-Ni bimetallic or equal
Chlorine consumption	140 metric tons/yr
Sulfuric acid consumption	33,000 metric tons/yr

A survey was made of all contending United States reactor manufacturers to determine those which could supply reactors for commercial operation in 1971. Only the boiling water reactor (BWR) and pressurized water reactor (PWR) manufacturers indicated that their reactors would be available on a commercial basis in 1971, and that they could supply operating characteristics and cost data now. Moreover, the ratios of power-to-water requirements for this plant are particularly well-suited to the steam conditions of light water reactors as compared with, say, high temperature gas cooled reactors; hence, further study was limited to BWR and PWR designs.

Estimates of cost and performance of several PWR and BWR nuclear plants at several thermal capacities were obtained from manufacturers and used as basis for the study. It was found that the annual cost, capital cost, and the cost of heat to the desalting plant were all essentially the same for the BWR and PWR nuclear plants of the same capacity. The selected nuclear plant includes a 1,250 MWt light-water reactor with a 250 MWe (200 MWe salable) turbine-generator exhausting to the brine heater of the desalting plant at 25 psia.

A study was made of the plant operating factor by assigning reasonable availability factors to the plant components. This study disclosed that the desalting plant operating factor will be 85 percent with the reference design.

The plant has the capability of being able to operate the reactor-turbine-generator combination when the water plant is shut down, and of being able to operate the reactor-water plant combination when the turbine-generator is shut down.

The overall plant occupies approximately 40 acres (160 dunams). The main Tel Aviv-Ashkelon railroad and adjacent highway are approximately three kilometers from the plant site. The plant would contain a warehouse and central repair shop. The multiple seawater intake structure would be located 450 meters offshore in seven meters of water depth. The outfall facility would consist of a buried concrete box culvert with transition to an open channel beyond the desalting plant limits; recirculation problems will require investigation.

The conceptual design of the reference plant employs certain desalting plant process and component design criteria considered to be reasonable extrapolations from current proven technology, but which should be confirmed in a developmental program. It should be noted that the scheduled 1971 initial operating date is dependent on the expeditious start of the module testing program and its completion in accordance with the schedule set forth in Section X, Recommended Development Program.

B. Site Evaluation

1. Description of Proposed Sites

Two sites proposed by the Israel Government were inspected and compared with respect to accessibility, site preparation, general construction costs and nuclear hazards. These sites are shown in Figure 4.

a. Site No. 1 - Nahal Soreq (Neve Rubin)

This site is a strip of the Mediterranean seashore, about 10 km north of .' shdod, west of the small town of Yavne. The site is part of a sand dune belt which extends from Tel Aviv in the north to Gaza in the south. The dune belt's average width near Site No. 1 is about 5 km. East of the dunes the fertile plains with many villages and small towns extend to the Judean Hills.

The area within a radius of 4 km from the plant site is unpopulated and uncultivated. The town of Yavne with its industrial suburb is situated some 4 km to the east of the site. The majority of the population within a radius of 6 km are agricultural workers, although some small industrial plants

are located 5 km from the site. The Israel Atomic Energy Commission's Soreq Nuclear Research Center, which includes a pool-type reactor and laboratories, is 1 km east of the site. There is a paved road to the site in a westerly direction from the main north-south highway near Yavne. A second paved road in a south-west direction leads from Rishon-Le Zion to Kibbutz Palmachim north of the site. A second-grade truck road runs along the shore from Palmachim to the site.

b. Site No. II - Nitzanim

Site No. II is on the seashore in the vicinity of Kibbutz Nitzanim. It is about 9 km south of Ashdod and similar in appearance and terrain to Site No. I. The Evtah Wadi forms the northern boundary of the site. The dune belt along the shore has a width of 2 to 3 km and is composed of a series of parallel ridges running parallel to the shore. The maximum height of the ridges is about 40 m above sea level. East of the dune belt is the cultivated coastal plain.

Within a radius of 4 km are the youth village of Nitzanim, the ruins of an abandoned British military camp and some cultivated fields. Some sandstone quarries are less than 1 km from the site. The Tel Aviv-Ashkelon Highway and a railroad running parallel to the shore are approximately 4 km from the shore. A paved road starts from the main highway, crosses the old British camp, and stops at a quarry approximately 1 km from the seashore.

2. Preliminary Site Evaluation

A preliminary site evaluation has been made of the two locations. This evaluation considered climate, topography, foundation conditions, oceanography, transportation, communications, and the availability of construction labor to each site. The nuclear hazard is treated as a separate subject in paragraph 3. The evaluation is based on a visual inspection of the two sites, conversations with Israeli personnel, and upon the data submitted by the staff of the Israel Joint Seawater Desalting Project in response to Kaiser Engineers' questionnaire.

It is concluded from this evaluation that both sites are essentially equally suitable for the construction of the proposed project.

This conclusion is related to the close proximity of the two sites and the fact that they generally share the same conditions of physical environment. In addition, major service facilities are common to both sites.

Particular attention has been given to foundation conditions to the extent that information is currently available. Available information at the Ashdod power plant, located between the two sites, has also been reviewed. It is assumed that spread footings will be suitable for both sites, and for preliminary studies an allowable bearing of 4,000 lb per sq ft (2.0 kg/sq cm) appears reasonable. Should a higher bearing value of 6,000 lb per sq ft prove possible, it would permit a small reduction in the plant cost.

Groundwater conditions and related problems during construction are also considered to be similar for both sites.

It is apparent that final selection between the two sites would be based on criteria other than the general site conditions described herein. Prior to final definition of site limits and plant orientation, further subsurface information should be obtained from test holes and related laboratory tests.

3. Comparison of Nuclear Hazards

A preliminary nuclear hazards comparison was made of the two proposed sites. This comparison was based partially on the procedures used for United States site evaluations (10 CFR 100 and TID-14844, "Calculation of Distance Factors for Power and Test Reactor Sites") as well as data and criteria supplied by Israel.

The following key assumptions were used to compute the whole body dose due to direct gamma radiation and the thyroid dose due to inhalation for exposures (after a maximum credible accident) of 2 hours and 3 days respectively:

• Reactor power	- 1500 MW (thermal)
• Containment building leakage rate	- 0.1%/day
• Fission product release to containment building	- 100% of noble gases - 50% of halogens (1/2 of which are subsequently adsorbed on building surfaces) - 1% of solids

- Meteorological conditions

Sutton Parameters	Inversion	Lapse
n	0.50	0.25
Cy	0.40	0.40
Cz	0.05	0.40
u (m/sec)	2.00	5.00

In our opinion, the above assumptions are fairly conservative in that they will result in an overestimate of the population exposure in the unlikely event of a maximum credible accident. However, the results can be used for comparison of the two proposed sites.

Based on the above assumptions and our analysis, the following conclusions have been reached:

- To make either site acceptable from a hazards standpoint, one or more "engineered safeguards" will be required. The design and cost of whatever engineered safeguards are adopted will be the same at either site. The "engineered safeguards" for a light water reactor are described in subsection D of this section and included in the cost estimates.

- If the southward expansion of Ashdod to within five km of Nitzanim occurs as planned, Site I (Nahal Soreq) is preferable from a hazards point of view. If the future expansion of Ashdod is not realized, or if the expansion takes place in a northward or eastward direction, then both sites would be equidistant from Ashdod. In this event the Nitzanim site would be preferred because of the presence of fewer population centers downwind of the prevailing sea breezes.

The U.S.-Israel Joint Board, having reviewed the above conclusions, indicated that Site II, at Nitzanim, is the preferred site.

C. Desalting Plant

1. Process Description

a. General

The reference desalting plant is based on the multi-stage flash evaporation process. This is a process wherein seawater is

heated as it flows within tubes under pressure and then allowed to flow into lower pressure chambers where portions of the brine stream flash. The flashed portion is condensed and becomes the product water. The unflashed brine is recycled after a portion is removed as blowdown and fresh seawater added as make-up water. The heating occurs without boiling, and this reduces the tendency for the brine to deposit scale on the tube surfaces.

The multi-stage flash evaporation process is regenerative in that the latent heat in the vapor leaving the flashing brine is transferred to the recycle brine flowing inside the same heat transfer tubes on which the vapor is condensed. The flow of the two liquid streams (recycle brine and flashing brine) is counter-current and the temperature difference between the vapor and the recycle brine is maintained by dividing the flow path into stages. In each stage, a pressure (and the corresponding equilibrium temperature) is established as a function of flashing brine temperature and the flow of heat in the condensing vapor. To make the flashing brine temperature range large, the brine is heated to as high a temperature as may be consistent with scaling and economic considerations; and it is flashed down to the lowest temperature consistent with the temperature of available cooling water. To compensate for heat lost by radiation and irreversible processes to the cooling water (heat sink), blowdown and product water, heat is added to the recycle brine in the brine heater by condensing steam from the backpressure turbine in the power generation part of the dual-purpose plant.

b. Flow

The process flow diagram is shown in Figure 7 and the engineering flow sheets (piping and instrument diagrams) are shown in Figures 8 through 10. Piping details of the brine heater and pump areas are shown in Figures 11 and 12. As shown in the flow diagram, seawater entering the intake is screened to remove trash. To discourage marine growth it is chlorinated for 30 minutes during each three-hour interval. During chlorination, chlorine is injected at the rate of 0.85 ppm Cl_2 (4 lb/min). One portion of this water is pumped to back-wash the screens. A second portion is taken by the heat reject pumps to provide water for heat removal in the heat

reject stages, and, through booster pumps, for heat removal in the condensers of the steam ejector vacuum system. The third and final portion of the seawater is taken for make-up by the seawater make-up pumps and is pumped to the CO_2 degassing tower. En route to the degassing tower, 140 parts of sulfuric acid (95% concentration) is added to each 1,000,000 parts of the make-up water for acidification. The sulfuric acid breaks down the bicarbonates and releases CO_2. Part of the CO_2 is released in the degassing tower which is open to the atmosphere. The water then passes through one of the four deaerators and other heat reject stages of each train in a path parallel to that taken by the above mentioned second portion by means of the vacuum maintained therein. Throughout this description, the lowest pressure heat reject stage is the deaerator. The passage through the heat transfer bundles in the deaerator and other heat reject stages raises the temperature of the make-up water about 12 F by condensation of vapor from the flashing brine on the outside of the tubes. The make-up water is then sprayed into the chamber section of the deaerating heat reject stage where most of the balance of the CO_2 and other noncondensables (plus some water vapor) are released It is in this chamber that the make-up water joins the brine recycle stream.

The major heat rejection by the brine recycle stream in the chamber sections of the heat reject stages is effected by pumping untreated seawater directly through the heat transfer bundles in three of the four deaerator and other heat reject stages of each train and discarding this water directly to the effluent canal which empties into the sea.

The flashing brine reaches its lowest temperature and maximum concentration of solids in the deaerator stage. Part of this brine is pumped to the effluent canal as blowdown, the streams being arranged to prevent mixing the make-up water with the blowdown. The balance of the brine, combined with the degasified make-up water, is pumped by the recycle pump through the tube bundles of the heat recovery sections of the evaporator. The recycle brine stream in the tubes is heated by vapor from the flashing brine of successively higher temperature stages condensing on the tubes. After leaving the highest pressure stage (Stage No. 1), the brine recycle stream enters the tube bundles of the brine heater where the brine

reaches its highest temperature from condensation of exhaust steam from the back-pressure turbine, supplemented when necessary by steam bypassing the turbine. The steam condensate from the brine heater is returned by pump to the power plant, along with part of the condensate from the vacuum system. By means of an adjustable throttling valve in the brine stream between the brine heater and Stage No. 1, pressure is maintained on the brine in the brine heater bundles to prevent premature flashing which could lead to scale formation.

From the brine heater tubes, the brine recycle stream enters the Stage No. 1 evaporator open brine channel where flashing takes place because of the lower pressure therein. The vapor flashed condenses on the tubes of Stage No. 1 tube bundles and is collected as product water in troughs underneath the tube bundles. The brine and product water pass through pressure seals in their respective channels and troughs into Stage No. 2 where flashing takes place to the lower pressure existing in that stage. Fixed restrictions act as seals to permit establishment of pressure differentials between adjacent stages. Additional product water collects in the trough in Stage No. 2 as a result of further flashing of the brine stream and condensation of this flashed vapor; the constantly increasing flow proceeds from stage to stage, flashing to lower pressures, until the deaerator heat reject stage is reached. At this point the product water, at a temperature in equilibrium with the pressure in that stage, flows into a sump from which it is pumped to an atmospheric tank.

The vacuum system also functions to remove noncondensable gases resulting both from in-leakage to the stages and from dissolved and entrained gases in the seawater make-up, such as the CO_2 and O_2 that were not completely removed in the degassing operation. Noncondensable gases must be removed to a very low concentration to permit equilibrium conditions to be established in the stages and to maintain the heat transfer coefficient of condensing vapor at its maximum value. A mixture of steam and gas is removed through a hood located in the inside of the heat exchange bundles to maintain a movement of vapor. This mixture goes to one of three steam jet systems depending on the pressure level in the particular stage. The multi-stage steam jet systems are equipped with pre-, inter-, and after-condensers. Motive steam comes

from turbine bleed, and untreated seawater is used as cooling water for the condensers, after which it is discarded to the sea. Part of the condensate joins the brine heater condensate and is returned to the steam generators, and the remainder joins the product stream. The noncondensable gases leave the system from the after-condenser to the atmosphere. Maximum steam economy in the jet system is obtained by a judicious arrangement of vent lines from the various stages to the high, intermediate or low vacuum systems.

Start-up is effected by initiation of flow of treated water until the required water inventory is obtained, using the recycle pump to distribute the water to the stages. The entire evaporator system is then put under vacuum. Steam is then fed to the brine heater, and heat reject water started, leading to the establishment of the required temperature and pressure profile.

The plant consists of four trains of evaporator sections, each of which can operate independently of the others. This simplifies scheduled shutdowns for maintenance. If the entire desalting plant is shut down, and it is desired to continue generating power, seawater can be pumped directly to the brine heaters which would act as condensers for the turbine. This is accomplished by using the heat reject pumps to deliver water through an emergency pipeline. To maintain the turbine back-pressure at the design value during this period, and at the same time maintain a non-fouling velocity of 5 ft/sec minimum in the brine heater tubes, the heat reject pumps will deliver about 25 percent of normal output and 25 percent of the brine heater surface will be utilized.

Since control of bicarbonate scale is effected by injection of acid, there is no need for routine acid cleaning of the tubes.

2. Desalting Plant Description

a. General

The reference 100 MGD plant consists of four evaporator trains, each having a capacity of 25 MGD. This arrangement is shown on the desalting plant plot plan, Figures 5 and 6. The characteristics of this plant are as follows:

Capacity	100,000,000 gallons per day
Trains	4
Stages	31 (28 heat recovery and 3 heat reject)
Terminal Temperature Difference	4.5 F (at first stage)
Velocity of Brine in Tubes	6 ft/sec
Maximum Brine Temperature	220 F
Design Cooling Water Temperature	70 F
Design Flashing Range	138 F
Blowdown Concentration	2.0
Economy Ratio at Design Conditions	10.3 lb product water/ 1,000 Btu steam used
Product Water Salinity Without Leaks	25 ppm TDS, including 14 ppm Cl^-
Product Water Salinity - Maximum	125 ppm TDS, including 69 ppm Cl^-
Product Water Salinity - Average	75 ppm TDS, including 41 ppm Cl^-
Recycle Flow	550,000 gpm
Recycle Ratio	8.34 lb of brine per lb of product water
Steam Pressure at Brine Heater Inlet	25.0 psia
Steam Temperature at Brine Heater Inlet	240 F
Steam Flow to Brine Heater	3.7×10^6 lb/hr
Steam Flow to Jet Ejectors	128,000 lb/hr @ 125 psig
Pumping Shaft Power	47,500 hp

Other data are presented in the computer printout on the following pages.

b. Intake Structure

This is more fully described in subsection E of this section. The vertical mixed-flow pumps provide seawater for trash screen heat reject, make-up, steam jet condensing and backwash. There are five heat reject pumps (four on-stream and one spare) and four make-up pumps. For economy of piping and for diversity of operation all heat reject pumps deliver water

CATALYTIC CONSTRUCTION COMPANY

PHILADELPHIA, PENNSYLVANIA

SALINE WATER CONVERSION STUDY

CATALYTIC CONSTRUCTION COMPANY CONTRACT 40970

FIXED NET SALABLE POWER JUNE 10, 1965

PRODUCTION 100.0 MMGAL/DAY, 34722222. LBS/HR.

RECYCLE RATIO 8.340 LBS/LB PRODUCT

CONCENTRATION RATIO 2.00, TOTAL NUMBER OF STAGES IS 31

TEMPERATURE OF FLASHING BRINE FROM BRINE HEATER IS 220.0 DEG F.

SEA WATER TEMPERATURE IS 70.00 DEG F. APPROXIMATE TTD 4.50 DEG F.

SOLIDS CONTENT OF SEA WATER IS 3.8600 PERCENT

STAGE NO.	FLASHING BRINE,MLB/HR	DISTILLATE PROD,MLB/HR	RECYCLE BRINE,MLB/HR	CONCENTRATION WT. PERCENT	PRODUCTION M LB/HR	PRESSURE PSIA	VAPOR FLOW CU FT/SEC	BOILING POINT ELEV. DEG F.
1	288346.	1242.	289588.	6.8236	1242.	14.8765	9288.16	3.0026
2	287112.	2476.	289588.	6.8529	1234.	13.6361	10008.55	2.9737
3	285884.	3703.	289588.	6.8824	1227.	12.4796	10801.84	2.9450
4	284664.	4923.	289588.	6.9119	1220.	11.4028	11676.12	2.9166
5	283451.	6137.	289588.	6.9414	1213.	10.4019	12641.31	2.8884
6	282245.	7343.	289588.	6.9711	1206.	9.4728	13708.71	2.8604
7	281045.	8542.	289588.	7.0009	1199.	8.6119	14891.18	2.8327
8	279853.	9735.	289588.	7.0307	1193.	7.8154	16203.40	2.8053
9	278667.	10921.	289588.	7.0606	1186.	7.0797	17662.13	2.7781
10	277488.	12100.	289588.	7.0906	1179.	6.4014	19286.49	2.7512
11	276316.	13272.	289588.	7.1207	1172.	5.7771	21098.38	2.7245
12	275150.	14437.	289588.	7.1509	1166.	5.2036	23122.83	2.6980
13	273991.	15596.	289588.	7.1811	1159.	4.6777	25388.50	2.6718
14	272840.	16748.	289588.	7.2114	1152.	4.1966	27928.18	2.6459
15	271695.	17893.	289588.	7.2418	1145.	3.7571	30779.43	2.6202
16	270557.	19031.	289588.	7.2723	1138.	3.3567	33985.26	2.5948
17	269426.	20162.	289588.	7.3028	1131.	2.9926	37594.79	2.5696
18	268303.	21285.	289588.	7.3334	1123.	2.6622	41664.22	2.5448
19	267187.	22400.	289588.	7.3640	1115.	2.3633	46257.69	2.5202

STAGE NO.	FLASHING BRINE, MLB/HR	DISTILLATE PROD, MLB/HR	RECYCLE BRINE, MLB/HR	CONCENTRATION WT. PERCENT	PRODUCTION M LB/HR	PRESSURE PSIA	VAPOR FLOW CU FT/SEC	BOILING POINT ELEV. DEG F.
20	266080.	23508.	289586.	7.3946	1107.	2.0933	51448.24	2.4959
21	264981.	24607.	289588.	7.4253	1099.	1.8502	57318.94	2.4719
22	263891.	25697.	289585.	7.4560	1090.	1.6318	63963.95	2.4482
23	262810.	26778.	289588.	7.4866	1081.	1.4361	71489.59	2.4248
24	261739.	27848.	289588.	7.5173	1071.	1.2612	80015.55	2.4017
25	260679.	28909.	289588.	7.5478	1060.	1.1054	89675.83	2.3790
26	259630.	29957.	289586.	7.5783	1049.	0.9669	100619.47	2.3566
27	258593.	30994.	289588.	7.6087	1037.	0.8441	113011.21	2.3347
28	257569.	32018.	289588.	7.6390	1024.	0.7357	127031.66	2.3130
			HEAT REJECTION SECTION					
			RAW SEA WATER					
29	256663.	32925.	280280.	7.6659	907.	0.6494	126547.61	2.2940
30	255761.	33826.	280280.	7.6930	901.	0.5720	141768.93	2.2752
31	254865.	34722.	280280.	7.7200	896.	0.5027	159158.80	2.2565

DISTRIBUTION OF RAW SEA WATER 210836. MLB/HR AS ONCE THROUGH
69444. MLB/HR AS MAKE-UP

STAGE NO.	TEMP FLASHING BRINE, DEG F	TEMP DIST PROD, DEG F	TEMP RECYCLE BRINE, DEG F	TERMINAL TEMP DIFFERENCE, F	LOG MEAN TEMP DIFFERENCE, F	HEAT TRANSFER MBTU/HR-STAGE	OVERALL U BTU/FT2/F/HR	AREA SQ FT/STAGE
1	215.62	212.62	208.12	4.5000	6.4458	1204287.	620.93	300888.
2	211.22	208.25	203.73	4.5197	6.4717	1206175.	619.45	300874.
3	206.82	203.87	199.33	4.5403	6.4980	1208129.	617.98	300856.
4	202.40	199.48	194.92	4.5607	6.5241	1210076.	616.54	300837.
5	197.97	195.08	190.50	4.5811	6.5501	1212022.	615.12	300818.
6	193.53	190.67	186.07	4.6013	6.5759	1213970.	613.73	300799.
7	189.07	186.24	181.62	4.6214	6.6015	1215921.	612.37	300780.
8	184.61	181.80	177.16	4.6415	6.6269	1217870.	611.04	300761.
9	180.13	177.35	172.69	4.6614	6.6522	1219808.	609.72	300742.
10	175.64	172.89	168.21	4.6813	6.6774	1221723.	608.42	300723.
11	171.14	168.42	163.72	4.7012	6.7025	1223597.	607.11	300704.
12	166.63	163.94	159.21	4.7212	6.7275	1225409.	605.78	300686.
13	162.11	159.44	154.70	4.7414	6.7526	1227130.	604.41	300668.
14	157.59	154.94	150.18	4.7620	6.7778	1228727.	602.98	300652.
15	153.05	150.43	145.64	4.7830	6.8031	1230163.	601.47	300637.
16	148.50	145.91	141.10	4.8046	6.8288	1231393.	599.84	300623.
17	143.95	141.38	136.55	4.8271	6.8548	1232365.	598.05	300611.
18	139.39	136.85	132.00	4.8505	6.8814	1233023.	596.08	300601.
19	134.83	132.31	127.43	4.8752	6.9086	1233304.	593.88	300595.
20	130.26	127.77	122.87	4.9014	6.9367	1233138.	591.40	300591.
21	125.70	123.23	118.30	4.9294	6.9657	1232448.	588.61	300590.
22	121.14	118.69	113.73	4.9594	6.9959	1231153.	585.44	300594.
23	116.58	114.16	109.16	4.9919	7.0275	1229165.	581.86	300602.
24	112.03	109.63	104.60	5.0270	7.0606	1226392.	577.90	300615.
25	107.49	105.12	100.05	5.0652	7.0955	1222737.	573.21	300634.
26	102.97	100.61	95.51	5.1066	7.1324	1218103.	568.04	300658.
27	98.47	96.13	90.98	5.1522	7.1714	1212389.	562.24	300689.
28	93.99	91.68	86.47	5.2017	7.2128	1205497.	555.76	300727.
							TOTAL AREA	5419557.
			HEAT REJECTION SECTION					
29	89.99	87.70	81.99	5.7099	7.5332	1074698.	548.59	260052.
30	86.00	83.72	77.99	5.7316	7.5559	1074699.	541.50	262663.
31	82.00	79.74	73.99	5.7531	7.5784	1074699.	533.74	265691.
							TOTAL AREA	788405.
							GRAND TOTAL AREA	9207962.

BRINE HEATER DATA

STEAM PRESSURE 25.0 PSIA, STEAM TEMPERATURE 240.0 DEG F.
TEMPERATURE RISE OF BRINE THROUGH HEATER 11.884 DEG F. LOG MEAN TEMPERATURE DIFFERENCE 25.480
OVERALL HEAT TRANSFER COEFFICIENT 621.21 BTU/FT2/F/HR
HEAT REQUIREMENT OF HEATER IS 3258.396 MMBTU/HR, AREA REQUIREMENT OF HEATER IS 205555. SQ.FT.

STEAM REQUIREMENT 3532031. LB/HR AS DRY SATURATED STEAM
INCLUDING 110000. LBS/HR FOR JETS
STEAM ECONOMY RATIO IS 10.324 LBS PRODUCT/M BTU

DESIGN DATA

HEAT RECOVERY SECTION

NUMBER OF TUBES PER STAGE IS 56997.
VELOCITY OF RECYCLE BRINE IN TUBES IS 6.000 FT/SEC
PRESSURE DROP THROUGH THIS SECTION IS 75.93 PSI
INCLUDING 17.30 PSI FOR EXTERNAL LOSSES
LENGTH OF TUBES IS 22.25 FEET
OUTSIDE DIAMETER OF TUBES IS 0.875 INCHES
WALL THICKNESS OF TUBES IS 0.035 INCHES
TOTAL WEIGHT OF TUBES IN EACH STAGE IS 449726. POUNDS

HEAT REJECTION SECTION

NUMBER OF TUBES PER STAGE IS 55920.
VELOCITY OF RAW SEA WATER IN TUBES IS 6.000 FT/SEC
PRESSURE DROP THROUGH THIS SECTION IS 21.25 PSI
INCLUDING 14.60 PSI FOR EXTERNAL LOSSES
LENGTH OF TUBES IS 20.52 FEET
OUTSIDE DIAMETER OF TUBES IS 0.875 INCHES
WALL THICKNESS OF TUBES IS 0.035 INCHES
TOTAL WEIGHT OF TUBES IN EACH STAGE IS 393047. POUNDS

BRINE HEATER

TOTAL NUMBER OF TUBES IN HEATER IS 45227.
VELOCITY OF RECYCLE BRINE IN TUBES IS 6.000 FT/SEC
PRESSURE DROP THROUGH THIS SECTION IS 8.93 PSI
INCLUDING 16.00 FT IN HEADERS
LENGTH OF TUBES IS 17.39 FEET
OUTSIDE DIAMETER OF TUBES IS 1.000 INCHES
WALL THICKNESS OF TUBES IS 0.035 INCHES
TOTAL WEIGHT OF TUBES IN BRINE HEATER IS 309480. POUNDS

TOTAL RECYCLE BRINE PUMP HEAD IS 99.24 PSI

through a common header to the evaporator trains; the header is divided into branches to each train and each branch is further subdivided to serve three of the four reject stage tube bundles.

The make-up pumps similarly discharge into one header which feeds water to the atmospheric deaerator. The spare heat reject pump can also supply make-up water when one, two or three make-up water pumps are out of service.

c. Evaporator Train

The plant consists of four parallel trains of evaporators, each train capable of operating alone or in parallel with the other trains. The description below is based on a steel evaporator enclosure. Should the testing of concrete and concrete coatings now being made by the Bureau of Reclamation in Denver, Colorado, result in data which confirm that concrete evaporator enclosures are suitable for 30-year life and will withstand the thermal transients expected, concrete can be used instead of the steel enclosures now included in the reference plant design. This will result in a reduction in the capital cost of approximately $3,600,000.

Each 25 million-gallon per day evaporator train consists of a recovery section, a heat reject section, three 50 percent-capacity brine recycle pumps, two 100 percent-capacity blowdown pumps, two 100 percent-capacity distillate pumps and the necessary pipe bays and sump pumps. Each train is further supplied with vacuum systems and a brine heater.

The recovery and heat reject sections consist of a series of steel stages separated by common walls. Following the brine heater is Heat Recovery Stage No. 1 at a pressure of approximately 15 psia. The pressure gradually drops in the succeeding stages and reaches a value of 0.3 to 0.8 psia in the last heat reject stage, depending on the seawater temperature.

Each stage (Figure 13) is subdivided into four modules in parallel. The brine flow channel and the vapor space of all modules are interconnected to prevent temperature and pressure gradients across the stage. All the heat recovery tube bundles and the first two heat reject tube bundles, arranged with tubes

at right angles to the stage dividers, straddle the stage divider, resulting in half the length of tube bundle in each module. One tube bundle serves two tandem modules covered with one removable roof section, making it possible to lift out a tube bundle for retubing. In the deaerator stage (third heat reject stage), one tube bundle occupies one module.

The tube bundles are made primarily of 7/8 in. OD x 20 BWG copper-nickel (90%-10%) tubes rolled into a tube sheet. Tubes exposed to excessively corrosive conditions on the vapor side, namely those in the deaerator stage and in the air cooling sections (about 150 tubes per bundle) of the recovery and heat reject bundles, are bimetallic. They consist of copper-nickel (90%-10%) on the inside and stainless steel on the outside, resulting in a combined thickness of 20 BWG. The copper-nickel tubes in Recovery Stages No. 1 and 2 are 18 BWG for greater reliability. Bundles in a module stream are interconnected on the brine side by pipes passing through sealed openings in the stage walls. Expansion joints are installed in these pipes as required, along with anchors. Venting is effected through a hood arranged to collect a mixture of steam and non-condensable gases from the center of the tube bundle at the colder end. Each hood is connected by a vent tube to headers conveying the mixture to steam jet evacuation systems.

The brine channel occupies the full width of the floor in each module and carries the brine flow in the opposite direction, but parallel to the flow in the tube bundle. A liquid seal and a dam between stages prevent blow-through, and thus permit maintenance of system pressure in each stage.

Vapor from the flashing brine passes through mesh demisters and condenses on the tube bundles. Troughs located beneath the bundles collect and convey the condensate from stage to stage, a liquid seal being used to prevent blow-through between stages.

The last heat recovery stage and the first heat reject stage are separated by a pipe-way where the circulating brine is distributed to the four tube bundles in the last heat recovery stage. Here also is located the pipe collecting the cooling water from the three tube bundles of the heat reject stages for transfer to the effluent canal which is located underneath this pipe-way.

The make-up water, heated in the fourth tube bundle of the reject stages, is collected here and conveyed to the last heat reject stage (deaerator) for spraying into the recycle brine stream.

The pipe-way is also the location of a part of the evacuation system used for removing noncondensables from the stages.

The evacuation equipment for each train consists of three separate systems. The first system consists of a pre-condenser, single stage jet, and after-condenser; it evacuates Stages 1 through 14. The second system consists of a two stage jet, pre-, inter- and after-condensers; it evacuates Stages 15 through 26. The third system handles the remaining stages including the deaerator; it consists of a three stage system with inter- and after-condensers. Systems I and II each have two parallel units. System III has four parallel units. This offers a possibility of saving on steam usage should the noncondensable load prove to be lower than expected. The condensers are cooled by untreated seawater from the heat reject booster pumps. Condensate is collected and pumped with conventional equipment partly to the brine heater condensate sumps for return to the power plant, and partly to the product line of the desalting plant as required to satisfy the material balance.

The brine stream and water distillate stream continue in uninterrupted flow through their respective flumes located beneath the pipe-way and into the respective channels in the reject stages. The product water is collected in a sump from the water channels in the final reject (deaerator) stage; it is pumped by the distillate pump to the product tank. A dump line from the distillate pump to the effluent canal enables the plant operator to take corrective measures, or to proceed with an orderly shutdown in case of excessive salinity of the product, without contaminating the product water in the storage tanks.

After reaching its lowest temperature and highest salt content in the deaerator stage, the brine is divided into a blowdown stream and a recycle stream. The blowdown stream drops into a sump from where it is rejected by a pump to the effluent canal. The recycle stream, joined by the deaerated make-up

water, also drops into a sump where it is picked up by the recycle pumps and pumped into the tube bundles of the last heat recovery stage.

The pumps noted above (product water, blowdown and recycle) operate with flooded suction and are installed in a pit to provide the NPSH requirements for pumping saturated water from vacuum.

The brine heater station is located between Heat Recovery Stage No. 1 and the steam turbine in the power plant. There is one brine heater for each evaporator train. Each brine heater consists of four tube bundles in one steel housing. The tube bundles are made of 1 in. OD x 18 BWG copper-nickel (90-10) tubes. Steam from the back-pressure turbine flows into a pipe header from which a branch feeds steam to each of the four brine heater housings. This steem, when condensed, is joined by condensate from the steam jet system, is collected and pumped to the power plant.

Heated recycle brine leaving the tube bundles of Heat Recovery Stage No. 1 is collected in a header in which it is transported to the brine heater header and is fed to the individual brine heater bundles. The heated brine then flows from the brine heater through similar header systems and is distributed into the brine channels in each module of Heat Recovery Stage No. 1.

For operation when the desalting plant is shut down and the power plant must generate electricity, one of the heat reject pumps will feed cooling water directly to one bundle of each brine heater acting as a condenser. Warm water leaving the brine heater will reach the sea directly through an emergency effluent channel.

Tube bundles in the evaporator trains can be removed for retubing by use of a gantry crane traveling on tracks straddling each train. The trolley will be positioned over a given module and the removable roof section lifted off. The tube bundle will then be unbolted from the piping, lifted and moved onto a trailer for transportation to the maintenance shop.

The gantry crane system is equipped with a transfer car arrangement thus making it possible to transfer the crane from one evaporator train to another.

d. Chlorination

Chlorine facilities include equipment to handle one-ton chlorine containers from the carrier to storage or to a manifold which feeds chlorine to automatic chlorination equipment. The equipment will also load empty containers on the carrier. The chlorine injection is done at the intake of the marine conduits.

e. Acid Treatment

Sulfuric acid of 95 percent concentration is delivered by carrier and unloaded into two 80,000-gal. storage tanks. A metering pump feeds acid to the seawater make-up line en route to the degasifier, using a corrosion-resistant mixing device in the pipe line.

f. Degasification

The make-up water, now containing CO_2 into which bicarbonate was converted by the acid treatment, is distributed over packing in a five-cell tower resembling an induced-draft water cooling tower. By using low capacity fans, only a low air flow is drawn through the water, effecting CO_2 removal.

g. Piping and Valves

Pipe is generally run in grating-covered trenches to permit ground-level access roads for maintenance. Where access roads are not a consideration, pipe is run above ground.

Valves for low pressure steam, vapor and liquids are of the butterfly type, motor operated for sizes above 18 in. High pressure steam lines are equipped with gate and globe valves. Control valves are butterfly or globe type to suit the service. Materials of construction are selected consistent with exposure conditions.

h. Instrumentation and Controls

Instrumentation will be applied to the desalting facility in accordance with standard industrial plant and utility practices. Special consideration is given to size, flows, and corrosive fouling characteristics of the fluids being handled. The

overall size of the facility is such that all transmitted signals to the control room area will be electrical or from electronic transmitters. The receiver instruments for remote recording, indicating, and alarming will be mounted on a control panel located in an air-conditioned central control room.

(1) Automatic Control

(a) Flow

There will be one flow control loop to maintain a ratio between make-up water flow and sulfuric acid flow. The acid flow will be the controlled variable, via a variation of the acid feed pump output. This will be automatically ratioed to the quantity of water being pumped to the degassing tower. The ratio setting will be manually adjusted on the basis of pH values of degassing tower feed and effluent.

There will be one flow control loop for each evaporator train maintaining a ratio between product water flow and blowdown flow. The blowdown flow will be the controlled variable, the final control element being a 24 in. butterfly valve equipped with an electropneumatic actuator and positioner. The ratio of product water flow to blowdown flow will be maintained manually by the operator.

(b) Level

All level control systems will be local, the purpose being to provide and guarantee a liquid seal on the suction of the various sytem pumps. Control valves will be butterfly valves on the pump discharge lines, with pneumatic actuators.

Level control systems will also be installed to control the outlet flow from the sumps under E-115D, E-215D, E-315D, and E-415D (Figure 10) to maintain the recycle brine level in each train. The level sensor will be located at the deaerator end of the train. Displacer type level sensors will be used, controlling by means of a butterfly valve in the make-up line.

(c) Chlorine

Chlorine residual will be controlled by the chlorination equipment.

(d) Miscellaneous

The remaining parameters of pressure, temperature, pH and conductivity are not automatically controllable parameters as the desalting plant cycle is set up.

(2) Primary Elements and Measuring Techniques

The various types of instruments to be employed are listed below by process parameter.

(a) Flow

Considering the significance of line size, permanent head loss, and operating costs vs first cost, magnetic flow elements will be employed on all water services for line sizes 48 in. and larger. The magnetic meter will also be employed for the measurement of sulfuric acid to the degassing tower. Differential producing primary elements will be employed for utilities, steam flow application, and water flows in lines less than 48 in. diameter.

The basic magnetic metering element provides an electric signal proportional to the flow. Electronic transmitters will be employed for the differential primary elements.

(b) Level

The measurement and indication of liquid levels in the various storage tanks and sumps will be made utilizing any of the standard devices which may be satisfactorily attached to the particular vessel. This would include differential indicators, float and tape, and flat glass gage types for local indication. The differential and float types may also be employed for remote signal transmission.

(c) Pressure

Pressure values from points requiring a record will be transmitted by means of pressure-current, or pressure-voltage transducers, the basic pressure sensitive element being selected for the magnitude and range of pressure operation required. Absolute pressure elements will be employed at vacuum locations, and bourdon tube elements at higher pressure ranges. Bourdon tube pressure gages will be employed on all pump discharges, and at other locations requiring local indication. Aneroid type pressure gages will be used for local indication of vacuum.

(d) Temperature

Local temperature indicators for visual checking purposes will be bimetallic element type dial indicators, with fully adjustable heads.

Remote indicating, recording, and alarming of temperature conditions will be made by employing thermocouples as the primary sensing element. The elements which are to penetrate inner liquid feed and collection troughs will be metal sheathed couples, entering the pressure (vacuum) areas through pressure-tight glands, and sheathed with a material which is compatible with hot, concentrated brine.

The glands will be leak-tight to full vacuum (0.2 psia), providing a seal for the thermocouple probe passing between zones of different pressures. Wells will be provided in pipe lines to allow for removal of the thermocouples during operation.

Duplex couples will be used at each point of measurement to provide separate circuits for scanning and/or recording or indicating.

(e) Chemical Analysis

Residual chlorine: both dissolved and free chlorine will be determined by means of an analyzer through which a

sample of water is passed between two electrodes. A current which is proportional to the free chlorine or free iodine in the sample is generated, readout being provided with a suitable potentiometric instrument.

Hydrogen ion concentration (pH): pH will be measured in the main feed stream at the required location (upstream and downstream of the degassing tower) using a glass electrode cell mounted in a flow-through chamber. A small bypass sample stream will be used for this purpose.

Dissolved solids: the total dissolved solids concentration of the distillate streams will be determined by conductivity measurement of the water. A sample stream will be piped from the distillate trough under each tube bundle, four streams manifolded from each train through a pressure-cell fitting. The conductivity-cell fittings will be valved to allow removal and inspection during operation. The conductivity in the trough under each of the heat rejection stages will be separately determined using a valved probe extending into the trough. Separately valved probes will be employed in the effluent streams from each module stream.

(3) Readout and Recording

(a) All transmitted signals for remote indication, recording and/or scanning will terminate at a control panel located in a centralized control room adjacent to the turbine room. All pertinent variables will be recorded on either miniature electronic recorders (4 in. wide strip chart) or multipoint potentiometric recorders (10 in. wide strip chart). The several variables will be functionally grouped where possible, such as pressure and temperature with a flow record. Where thermocouple inputs are used with miniature recorders, appropriate signal conditioning equipment will be provided. The magnetic meter output signal (a-c) will be converted to the appropriate direct current signal for input to the miniature recorders. The magnetic meter output for product water from each train will be totalized, providing a gross volume record.

(b) The readout of dissolved solids will be independently monitored and recorded. The conductivity cells for the manifolded samples from the trains will be zoned according to temperature range and automatically scanned. There will be three such scanning zones. Two additional multipoint strip chart recording potentiometers will be provided for the monitoring of the conductivity of the product water stream from each module stream and the combined product water stream.

(4) Accuracy Requirements

The accuracy requirements as listed below are obtainable with standard industrial process instrumentation equipment and devices.

(a) Flow

Magnetic flow meter accuracy will be ± 1.0 percent of full scale for the complete system (transmitter and readout instrument) with a repeatability of ± 0.5 percent.

System accuracy of differential flow metering systems will be ± 1.5 percent of the full scale range.

(b) Level

Differential level transmitters will have an accuracy of ± 0.5 percent of full scale.

Capacitance level probes will have an accuracy better than ± 2 percent with an indicator system accuracy of ± 1 percent.

Float-tape level accuracy will be ± 1 percent of full range for the complete system.

(c) Pressure

Low range and absolute pressure transmitters will have an accuracy of ± 1 percent of full scale and a sensitivity of 0.05 percent.

Pressure transmitters will have an accuracy of ± 0.5 percent of full scale and a sensitivity of 0.05 percent.

Pressure gages for local indication of pump discharge pressures and pipe line pressures will have an accuracy of ± 0.5 percent of full scale.

Absolute pressure indicators will have an accuracy of ± 0.33 percent and a sensitivity of 0.2 percent of full scale.

Local differential pressure indicators will have an accuracy of ± 0.5 percent and a sensitivity of 0.10 percent.

(d) Temperature

Thermocouple sensor and indicator accuracy will be ± 0.5 F for 200 F spans. Multipoint recorders will have an accuracy of ± 0.25 percent of span.

Local temperature indicators (bimetal thermometers) will have an accuracy of 1.0 percent of the full scale range.

i. Electrical Distribution, Control and Lighting

Power will be received from an overhead 161 kv, 3-phase, 50 cycle lines . the desalting water plant substation. One incoming line will be from the Israel Electric Corporation's grid; the other incoming line will be from the main switchyard at the nuclear power plant.

As shown in the single line diagram, (Figure 15), the power distribution is accomplished by dividing the load into five 4.16 kv buses which are fed by two 161/4.16 kv transformers, rated 20/26.7/33.3 MVA each.

The load side of these transformers will feed outdoor switchgear line-ups for circuit breaker motor control and feeder breakers.

Tie breakers between the various buses allow for flexibility of operation.

All large water pumps including recycle brine, make-up, heat reject, blowdown and product--will be operated on 4,160 volt, 3-phase, 50 cycle power. All other pumps will be on 400 volt, 3-phase, 50 cycle. The recycle brine (5,000 hp) and the heat reject (2,000 hp) pumps will be driven by synchronous motors--all others will be squirrel-cage induction motors.

Power will be transformed from 4,160 volts to 400 volts for motors smaller than 150 hp and for lighting.

A motor control center will be located at the pump pit of each train, and additional motor control centers will be located at points of concentrated motor load. Motors will be started locally. Running indication will be provided in the control house and, in case of emergency, it will be possible to stop any motor from this point.

Motor feeders and control wiring will be run in underground conduits except where available pipe racks would make it more feasible to run the conduits along the racks with the piping.

Electrical leads will be run from local instrumentation to the control house for indication and for recording operations.

The area will have general illumination provided by floodlights. Individual lighting units will be provided at operational locations and at platforms and stairways to provide local illumination.

A ground loop will be provided to ground motors, electrical equipment rated 400 volts and above, and non-electrical equipment where it might be deemed necessary to protect operating personnel.

Electrical receptacles will be provided for welding at 400 volts, 3-phase, and for miscellaneous maintenance equipment at 230 volt single-phase. The welding receptacles will be spaced to accommodate 200-ft welding machine leads. The 230 volt receptacles will be located at strategic points to facilitate maintenance operations.

Electrical control equipment will generally be housed in weather-protected or water-tight enclosures except in cases

where it will be located in buildings, in which case the equipment will be housed in general purpose enclosures.

D. Nuclear Power Plant

Based on data received from the leading manufacturers of pressurized and boiling water reactors and of steam turbine-generators, conceptual designs and cost estimates were prepared for the power plant portion of the reference dual-purpose plant. The descriptions of power plants using PWR and BWR nuclear boilers which follow are, in each case, based on the systems and equipment normally supplied by a particular reactor manufacturer. The systems and equipment supplied by other reactor manufacturers may differ in detail from those described.

1. Nuclear Power Plant - Pressurized Water Reactor

The reference nuclear power plant using a pressurized water reactor will consist primarily of:

- A "nuclear boiler" using an indirect cycle, pressurized light-water cooled and moderated nuclear reactor and its auxiliaries.
- A 3,000 rpm noncondensing turbine-generator unit.
- Power plant auxiliaries such as condensate and boiler feed pumps and feedwater heaters.
- A containment building for the reactor consisting of a pressure tight enclosure either in the form of a steel sphere or a concrete cylinder.
- A radioactive waste treatment facility.
- A reactor auxiliary building, turbine-generator building and several smaller service buildings.

Although the brine heaters are considered part of the desalting plant they also serve as a condenser for the power plant. The steam piping up to the brine heaters (including the steam isolation valves), the condensate pumps and condensate piping are all included with the power plant. The average quantity of heat

supplied to the desalting plant brine heaters is approximately 3.3×10^9 Btu/hr. This will increase during periods of coldest seawater temperature to approximately 3.5×10^9 Btu/hr and will decrease during periods of warmest temperatures to approximately 3.0×10^9 Btu/hr.

As can be seen from a turbine manufacturer's power plant heat balance utilizing a typical PWR nuclear boiler (Figure 16), the average reactor thermal power is about 1,250 MWt. During the periods of the coldest seawater temperature the reactor thermal power will increase to about 1,330 MWt (which is within the stretch capability of the reactor); during the periods of the warmest seawater temperature the reactor output will decrease to about 1,160 MWt.

a. Reactor Coolant System

The PWR nuclear boiler system consists of the reactor vessel with its core and control rod drives, two primary coolant loops connected in parallel to the reactor vessel, pressurizer and supporting auxiliary systems. Typically, each loop contains a reactor coolant pump, steam generator, and interconnecting piping. At least one PWR manufacturer, however, provides a loop consisting of two pumps and one steam generator. High-pressure water enters the reactor vessel through the coolant inlet nozzles, passes through the reactor core to remove the heat generated by the nuclear reaction, and leaves the vessel through the coolant outlet nozzles. The water then flows to the steam generators where it is cooled, generating steam in an indirect cycle, and is pumped back to the reactor vessel. All surfaces in contact with the reactor coolant are stainless steel, except steam generator tubes which are Inconel and fuel element tubes which are Zircaloy.

b. Core

The reactor core is divided into three concentric regions of fuel assemblies. The inner region has the lowest enrichment and the outer region the highest. At the end of each cycle of core operation the inner region fuel is removed for reprocessing, the other two regions are moved inward, and new fuel is added to the outer region. The fuel assemblies are composed of fuel rods consisting of uranium-dioxide pellets assembled

into thin Zircaloy tubes welded shut at the ends. Provision is made for loading and unloading fuel under water.

c. Steam Generator

The steam generators provide the link between the reactor primary cycle and turbine-generator secondary cycle. The steam generator design utilizes vertical U-tube units with primary water on the tube side and boiling feedwater on the shell side. The steam generators employ Inconel tubing which offers added corrosion resistance and heat transfer advantages over other materials. Integral moisture separation equipment reduces the steam moisture content to less than 0.25 percent. Alternative steam generator designs, which employ a once-through steam generator system, have been proposed by some pressurized water reactor manufacturers.

d. Coolant Pumps

The reactor coolant pumps provided are of the vertical, single stage, centrifugal, controlled-leakage type.

e. Pressurizer

A pressurizing and pressure relief system is connected to one reactor coolant loop to maintain the required reactor coolant pressure in all loops during steady-state operation of the reactor. Typical primary coolant pressures are 2,000-2,500 psi. This system also limits pressure variations during plant load transients and keeps all loop pressures within design limits during abnormal conditions. The pressurizer portion of the system consists of a pressure vessel equipped with submerged replaceable electrical heater elements and a nozzle through which reactor coolant is sprayed into the top of the vessel.

f. Auxiliary Systems

Conventional pressurized water reactor plant auxiliary systems are provided to purify reactor coolant water, discharge and vent the reactor coolant system, charge the reactor coolant

system and supply make-up water, add chemicals for corrosion inhibition and reactor control, cool system components, and remove decay heat when the reactor is shut down. Additional safeguard systems are incorporated to minimize the possibility of personnel exposure to excessive radiation. These additional safeguards include a safety injection system, a containment spray system and a containment air cooling and purification system. A radioactive waste disposal system is provided to concentrate safely and store radioactive wastes generated during operation at the plant.

The coolant purification system removes dissolved and suspended solid impurities, principally corrosion products, from the reactor coolant, and maintains the coolant at its nominal pH value by bypassing a small percentage of the coolant flow through a demineralizer. In the event of a fuel cladding defect this system will assist in reducing primary system contamination.

The coolant discharge and vent system collects primary coolant discharge during plant warm-up, pressurizer level adjustment, plant or loop decontamination, relief valve operation, plant venting, and any steam leakage from the various motor-operated valves in the primary plant. These plant effluents are transferred to the radioactive waste disposal system where they are processed for permanent disposal.

The coolant charging and chemical addition system provides water at the required pressure for plant filling, hydrostatic testing, and plant make-up during normal operation, cool-down, and emergencies. The system is also used to add chemicals for maintaining normal plant chemistry and chemical shim control.

The reactor plant component cooling water system removes heat from various plant components such as the reactor coolant pumps, and transfers this heat to the service water side of the system heat exchangers.

The decay heat removal system provides water to dissipate reactor decay heat and, thus, protects the core from damage following an emergency shutdown caused by the complete loss of electrical power to the main reactor coolant pumps.

The safety injection system is designed to operate in the unlikely event of a loss-of-coolant accident due to a rupture in the reactor coolant system. This system provides the means for injecting cooling water into the reactor core to prevent excessive temperatures which might otherwise lead to rupture of the fuel element tubes and gross release of fission products.

The containment spray system provides atomized spray inside the containment building in the unlikely event of a loss-of-coolant accident. The spray reduces the pressure inside the container and washes down radioactive airborne materials. The resulting pressure reduction also minimizes any container leakage to atmosphere and the washing action minimizes the probability of any radioactive material leaking from the containment building.

During normal plant operation the reactor plant air cooling and purification system maintains the temperature of the containment building air within suitable limits, provides sufficient ventilation to the instrumentation and valve access areas to allow short-time occupancy, and provides the means for purifying the air in the reactor area prior to personnel entry. Should a loss-of-coolant accident occur, the system provides cooling and filtration of the containment building atmosphere, and thus reduces the possibility of any leakage from the containment.

The radioactive waste disposal system (located in a separate building near the reactor building) provides the tankage and facilities necessary to collect, segregate, and safely process radioactive wastes, including gases, liquids and solids (Figure 24). A combination of processes provides holdup for decay and dilution of gases before discharge to the atmosphere, containment of solid wastes in drums, and holdup for decay, gas stripping, filtration, evaporation, demineralization, and/or flocculation-clarification of radioactive liquid wastes. Purified effluent from the liquid process will be utilized as make-up water to the reactor and steam plants. The radioactivity removed from the liquid wastes will be contained on ion-exchange resins or in the sludge from the evaporation or flocculation treatment.

g. Fuel Handling

The reactor is refueled with equipment designed to handle the spent fuel under water from the time it leaves the reactor vessel until it is placed in a cask for shipment from the site. Underwater transfer of spent fuel provides an effective and economical transparent radiation shield, as well as a reliable cooling medium for removal of decay heat. Boric acid is added to the water during refueling to ensure subcritical conditions.

The fuel handling system may be generally divided into two areas: (1) the reactor cavity which is flooded only during plant shutdown for refueling and, (2) the spent fuel pit in the fuel storage building which is kept full of water and is normally accessible to operating personnel. These two areas are connected by the fuel transfer system that carries the fuel through an opening in the containment building.

In the reactor cavity, fuel is removed from the reactor vessel, transferred under the water and placed in the fuel transfer system by a manipulator crane. In the adjoining fuel storage building the fuel is removed from the transfer system and placed in underwater storage racks. After a sufficient decay period, the fuel is removed from storage and loaded into a shipping cask for removal from the site.

New fuel assemblies are received and stored in the fuel storage building. New fuel is delivered to the reactor by lowering it into the spent fuel pit and taking it through the transfer system. Alternatively new fuel may be taken through the containment building equipment hatch and lowered directly into the reactor cavity.

h. Instrumentation and Control

The reactor is controlled by the negative temperature coefficient of reactivity; by control rod motion, which is required to follow larger load transients and for start-up and shutdown; and by a soluble neutron absorber, which is inserted during cold shutdown, partially removed to start-up and gradually further removed to compensate for such long term decreases in reactivity as fuel burn-up and fission product accumulation.

The control system, subject to limitations imposed by xenon buildup, is designed to accept step load changes of 5 percent and ramp load changes of 3 percent per minute over the entire load range (15 to 100 percent of full power), and to accommodate (by steam dump) an instantaneous loss of 40 percent of rated load without scram. The plant is able to accept instantaneous loss of full load with scram without damage to the plant. Complete supervision of both the nuclear power plant and desalting plant is accomplished from a central control room.

i. PWR Containment Building

The reactor and systems containing high pressure primary coolant are housed in a containment building designed to contain all of the primary coolant and any fission products released in the unlikely event of a rupture in the primary system.

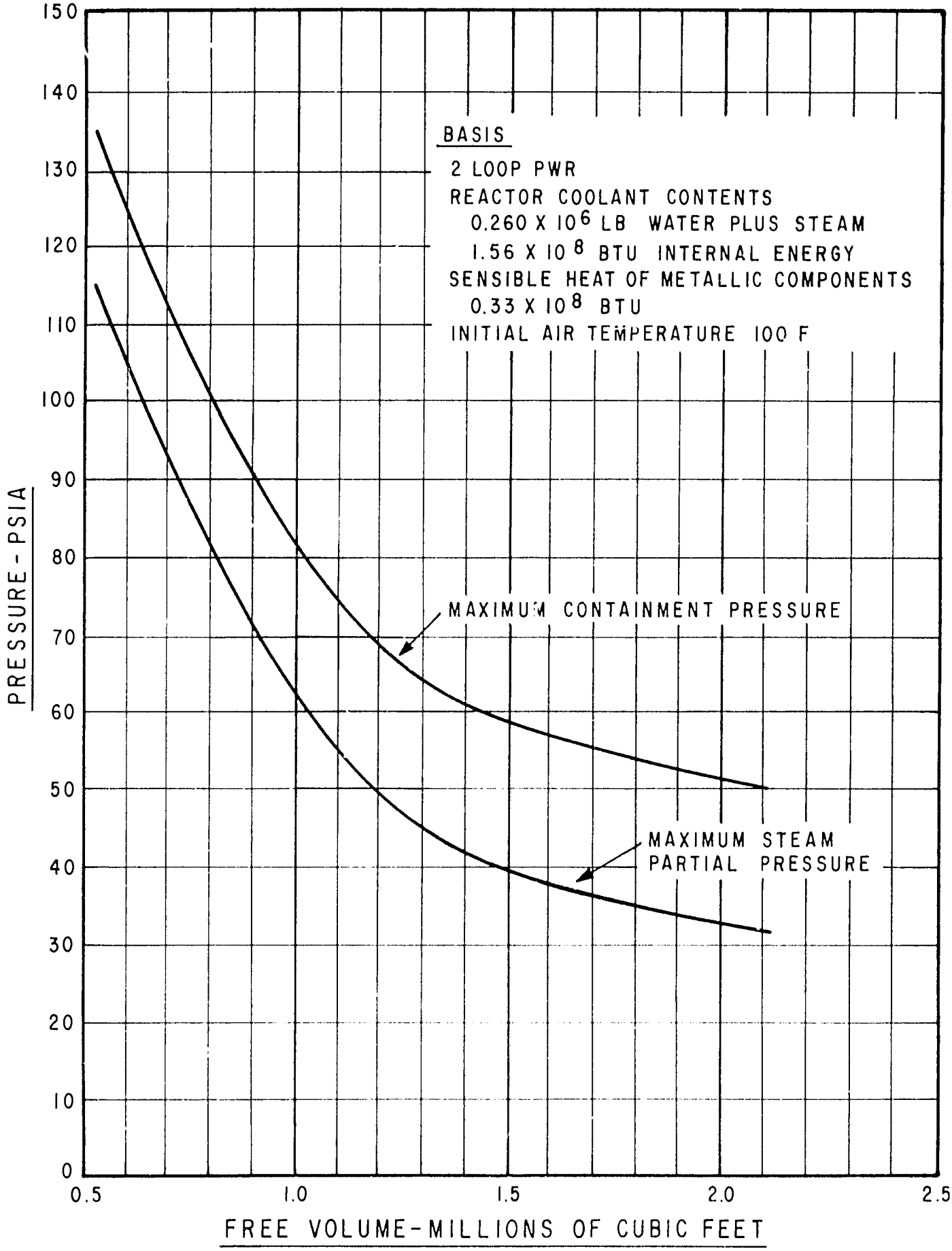
A curve showing the pressure resulting from such a rupture as a function of the free volume of the containment building is shown in Chart No. 1 which follows. The leakage rate from the containment building, under the pressure conditions resulting from the release of all of the primary coolant to the containment atmosphere, will be less than 0.1 percent of the containment contents per day. Leakage testing of the building will be measured by either the absolute method or the reference vessel method, as set forth in proposed Standard ANS 7.60 of the American Nuclear Society, "Leakage Rate Testing of Containment Structures for Nuclear Reactors". To minimize the leakage of radioactive fission products that could occur after a "maximum credible accident" the containment building spray system (previously described) is included in the plant facilities. No secondary shielding is provided exterior to the containment building, on the assumption that an exclusion radius of at least 2,000 meters will be provided.

Three types of containment building for the PWR power plant were investigated: a steel sphere, a reinforced concrete cylinder with a hemispherical dome, and a prestressed concrete cylinder. All three types are considered generally suitable for containment building designs at sites similar to that selected for the proposed plant. The direct construction cost estimates for the three types of containment differ by less

CHART NO. 1

CONTAINMENT SHELL

PRESSURE-VOLUME RELATIONS



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than $240,000 or 7 percent; the steel sphere results in the highest cost and the prestressed concrete cylinder, the lowest cost. However, it is anticipated that the increased engineering cost and indirect construction costs for the concrete containment, as compared with the steel sphere, will more than offset the lower direct construction costs for concrete. It can, therefore, be concluded that the use of any of the three containment types will not significantly affect the capital cost of the dual-purpose plant.

The concrete containment schemes offer certain advantages compared to the steel sphere. These are:

- Greater use of Israeli materials and labor.
- Increased safety by virtue of the secondary shielding inherent in the concrete containment walls.
- Lesser susceptibility to major damage as a result of sabotage or other acts of conventional warfare.

On the other hand, a preliminary analysis of the construction schedule for both steel and concrete containment indicates that the use of concrete will delay the plant start-up by about 6 months. Moreover, assuming contract award to a reactor manufacturer will not be accomplished earlier than May 1967, the use of a concrete containment building will not permit plant start-up in 1971. Therefore, unless further review develops methods of shortening the construction schedule for concrete containment, the steel sphere is the recommended containment building for PWR power plants. Descriptions of the three containment buildings follow.

The steel containment, in the form of a sphere 136 ft in diameter (Figures 17 and 18), will be fabricated of "fire box" quality steel plate approximately 1-3/8 in. thick. It will be constructed in accordance with the ASME Boiler and Pressure Vessel Code - Sections III and VIII, using Type A 212 Grade B or A 516 Grade C steel. With either of the above grades of steel stress relieving after welding is not required provided that the wall thickness does not exceed 1-1/2 in.

The reinforced concrete containment will be in the form of a right circular cylinder, 114 ft inside diameter by 120 ft inside height, surmounted by a hemisphere of 114 ft inside diameter (Figure 19 and 20). The walls in the cylindrical portion will consist of reinforced concrete approximately 6 ft thick; the walls in the hemispherical portion will be approximately 3 ft thick. To prevent leakage, the containment building will incorporate an inner steel liner with an average thickness of 3/8 in. The reinforcement will be provided by ASTM A-431 steel reinforcing bars, of sizes up to No. 18S, with a minimum yield strength of 75,000 psi. The structure will be designed in accordance with the applicable provisions of the standards of the American Concrete Institute No. 318.

The prestressed concrete containment will be similar to that of reinforced concrete, except that the cylindrical section has an inside height of 128 ft and the dome is a spherical segment with an inside radius of 114 ft. The concrete walls in the cylindrical portion will be approximately 3 ft thick and in the dome 2 ft thick. A steel liner with an average thickness of 3/8 in. will be provided. Hoop prestressing in the cylindrical section will be accomplished by the wire-wrap technique using steel wires with an ultimate strength of 240,000 psi. Six layers of wire wrapping will be required with a 3/8 in. gunite concrete coating between layers. Vertical prestressing of the cylinder and prestressing of the dome will use post-tensioned tendons consisting of cables built up of 84-1/4 in. diameter steel wires. Steel reinforcing rods will also be provided at the inside surface of the walls to aid in withstanding temperature-induced stresses.

2. Nuclear Power Plant - Boiling Water Reactor

The reference nuclear power plant using a boiling water reactor will consist primarily of:

- A "nuclear boiler" using a direct cycle, boiling light-water cooled and moderated nuclear reactor and its auxiliaries.
- A 3,000 rpm noncondensing turbine-generator unit.

- Power plant auxiliaries such as condensate and boiler feed pumps and feedwater heaters, and certain special power plant auxiliaries such as full-flow condensate demineralizers and a heat exchanger to generate nonradioactive steam for use in the desalting plant air ejectors.

- A reactor building which will include a pressure-suppression containment system consisting of a steel pressure vessel drywell venting into a steel toroidal-shaped suppression pool.

- A radioactive waste treatment facility.

- A reactor auxiliary building, turbine-generator building and several smaller service buildings.

Although the brine heaters are considered part of the desalting plant they also serve as a condenser for the power plant. The steam piping up to the brine heaters (including the double steam isolation valves), the condensate pumps and condensate piping are all included with the power plant. Shielding is provided around the steam piping and the brine heaters. The average quantity of heat supplied to the desalting plant brine heaters is approximately 3.3×10^9 Btu/hr. This will increase during periods of coldest seawater temperature to approximately 3.5×10^9 Btu/hr and will decrease during periods of warmest temperature to approximately 3.0×10^9 Btu/hr.

As can be seen from a power plant heat balance utilizing a typical BWR nuclear boiler (Figure 21), the average reactor thermal power is about 1,250 MWt. During the periods of the coldest seawater temperature the reactor thermal power will increase to about 1,330 MWt (which is within the stretch capability of the reactor); during the periods of the warmest seawater temperature the reactor output will decrease to about 1,160 MWt.

a. Reactor Coolant System

The BWR nuclear boiler consists of the reactor vessel with its core, internal steam separators and dryers, and control rod drives; two recirculation pumps; and supporting auxiliary systems. The nuclear fuel core, generating heat within the reactor vessel, boils water, producing saturated steam which, after drying, passes directly into the turbine.

Within the reactor vessel, the steam generated by the nuclear fuel passes into the steam separators where moisture content is reduced to less than 5 percent, then to the steam dryers where it is reduced to less than 0.1 percent before passage to the turbine. Water discharged from the separators and dryers flows downward in the annulus between the shroud and the vessel wall and is joined by the incoming feedwater; a portion of the recirculated water exits to the external loop system via the recirculation outlet. The external recirculation flow can be varied over a specified range by means of variable speed motor driven pumps. The external recirculation flow re-enters the vessel via the recirculation inlet, enters a manifold, passes through pipe risers, then turns back down, acting as driving flow for the remaining water in the jet pumps. In the jet pumps, the driving and the driven flow join to be mixed and discharged through the shroud to the bottom of the core--thus completing the recirculation cycle.

b. Core

The nuclear fuel is stacked in a modular array between the core support plate and the upper support grid. Cruciform-shaped control blades are positioned between the fuel assemblies by bottom-entry, locking-piston control drives. The movement of the control blades below the core is supported by a control rod guide tube, which also supports a group of four fuel assemblies.

Each fuel assembly is uniform in size with a 7 by 7 rod array of slightly enriched UO_2 pellets within Zircaloy-2 cladding. Each 7 by 7 rod array is enclosed in a Zircaloy-4 channel. The fuel rods are 0.570 in. in diameter with an active fuel length of 12 ft. The core is built up of modules consisting of one control blade and four fuel assemblies.

During refueling a portion of the fuel assemblies is removed and replaced with new fuel. Rather than "zone refueling," as described for pressurized water reactors, a leading BWR manufacturer uses a "scatter pattern" refueling system. At equilibrium approximately 20 percent of the core is replaced at each annual refueling.

c. Recirculation Pumps

The system utilizes high efficiency water jet pumps and centrifugal pumps in combination to provide forced recirculation coolant. With the jet pumps located within the reactor vessel, in the peripheral annulus around the reactor core, a portion of the coolant is extracted from the vessel and returned by the centrifugal pumps at a pressure sufficient to provide the jet pump nozzle or "driving" flow. The high energy driving flow provides the total reactor core recirculation flow required.

The jet pump system requires very little modification of a "conventional" reactor vessel. It is basically the same vessel except for the housing provision for the pumps. These are located in the annulus around the core.

d. Instrumentation and Control

Reactor power is monitored from the source range up through the power operating range by neutron monitoring channels. All detectors for neutron monitoring are placed inside the reactor vessel.

Three separate neutron monitoring systems--the Source Range, Intermediate Range and Power Range--monitor and protect the core during all periods of start-up and power operations.

The power range in-core monitoring system gives the operator confirming information on static and dynamic core conditions. It provides him with a "cause and effect" understanding through immediate visual information of the effects of rod movement or other actions that may affect the reactor.

The reactor is normally controlled by changing the recirculation rate (taking advantage of the negative power coefficient) and by control rod motion. Temporary "poison curtains" of boron-stainless steel are inserted with the first core to control the large excess reactivity required at "clean" start-up; they are removed at the time of the first refueling.

Reactor power can be controlled over a 25-30 percent range of adjustment using reactor recirculation flow without requiring control rod movement. The rate of power change is in the

range of 15-30 percent per minute. Reactor power change is accomplished by utilizing the large negative power coefficient found in the BWR design. To increase reactor power, recirculation flow is increased. This reduces the void accumulation in the core by removing the steam formation at a faster rate, thus increasing reactivity in the core. As reactor power increases, a new power level is established where the transient excess reactivity is balanced by the new void formation. Conversely, when a power reduction is required, recirculation flow is reduced.

Present commercial boiling water reactors use bottom-entering control rod drives. The top of the reactor vessel is thus available for steam separators and dryers. The principal BWR manufacturer employs hydraulically-operated drives of the "locking-piston" type. The cruciform shaped control rods employ boron-carbide pellets clad in stainless steel as the control material.

A steam bypass system which can dump 40 percent of the rated steam flow to the brine heaters is supplied with the turbine to prevent serious pressure transients and to avoid operation of the safety valves or emergency condenser following sudden closure of the turbine control valves or stop valves.

Complete supervision of both the nuclear power plant and desalting plant is accomplished from a central control room.

e. Fuel Handling

The reactor is refueled with equipment designed to handle the spent fuel under water from the time it leaves the reactor vessel until it is placed in a cask for shipment from the site. Underwater transfer of spent fuel provides an effective and economical transparent radiation shield, as well as a reliable cooling medium for removal of decay heat.

At the beginning of a reactor refueling, an inflatable seal is installed between the vessel flange (the flange to which the top head is bolted) and the drywell wall. This seal permits the reactor water level to be raised above the vessel flange and in the flooded area of the drywell (above the vessel flange level) up to the water level in the storage pool.

Shielding blocks in the connecting slots between the reactor equipment storage pool and the drywell are removed prior to flooding the drywell. A protective cover over the fuel storage pool slot and drywell wall opening is also removed prior to flooding. Following the flooding of the drywell, the water gate between the storage pool and connecting drywell slot is opened, thereby permitting the underwater passage of fuel into the storage pool. The pool for storing reactor internal equipment is also flooded when the drywell is flooded.

To ensure that outage time is kept to a minimum, irradiated fuel is moved directly from the reactor to the storage pool racks. As a general rule, no attempt would be made to perform fuel channel stripping or new fuel rechanneling concurrently with reactor fuel removal or loading operations. No attempt would be made to load new fuel into the vessel until all the old fuel removal and shuffling have been completed.

The storage pool contains sufficient area to store up to 150 percent of a core load of fuel elements plus a full complement of control elements and temporary poison curtains. It is possible to store two reload batches and still have space for storing an operating core load of fuel if it were necessary to do so. The large storage capacity ensures that the plant maintenance operation will not be hindered by a lack of fuel storage capacity and it also allows the plant operators to vary the procedures and schedules for shipping spent fuel to the reprocessing centers in accord with variations in reprocessing economics.

New fuel bundles are stored in a dry vault located in the reactor building. This vault is sized to store up to 30 percent of a core load of unirradiated fuel elements. Prior to a refueling outage, new fuel bundles are shipped to the plant, inspected, and stored in racks in a new fuel vault. Shortly before the shutdown is scheduled, these fuel bundles are removed from the vault and placed in the fuel storage pool. In the storage pool, they are fitted with new or previously irradiated reusable fuel channels and placed in a storage rack until time for insertion in the reactor.

f. Auxiliary Systems

Boiling water reactor power plant auxiliary systems are provided to purify reactor coolant water, cool the spent fuel storage pool, supply high pressure demineralized water to the

control rod drive system, and remove decay heat when the reactor is shut down normally and when isolated from the brine heaters. Additional safeguard systems are incorporated to minimize the possibility of personnel exposure to excessive radiation. These additional safeguards include a core spray system, a liquid poison injection system and a containment spray system. A radioactive waste disposal system is provided to concentrate safely and store radioactive wastes generated during operation at the plant.

The coolant purification system provides continuous purification of a portion of the recirculation flow with a minimum of heat loss and no water loss from the cycle. It can be operated to purify primary system water during startup, shutdown and refueling operations as well as during normal operations. Water is normally removed under reactor pressure and cooled in a regenerative heat exchanger and a nonregenerative heat exchanger, reduced further in pressure, filtered, demineralized and pumped through the shell side of the regenerative heat exchanger to the reactor. Whenever reactor pressure is insufficient to maintain cleanup system recirculation pump suction pressure, an auxiliary pump is used.

The fuel pool cooling system will prevent steaming in the fuel storage pool by removing decay heat from spent fuel which is awaiting shipment to a reprocessing plant. The system will be designed to maintain fuel storage pool temperature at or below 52 C (125 F).

In addition to maintaining the specified pool water temperature, the fuel pool cooling system provides continuous filtration of storage pool water to minimize the amounts of crud and corrosion products in the system.

The control rod drive feedwater system supplies high pressure demineralized water to the control drive system to provide hydraulic operating pressure and a flow of water into the reactor from the drive mechanisms to provide cooling for the drive unit.

The system is made up of high-head, low-flow pumps, filters, control valves and process instrumentation. Each pump is capable of supplying the requirements of the rod drive systems.

The shutdown cooling system is provided to remove decay heat from the reactor water during shutdown. In cooling the reactor, the turbine bypass system is initially used to dump steam to the brine heaters. When the reactor water temperature reaches 121 C (250 F), approximately three hours after shutdown, the shutdown system is placed in service. It is designed to reduce the reactor water temperature from 121 C (250 F) to 52 C (125 F) within twelve hours after the system is put in operation. The system is then used to maintain reactor water temperature at or below 52 C (125 F) which is a practical maximum for refueling and servicing operations.

To provide for maximum flexibility of operations over a wide range of thermal conditions, the shutdown cooling system consists of two parallel circuits. Each circuit consists of a pump, heat exchanger, and related piping, valves and instrumentation. Cooling for the shutdown heat exchangers is provided by the reactor building cooling water system.

The purpose of the Reactor Core Isolation Cooling system (RCIC system) is to remove decay heat from the reactor in the event it becomes isolated from the brine heater by a closure of the main steam isolation valves.

Heat is removed from the reactor by the RCIC system by continuous venting of steam from the reactor vessel to the pressure suppression pool. The venting is accomplished by the reactor pressure relief valves. These valves open automatically or manually at 85 psi to 100 psi above reactor normal operating pressure and discharge directly to the suppression pool. These valves also serve to prevent lifting of the reactor safety valves on a reactor scram. It should be noted that the incorporation of the RCIC system was accomplished too late to be reflected in Figures 22 and 23. The cost estimate for a BWR power plant does reflect the use of the RCIC system.

Makeup to the reactor vessel to replace the steam vented to the pressure-suppression pool is provided by the turbine-driven makeup pumping system. A small fraction (10%) of the steam produced in the reactor by core decay heat is needed to drive the turbine. The turbine exhausts directly to the pressure suppression pool. The makeup pump takes suction directly from the condensate storage tank and discharges directly to the reactor.

Reactor and decay heat can be transferred to the pressure suppression pool for a period of about eight hours without cooling of the pool water being required.

The core spray cooling system is provided to prevent core meltdown under postulated accident conditions involving loss-of-coolant. The system also prevents large-scale cladding ruptures and reduces the mobility of radioactive iodine by absorption of the gas in the spray water. The release of fission products from the core as a consequence of this assumed "maximum credible accident" is essentially zero.

The system consists of two independent spray systems; either system has sufficient capacity to accomplish the core spray function. Each system uses an array of water spray nozzles and distribution headers over the core to deliver cooling water in spray form from the pump.

Activation of the core spray cooling system is automatic on indication of emergency low water level in the reactor or of high pressure in the reactor drywell enclosure.

The liquid poison system is provided to keep the reactor shut down in the unlikely event that sufficient control rods are not inserted in the core to keep the reactor subcritical in the cold shutdown condition. For example, less than one-half of the total control rods are needed to make the reactor subcritical in the hot condition. However, if a large fraction of the rods should remain in the withdrawn condition, the reactor could conceivably slowly return to criticality as reactor temperature is reduced. This means that the reactor temperature would stabilize and no further reduction would be possible. In this event, the liquid poison system can be initiated by the reactor operator, causing a sufficient negative reactivity to render the reactor totally subcritical in the cold condition. The poison solution is sodium pentaborate which is injected into the reactor through spray nozzles over the core.

The post incident cooling system, or containment spray system, serves two basic functions. The first function is to remove heat from the water in the suppression system torus and thereby aid in reducing the residual pressure in the containment system in the unlikely event of a loss-of-coolant. This

reduction of pressure is a major factor in minimizing the potential for release of activity from the plant if an accident should occur. The second function of the system is to provide back-up for the reactor core spray system. The system will consist of two vertical pumps which take suction from the pressure suppression torus and pump through heat exchangers. From the heat exchangers, the water is directed to spray heads located in each drywell vent.

The radioactive waste disposal system (located in a separate building near the reactor building) provides the tankage and facilities necessary to collect, segregate, and safely process radioactive wastes, including gases, liquids and solids (Figure 24). A combination of processes provides holdup for decay and dilution of gases before discharge to the atmosphere, containment of solid wastes in drums, and holdup for decay, filtration, evaporation, demineralization, and/or flocculation-clarification of radioactive liquid wastes. Purified effluent from the liquid process will be utilized as make-up water to the reactor and steam plants. The radioactivity removed from the liquid wastes will be contained on ion-exchange resins or in the sludge from the evaporation or flocculation treatment.

g. BWR Containment

Recent boiling water reactor plants have used a pressure-suppression containment system. This type of containment is particularly well suited to boiling reactors because of their physical arrangement and relatively low stored energy.

In the BWR pressure-suppression containment system, the nuclear boiler and the recirculation system are contained in a drywell, which is itself a steel pressure vessel. The drywell is normally filled with air at near atmospheric pressure. Vents lead from the drywell into a pool of water which is in a separate steel pressure vessel, the suppression chamber. In the very unlikely event of a break in the reactor primary system, water and steam release would cause a rise in drywell pressure. Air, steam and water would then flow from the drywell through the vents to the suppression chamber water pool where the steam would be condensed.

The reactor containment is actually two structures in one. The primary barrier consists of the combination of the drywell and the pressure-suppression pool. The secondary barrier is the concrete reactor building (not designed for significant pressure containment), enclosing the auxiliary equipment, including the fuel storage pool, fuel handling facilities, the clean-up loop, the isolation condenser and the shutdown cooling loop.

Shielding is provided for access to various areas within the building during operation of the plant. This permits work around the fuel storage pool and allows maintenance of equipment and instrumentation during reactor operation.

The design pressure for the drywell is approximately 60 psig and that for the suppression pool is 35 psig. Since structural considerations rather than pressure stresses set the steel thickness, it is often convenient to design and test both the drywell and suppression pool for 60 psig.

The leakage rate from the pressure-suppression system, under the pressure conditions resulting from the release of all of the primary coolant, will be less than 0.1 percent of the containment contents per day Leakage will be measured by either the absolute method or the reference vessel method, as set forth in proposed Standard ANS 7.60 of the American Nuclear Society, "Leakage Rate Testing of Containment Structures for Nuclear Reactors." To minimize the leakage of radioactive fission products that could occur after a "maximum credible accident" the containment spray system (previously described) is included in the plant facilities. Sufficient concrete shielding is normally provided exterior to the drywell and suppression pool to permit normal access to the other areas of the reactor building. This concrete will also reduce the direct radiation levels in the event of a maximum credible accident.

Preliminary estimates indicate that the cost of the reactor building (including pressure-suppression) and auxiliary buildings for a BWR plant using pressure-suppression containment are approximately $300,000 less than the cost of the corresponding structures for PWR plants. The use of pressure-suppression containment with a BWR nuclear boiler will permit a construction schedule consistent with 1971 plant startup.

It has been concluded that the BWR pressure-suppression containment is suitable for the proposed dual-purpose plant in Israel. A description of the arrangement of such a pressure-suppression system and its surrounding reactor building follows:

The drywell (Figures 22 and 23) consists of a "pear-shaped" steel pressure vessel--a spherical section, approximately 58 feet diameter, surmounted by a vertical cylindrical section, approximately 32 feet diameter by 30 feet high. The cylindrical section necks down to a flanged closure with a 24 foot internal diameter. The suppression pool is in the form of a torus with a 122 feet outside diameter and a circular cross section of 26 ft diameter. The drywell and torus are interconnected by ten vent pipes approximately six feet in diameter. The pressure-suppression system and the reactor plant equipment are housed in a reactor building approximately 176 feet above grade and 15 feet below grade. It is approximately 133 feet long by 100 feet wide. Walls are of concrete construction, approximately one foot thick with reinforced concrete columns and beams; the roof structure is of precast concrete decking. Although reasonably leaktight, the building is not designed for pressure containment.

3. Turbine-Generator Plant Description

The turbine-generator plant is designed to generate approximately 250 MWe (gross) electricity from steam produced in the reactor plant while delivering sufficient exhaust steam to the water desalting plant to produce 100 MGD water. The net salable power is 200 MWe after providing for all dual-purpose plant requirements.

The specific turbine-generator requirements depend upon the reactor selection, as the turbine inlet steam conditions, and the nuclear power plant auxiliary power are dependent upon this selection. For example, the general description of the turbine-generator required by the PWR and BWR nuclear reactors described previously in this subsection is as follows:

	PWR	BWR
KW rating required	253,000	251,000
Type	Tandem compound two-flow	Tandem compound two-flow
RPM	3,000	3,000
Throttle pressure	752.7 psia	965 psia
Throttle enthalpy	1,197.36	1,191.2
Throttle moisture	0.36% maximum	0.28% maximum
Exhaust back pressure	26 psia	26 psia
Generator rating	320,000 kva	320,000 kva
Generator power factor	0.85	0.85
Power characteristics	3-phase, 50 cycle	3-phase, 50 cycle

The turbine unit is provided with the standard auxiliary equipment or features including the turbine governor and stop valves, oil system, gland sealing system, turning gear, and normally installed protective devices.

The generator unit is provided with the standard auxiliary equipment features including hydrogen cooling, shaft-driven and auxiliary exciter and normally-installed instrumentation.

The turbine generator unit is installed in the turbine building as shown in Figures 25 and 26. Included in this installation are the two moisture separators which remove the moisture from the partially expanded steam at the crossover between the two turbine casings. The turbine room equipment includes the feedwater heaters and condensate booster pumps, shaft driven and auxiliary exciter, hydrogen cooling system, oil coolers and oil system. Adjacent to the turbine room is a pump room which houses three boiler feed pumps, a heating boiler with deaerator and the plant air compressors.

Adjacent to the turbine room is the demineralizer room with equipment for purifying makeup water.

The turbine exhaust steam passes from the turbine room to the desalting plant where it is condensed in the brine heaters at 25 psia (allowing a 1 psi pressure drop between the turbine exhaust flange and the brine heater inlet flange). The condensate is pumped from the brine heater sumps to the turbine room where it is heated in closed feedwater heaters before returning to the

reactor plant steam generator. Four one-quarter capacity condensate pumps (one for each brine heater) and three one-half capacity booster and feedwater pumps are provided.

The turbine-generator plant includes all of the accessory electrical equipment required for its operation and the 15,800 volt generator buses up to the low voltage side of the step-up transformer.

4. Power Plant Electrical System

The schematic arrangement of the power plant electrical system is shown on Figure 27 "Electrical Single Line Diagram, Nuclear Power Plant".

The plant electrical system includes the main generator, its auxiliary electrical equipment, the station service transformers, the starting transformer, all 4.16 kv and low voltage switchgear, emergency generator sets, and all bus and wiring installations to ensure operation of the plant during normal and emergency conditions. The plant auxiliary system requirements are normally supplied by the station transformers. During starting conditions power is fed by means of a starting transformer tied to the 161 kv switchyard bus energized by the 161 kv Israel Electric Corporation network tie lines.

The main switchyard is connected by one tie line to the Israel Electric Corporation network and one tie line to the water plant substation. The other tie line to the Israel Electric Corporation network is connected at the 161 kv bus of the water plant substation.

a. Description of Major Equipment and Arrangement

The generator is a 3,000 rpm 50 cycle 3-phase synchronous machine of the conductor cooled type with liquid cooled stator and with the following characteristics.

Capability	320,000 kva
Power factor	85%
Hydrogen pressure at rating	45 psi
Short circuit ratio	58
Sub-transient reactance	9%

The excitation is supplied by a directly connected gear driven exciter or by a spare motor generator exciter set arranged for quick starting upon loss of field and provided with a suitable flywheel. The generator neutral is grounded through a suitable distribution transformer and current limiting resistor.

b. Main Transformer

Although the main step-up transformer is not included in the production plant account, for purposes of determining breaker interrupting capacities it was assumed that the main step-up transformer has the following characteristics.

Rating: 300 MVA FOA
Voltage Ratio: 15/161 kv $\pm$ 2 x 2.5%
Impedance: 12.75%
Delta-Star connection
Grounded secondary neutral

No breakers are used between the generator and the low voltage side of the transformer.

c. Station Transformers

During normal operation, the station service requirements are supplied by two 15 kv/4.16 kv station service transformers fed by the generator bus. These transformers have the following characteristics:

Rating: 12/16 MVA, OA/FA
Voltage Ratio: 15/4.16 kv $\pm$ 2 x 2.5%
Impedance: 7.2%
H. V. Delta - L. V. Star grounded neutral

d. Startup Transformer

With the turbogenerator shutdown and during starting and shutdown periods the station service requirements are met by one starting transformer fed by the 161 kv switchyard bus. This transformer has the following characteristics.

Rating: 15/20/25 MVA OA/FA/FA. 65 C
Voltage Ratio: 161/4.16 kv $\pm$ 2 x 2.5%
Impedance: 9%
650 kv BIL

e. Plant Auxiliary Distribution System

The plant auxiliary distribution system is rated at 4.16 kv and 400 v and is designed for good performance and reliability. The system has two main sources of power: (1) the generator bus through the two station service transformers and (2) the 161 kv switchyard bus by means of the starting transformer. The system is provided with a no loss of load quick transfer arrangement to change the source of supply.

The 4.16 kv portion of the system is arranged in a double bus system serving both the reactor and turbogenerator portions of the plant and also includes the 4.16 kv shutdown bus provided with its own 3750 kw diesel generator set. The shutdown bus is normally energized by either one of the 4.16 kv buses.

A quick transfer arrangement triggered by loss of voltage transfers the shutdown bus supply to the alternate 4.16 kv bus. Return to normal supply is done manually. A tie to the water plant substation is also interlocked with the other bus sources. In the event of complete loss of voltage from all sources the 4.16 kv bus is disconnected from them and the emergency diesel generator is automatically started to ensure an orderly shutdown.

The 400 volt system consists essentially of a double bus system in both the reactor and turbogenerator portions of the plant. Each of the A and B 400 volt buses is energized by means of its own 4.16 kv/400 volt transformer fed by the respective A and B 4.16 kv bus. Alternate supply is assured by the 1,000 kva auxiliary transformer fed from the 4.16 kv shutdown bus. Only the radioactive waste disposal bus has a sole source of supply.

The 400 volt system also includes a single reactor pressurizer bus and shutdown bus provided with its own 500 kw small diesel generator set which will enable it to provide the most

essential power requirements during emergencies. The 400 volt shutdown bus is normally energized by the 4.16 kv bus through a 750 kva transformer.

All auxiliary buses are of the totally enclosed type, metal clad cubicle construction and equipped with drawout air circuit breakers. They can be divided into three categories:

- Metal-clad switchgear rated for 4.16 kv service and with 250,000 kva interrupting capacity using stored energy electrically operated drawout type air circuit breakers. Source breakers have 3,000 amp continuous rating and feeder breakers are rated 1,200 amps. All breakers in the 4.16 kv bus are remotely operated from the control room. In the control room a mimic bus represents the actual breaker arrangement.

- Metal-clad switchgear rated for 400 volts service furnished with electrically or manually operated drawout air circuit breakers rated at 30,000 symmetrical amps interrupted capacity. Source breakers have a rating of 1,600 amps continuous duty while feeder breakers have 600 amps continuous duty rating.

- Metal enclosed 400 volt motor control centers serving motors up to 25 hp. The motor control centers have molded case circuit breakers provided with thermal or magnetic overload trips.

f. Physical Location of Switchgear

All the 4.16 kv switchgear is located in the reactor auxiliary building. The 400 volt buses and switchgear are located adjacent to their service areas in the reactor auxiliary building and in the turbine room. The radioactive waste disposal bus and switchgear is located in the radioactive waste disposal building.

g. Cables, Trays, Conduits and Cable Ducts

The 4.16 kv auxiliary power circuit cables are of single conductor type, ozone resistant, rubber insulated, shielded and neoprene jacketed. The 400 volt cables are also single conductor, polyethylene insulated with polyvinyl chloride jackets

and rated for 600 volts service. Control cables are both single and multi-conductor type and rated 600 volts. Cable trays are used extensively throughout the plant, however, where indicated, aluminum or galvanized conduits are used.

h. Motors

All motors in the power plant above one hp are 3-phase, squirrel cage induction type and unless otherwise indicated are arranged for full voltage starting. The motor voltage ratings are 4.16 kv for motors rated above 200 hp and 400 volt for motors rated less than 200 hp. Indoor motors are of the drip proof type, while outdoor motors such as hotwell pumps are of the totally enclosed type.

i. Grounding System

A dependable low resistance ground system is provided for protection of personnel and proper functioning of electrical equipment.

j. Lighting

The lighting system has a voltage rating of 220 volts and the various lighting transformers (400/220 v) are fed by the 400 volt buses. Provision is made for an emergency a-c lighting system fed normally by the 400 volt shutdown bus and automatically switched to the emergency d-c source in the event of loss of power. Standard industrial fixtures are used throughout the plant. Vapor proof fixtures are used in areas subject to vapor or moisture.

k. D-C System

The 220-230 volt d-c system is not shown in the one-line electrical diagram drawing. It consists of two buses each having its own storage battery. Its battery charger and inverters are used to supply the instrumentation and control buses during emergency conditions.

The emergency lighting system can also be fed by this system.

5. Maintenance and Service Facilities

Facilities are provided for ordinary maintenance and repair of power plant components. These facilities are housed in the machine shop and central repair shop as shown in Figure 5, Dual-Purpose Plant Plot Plan. A decontamination facility, located adjacent to the nuclear reactor building, is provided to permit decontamination of radioactive components prior to their repair.

6. Emergency Cooling Line

In the event the desalting plant is shut down, provision has been made to supply cooling seawater to the brine heaters which act as condensers and allow continued full power operation of the power plant. A 1.5 meter diameter emergency cooling water line is shown in Figure 5; it provides seawater to the brine heaters directly from the intake seawater pumps, thus allowing the brine heaters to be operated as condensers.

E. Intake and Outfall

1. Intake Facility

The intake facility for the dual-purpose plant must continuously supply seawater for condensing vapor in the evaporator heat reject stages for seawater make-up to the evaporator and for auxiliary cooling. The facility must avoid constrictions due to seaweed, drifting sand, fish, and marine growth.

The required seawater intake capacity for the 100 MGD dual-purpose plant is 570,000 gpm. This includes 420,000 gpm for desalting plant heat rejection, 139,000 gpm for make-up to the evaporators and 11,000 gpm for other services.

The intake facility will consist of two intake structures located approximately 450 meters offshore (which is beyond the turbulent surf zone) in 7 meters of water depth, and separated from each other by a distance of about 90 meters as shown in Figure 28. Each intake will have a "fish cap", the top being 3 meters below minimum water level. The bottom of the openings in the intake structure will be 2 meters above the sea floor. The intake structures will each be connected to the pumping structure with reinforced concrete conduits buried in a trench in the sea floor. At

the pumping structure, each conduit will enter a separate compartment equipped with the usual stop-logs, static and traveling screens, screen cleaning facilities, and a provision for the collection and mechanical removal of sand. Each conduit can be isolated to facilitate the use of chlorine for the control of marine growth.

In the pumping structure are nine vertical direct drive pumps which supply water to the desalting plant and salt water cooling system.

2. Outfall Facility

The outfall facility will consist of a buried reinforced concrete box culvert with transition to an open channel beyond the water plant limits. The open channel will discharge at the shoreline.

Hydraulic characteristics will be established to minimize back pressure on the system and to provide sufficient velocity to eliminate sand deposit at the point of discharge.

Recirculation problems will require further investigation; however, the proposed conduit intake will reduce this to a minimum due to the mixing which will occur as the effluent passes through the surf zone.

The arrangement of the outfall canal and the reject seawater and brine piping are shown in Figure 5.

F. General Plant Facilities

The two sites under consideration are on the coastal sand dunes near Ashdod (Figure 4), and are described more fully in subsection D of this section. Approximately 40 acres (160 dunams) are required for the power and water plants, substation, and general plant facilities (Figure 5). Both sites being considered are suitable for grading to a nearly level area, and have sufficient area to accommodate several dual-purpose plants of the size of plant selected for this study.

The sites are now accessible by existing hard surface all-weather roads. The cost estimates provide for a new heavy-duty asphaltic access road to be used during construction and for hauling of operational supplies. Inside the plant boundaries would be paved access

roads to all important maintenance areas, a vehicle parking area, and paved general working areas.

The yard services include fencing for the entire plant site, fire mains and hydrants, domestic water and sanitary sewers with a septic tank; storm sewers, yard lighting and landscaping.

The on-site facilities include a warehouse, a machine shop and a cafeteria.

1. Access Roads

During the construction of the dual-purpose plant, it will be necessary to transport a large amount of material to the site. Probable maximum weights and dimensions of the largest pieces of mechanical equipment are as follows:

- nuclear steam generator
  67 ft long x 18 ft wide, weighing 500 tons

- electric generator stator
  30 ft long x 15 ft wide, weighing 280 tons

- desalting plant evaporator
  80 ft long x 10 ft wide, weighing 200 tons

In addition to transportation of these major items of equipment, approximately 160,000 tons of aggregate, and 24,000 tons of steel will be required during construction.

The main Tel Aviv-Ashkelon railroad and adjacent highway are parallel to the seacoast and are approximately 3 kilometers inland from Site II, and 7 kilometers inland from Site I. The existing hard surface road to the two sites is not adequate for use during construction. For this study, the conservative assumption was made that extensive roadwork will be required to handle the major items of equipment which will be unloaded at one of the ports of Israel and transported by rail to the railroad siding servicing the plant. The new roadwork will also accommodate those major items which will be transported from Ashdod by truck.

The existing Tel Aviv-Ashkelon highway from Ashdod to a point closest to the selected site should be modified so that no grades

greater than 6 percent or curves of radius less than 20 meters will occur (this will accommodate a 20 meter wheelbase trailer). A new road will be required connecting a new rail siding to the existing Tel Aviv-Ashkelon highway and the highway to the dual-purpose plant.

The capital cost estimate includes an allowance to cover the new roads from the highway to the rail siding; the highway to the plant site; modifications to the existing highway to accommodate the large heavy loads expected; and repairs to the road resulting from the construction traffic. This allowance is equivalent to the cost of building a new asphaltic surface highway 6 meters wide and 8 kilometers long.

2. Rail Siding

A siding is required on the Ashdod-Ashkelon railroad for transfer of materials shipped by rail. Transfer facilities will be required in the event sulfuric acid is shipped by rail. These transfer facilities will consist of flexible transfer piping, platforms for access to the tank cars, transfer pumps and a pump house and a 700-ton sulfuric acid storage facility. The unloading and loading of packaged and skidded materials will be accomplished at the truck loading dock by a fork-lift truck. Bulk materials, particularly those hauled in during construction, can be stored in piles and stacks at the railroad siding site and trucked to the plant site as required. Provision has been made in the estimate for the acid unloading facilities, unloading dock, fork-lift truck and bulk materials handling equipment.

3. Site Grading

A site of approximately 40 acres is required to accommodate the plant shown on the plot plan. After the core drillings from the recommended site are analyzed, the exact location of the plant will be determined. It may be suitable to level the required area to one elevation. It may, however, be desirable to choose a stepped-plant design, placing the evaporator reject stages at the lowest elevation, and the evaporator recovery stages and nuclear reactor building and turbine room at a higher elevation. Such an arrangement will provide some advantages to the process design. Provision has been made in the estimate for leveling the site to a plant bench of approximately 5 meters for the desalting plant and to 10 meters for the nuclear power plant.

4. Potable Water System

A potable water system distributes potable water to the principal plant buildings and to the potable water yard service system. Hose bibs are provided at convenient locations along the yard service system. The water is stored in the plant potable water tank.

5. Fire Main System

Fire protection, using seawater, will be provided by a dual-drive pump (electric motor and gasoline driven internal combustion engine) to the fire main system. This pump will have a rated capacity of 1,000 gpm. The fire system is a loop system available throughout the yard for fire protection. The fire main is equipped with approximately 25 hydrants located to reach all parts of the plant with a hose no more than 500 ft long. The fire main loop is a 12 in. line with 8 in. and 10 in. branches.

6. Sanitary Sewage System

The transite sanitary sewage system will include a collection system and four septic tanks. The effluent from the septic tanks will be discharged into disposal fields.

7. Storm Drainage

A storm sewer system is provided to handle the run-off from gutters and buildings, dumping the run-off into the brine effluent channels. Storm drainage from the desalting plant, the parking areas and access roads, and similar areas will be accomplished by providing appropriate slope and surface gutters.

8. Fences

A chain link fence of approximately 2,000 meters in length surrounds the plant site of 40 acres (160 dunams). A similar protective fence around the main 161 kv switchgear water plant substation and warehouse yard is also provided.

9. Yard Lighting

The nuclear power plant, desalting plant, cafeteria, workshop, warehouse, switchyard, and substation, chlorine and acid

handling areas, and pump house will be illuminated by pole mounted floodlights. Individual lighting units will be provided at operational locations and at platforms and stairways sufficient for normal night work safety and security. Entrance ways and roadways, and principal buildings will have floodlights for public viewing and safety. Approximately 100 light standards are included in the estimate.

10. Plant Roads and Parking Area

Access roads within the plant site will be provided for trucking supplies and materials between buildings and work areas as shown in Figure 5. Provision is made in the estimate for 16,000 square meters of paved access road area. In addition, provision is made for parking up to 60 cars for workers and visitors; this consists of 8,000 square meters of paved parking area.

11. Cafeteria

A cafeteria building 40 ft by 80 ft is provided; it will accommodate up to 60 people. This building includes a kitchen for preparation of food for plant employees and visitors. The building is constructed of concrete block with lightweight steel roof trusses, metal decking and insulated roofing. The kitchen will have glazed tile walls and quarry-tile floors. The public area of the cafeteria will have asphalt tile floors and painted concrete block walls.

12. Warehouse

A warehouse 80 ft by 125 ft is provided for storage of supplies and spare parts. This warehouse is constructed of concrete block with lightweight steel roof trusses, metal decking and insulated roofing. Two internal partitions are provided within the warehouse. Adjacent to the warehouse is a fenced gravel yard 80 ft by 125 ft for storage of bulky materials.

13. Central Repair Shop

A central repair shop 100 ft by 150 ft is provided. The building is of concrete block construction with lightweight steel roof trusses, metal decking and insulated roofing. A locker and change room is provided within the repair shop. The repair

shop is wired for heavy duty portable equipment in addition to the permanently installed wiring.

14. Guardhouse

A 20 ft by 25 ft guardhouse is provided for plant security at the main entrance to the site. This guardhouse is of concrete block construction with lightweight steel roof trusses, metal decking and insulated roofing. One partition is provided within the guardhouse to separate the office into two parts.

15. Administrative Offices and First Aid

Administrative offices and the first aid rooms are located in the reactor auxiliary building.

VII. CAPITAL COST ESTIMATES

A. Summary

The capital cost estimates of equipment, materials, labor and other costs which constitute the investment required to construct and put in operation a dual-purpose plant are itemized in this section. The estimates have followed as a guide certain of the Electric Power Plant Instructions of the Federal Power Commission's Uniform System of Accounts.

The estimates are based upon information obtained from construction contractors currently performing major work in Israel, from vendors and from other sources.

The dual-purpose plant has been divided into the following units for convenience in preparing the construction cost estimates:

- Power Plant (nuclear or fossil-fueled)
- Desalting Plant
- Intake and Outfall Facilities
- General Plant Facilities

Indirect costs include engineering, design, inspection, owner's expenses and interest during construction. An allowance for contingency is provided as a separate account.

All costs detailed in this study are based on current labor rates and material prices.

The accounts for land and land rights have been listed, even though no cost has been assigned to the land and land rights.

The accounts for working capital include (a) the cost of inventory of nuclear or fossil fuel, (b) materials and supplies, (c) spare parts, (d) the cost of operation, maintenance and fuel consumption for a limited period, and (e) reserve for insurance prepayment; all of the working capital is considered to be nondepreciable.

The total of the foregoing items constitutes the total capital required for the dual-purpose power and water desalting plant.

TABLE X

ESTIMATE OF CAPITAL COST - 1965 BASIS
DUAL-PURPOSE NUCLEAR POWER - WATER DESALTING PLANT
(In Thousands of Dollars)

	Nominal Fixed Charge Rate		
	5%	7%	10%
I. DEPRECIABLE ITEMS			
A. Construction Costs			
1. Power Plant			
Structures	$ 6,160		
Reactor Plant Equipment	24,140		
Turbogenerator Unit	13,010	Same	Same
Accessory Electrical Equipment	2,830		
Miscellaneous Power Plant Equipment	1,090		
Indirect Construction Costs	5,620		
Subtotal	$ 52,850		
2. Desalting Plant			
Structures	$ 20,460		
Brine Heater	1,240		
Evaporator Bundles	33,000	Same	Same
Pumping Equipment	4,930		
Miscellaneous Chemical and Mechanical Equipment	1,650		
Other Direct Costs	5,330		
Indirect Construction Costs	7,930		
Subtotal	$ 74,540		
3. Intake and Outfall Facilities			
Structures	$ 1,580		
Intake Conduits	2,590	Same	Same
Outlet Channels	250		
Indirect Construction Costs	530		
Subtotal	$ 4,950		
4. General Plant Facilities			
Site Work and Buildings	$ 2,180	Same	Same
Indirect Construction Costs	260		
Subtotal	$ 2,440		
Total Construction Costs	$134,780	$134,780	$134,780
B. Other Costs			
1. Engineering, Design, Inspection and Procurement	$ 8,200	$ 8,200	$ 8,200
2. Owner's Expenses, Including Start-up	4,000	4,000	4,000
3. Interest during Construction	4,780	13,890	25,360
Total Other Costs	$ 16,980	$ 26,090	$ 37,560
Total Before Contingency	$151,760	$160,870	$172,340
C. Contingency @ 12%	18,240	19,330	20,660
TOTAL DEPRECIABLE ITEMS	$170,000	$180,200	$193,000
II. NONDEPRECIABLE ITEMS			
A. Land and Land Rights	—	—	—
B. Working Capital			
Nuclear Fuel Cycle	$ 12,790*		
Insurance Prepayment	90		
45 Days' Operation	960	Same	Same
Materials and Supplies - 60 Days	260		
Spare Parts	1,900		
Total Before Contingency	$ 16,000		
C. Contingency @ 6%	1,000		
TOTAL NONDEPRECIABLE ITEMS	$ 17,000	$ 17,000	$ 17,000
TOTAL CAPITAL COST DUAL-PURPOSE PLANT	$187,000	$197,200	$210,000

*This is initial cost. After nuclear core has reached equilibrium (approximately 4 years), the average fuel cycle working capital would be $11,600,000 which was used in computing the annual fixed charges on working capital.

Note: It is estimated the additional investments required for electrical transmission facilities and water conveyance facilities are $5,000,000 and $25,000,000, respectively.

The facilities for power transmission and water conveyance outside the dual-purpose plant boundaries require additional capital. The study did not investigate the requirements or costs of these facilities. The estimates herein include the costs given in the United States-Israel Joint Team Report, October, 1964.

Table X summarizes the various elements of the cost estimate for the dual-purpose plant, the electrical transmission facilities and the water conveyance facilities.

Subsections B, C, D, E and F which follow define which items are included in each of the major cost sections and the bases for estimating the cost of such items as working capital, and contingency. Subsection G lists the bases for the capital cost estimates.

B. Dual-Purpose Plant (Depreciable Items)

1. Construction Costs

The estimates for each of the construction cost accounts listed below include the cost of permanent equipment, labor (including labor burden), construction materials, equipment usage, and a prorated share of the indirect construction costs. Indirect construction costs are expenses accrued for the owner's account by the construction contractor: administrative; field engineering and superintendence; accounting, purchasing, personnel services; security; office furniture, fixture, supplies; construction equipment and tools not chargeable to direct accounts. Also included are temporary facilities provided for use on the construction work and other expenses incurred by the construction contractor such as: medical and canteen expenses; fire protection; all risk insurance (including nuclear insurance rider) during construction as well as construction contractors' fees or profits.

a. Power Plant

The Power Plant Account includes the nuclear steam generator, turbogenerator, feedwater treatment, fuel handling and fuel cycle equipment and facilities, and all buildings, facilities, and equipment identifiable as predominantly necessary for the production of electrical power erected in place in Israel.

The turbine exhaust and condensate return to and from the brine heater flanges are considered a part of the Power Plant Account; the brine heater is part of the Desalting Plant Account.

The Power Plant Account includes all main and auxiliary electrical power plant equipment up to the low voltage side of the step-up transformer. The step-up transformer and switchyard facilities are not included in the dual-purpose plant.

The service systems, such as electrical wiring, switchgear and equipment, and steam, water, vacuum, and air systems, which exclusively or predominantly serve the power plant are included in this account. In instances where no predominant plant account can be clearly identified, that portion of the service systems is included in the General Plant Facilities Account.

The portions of the shared facilities and equipment, such as control rooms, laboratories, office space, maintenance facilities, storehouse structures, and yard equipment, which predominantly serve the power plant, are included in this account. In the instances where no predominant plant account can be clearly identified, that portion of the shared facilities and equipment is included in the General Plant Facilities Account.

In developing the capital cost estimates for the power plant, five quotations were obtained for the nuclear steam supply (three PWR and two BWR), and four quotations were obtained on back-pressure turbines (two for each reactor type).

When adjustments are made in the power plant construction costs for differences in containment and reactor auxiliaries associated with the BWR-PWR alternates, the normalized construction cost estimates for the BWR and PWR are within $300,000 of each other when comparing the quotations from the two major suppliers; the quotations from two other experienced suppliers (one BWR and one PWR) were approximately one million dollars less than those from the major suppliers. The estimates for the reference plant are based on quotations from the two major suppliers.

The small spread between the quotations from all the suppliers and the large percentage these quotations represent in the power plant construction cost are the basis for a high degree of confidence in the cost estimates in this account.

b. Desalting Plant

The Desalting Plant Account includes the brine heater, heat recovery and heat reject stages of the evaporators, seawater or desalted water chemical treatment facilities (except those facilities required for screening of the intake water which are included in the Intake and Outfall Facilities Account), vacuum and venting equipment, and all equipment exclusively or predominantly necessary for the production of desalted water erected in place in Israel.

The brine heater and the structure required for its operation and servicing are included in this account except that equipment and piping which is connected to the steam inlet or condensate outlet flange which are assigned to the Power Plant Account.

All seawater piping, facilities, and equipment between the inlet flange of the seawater intake pumps to the outlet flange of the brine blowdown pumps, and seawater conveyance up to the effluent discharge weir of the outfall canal, which is exclusively or predominantly necessary for the desalting of seawater, are included in the Desalting Plant Account.

The service systems, such as electrical wiring, switchgear and equipment, and steam, water, vacuum, and air systems, which exclusively or predominantly serve the desalting plant, are included in the Desalting Plant Account. In the instances where no predominant plant account can be clearly identified, that portion of the service system is included in the General Plant Facilities Account.

The portions of the shared facilities and equipment, such as control rooms, laboratories, office space, maintenance facilities, storehouse structures, and yard equipment, which predominantly serve the desalting plant, are included in this account. In the instances where no predominant plant account

can be clearly identified, that portion of the shared facilities and equipment is included in the General Plant Facilities Account.

In developing the capital cost estimate for the desalting plant, preliminary quotations were obtained on all major components as follows.

Item	No. Of Quotations
Condenser Bundles	3
Brine Heaters	5
Condenser Tubes	7
Check Valves	2
Gantry Crane	3
Degassing Tower	2
Butterfly Valves	3
Vacuum Equipment	5
Major Pumps	6

The estimate of the desalting plant construction cost was developed by taking additively the appropriate individual equipment component quotations and estimating the construction and indirect costs.

In addition, the cost of contracting with a single manufacturing company for a desalting plant to meet the owner's specifications was determined by obtaining preliminary quotations in response to performance type specification for a 100 MGD desalting plant.

Quotations were received from three manufacturers:

Manufacturer A - The basis was erected in Israel

Manufacturers' B and C - The basis was FAS Eastern U.S. port

The quotations were then normalized to include shipping charges, erection costs, indirect charges, and other costs necessary to achieve a complete working plant, and were then compared with the reference desalting plant estimates. This

comparison reveals a cost spread of the manufacturers' normalized quotations of approximately $9,000,000. The reference desalting plant estimate (without contingency) was within this range.

While the extent to which the manufacturer's quotations contain contingency is not known, the reference plant estimate including contingency is more than $3,000,000 higher than the highest of the manufacturers' normalized quotations.

c. Intake and Outfall Facilities

The Intake and Outfall Facilities Account includes the marine conduits and treatment systems for control of marine growth and for screening, forebays and structures. The seawater intake pumps, the intake house, and all switchgear, controls, and other equipment used predominantly for their operation and maintenance are included in the Desalting Plant Account.

The main outfall canal with the exception of that portion which passes underneath the desalting plant, and the auxiliary outlet channel are included in the Intake and Outfall Facilities Account.

The service systems, such as electrical wiring, switchgear and equipment, and steam, water, vacuum, and air systems, which exclusively or predominantly serve the intake and outfall facilities, are included in the Desalting Plant Account.

d. General Plant Facilities

The General Plant Facilities Account includes the direct capital costs of structures, facilities, buildings, equipment, and service systems not properly includable in other accounts.

In particular, this account includes miscellaneous site structures such as the guardhouse, cafeteria, and central repair shop. Also included are such items as access roads, site grading, in-plant roads and parking lots, fencing, storm sewers, fire lines and hydrants, sanitary sewers and septic tanks, domestic water system, yard lighting, and landscaping.

2. Other Costs

A description of the various items included in the Other Costs Account follows:

a. Engineering, Design, Inspection and Procurement

This account includes all of the engineering, design, and inspection services applicable to construction work, whether incurred directly by the owner or accrued for the owner's account by the architect-engineer.

It also includes preliminary investigations; expediting, inspection and procurement of materials and equipment in vendors' shops; engineering consultant services; and engineering supervision in connection with construction work.

Reactor hazards work, initial radiological site surveys, and related items are included in the engineering design and inspection costs. Nuclear engineering and design services for the reactor plant and auxiliary systems (including core physics analyses and reactor systems design) are included in the direct cost of the nuclear steam supply package as part of the Power Plant Account.

Engineering and design for the desalting plant, adjusted to reflect the very repetitive nature of the desalting plant components, is included in this account. The engineering and design of the evaporator tube bundles, brine heaters and other desalting plant equipment is included in the direct cost of the desalting plant.

b. Owner's Expenses, Including Start-up

Owner's expenses (including salaries and expenses for the owner's engineers assigned to the project) have been estimated by Israel's Joint Seawater Desalting Project Staff. This includes personnel assigned predominantly for training purposes.

Start-up cost is the net cost of operating the dual-purpose plant during the test period prior to becoming available for commercial service after credit for power and water produced during the test period.

c. Interest During Construction

This item is the interest on funds used for engineering, construction, and start-up and is based upon the expenditure table described in subsection D of this section.

3. Contingency

The principal categories which make up the capital cost have been examined and an uncertainty assigned to each based on a percentage of various elements of costs. These uncertainties have been summed to determine the uncertainty associated with the total depreciable capital costs. Also, an allowance has been added to cover items which may have been inadvertently omitted from the estimates. The total of the uncertainties and this allowance is the contingency. At this level of conceptual design and development of the process and its components, an overall contingency of 12 percent has been considered as realistic.

4. Escalation

Escalation was not included in the estimates of capital cost. The capital cost estimates are based on 1965 prices.

C. Dual-Purpose Plant (Nondepreciable Items)

1. Land and Land Rights

The Land and Land Rights Account (dual-purpose plant) includes the cost of land rights necessary for the power plant, the desalting plant, the intake and outfall facilities, general plant facilities, and exclusion area.

Consistent with the ground rules, no land and land rights costs were included in this report. However, the cost of improvements, surveys, roadways, and other site development work for the dual-purpose plant are included in the General Plant Facilities Account.

2. Working Capital

The amount of working capital required is equal to the cost of:

- Nuclear fuel inventory (see page 138 for detail description)
- 45 days' operating, maintenance and fuel costs
- Reserve for insurance prepayment
- 60 days' inventory of materials and supplies
- Spare parts have been estimated as follows:

ALLOWANCE FOR SPARE PARTS

Item	Allowance	Remarks
nuclear boiler	$ 210,000	as recommended by supplier
other reactor plant equipment	150,000	approximately 5% of equipment cost
turbine generator plant	630,000	approximately 5% of equipment cost
intake and outfall facilities	20,000	approximately 5% of equipment cost
desalting plant	850,000	four tube bundles and other evaporator components such as one rotor assembly for each type of pump, spare valves, electrical equipment and instruments
miscellaneous	40,000	
	$1,900,000	

3. Contingency

The largest item in working capital is the nuclear fuel inventory which needs little, if any, contingency, because historically the price of nuclear fuel has been decreasing each year.

Contingency on working capital has, therefore, been assumed to be one-half that necessary on the depreciable capital (subsection B. 3.).

D. Bases for Capital Cost Estimate

1. The Israeli pound exchange rate is 3 IL to 1 U. S. dollar.

2. Israeli duties and taxes are excluded.

3. Foreign equipment and material prices are those in effect June 1965.

4. Israeli construction costs are those in effect June 1965.

5. Direct construction costs include the following:

   a. Israeli Pound Costs

      (1) Labor - Base wage rate plus cost of living allowance in effect June 1965 for journeymen, foremen and general foremen.

      (2) Labor Burden - Payroll additives required by law or agreement (28 percent) plus an additional amount to cover local custom and area practice (40 percent for civil work and 52 percent for mechanical, piping and electrical work).

      (3) Material - Local prices for Israeli manufactured or produced material (see also U. S. material purchases).

      (4) Construction Equipment - Rates for local construction equipment including rental, maintenance, repairs and operating supplies.

      (5) Small construction tools and consumable construction supplies.

      (6) To the sum of items (1) through (5), 20 percent has been added for local subcontractors' overhead and profit.

      (7) Port handling and inland freight charges.

b. U. S. Dollar Costs

(1) Equipment purchases for FAS East Coast (U. S.) port. Although small electric motors, panel boards, etc. are manufactured in Israel, the estimate was based on U. S. costs.

(2) Material purchases such as steel, pipe, wire and conduit, but excluding concrete and siding. Although some carbon steel pipe, conduit and wire are produced in Israel, the estimate was based on U. S. costs.

(3) Ocean freight from U. S. East Coast to Israel port.

6. The standard construction work week in effect June 1965. Premium time and shift work to expedite the construction, manufacturing and engineering are not included.

7. Engineering costs as of December 1965.

E. Funding Requirements

The basic capital cost estimate was prepared as outlined in Section D. above. As a result of this procedure, separate estimates were prepared for the U. S. dollar and Israeli pound costs for each of the major elements of capital cost. In the Capital Cost Estimate Summary, Table X on page 114, the Israeli pound costs have been converted to U. S. dollars at the current rate of exchange (3IL = 1 U$S). Table XI, on the following page, shows an approximate breakdown of the expenditures between U. S. dollars and Israeli pounds. It has been assumed that the interest during construction (the estimate shown is for a 7 percent fixed charge rate - 4.6 percent interest) will be incurred in the same monetary unit as the expenses upon which the interest is accrued. In preparing this division of costs between U. S. dollars and Israeli pounds, certain assumptions were made in addition to those listed in Section D; namely, that all of the "Engineering, Design, Inspection, and Procurement" costs will be incurred in U. S. dollars and all of the "Owner's Expenses" will be incurred in Israeli pounds.

The division between U. S. dollars and Israeli pounds may change depending upon the availability and cost of Israeli materials and equipment at the time of construction. In order to estimate the interest

TABLE XI

CAPITAL COST BREAKDOWN BETWEEN U.S. DOLLARS AND ISRAEL POUNDS
BASED ON 7% FIXED CHARGE RATE
(In Thousands Of Dollars)

	U.S. Purchase U$S	Local Cost IL	Local Cost U$S Equivalent	Total Amount U$S
I. DEPRECIABLE ITEMS				
A. Construction Costs				
1. Power Plant	$ 41,780	L 33,230	$ 11,080	$ 52,860
2. Desalting Plant	55,260	57,850	19,280	74,540
3. Intake and Outfall Facilities	1,990	8,890	2,960	4,950
4. General Plant Facilities	580	5,560	1,850	2,430
Total Construction Costs	$ 99,610	L105,530	$ 35,170	$134,780
B. Other Costs				
1. Engineering, Design Inspection and Procurement	$ 8,200	L -	$ -	$ 8,200
2. Owner's Expenses, Including Start-up	-	12,000	4,000	4,000
3. Interest during Construction	10,190	11,090	3,700	13,890
Total Other Costs	$ 18,390	L 23,090	$ 7,700	$ 26,090
Total Before Contingency	$118,000	L 128,620	$ 42,870	$160,870
Contingency @ 12%	14,200	15,380	5,130	19,330
TOTAL DEPRECIABLE ITEMS	$132,200	L 144,000	$ 48,000	$180,200
II. NONDEPRECIABLE ITEMS				
A. Land and Land Rights	$ -	L -	$ -	$ -
B. Working Capital	16,400	1,800	600	17,000
TOTAL NONDEPRECIABLE ITEMS	16,400	1,800	600	17,000
TOTAL CAPITAL COST DUAL-PURPOSE PLANT	$146,600	L 145,800	$ 48,600	$197,200

TABLE XII

FUNDING REQUIREMENTS FOR DEPRECIABLE CAPITAL

QUARTERLY EXPENSES AND INTEREST DURING CONSTRUCTION

(Thousands of Dollars)

			5% Fixed Charge Rate (1.6% Interest)			7% Fixed Charge Rate (4.6% Interest)			10% Fixed Charge Rate (8.4% Interest)		
		Quarterly Expense Without Interest	Quarterly Interest	Quarterly Expense Including Interest	Cumulative	Quarterly Interest	Quarterly Expense Including Interest	Cumulative	Quarterly Interest	Quarterly Expense Including Interest	Cumulative
1966	1										
	2	390*	1*	390*	390	2*	390*	390	3*	390	390
	3	470	2	470	860	7	480	870	13	480	870
	4	380	4	380	1,240	12	390	1,260	22	400	1,270
1967	1	370	5	380	1,620	16	390	1,650	30	400	1,670
	2	2,910	12	2,920	4,540	35	2,940	4,590	64	2,970	4,640
	3	3,620	25	3,640	8,180	73	3,690	8,280	133	3,750	8,390
	4	3,610	40	3,650	11,830	114	3,720	12,000	209	3,820	12,210
1968	1	3,950	55	4,000	15,830	158	4,110	16,110	288	4,240	16,450
	2	3,740	70	3,810	19,640	202	3,940	20,050	369	4,110	20,560
	3	3,680	85	3,760	23,400	245	3,930	23,980	447	4,130	24,690
	4	3,020	98	3,120	26,520	283	3,300	27,280	517	3,540	28,230
1969	1	5,570	116	5,690	32,210	334	5,900	33,180	609	6,180	34,410
	2	5,200	137	5,340	37,550	395	5,600	38,780	720	5,920	40,330
	3	9,770	167	9,940	47,490	480	10,250	49,030	877	10,650	50,980
	4	9,050	205	9,260	56,750	589	9,640	58,670	1,075	10,120	61,100
1970	1	10,790	244	11,030	66,780	703	11,490	70,160	1,283	12,070	73,170
	2	17,590	301	17,890	85,670	866	18,460	88,620	1,581	19,170	92,340
	3	11,490	359	11,850	97,520	1,033	12,520	101,140	1,887	13,380	105,720
	4	11,760	406	12,170	109,690	1,167	12,930	114,070	2,131	13,890	119,610
1971	1	10,620	450	11,070	120,760	1,296	11,920	125,990	2,366	12,990	132,600
	2	10,710	493	11,200	131,960	1,416	12,130	138,120	2,590	13,300	145,900
	3	6,600	528	7,130	139,090	1,516	8,120	146,240	2,772	9,370	155,270
	4	4,290	550	4,840	143,930	1,580	5,870	152,110	2,866	7,180	162,450
1972	1	2,670	208	2,880	146,810	654	3,320	155,430	1,227	3,900	166,350
	2	2,570	143	2,710	149,520	458	3,030	158,460	836	3,410	169,760
	3	1,560	75	1,640	151,160	250	1,810	160,270	421	1,980	171,740
	4	600**	1*	600**	151,760	2**	600**	160,870	4**	600**	172,340
Total Before Contingency		146,980	4,780	151,760		13,890	160,870		25,360	172,340	
Contingency @ 12%		17,670	570	18,240		1,660	19,330		2,990	20,660	
Total Depreciable Capital		164,650	5,350	170,000		15,550	180,200		28,350	193,000	
Working Capital (Incl Contingency)		17,000	-	17,000		-	17,000		-	17,000	
Total Capital Cost		181,650	5,350	187,000		15,550	197,200		28,400	210,000	

* Two Months Only
** One Month Only

All figures have been rounded to the nearest $10,000

during construction, a preliminary forecast of the rate of expenditure of capital funds was prepared as shown in Table XII. This estimate is based upon the preliminary construction schedule (Section IX), preliminary information on terms of payment obtained from manufacturers of major equipment items, and the assumption that payments for construction work in the field would be made at the time the work is performed.

The construction schedule presently indicates that the power plant, the brine heater portion of the desalting plant, the seawater intake and discharge facilities, and the general plant facilities will be completed in late 1971, and will reach full commercial operation by January 1, 1972. The first of the four evaporator trains in the desalting plant will also be completed at about that time. Each of the other three evaporator trains will be completed in approximately three-month intervals, thereafter; the last unit achieving commercial operation in the last quarter of 1972. In estimating the interest during construction, it has been assumed that as soon as any of the plant production units reaches commercial operation, the construction of that unit would be considered complete, the expenditures and revenue for the unit would be transferred to an operating account, and no further interest during construction would be accrued.

F. Transmission Facilities

The Transmission Facilities estimate includes the capital cost required to provide in place the facilities necessary for the transmission of the net salable electric power from the low voltage side of the step-up transformer to the connection to the existing Israeli electrical network.

This estimate also includes all service systems and operation and maintenance facilities required in whole or in part for the operation and maintenance of the transmission facilities unless such systems and facilities are previously provided in another account.

G. Water Conveyance Facilities

The Water Conveyance Facilities estimate includes the direct capital cost required to provide in place the facilities necessary for the conveyance of the product water from the desalting plant fresh water pump outlet flange to the connection to the existing Israeli water distribution network.

This estimate includes the cost of all modifications to the water network resulting from the introduction of the desalted water.

This estimate also includes all service systems and operation and maintenance facilities required in whole or in part for the operation and maintenance of the water conveyance facilities unless such systems and facilities are previously provided in another account.

The United States-Israel Joint Board requested that the capital cost of these facilities be assumed at $25,000,000 as shown on page 54 of the Report of the United States-Israel Desalting and Power Team, October 1964. This cost was based on 1964 prices and is assumed to include contingency.

VIII. UNIT WATER COST ESTIMATES

A. Summary

The unit cost of water is defined as the quotient of net annual cost of water divided by the annual water produced. The net annual cost of water consists of:

Annual fixed charges
Annual operating and maintenance cost
Annual fuel cost
Total annual cost
Less power credit
Net annual water cost

The power credit is based upon 200 MWe salable at 5.3 mills/kwhr. This figure of 5.3 mills/kwhr has been estimated by Israel Electric as the cost, based on 1965 prices, of producing power in a single-purpose power plant of 200 MWe capacity operating at 85 percent plant operating factor and consistent with the prevailing 10 percent fixed charges for electric power plants in Israel. Israel Electric's estimate of 5.3 mills/kwhr as described in the Joint Team Report has been reviewed for the purposes of this report. Although the power plant portion of the reference dual-purpose plant is expected to be available 89 percent of the time, the annual power production herein is based on a power plant operating factor of 85 percent.

Annual water production is based upon a plant capacity of 100 million gallons per day and a desalting plant operating factor of 85 percent.

Table XIII shows the elements of annual and unit water costs for a nuclear fueled dual-purpose plant under each of the three fixed charge rates (5, 7 and 10%) and based upon 1965 costs. The unit water production costs are summarized below:

	Unit Water Costs at Plant Boundary		
Fixed Charge Rates	5%	7%	10%
Cents/1,000 gallons	28.6	43.4	67.0
Cents/cubic meter	7.6	11.5	17.7
Agorot/cubic meter	22.6	34.4	53.1

TABLE XIII

DUAL-PURPOSE NUCLEAR POWER-WATER DESALTING PLANT FOR ISRAEL ANNUAL COST AND UNIT COST

	Fixed Charge Rate		
	5%	7%	10%
A. ANNUAL COSTS (Thousands of Dollars)			
Fixed Charges			
Depreciable capital	$ 8,500	$12,610	$19,300
Nondepreciable capital			
Inventory assets	350	820	1,430
Non-inventory assets	20	60	110
Total	$ 8,870	$13,490	$20,840
Operating and Maintenance Cost			
Staff	$ 760	$ 760	$ 760
Supplies and materials (desalting)	1,020	1,020	1,020
Supplies and materials (other)	430	430	430
Interim replacements (desalting)	500	500	500
Interim replacements (other)	200	200	200
Additional nuclear property insurance	110	110	110
Nuclear indemnity insurance	300	300	300
General and administrative	150	150	150
Total	$ 3,470	$ 3,470	$ 3,470
Fuel Costs	$ 4,430	$ 4,410	$ 4,390
Total Annual Costs	$16,770	$21,370	$28,700
Annual Power Credit	$(7,900)	$(7,900)	$(7,900)
NET ANNUAL WATER COSTS	$ 8,870	$13,470	$20,800
B. UNIT WATER COSTS			
Annual Water Production			
Million gallons per day	100	100	100
Million gallons per year	31,050	31,050	31,050
Million cubic meters per year	117.5	117.5	117.5
Unit Water Cost			
Cents per thousand gallons	28.6	43.4	67.0
Cents per cubic meter	7.6	11.5	17.7
Agorot per cubic meter	22.6	34.4	53.1
Dollars per acre-foot	93.1	141	218

The subsections which follow the tables discuss the elements of annual cost such as fixed charges, operating and maintenance costs, fuel costs and power credit.

B. Annual Fixed Charges

The annual fixed charges are obtained by multiplying the depreciable and nondepreciable capital costs, including the working capital, by the appropriate fixed charge rates.

In an established industry, the appropriate fixed charge rate to be applied to the various capital cost categories has been fairly well established. For large desalting plants, established practice does not exist. Since the factors which may influence the fixed charge rate are not presently predictable, particularly with respect to interest rates, three alternate fixed charge rates of 5 percent, 7 percent and 10 percent were used in this study.

Fixed charge rates for Israel which could apply to a dual-purpose power and desalting plant fall within the range shown below.

Elements of Fixed Charge Rates

Interest	1.6	4.6	8.4
Depreciation (30-year sinking fund basis)	2.6	1.6	0.8
Israel War Risk Insurance	0.4	0.4	0.4
Property and Normal Liability Insurance	0.2	0.2	0.2
Cost in Lieu of Local Taxes	0.2	0.2	0.2
Total Percent of Depreciable Capital Cost	5.0%	7.0%	10.0%

Normal power plant accounting practice often includes interim replacement costs in the fixed charges. In a desalting plant, interim replacement is affected significantly by the type of material used for heat transfer surfaces, and since this in turn affects the optimizations equally significantly, it was considered advisable to include

the cost of interim replacements in operating-maintenance costs where the variable effect could be accounted for more readily than in nominal fixed charges, i.e., 5, 7, and 10 percent.

With respect to depreciation, the use of a 30-year plant lifetime is accepted practice among the U.S. power industry and a plant of 40 years or longer is common for water utilities. The conceptual design of the reference plant incorporates designs, materials and equipment similar to those used in power plants and are expected to enable this facility to operate at a high plant operating factor for 30 years.

The method of determining the total annual fixed charges used in the study is as follows:

- The fixed charge rate associated with the depreciable capital cost has been specified by the U.S.-Israel Joint Board at 5, 7, or 10 percent for this study. The rate includes:

  Interest
  Depreciation
  War Risk Insurance
  Property and Normal Liability Insurance
  Cost in Lieu of Local Taxes

- The annual fixed charges have been determined by multiplying the total capital cost (depreciable) by 5 percent, 7 percent, and 10 percent.

- The fixed charges associated with the nondepreciable capital cost are limited to charges on working capital only, since there are assumed to be no land costs for this plant.

  The working capital is composed of funds invested in "inventory assets" such as nuclear fuel cycle material and plant materials, supplies and spare parts; and "non-inventory assets" such as prepayment of insurance and reserve for 45 days' operating-maintenance-fuel costs. The fixed charges on the inventory assets portion of the working capital would be for interest and insurance, equal to 2.2 percent, 5.2 percent and 9.0 percent for the three fixed charge rate cases. The fixed charges on the non-inventory assets portion of the working capital would be only for interest equal to 1.6 percent, 4.6 percent, and 8.4 percent.

- The property insurance and normal (non-nuclear) liability insurance are included in the fixed charge rates.

  The rider for nuclear liability has been determined as a percentage of the capital cost of the nuclear power plant and included in the operating and maintenance expense of the nuclear power plant. The method used in determining the nuclear rider is described in paragraph 3 of subsection C which follows.

- The costs in lieu of local taxes include community services furnished by surrounding towns, such as fire brigade, garbage disposal, and police protection.

C. Operating and Maintenance Cost

This section presents estimates of the operating and maintenance cost of generating electric power and desalting seawater in the reference nuclear dual-purpose plant. The Federal Power Commission Uniform Code of Accounts has been used as a guide in determining the expenses charged to the Operating and Maintenance Account.

The annual operating and maintenance costs are based upon United States utility experience in similar nuclear power plants. These costs have been adjusted for Israeli conditions. The annual operating and maintenance costs of the dual-purpose plant have been established in the following manner:

1. The operating and maintenance staff requirements for a nuclear fueled dual-purpose plant located in Israel have been estimated by the client at 170 employees (Chart No. 2). The labor cost is based upon $4,500 per man per year (annual salary and fringe benefits, but excluding general and administrative expense).

2. Dual-purpose plant operating supplies, maintenance materials, and interim replacement costs have been determined as follows:

   Operating supplies and maintenance materials for the desalting plant have been estimated at 3.3 cents per thousand gallons of product water: an amount including 3.0 cents for H_2SO_4, 0.1 cents for chlorine and 0.2 cents for other disposable materials.

Operating supplies and maintenance materials for other portions of the plant have been estimated at 0.8 percent per year of the direct construction cost of the electric power plant, intake and outfall facilities and of the general plant facilities (depreciable items). This amount is consistent with the Federal Power Commission electric utility data and with manufacturer's recommendations.

- The annual allowance for interim replacement for the electric power plant, the intake and outfall facilities and general plant facilities, has been estimated at 0.35 percent of their construction costs, an amount consistent with normal utility practice.

- Desalting plant experience offers little precedent for selecting the appropriate desalting plant interim replacement rate. The most important component to consider in establishing this interim replacement is the desalting plant tubing.

  The desalting plant tubing selection of 90/10 Cu-Ni alloy material was based on the available but limited experience of several power plant condensers with 7 years' seawater service. In the areas of severe environment, a superior bimetallic or similar tube material has been specified for the reference plant. The tube failure rate believed appropriate for the reference plant is 0.1 percent in 10 years. This rate is consistent with the 85 percent desalting plant operating factor, and will result in the failure and plugging of less than one percent of the heat exchanger tubing during the 30-year life.

  Although for this significant portion of the desalting plant equipment, no interim replacement would be required. An allowance has been made for the costs of a partial replacement in the event the tube life assumptions prove too optimistic. This allowance is obtained by using an annual interim replacement allowance of 0.7 percent of the desalting plant construction cost. On an overall basis, this rate is twice that assumed for the rest of the plant.

3. Normal plant insurance charges are included in the fixed charge rate at 0.2 percent of the dual-purpose plant construction cost (and part of the working capital) to provide for the normal plant

CHART NO. 2

ORGANIZATION CHART

NUCLEAR DUAL-PURPOSE POWER - WATER DESALTING PLANT

SUMMARY OF PERSONNEL:

SUPERVISION	20
POWER PLANT	31
DESALTING PLANT	28
MAINTENANCE	46
SERVICES	45
TOTAL	170

PLANT SUPERINTENDENT (1)

ASSISTANT PLANT SUPERINTENDENT (1)

SUPERVISOR OF MAINTENANCE (1)

ELECTRICAL FOREMAN (1)

INSTR. & CONTROL ENGINEER (1)

MECHANICAL FOREMAN (1)

MECHANICS	30
ELECTRICIANS	10
INSTR. TECHNICIANS	4
STOREKEEPERS	2
TOTAL	46

SUPERVISOR OF OPERATIONS (1)

ASSIST. SUPERVISOR OF OPERATIONS (1)

SHIFT SUPERVISOR (5)

ASSIST. SHIFT SUPERVISOR (5)

POWER	
SR. CONTROL OPERATORS	5
CONTROL OPERATORS	4
EQUIPMENT OPERATORS	5
ASSIST. EQUIPMENT OPERATORS	9
TOTAL	23

DESALTING	
CHIEF OPERATORS	5
EQUIPMENT OPERATORS	5
ASSIST. OPERATORS	14
TOTAL	24

SUPERVISOR OF PLANT ENGINEERING (1)

POWER	
NUCLEAR ENGINEER	1
HEALTH PHYSICIST	1
CHEMIST	1
LAB. TECHS. & HEALTH PHYSICS TECHS.	5
TOTAL	8

DESALTING	
PLANT ENGINEER	1
CHEMIST	1
LAB. TECHNICIANS	2
TOTAL	4

SUPERVISOR OF SERVICES (1)

BUYER & ACCOUNTANT	2
CLERKS & STENOS	6
PAINTERS & CARPENTERS	5
DRIVERS & GARDENERS	7
JANITORS & LABORERS	10
GUARDS & FIREMEN	15
TOTAL	45

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insurance charges. There are abnormal insurance costs associated with nuclear plants, and to the extent that there are insurance charges in excess of the above mentioned allowance in fixed charges, they are charged to the operating and maintenance expense of the nuclear power plant. This excess consists of nuclear indemnity and nuclear property insurance determined as follows:

- The annual cost of nuclear indemnity insurance was assumed to be the same as for typical U.S. plants of the same thermal capacity, which was estimated as $300,000 per year for a 1,250 MWt plant.

- In addition, the annual cost of property insurance (including the nuclear rider) which is in excess of that provided in the fixed charge rate is assumed to be 0.2 percent of the power plant capital cost (depreciable items).

4. Annual general and administrative expense of the dual-purpose plant has been estimated by the client as $150,000.

D. Fuel Costs

Table XIV summarizes the nuclear fuel costs for the proposed dual-purpose plant, based on equilibrium conditions at a reactor thermal output of approximately 1,250 MWt. The fuel cost calculations assume ownership of the nuclear fuel materials by the Government of Israel throughout the fuel cycle. The cost estimate includes:

Purchase of uranium ore concentrates
Toll conversion (to UF_6) and enrichment of the uranium
Fabrication into fuel element assemblies
Shipping to the plant site
Irradiation
Spent fuel storage and shipping
Chemical processing and reconversion
Sale of recovered uranium and plutonium

Fuel element fabrication and spent fuel shipping and reprocessing cost estimates are based on (a) having the fabrication and spent fuel reprocessing done in commercial facilities in the United States, and (b) current prices and estimates for these services. The cost estimate for conversion and enrichment of natural uranium, to produce

TABLE XIV

FUEL COSTS FOR A TYPICAL EQUILIBRIUM BATCH THREE ZONES (BATCHES) PER CORE, OUT-IN SHUFFLE

GENERAL DATA

Reactor Thermal Power MWt	1,250
Core Loading (3 Batches), Kg	47,000
Average Exposure, (Megawatt-days/Metric ton of U)	27,000

COST ANALYSIS

Operation	Quantity of Material	Unit Cost	Total Cost
Ore Purchase	99,030 Kg U	$ 15.60/Kg U ($6/lb U_3O_8)	$1,545,000
Conversion to UF_6	99,030 Kg U	$ 2.60/Kg U	257,000
Enrichment	15,590 Kg U @ 3.0% U-235	$107.00/Kg U	1,669,000
Fabrication	15,590 Kg U	$100.00/Kg U	1,559,000
Spent Fuel Shipping	15,010 Kg U @ 0.96% U-235	$ 15.00/Kg U	225,000
Chemical Processing*	15,010 Kg U	$ 36.40/Kg U	546,000
Reconversion	14,860 Kg U	$ 5.60/Kg U	84,000
Uranium Recovery	14,860 Kg U @ 0.96% U-235	$ 35.60/Kg U	(529,000)
Plutonium Recovery	93.4 Kg of fissile Pu	$ 8,020/Kg Pu	(749,000)
TOTAL COST PER BATCH (without interest)			$4,607,000

Energy Output Per Batch

27,000 MWD/MTU x 15,590 MTU x 3.413 million Btu/MWhr x 24 hr/day = 34.5×10^6 million Btu/Batch

Unit Fuel Cost (without interest)

$$\frac{\$4,607,000 \times 100¢/\$}{34.5 \times 10^6 \text{ million Btu}} = 13.4¢/\text{million Btu}$$

UF_6 of 3.0 percent U-235 concentration, is based upon recent USAEC estimates of their probable charges for toll enrichment. The recovered uranium and plutonium have been assumed to be sold on the world market, the value of the recovered uranium being computed by the same technique used to compute the value of feed uranium; the value of plutonium was computed by assuming that the price of fissile plutonium isotopes is 80 percent of the price of 93 percent U-235.

The cost estimates shown in Table XIV are probably conservative when averaged over the 30-year life of the plant, because fuel costs have been decreasing each year during the past few years and most manufacturers believe the trend will continue. This is discussed under subsection 3, "Fuel Cycle Trends".

1. Cycle Costs

The fuel cycle costs are based upon the performance of a "reference" core, data for which were supplied by a leading U.S. water reactor manufacturer. The reference core design is divided into three concentric regions of fuel assemblies. The inner region has the lowest enrichment and the outer region the highest. At the end of each cycle of core operation the inner region is removed for reprocessing and the other two regions are moved inward. New fuel is then added to the outer region. The fuel assemblies are composed of fuel rods which consist of uranium dioxide pellets assembled into thin Zircaloy tubes welded shut at the ends. Provision is made for loading and unloading fuel under water.

As discussed in subsection F of this section, the plant operating factor for both power and water production is 85 percent. This plant operating factor allows for a 10 percent outage of the reactor: 8 percent (one month/yr) planned outage for refueling and maintenance and 2 percent forced outage. During the remaining 90 percent of the time when the reactor is operable, either the power plant or desalting plant or both may be shut down, operated at part load, or operated at full load. This mode of operation will result in increased fuel consumption per unit of combined power-water production, so the plant operating factor for nuclear fuel consumption is 87 percent rather than 85 percent.

The fuel costs shown in Table XIV do not include interest or other carrying charges, since these costs are included in the fixed charges on working capital. The overall fuel cycle cost for an equilibrium batch of fuel is 13.4¢/million Btu. For the three fuel batches which comprise the first core, the fuel cycle costs are somewhat higher, averaging 14.4¢/million Btu. The average nuclear fuel cost over the 30-year life of the plant is 13.5¢/million Btu. At 80 percent plant operating factor the annual energy requirement is 33.0×10^6 million Btu; hence the annual nuclear fuel cost exclusive of charges on working capital is $33.0 \times 10^6 \times 13.5 \times 0.01 = \$4,450,000$.

In addition to this cost an amount has been added to the annual fuel cost to account for the unrecovered portion of the last core; i.e., that fuel in the reactor at the time of plant shutdown--assumed to be at the end of 30 years. This annual amount will vary with the interest rate, hence the fixed charge rate. For 5 percent fixed charges, the annual amount is $63,000 per year; at 7 percent fixed charges, the annual amount is $39,000 per year; at 10 percent fixed charges, the annual amount is $19,000 per year.

2. Working Capital Costs

The working capital requirement of the dual-purpose plant includes funds invested in the fuel cycle. The bulk of the fuel cycle expenditures (ore purchase, enrichment, fuel fabrication) occur well in advance of the revenue from the sale of electricity and water; this results in a large working capital requirement for the fuel cycle and the financial charges on this working capital represent an appreciable portion of the total annual costs.

To estimate the average fuel cycle working capital requirements, a "cash-flow" schedule is prepared for a single batch of fuel, which can then be used to estimate the annual average investment (working capital) in the fuel cycle.

The first expenditure for a new batch of fuel occurs some nine months before insertion of the fuel into the reactor, with payment for the purchase of a new supply of natural uranium ore. Payments for the conversion (to UF_6) and enrichment by the USAEC are assumed to occur about eight months before fuel insertion, and payments for fuel fabrication about six months before fuel insertion.

The cost of a fuel batch is amortized over the three periods of reactor operation during which it is irradiated. The amortization is taken as a straight line, and is equal to the difference between the initial value (the sum of ore purchase, conversion and enrichment, fabrication and shipping costs) and the final value (the spent fuel credit less the cost of spent fuel shipping and reprocessing). Four months are allowed for decay storage at the dual-purpose plant, and two months each are allowed for spent fuel shipping and reprocessing. To simplify the analysis, it was assumed that the spent fuel was sold at the completion of reprocessing and a completely new supply of uranium ore was procured for subsequent enrichment. Alternatively, the slightly enriched uranium plus plutonium recovered from spent fuel could be used to reduce the uranium ore purchase and "toll enrichment" requirements of the next fuel batch. This alternative fuel program would result in approximately the same fuel cycle cost and fuel cycle investment as the assumed program.

No "spare" fuel assemblies will be maintained on site except that each new fuel batch will be available on site for a 4-5 month period before reactor shutdown, thus providing spare fuel for this portion of the fuel cycle. At other times "dummy" fuel assemblies will be retained on site which will be inserted in the core to replace defective fuel assemblies.

Based on the above assumptions the initial working capital required for the first core is $12,790,000; the average working capital requirement over the life of the plant is $11,600,000.

3. Fuel Cycle Trends

The effect of potential decreases in nuclear fuel costs have been evaluated. The nuclear fuel cycle costs shown in Table XIV include prices for fuel fabrication and spent fuel reprocessing presently being quoted on a firm basis by U.S. manufacturers and "Nuclear Fuel Services, Inc.", respectively; the assumed cost of uranium ore ($6/lb) is higher than the present world market price; the cost of toll enrichment reflects present USAEC estimates for this service. A leading reactor manufacturer has recently published predictions of fuel cycle costs for the period of the 1980's and 1990's, which are based on more optimistic estimates for the major elements of nuclear fuel cycle cost. These optimistic estimates take into account the greatly increased scale of nuclear

fuel operations anticipated during this time period. Also included are certain technological improvements, such as fuel elements manufactured from uranium powder compacted within the fuel tube (rather than the use of prepelletized fuel), fluoride volatility reprocessing techniques, etc. Table XV summarizes the difference between the conservative assumptions which result in cost estimates shown in Table XIV and the more optimistic values mentioned above.

The effect of the more optimistic fuel cycle costs on the cost of water produced in the dual-purpose plant is shown in Chart No. 3. Also shown on this curve is the "first core" fuel cost and the "average" fuel cycle cost over the plant lifetime for both the conservative and optimistic cases. It can be seen that if the optimistic fuel costs are achieved shortly after reaching fuel cycle equilibrium, the cost of water has been overestimated by approximately 4¢/1,000 gal. Since not all of the predicted cost reductions may be achieved, or will be achieved late in the plant lifetime, it is likely that the saving actually achieved will be in the order of 2¢ or 3¢ per 1,000 gal.

E. Power Credit

Israel Electric Corporation has estimated that the cost of producing power in a single-purpose (power only) plant of 175-200 MWe salable power capacity would be 5.1 to 5.3 mills/kwhr based on 1965 costs. The Israel Electric estimate has been reviewed. A ground rule for this study is that the annual costs of the dual-purpose power-water plant are credited with the salable power of 200 MWe at 5.3 mills per kwhr.

At some time during the 30-year life of the plant it may be possible to generate the base load of the Israel Electric system more economically if this dual-purpose plant is not base-loaded. To the extent that this occurs, a base-load penalty will result from the operation of the dual-purpose plant as a base-load plant. Such a penalty, if required, will reduce the power credit used herein. However, offsetting this potential penalty is the fact that the probable plant operating factor of the power plant is in excess of 85 percent (see subsection F) and during those years when this plant is base-loaded, the annual power credit may be higher than calculated in this study.

CHART NO. 3

EFFECT OF ANTICIPATED REDUCTION IN FUEL CYCLE COST ON WATER PRODUCTION COST

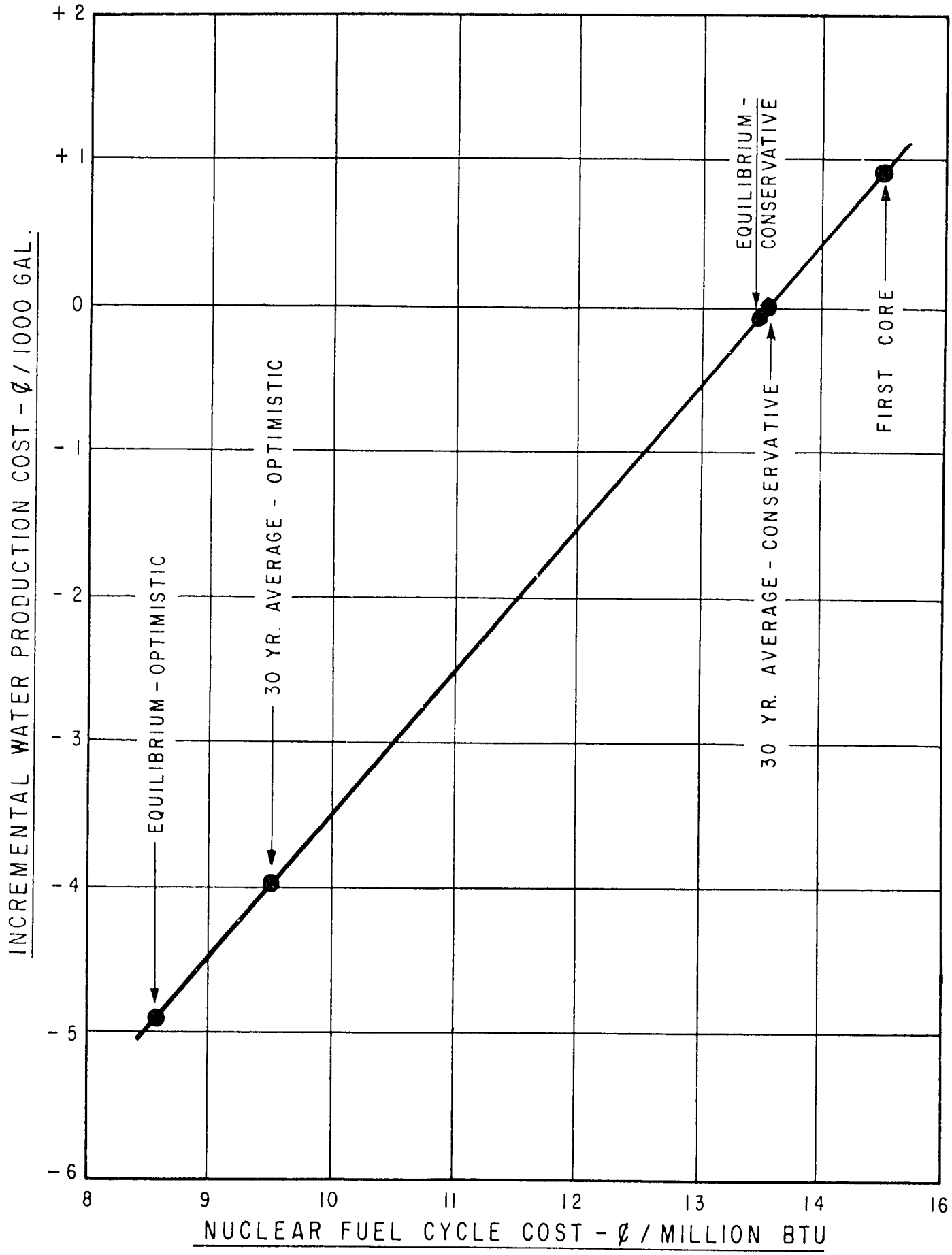

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TABLE XV

COMPARISON OF CONSERVATIVE VS OPTIMISTIC FUEL CYCLE COST ELEMENTS

	Conservative Assumptions	Optimistic Assumptions
Ore Price, \$/lb U_3O_8	\$ 6.00	\$ 4.50
Conversion to UF_6, \$/Kg U	\$ 2.70	\$ 1.10
Enrichment (Separative Work), \$/Kg	\$ 30.00	\$20.00
Fabrication, \$/Kg U	\$100.00	\$70.00
Spent Fuel Shipping, \$/Kg U	\$ 15.00	\$ 5.00
Reprocessing		
Chemical Separation, \$/Kg U	(1)	\$30.00
Uranium Conversion, \$/Kg U	\$ 5.60	
Fissile Pu Credit, \$/gm	\$ 8.10	\$ 8.10
Uranium Sell-back, \$/Kg	(2)	(2)

(1)

$$\$/\text{Kg U} = \frac{\$23,500 \dfrac{w}{(1,000 + T)}}{w}$$

Where w = Batch size, Kg

T = Turn around time, days

$T = 8$, if $8 \leq \frac{w}{1,000} \leq 24$

$T = w/3,000$, if $\frac{w}{1,000} > 24$

(2) Same value as feed uranium of same enrichment

F. Plant Operating Factor

The plant operating factor was assumed to be 85 percent during Phase I. During Phase II, a study was made of the plant operating factor by estimating availability factors for the plant components. The study was based on the following assumptions:

1. When each discrete water plant train is operating, it will be producing the designed water capacity. It is assumed that some loss of production will take place due to gradual accumulation of scale. This factor is compensated for in the fouling components in the heat transfer rates. It is also assumed that wear on the pumps will cause some loss in their capacity. This, however, can be compensated for by designing the pumps for slightly higher initial capacity.

2. A planned or forced outage of the steam generating plant will shut down the water plant.

3. During an outage of the turbine only, steam will be supplied via a bypass and pressure-reducing station to the brine heater; auxiliary power obtained from the Israel Electric grid.

4. Planned maintenance outage of the desalting plant will be scheduled for completion during the planned outages of the steam plant.

5. Planned outages of the steam plant are taken as 8 percent of the available time (=700 hr per year) and the forced outages will be 2 percent (=175 hr per year).

6. Outages of the dual-purpose plant, either planned or forced, due to marine fouling in the intake structure and facilities (not including the reject and make-up pumps) is included in the 10 percent outages of the steam plant discussed under 5 above.

7. Salinity level of the product water is not to exceed 125 ppm total dissolved solids (TDS), including 69 ppm Cl^- content.

8. The plant operating factor was evaluated on the basis that the water plant has gone through a period of "debugging" during test operation period, and all the failures that are due to faulty

materials, faulty fabrication or assembly will have been corrected. It is realized that this "debugging" period may take as long as one year during which time the plant operating factor may be below 85 percent.

9. Failures in any component which will force the plant to shut down will not occur simultaneously with other components which cause the same effect.

Thus, the combined effectiveness of the two components is the product of the effectiveness of each.

A number of features were incorporated in the desalting plant design to increase the effectiveness of critical components such as:

- The heat reject section, consisting of three stages (of which one is the deaerator), has one tube bundle straddling two stages and a separate tube bundle in the deaerator stage. Since the deaerator stage represents the most severe corrosion environment for the tubes, this design permits the deaerator bundles to be equipped with more corrosion resistant tubes than the upstream heat reject bundles. These tubes may be bimetallic (stainless steel on the outside, 90-10 copper-nickel on the inside) or titanium.

- The air cooling section of the tube bundles (heat recovery and heat reject) similarly represent a corrosive environment. These tubes, representing 4 percent of the surface area, will be bimetallic.

- The brine heater, because of the high operating temperature and the need for maximum reliability, will be tubed with 18 BWG 90-10 copper-nickel tubes.

- A fifth heat reject water pump will act as a spare, not only for cooling water pumping, but also for water make-up.

- At each train there will be installed:

  3 recycle pumps, each having 50 percent recycle capacity
  2 blowdown pumps, each having 100 percent blowdown capacity
  2 distillate pumps, each having 100 percent distillate capacity

The plant availability factors assumed for the plant components are as follows:

1. Turbine generator (excluding overhaul time during nuclear steam supply shutdown) — 99%

2. Pump and pump drives (because each critical service has an installed spare) — 100%

3. Vacuum equipment (because each unit has an installed spare) — 100%

4. Evaporator structure (assuming leaks could be repaired without shutdown) — 100%

5. Instrumentation, control and auxiliary equipment — 99%

6. Evaporator tube effectiveness

   a. 0.1% failures will occur in 10 years.
   b. Total number of failures is expressed by $F = 1 - e^{-\frac{t}{a}k}$ where

      F = fraction of tubes which fail (total number of tube failures/total number of tubes)
      t = time in years
      k = 2.5
      a = a constant determined by failure rate assumption; for 0.1% in 10 years: a = 159.
   c. Tube failure will occur because of a pitting type of corrosion and the hole diameter will increase linearly at the rate of 1/8-inch every 10 days.

The foregoing component availabilities were combined to analyze the availability of the major plant systems for full-load operation over the life of the plant. The nuclear steam supply system is estimated to have scheduled outage of 8 percent for refueling and 2 percent unscheduled outage; the net of 90 percent availability is consistent with the predicted availability of new nuclear power plants in the United States.

Repairs to the turbine-generator can be scheduled at the same time as the 8 percent scheduled outage of the nuclear steam supply. The turbine will not be furnished steam during the 2 percent unscheduled outage of the nuclear steam supply system, and will not be operating during its own additional unscheduled outage of one percent; this leaves a turbine-generator operating factor of 89 percent. However, from the operational point of view, it may not be possible to run this power plant at full load during the entire period of its availability, so the overall turbine-generator operating factor is set at 85 percent for this study.

With respect to the desalting plant, the evaluation consisted of analyzing the specifications for and the conditions to which the various components are exposed, and assigning an effectiveness factor for each group of components. The tubing materials are by far the most susceptible to corrosion attack and their effectiveness appreciably influences the plant operating factor.

After allowance for a nuclear steam plant operating factor of 90 percent, the desalting plant will have the following plant operating factors:

First year of commercial operation	88 percent
Tenth year of commercial operation	86 percent
Fifteenth year of commercial operation	85 percent
Twentieth year of commercial operation	84 percent
Thirtieth year of commercial operation	81 percent
Overall thirty-year average	85 percent

These values were calculated on the assumption that periodic shutdown of the trains would be required to plug leaking tubes, but that no general retubing would be done.

At the fifteenth year of operation, or at any other appropriate time, the pattern of tube failures would be examined. If the tube failures were concentrated in the tube bundles of a few stages, these bundles could be retubed, returning the plant to a high operating factor. However, if the tube failures occurred at random (an unlikely situation), it would have to be determined on an economic basis whether the cost of total retubing would be justified by improvement in plant operating factor.

IX. CONSTRUCTION SCHEDULE

A. Introduction

The construction schedule for the plant described herein is presented in the form of critical path networks (See Figures 29 and 30) and a construction schedule bar chart with key events identified (Chart No. 4).

The application of the Critical Path Method of planning defines the chain of activities (Critical Path) that controls the length of the project and also defines the activities the schedules for which have some latitude of execution and completion. Delay in any of the activities along the critical path, unless corrected in the subsequent critical path activities, will cause a delay in the whole project. Likewise, early completion of certain activities on jobs along the critical path may indicate during progress reviews, that other activities have instead become the project controlling factors and that a new critical path may have been established.

B. Construction of Modified Critical Path Network

The construction of the modified critical path network for this project is based on the following information and assumptions:

1. Use of a pressurized water reactor steam generating source.*

2. Use of a steel sphere containment building for the PWR reactor.*

3. Manufacturers' estimates concerning the manufacturing and delivery time of major equipment and components.

4. Proper shipping time allowances (two to three months) for heavy pieces of equipment due to lack of high capacity unloading facilities at point of destination.

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*Use of a BWR and vapor suppression containment will fit within the critical path shown in Figure 29.

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5. Adequate time allowance for Customer review and approval of drawings, specifications and contract forms for major equipment items and construction contracts.

6. Adequate time allowance for Customer representatives in the United States to approve procurement of minor equipment items.

7. Adequate proposal time allowances to permit manufacturers and contractors to arrive at realistic prices and costs.

8. The construction contract is divided to minimize construction costs, move-in and set-up expenses and reduce interferences in work areas. The work is separated according to contractors' capabilities and fields of specialization. Based on the above considerations, the major civil and structural work is divided in the following separate contracts:

   a. Major site excavation and grading.

   b. Site improvements.

   c. Reactor foundation

   d. Reactor containment fabrication and erection.

   e. Construction of reactor auxiliary building, office and health physics buildings, concrete structure inside the containment, turbine room and radioactive waste disposal facility.

   f. Water plant facility and appurtenant structures.

   g. Intake structure.

   h. Submarine pipe intake.

9. All requests for construction bids will be issued only after adequate engineering drawings, work scope specifications and other required information are available, thus reducing the cost of "extras" and enhancing the possibility of awarding lump-sum contracts.

10. The San Diego Saline Water Test Facility will be in operation by January 1968 and will provide at least five months testing time before the start of the final water plant design phase in order to capitalize on this module operation data.

The construction schedule shown in the critical path diagrams (Figures 29 and 30) is based on selection of an Architect-Engineer prior to mid-1966. The Architect-Engineer would prepare detailed plans and specifications which would permit procurement of all the dual-plant components on a competitive basis from suitable suppliers. Construction would be performed by one or two principal construction contractors and local subcontractors.

An alternate to the above approach is the selection of the Architect-Engineer to prepare power and desalting plant performance specifications and to obtain vendor "turnkey" bids. The Vendor-Contractor(s) would then design, procure and construct a complete nuclear power plant and a complete desalting plant either separately or together on a "turnkey" basis. This alternate, assuming selection of an Architect-Engineer prior to mid-1966 as above, will allow only one year from mid-1966 for the preparation of performance specifications, qualifying of bidders, preparing of bids (by vendors), review and normalization of bids, and the selection of a "turnkey" power plant contractor (and two years for the selection of the "turnkey" desalting plant contractor) to achieve commercial operation on the same schedule as above -- by November, 1972.

C. Major Events Sequence

The CPM network shows the following sequence of major events:

January 1966	Start the conceptual design of the OSW test modules.
May 1966	Start preliminary design of dual-purpose plant and start preparation of reactor specification.
May 1967	Complete reactor bid evaluation and order the reactor.
June 1967	Start construction of OSW test modules (per OSW (DiLuzio) letter of November 10, 1965).
September 1967	Start Israel site improvement work.
November 1967	Place order for containment structure.
January 1968	Start operation of test module.

June 1968	Freeze final design of desalting plant, utilizing information obtained by operation of the test module. Place order for major desalting plant equipment.
December 1968	Begin construction of desalting plant.
July 1969	Complete erection and test of reactor containment and begin construction of containment internal structures.
January 1970	Delivery of and start installation of desalting plant equipment.
June 1970	Delivery of and start installation of major reactor equipment.
August 1971	Completion of reactor equipment installation and begin pre-critical test period.
December 1971	Completion of first evaporator train and start operation.
March 1972	Completion of second evaporator train.
June 1972	Completion of third evaporator train.
September 1972	Completion of fourth evaporator train.
November 1972	Commercial operation of dual-purpose plant.

D. Concrete Containment Vessel Alternates

The utilization of a prestressed or reinforced concrete reactor containment would cause a delay of approximately six months in the above overall schedule for the power plant portion of the project and therefore, operation could not start until June of 1972. At that time three evaporator trains could be ready for operation.

E. Conclusions

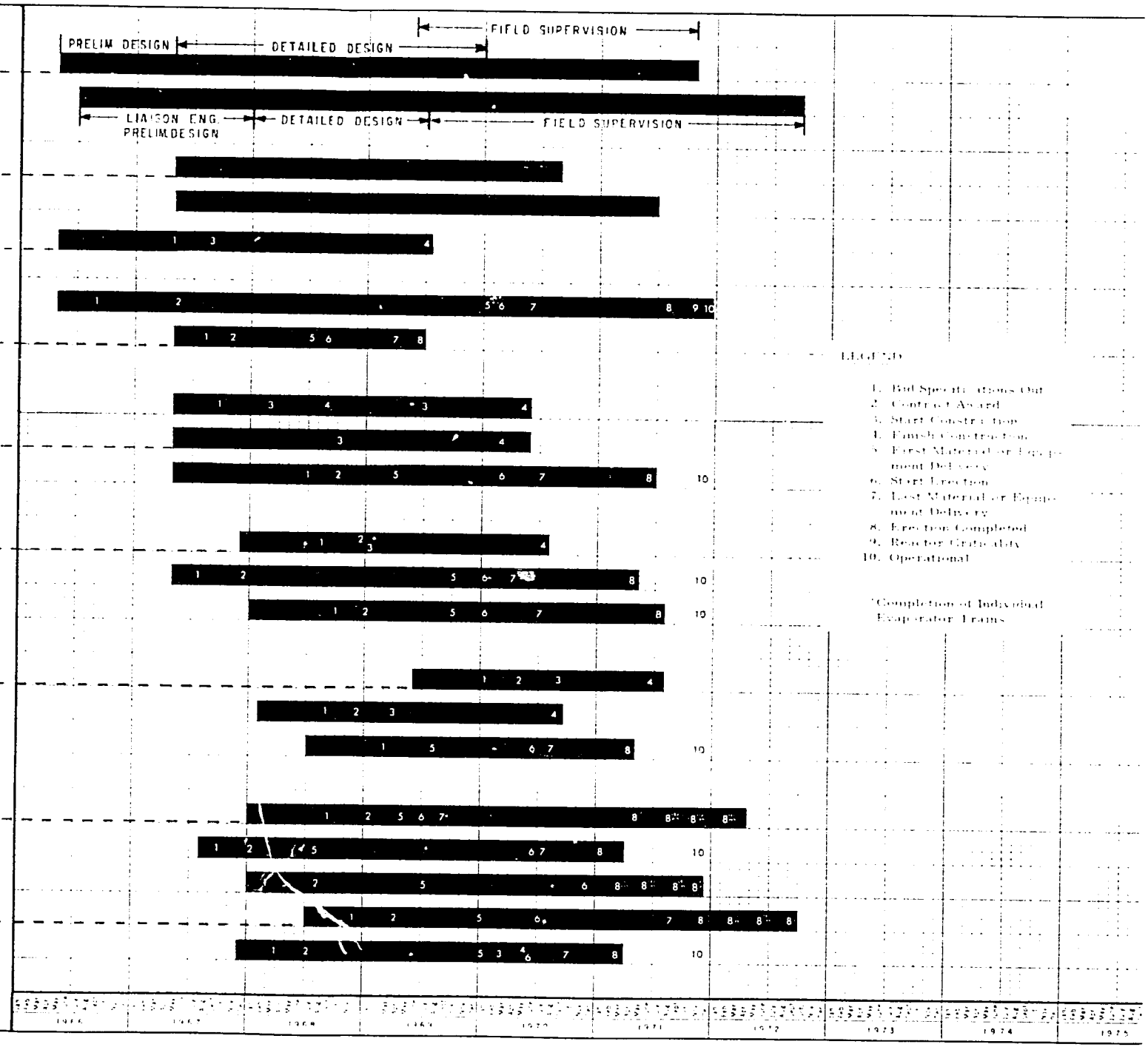
The analysis of the critical path network leads to the following conclusions:

1. Start of the preliminary design of the plant and start of preparation of nuclear plant specifications cannot be delayed beyond May of 1966, if the late 1972 date for commercial operation of the dual-purpose plant is to be met. If preliminary design is started earlier commercial operation of the power plant could be realized with attendant financial benefit.

2. The execution of the OSW's development program and the operation of the San Diego test modules by January of 1968 is of utmost importance, as it is vital to incorporate the experience obtained from this pilot installation in the final design of the desalting plant. As the schedule shows, the critical path for the desalting plant allows for only six months' operation of the test modules prior to freezing design of the desalting plant. Any delay in acquisition of the test module operating data will delay the commercial operation of the desalting plant by an equivalent time.

3. The installation of the brine heaters and emergency cooling water line should be completed by the time the power plant portion is completed to be able to obtain the full electrical output of the plant while the construction of the three remaining evaporator trains continues.

CONSTRUCTION SCHEDULE



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X. RECOMMENDED DEVELOPMENT PROGRAM

A. Summary

A basic tenet of this study has been that the reference dual-purpose plant will be an operating utility rather than a developmental type installation. Therefore, every process concept, every material of construction, and every piece of equipment utilized in the plant must carry with it the maximum degree of confidence. Since plants of the size being considered in this study are not in existence, inevitably there will be a requirement to confirm the adequacy of certain design features prior to their inclusion in the plant. This confirmation, then, is one objective of this development program.

A second, and equally important benefit of this proposed development program is in the area of cost reduction. It is entirely possible and practicable to build a plant of the size selected using equipment and design concepts available today. A high degree of assurance may be assumed with respect to the operation of a plant so designed. However, such a plant whether supplied by a desalting plant vendor or based on a design similar to the reference plant described herein would include overdesign and have imbalance in the capacity of the various portions of the plant unless it were the more expensive multiple version of today's small units. The second objective of the development program is, thus, the reduction of cost resulting from overdesign and use of small units, and the confirmation of capacity balance among the various plant sections.

The development program covers three principal areas of work.

One area involves testing of full-scale modules of the reference multi-stage flash plant. They will be large enough and sufficiently close in concept to the final plant to require minimum extrapolation of test information for application to detailed design. The basic concept of this part of the development program is to confirm those design criteria which are not yet proven in commercial practice. Typical items of investigation would be the relation of brine mass flow vs disengaging surface area, the possible requirement for demisters, and the design of flashing devices.

The second area of work is the testing of seawater properties and related oceanographic phenomena affecting the desalting plant design

and operation. This work should be performed in Israel, using seawater near the proposed plant site, and requiring relatively inexpensive equipment.

The third area of work involves obtaining test information relative to the possible use of concrete for the evaporator shells. Some work of this nature is already under way at the U.S. Department of Interior Bureau of Reclamation, and additional testing could be done in Israel. The latter work would be concerned with protection of concrete from the effects of "distilled" water.

The schedule presented by the U.S. Department of Interior, Office of Saline Water, for the construction of the San Diego Saline Water Test Facility shows that there will probably be six months' operating data from the test modules prior to the time when the design of the Israel desalting plant must be "frozen". Thus, any delay in the Test Facility schedule will undoubtedly delay completion of the Israel project.

The module development program proposed herein is capable of accomplishment in the San Diego Saline Water Test Facility.

If this portion of the development program were not implemented, it would be necessary to design more conservatively for the reference plant and this could add to the capital cost as shown in Table XVI.

TABLE XVI

EFFECT OF DEVELOPMENT PROGRAM ON REFERENCE PLANT COSTS

Item to be Tested	Increase in Cost of Reference Plant if Development Program Is Not Successful	Decrease in Cost of Reference Plant if Development Program is Fully Successful
Mass flow and nonequilibrium allowance values	$9,000,000(1)(4)	$ 2,500,000(2)
Use of concrete for enclosure	-	3,600,000(3)
Demister requirements to obtain 25 ppm purity (due to carryover)	-	2,800,000(5)
Lining of stages (concrete enclosures)	-	2,500,000(6)
	$9,000,000	$11,400,000

(1) Reference plant mass flow design value is 1,000,000 lb/hr-ft of weir width with an 0.7F nonequilibrium allowance. While this value is considered reasonable, the highest demonstrated value (Pt. Loma) is 500,000 lb/hr-ft of weir width. The reference plant design is based on steel evaporation enclosures whose cost would increase by approximately $9,000,000 if the higher mass flow is not demonstrated and it becomes necessary to design the reference plant for a mass flow of 500,000 lb/hr-ft of weir width.

(2) Contingent upon the development program confirming a mass flow value of 1,500,000 lb/hr-ft of weir width is suitable for the reference plant design.

(3) Concrete evaporator enclosures could reduce the reference plant cost by approximately $4,300,000 if concrete is shown to be suitable for these service and environmental conditions (for a mass flow value of 1,000,000 lb/hr-ft of weir width).

(4) Should the use of concrete be confirmed for evaporator enclosures, but the mass flow value of 500,000 be required as described in Note (1), the net increased cost of the reference plant would be approximately $2,100,000, instead of $9,000,000: obtained by a saving of $4,300,000 as in Note (3), and an increase of $6,400,000 due to the lower mass flow.

(5) Contingent upon the development program confirming that product water of 25 ppm is obtainable without demisters. (The reference plant estimate includes the cost of demisters and the cost of the heat transfer surface increase required by the pressure drop through the demisters.)

(6) Contingent upon confirming that a suitable lining for the concrete evaporator enclosures can be obtained for 50 cents per sq ft, instead of the $2.00 per sq ft used in the reference plant estimate, a further saving of $2,500,000 would be realized beyond that described in Note (3) or (4).

While this cost saving is sufficient to justify the development program, a result more important than the saving is the fact that the data therein developed is sure to permit a better plant design; provide a means of correcting component imbalance; improve the confidence in the reference design; and most important, prevent a substantial lengthening of the start-up period.

Kaiser Engineers and Catalytic Construction Company strongly recommend all parts of this recommended development program be accomplished, and every effort be made to avoid any delay in the schedule of the module test at the San Diego Saline Water Test Facility.

B. Background

One important basis for this study is that the reference plant be an operating utility. To meet this requirement it is necessary that the process and component technology be proven at the present time, or there must be reasonable assurance that whatever development work will be necessary to "prove out" those features not currently in commercial operation, will be successfully completed in time for commercial operation of the dual-purpose plant by mid-1972.

This operating utility concept is consistent with the state-of-the-art of the nuclear power plant portion of the dual-purpose plant. Reactors of the type and capacity required in this plant will be in operation by 1968.

Since no desalting plants of the size required in this dual-purpose plant are in operation or under construction, it is necessary to have a plant for "proving out" those features which are extrapolations of the state-of-the-art.

The development program described herein is reasonable in cost and can provide the required data (assuming no slippage of its schedule) before the desalting plant design is frozen.

In response to the Industry Survey, several vendors submitted preliminary quotations for desalting plant packages FAS East Coast and erected in Israel. The proposed development program should provide information enabling these vendors to reduce over-design allowances and thereby reduce their quotations in addition to providing data for use in refining the design of the desalting plant described

herein. The proposed development program should also provide information on hydrodynamics of full-sized modules which will reduce the time required from the end of construction to full commercial operation in the dual-purpose plant.

C. Recommended Development Program

The needs for process and component validation and/or development lead to a program with these principal parts:

- Erection and testing of full size modules under conditions comparable with the reference plant. These modules should be located at the OSW San Diego Saline Water Test Facility.

- Investigation of the oceanography and seawater characteristics under conditions contemplated for the reference plant. This work would be done in Israel.

- Testing of concrete under conditions contemplated for the reference plant. This work would be done both in Israel and the United States.

1. Module Test Facility

The information expected from work in the San Diego Test Facility would consist of the following:

a. A determination of the ability of this type of module to perform properly under conditions imposed by the process throughout the temperature and pressure ranges employed. This would include evaporator shells and foundations, tube bundles, seals, covers, expansion joints, vacuum equipment, demisters, weirs and flash promotion equipment.

b. A validation of the stage geometry considered, including mass flow, disengaging rate, temperature and pressure drops and brine depth, over the entire range of reference plant temperatures.

c. A validation of the flashing devices being considered, including determination of flow characteristics as a function of temperature and pressure.

d. A determination of brine entrainment as a function of flashing devices used, flow, temperature, pressure and an evaluation of the need for demisters throughout the plant.

e. A determination of the ability of the deaeration devices recommended to reduce dissolved oxygen and carbon dioxide to tolerable levels.

f. An evaluation of the pumps, particularly of the recycle pumps, to perform satisfactorily under the suction conditions and discharge head existing in the actual plant.

The module test facility to be used for development of the above information required to finalize the Israel plant design would be located in the San Diego Test Facility. To assure that the modules will be designed to investigate parameters of a plant of interest to this report, it is essential that close liaison be maintained with the OSW during the design of these modules.

The test modules should be so constructed as to permit variations in mass flow of from 400,000 lb/hr-ft of weir width to 1,400,000 lb/hr-ft of weir width. This variation could probably be accomplished best by artificially narrowing the flashing brine stream in the test module to simulate conditions of higher mass flow. Further, the module should be so designed as to permit disengaging rates varying from approximately 160 lb/hr-sq ft area, to 220 lb/hr-sq ft area.

It would be particularly valuable to achieve a capability for operation of the modules at conditions corresponding to those in any of the stages of the reference plant. To achieve this capability the brine heater should be designed to operate at a steam supply pressure of from 2 to 32 psia. Also, provision must be made to permit recycle of a portion of the otherwise rejected cooling water used in the heat rejection stages.

g. In addition to the above list, other items which should be checked in a test facility include evaporator body coatings. There are three principal areas of investigation:

- Corrosion resistant coatings for use on areas exposed to the flashing brine stream.

- Coatings for use on areas exposed to the distilled condensate.
- Coatings for use on external areas for insulation.

It would appear that there are no problems involved in applying several selected coatings to discrete areas of the test modules and observing their performance over the complete range of pressure and temperature conditions encountered for the period of time the module is in operation. This would give background information with respect to methods of application and cost as well.

2. Israel Oceanography and Seawater Characteristics

The investigation of oceanography and seawater characteristics, to be conducted in Israel would have the following objectives:

a. An evaluation of the effect of local water on materials of construction proposed for the Israel plant.

b. An evaluation of the extent of marine life in the feed seawater and a determination of the effect on this marine life of the chemical treatments being considered. This would also include the effect of chemicals such as ammonia, resulting from a reaction between treatment materials and marine life, on the materials of construction.

c. An evaluation of the variation in seawater analysis, including dissolved gases (primarily CO_2, O_2, NH_3, and H_2S), throughout the year, and the effect of this variation on the rate of scale formation.

d. An evaluation of the possibility of reducing acid treatment of the seawater below 100 percent stoichiometric requirement without creating a scaling condition in the evaporator.

e. A determination of the effect on rate of scale formation of various brine temperatures and concentration ratios.

Following a decision with regard to site location, a program should be instituted to determine the physical, chemical, and biochemical characteristics of the seawater, as well as the oceanography of the sea in the surroundings of the intake. For

a 100 MGD plant with 220 F maximum brine temperature, the flow through the intake will be about 562,000 gpm, 25 percent of which (135,000 gpm) will be processed through the plant. The remaining flow of 427,000 gpm of seawater plus the flow of 66,000 gpm of brine (at a concentration of 7.7 percent by weight) at a temperature of 12 F above that of the feedwater, will be rejected to the sea.

Handling of flows of this magnitude will require better knowledge of the characteristics of the sea, particularly with respect to backmixing and dilution of reject and blowdown streams. The proposed location of the seawater intake should be surrounded by a number of test station belts, suitably distributed and marked by floats. Similar test belts will be located in the general area where it is proposed to have the effluent canal discharge to the sea. At appropriate time intervals, temperature readings will be taken at each test station and at varying depths. A sample of water will be collected and tested for pH, free CO_2, O_2, NH_3, alkalinity, hardness, turbidity and dissolved solids. In addition to temperature recording and chemical testing, it will be necessary to count and identify the various living organisms as well as possible bacteriological contamination. It will also be necessary to establish the seawater currents in the general areas of the intake and outfall and between these two locations.

Logging the data collected will establish seawater temperature and current profiles, possible stratification of the sea and the seasonal variations in its properties. It will also permit evaluation of dilution properties of the sea at the outfall.

Certain physical properties of the seawater which have a direct influence on the design of the water plant must also be determined. It will be required to record the boiling point elevation, specific heat and density versus concentration and temperature. This can be accomplished with conventional laboratory equipment.

The effect of brine temperature at the brine heater outlet on performance of the plant should be investigated. Scale, corrosion, and structural problems become more severe at higher brine temperatures, and in this study 220 F has been taken as a conservative upper limit. However, it seems that more favorable water cost economics may be realized at higher temperatures; consequently, some investigative work in this direction appears

justified. In order to base the design on firm data with feedwater taken at the specific site location being considered, it is proposed that a test apparatus be constructed where the full range of conditions, particularly those existing at the brine heater, can be simulated. Operation of such test apparatus will facilitate testing the scaling tendency of brine at various methods of scale control. Figure 31 shows a flow diagram of the recommended test apparatus.

The operation of the proposed test apparatus is based on the flow path taken by the brine. Brine at the desired concentration and temperature, and at a controlled rate of about 20,000 lb/hr, is pumped through the brine heater into a collecting drum. Final adjustment of the brine temperature, prior to entering the brine heater, is effected by means of a temperature-controlled electric heater. The capacity of the brine in the drum (about 100 gallons) allows for enough residence time to simulate the conditions in a real plant situation. The temperature of the brine flowing through the heater is raised to the desired level, controlled by means of a pressure controller which regulates the flow of about 300 lb of steam per hour into the heater. From the drum, a major portion of the brine is introduced into the flash chamber where about 300 lb/hr flashes into vapor, effecting increase in concentration and drop in temperature; the balance of the brine under flow control is blown down through the make-up heater. The flashed vapor is introduced into the heat reject exchanger to be condensed on the outside surface of tubes cooled by seawater flowing inside. Treated make-up water is heated to the flash chamber outlet temperature in the make-up heater utilizing the heat released by cooling the blowdown and distillate streams flowing inside the tubes.

To achieve full benefit of the test apparatus, provision should be made for operation using raw seawater acidified to various degrees. Making runs with seawater acidified to levels from 70 percent to 110 percent of the amount theoretically required for complete decomposition of the carbonates and bicarbonates will yield data which may result in a saving of as much as one cent per thousand gallons of product water. Further, by combining these runs with runs at brine heater outlet temperatures of from 220 to 235 F, it will be possible to evaluate the merits of plant operation at temperatures higher than 220 F.

Also during operation of this test apparatus, some data should be developed regarding chemical products resulting from action of feedwater treatment chemicals on the organisms in the seawater. Certain products might be evolved which would have an extremely deleterious effect on the materials of construction considered for the plant, an example of this would be ammonia. Only if accurate determination of any chemical "by-products" resulting from treatment chemicals is made can appropriate precautions be taken.

3. Concrete Testing

There is a good possibility that the use of concrete for evaporator shells could result in a significant saving in construction cost. Under conditions in Israel, preliminary estimates indicate that the use of concrete evaporator shells might yield a saving of approximately 3.6 million dollars.

Practically all saltwater evaporating plants in service have been provided with metallic shells. Although there is almost a total lack of experience with concrete in distillation equipment, there appears to be no overriding reason which would prevent its use. For a top brine temperature of 220 F, it should be suitable for all of the stages provided it is properly formulated, reinforced, prestressed or post-tensioned to prevent cracking and adequately protected. At brine temperatures above 220 F the shell must be designed as a pressure vessel. The design of the structure will require a thorough stress analysis to ensure against cracking from thermal gradients.

The OSW has awarded a study contract to the U.S. Department of the Interior Bureau of Reclamation to investigate the problems of sealants, protective coatings and concrete formulations for use with seawater at various temperatures and concentrations.

While the questions regarding coatings and sealants for various exposures can be determined from tests of the types being conducted at the Bureau of Reclamation, questions regarding the ability of the concrete to withstand structural and thermal strain from operating conditions as well as the problems associated with the actual construction can best be resolved from actual construction of an operating module. Furthermore, inasmuch as the properties of concrete are quite dependent on the aggregates used, the test module should be fabricated of the same materials (i.e., cement, sand, aggregate) as would be used in the reference plant.

In addition to the work being sponsored by OSW, a number of experienced vendors are actively at work developing appropriate protective coatings. If suitable nonmetallic coatings are not developed, it should still be possible to line the concrete (where necessary) with a carbon steel sheet of the appropriate thickness --possibly as much as 5/16 in. --and let it serve as part of the form for the concrete. Unless a concrete module is built and tested, it is probable that steel would have to be specified as the material of construction for the evaporator shells.

An area of concern has been the ability of treated and untreated concrete to withstand the leaching action of the distillate product of the desalting plant. To evaluate this fully, a series of small test blocks should be cast, treated in appropriate ways, carefully analyzed and weighed, then placed in the vapor spaces and product water channels in an existing desalting plant. Periodic inspection of these test blocks should provide cumulative information which will make trend determinations possible. These could lead to conclusions as to the advisability of using various coating systems in the reference plant.

D. Relation of Development Program to San Diego Saline Water Test Facility

Since the final design of the Israel Desalting Plant will be based partly on information derived from the San Diego Saline Water Test Facility, it is important that the required information be available in timely fashion.

The critical path for the Israel plant (Figure 30) shows that desalting plant equipment installation must begin in January 1970 to be able to meet the start-up date of late 1971. This, in turn, requires "freezing" the detailed design in June 1968, only six months after start of final design, to allow for subsequent bidding, purchasing, fabrication and delivery by the end of 1969. Detailed design of the desalting plant must start no later than June 1968 to meet the above requirements; but detailed design is dependent on results obtained on the test modules at the San Diego Test Facility. Therefore, it appears that the OSW schedule (letter dated November 10, 1965, from Frank C. Di Luzio to C. E. Ennis, copy included herein) will allow approximately six months from January 1968 through June 1968 for collection of test data after start-up of the San Diego Test Facility

modules. The above analysis shows the critical nature of the dependency of the Israel project on the San Diego Test Facility schedule as well as test results. Any delay in the Test Facility schedule will undoubtedly delay completion of the Israel project.

IN REPLY REFER TO:

601

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
WASHINGTON, D.C. 20240

Mr. Charles Ennis
Assistant to the Executive Vice President
Catalytic Construction Company
1528 Walnut Street
Philadelphia, Pennsylvania 19102

Dear Mr. Ennis:

Subject: Program for the San Diego Saline Water Test Facility and its application to the proposed Israeli desalting plant

We recognize your interest in determining our plans for the use of the San Diego Saline Water Test Facility as it might apply to module testing, and your suggested development program for the Israel desalting plant. Although our plans are not finalized in regard to the type and size of the modules to be tested, it is possible to delineate the program which will lead to decisions of this kind. Our plan is essentially as follows:

1. An early selection of a capable architect-engineer firm will be made to prepare designs and bid packages for the module. It is hoped this firm will be selected by December 15, 1965.

2. The architect-engineer will be required to prepare a preliminary conceptual design of a 50 mgd stream of a desalting plant. This design should meet the general requirements of both the Metropolitan Water District (MWD) and the Israel plants. This conceptual design will include the most desirable features from the various studies which will be complete and on hand at that time; i.e., the MWD study, Kaiser-Catalytic study for Israel, the ORNL flash plant conceptual design, and the 15 50-mgd conceptual designs prepared for this Office and now under evaluation. The requirements of the MWD and the Israel desalting team will be taken into consideration to the fullest extent possible by consultations and review of designs.

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3. Upon approval by all interested parties of the preliminary conceptual design described above, the architect-engineer will proceed with the design of a module for construction and test at our San Diego Saline Water Test Facility. This module will be no larger than is necessary to insure that it duplicates as nearly as possible the hydraulic, heat transfer, and structural requirements at the low temperature end of the 50 mgd stream of the pilot plant. This module is expected to be complete with one recirculating brine pump, several heat rejection stages, the required number of full-size condenser bundles, flash chambers, deaerators, vacuum pumps, demisters, and product and brine pumps.

4. Upon approval of the module design, again by all interested parties, the architect-engineer will proceed with specifications and bid packages. In this way the modules can be placed on order in the early summer of 1966 and, if necessary, the large items of hardware, i.e., pumps and tube bundles, might be placed on order at that time. Schedules for the design, procurement, and construction will be such that the module will be in operation by January 1968.

Although we cannot assure you that all of the proposed development program requirements included in your letter of September 17 will be realized in the OSW module, you will have ample opportunity to review the requirements of the Israel desalting team with this Office prior to the time the design is finalized.

Sincerely yours,

Frank C. Di Luzio
Director

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XI. EFFECT OF VARIANTS

The capital cost and unit water cost estimates reported in Sections VII and VIII, respectively, are based on quotations from vendors of major components and on construction experience in Israel, and are believed to be realistic. However, because desalting plants of this size have not yet been built, it is prudent to examine the sensitivity of the capital, annual and unit water costs to the major design and cost parameters.

Table XVII lists a series of variants and the effect that changing each of these variants has on the capital, annual and unit water costs. It should be noted that the effect of each variant is reported in the table for the condition where only that variant changes.

The values of the capital, annual and unit water costs were estimated without reoptimization of the design parameters. Experience has shown that reoptimization, while necessary for accurate evaluation, will result in capital, annual and unit water costs only a few percent lower than those resulting from un-reoptimized design parameters in the ranges of power and water production selected for the reference plant.

TABLE XVII

EFFECT OF VARIANTS ON THE DUAL-PURPOSE PLANT CAPITAL, ANNUAL AND UNIT WATER COSTS (7% FIXED CHARGE RATE)

VARIANT	DESCRIPTION OF VARIANT	RANGE OF VARIATION	APPROXIMATE CAPITAL COST RESULTING FROM VARIANCE	APPROXIMATE UNIT WATER COST RESULTING FROM VARIANCE
A. CAPITAL COST VARIANTS				
1. BASE CASE	The reference plant described in Section VI and whose cost estimates are described in Sections VII and VIII is the base case.		$197, 200, 000	43.4¢/1, 000 Gallons
2. GENERAL CONSTRUCTION COST	The total capital cost of the dual-purpose plant is based on preliminary vendor quotations on major components and on unit construction costs obtained from contractors experienced in Israel. Several factors may increase the total capital cost such as increases in general construction costs, increases in heat exchanger material cost, increase in world copper price, and increased construction schedule.	For example, should some combination of the variants result in increasing the capital cost of the dual-purpose plant by $10,000,000.	$197, 200, 000 + 10, 000, 000 $207, 200, 000	45.6
	Several factors may result in a decrease in the total capital cost such as conservatism in the reference plant estimate and use of concrete for the evaporator enclosures rather than steel.	For example, should some combination of the variants result in decreasing the capital cost of the dual-purpose plant by $5, 000, 000.	$197, 200, 000 - 5, 000, 000 $192, 200, 000	42.3
3. DESIGN VALUE OF EVAPORATOR MASS FLOW	The reference plant mass flow design value is 1, 000, 000 lb/hr-ft of weir width with a 0.7 F nonequilibrium allowance. While this value is considered reasonable, the highest demonstrated value (Pt. Loma) is 500, 000 lb/hr-ft of weir width.	If the design mass flow is not confirmed in the development program, and it becomes necessary to design the desalting plant for 750, 000 lb/hr-ft of weir width mass flow value, it will be necessary to increase the evaporator stage enclosure width from the present 17 ft to a width of possibly 23 ft.	$197, 200, 000 + 5, 500, 000 $202, 700, 000	44.6
		If the development program were to demonstrate that the design mass flow can be increased from the design value of 1, 000, 000 lb/hr-ft of weir width to a value of 1, 250, 000 lb/hr-ft of weir width. the stage width could then be decreased from the present 17 ft to possibly 14 ft.	$197, 200, 000 - 2, 700, 000 $194, 500, 000	42.8
4. DESIGN VALUE OF TUBE BUNDLE HEAT TRANSFER COEFFICIENT	The reference plant design is based on heat transfer data supplied by the OSW. The design overall heat transfer coefficient has an average value of about 600 Btu/hr-sq ft-F which includes a fouling factor with an average value of 0.0003.	Should it be necessary to design the desalting plant using a heat transfer coefficient of approximately 500 Btu/hr-sq ft-F, instead of the present design value of about 600 Btu/hr-sq ft-F, a value equivalent to changing the average fouling factor from 0.0003 to 0.0007.	$197, 200, 000 + 7, 600, 000 $204, 800, 000	45.1
		Should it be possible to design the desalting plant using a heat transfer coefficient of approximately 700 Btu/hr-sq ft-F, instead of the present approximate design value of 600 Btu/hr-sq ft-F, a value equivalent to changing the average fouling factor from 0.0003 to 0.0001.	$197, 200, 000 - 5, 400, 000 $191, 800, 000	42.2
5. CONSTRUCTION PERIOD	The construction period for the dual-purpose plant is based on the selection of an Architect-Engineer by May 1966 and has a completion date (commercial operation) of December 1972.	An increase of one year in the construction schedule, assuming this year occurs approximately at mid-construction, will result in an increase in the capital cost due to an increase in the interest during construction.	$197, 200, 000 + 6, 600, 000 $203, 800, 000	44.9
6. HEAT EXCHANGER COST	The cost of the heat exchanger tube bundles is based on information and preliminary quotations obtained from vendors and is based on 1965 material prices.	Should the cost of the heat transfer surface increase by approximately 10%.	$197, 200, 000 + 3, 800, 000 $201, 000, 000	44.3
		Should the cost of the heat transfer surface decrease by approximately 10%.	$197, 200, 000 - 3, 800, 000 $193, 400, 000	42.6
7. DEMISTERS	The reference plant estimate includes the cost of demisters and an allowance for the pressure drop through the demisters.	Should the development program confirm that product water of 25 ppm (without tube leaks) is obtainable without demisters:	$197, 200, 000 - 2, 500, 000 $194, 700, 000	42.9

7. DEMISTERS	The reference plant estimate includes the cost of demisters and an allowance for the pressure drop through the demisters.	Should the development program confirm that product water of 25 ppm (without tube leaks) is obtainable without demisters:	$197,200,000 - 2,500,000 $194,700,000	42.9
8. EVAPORATOR ENCLOSURES (USE OF CONCRETE)	The reference plant is based on the use of steel for the evaporator enclosures. Should a development program confirm that concrete can be used, a significant cost saving can be realized.	The use of concrete for the evaporator enclosures (contingent upon demonstrating in a development program that concrete is suitable for this service) may result in reducing the capital cost of the plant by approximately $3,600,000.	$197,200,000 - 3,600,000 $193,600,000	42.6
VARIANT B_ANNUAL COST VARIANTS	DESCRIPTION OF VARIANT	RANGE OF VARIATION	NET ANNUAL COST RESULTING FROM VARIANCE	APPROXIMATE UNIT WATER COST RESULTING FROM VARIANCE
1. BASE CASE	The reference plant described in Section VI and whose cost estimates are described in Sections VII and VIII is the base case.		$13,470,000	43.4¢/1,000 Gallons
2. PLANT LIFE	The life of the dual-purpose plant has been assumed to be 30 years, a life consistent with conventional power plant and utility practice. While the life of water plants and water utilities is usually higher than 30 years, the similarity of the equipment in a desalting plant to that found in steam power plants appears to justify a 30-year life for each.	Should it appear justified to change the life of the dual-purpose plant from the 30-year design value to 25 years, it will be necessary to increase the fixed charge rate to 7.6%.	$13,470,000 + 1,090,000 $14,560,000	46.9
		Should it prove possible to increase the life of the plant to 35 years, instead of the design value of 30 years, there will be a reduction in the fixed charge rate to 6.6%.	$13,470,000 - 720,000 $12,750,000	41.1
3. WATER OUTPUT				
a. Desalting Plant Capability	The desalting plant design capacity is 100 MGD. Should the plant produce more than the design value, there will be a small increase in the annual cost due to an increased usage of fuel and chemicals. However, the increase in the annual water production will result in lower unit water costs.	Because of the lack of experience in the construction of large desalting plants, it is possible the over-design could result in a desalting plant capacity as high as 110 MGD (129 MCM/yr) with companion reduction in the unit cost of water.	$13,470,000 + 350,000 $13,820,000	40.5
b. Desalting Plant Operating Factor	The plant operating factor for the reference desalting plant is estimated at 85%. Should the availability of plant components, particularly evaporator tube bundles, be higher or lower than those assumed in the plant operating factor analysis, a higher or lower annual water production will be realized.	Should it become possible to increase the desalting plant operating factor to 89% (based on 90% reactor availability), water production would be 123 MCM/yr instead of 118 MCM/yr.	$13,470,000 + 270,000 $13,740,000	42.2
		Should it develop that the desalting plant operating factor is only 80%, water production would be 111 MCM/yr instead of 118 MCM/yr.	$13,470,000 - 140,000 $13,330,000	45.6
c. Tube Failure Rate	The experience with 90-10 copper-nickel tubing materials in seawater service is limited to about seven years. The basis for tube failure used in the reference plant design is that 0.1% of the tubes will have failed at the end of the first 10-year period. The plant operating factor of 85% includes consideration of the time required to plug tubes failing at the design rate along with considerations of other plant component availabilities.	Should the tube failure rate of the 90-10 copper-nickel tubing be twice that assumed in the reference plant design, namely, 0.2% tube failures during the first 10 years, the plant operating factor over the 30-year life of the plant will average 82% instead of 85%, with a resulting increase in the unit cost of water.	$13,470,000 - 130,000 $13,340,000	44.5
4. INTERIM TUBE REPLACEMENT	An allowance has been made for occasional retubing of selected areas of the desalting plant which may fail due to locally corrosive conditions in the evaporators. With this provision, and with the use of superior materials at certain critical points, the expected life of the tube bundles in the desalting plant is 30 years.	Should future information show it is necessary to provide for full retubing of the desalting plant after approximately 15 years' operation of the plant.	$13,470,000 + 640,000 $14,110,000	45.5
5. TOP BRINE TEMPERATURE	The design value of the top brine temperature of the reference plant is 220 F.	It would appear as a result of recent information the top brine temperature can be increased to 235 F without scaling, and this increase would result in a decrease in the unit water costs.	$13,470,000 - 420,000 $13,050,000	42.0
6. POWER OUTPUT	The turbine generator capacity of the reference plant is sufficient to generate 200 megawatts of salable electric power and the credit for salable power has been based on 200 megawatts and an 85% plant operating factor.	Should the over-design and stretch characteristics of the plant permit operation of the turbine generator at a higher capacity and should it develop that the Israel Electric Corporation can efficiently absorb this power, i.e., 210 megawatts at an 85% plant operating factor, the increase in annual power credit will result in a decrease in the annual water costs.	$13,470,000 + 190,000 $13,660,000 - 400,000 $13,260,000	42.7
7. FUEL COST	The nuclear fuel cycle costs include prices for fuel fabrication and spent fuel reprocessing presently being quoted on a firm basis by U.S. manufacturers and "Nuclear Fuel Service, Inc." and on a uranium cost of $6/lb of U_3O_8 as described in Section VIII. A leading reactor manufacturer has recently published predictions of lower fuel cycle costs for the period of the 1980's and 1990's.	Should the fuel cycle cost estimates of a leading reactor manufacturer be realized, there will be a significant reduction in the unit cost of water shown in Chart No. 3 of Section VIII.	$13,470,000 - 1,220,000 $12,250,000	39.4

XII. EQUIPMENT LIST

The nuclear power plant and desalting plant major items of equipment which are required for the reference plant are listed below:

A. Power Plant

1. Nuclear Boiler

a. (Alternate 1) Indirect Cycle Nuclear Boiler (PWR), 1,250 MWt, designed for steam conditions of 780 psia (min) and 0.3 percent moisture (max); feedwater conditions of 270 F (min), including:

(1) Reactor Vessel System
(2) Reactor Control System
(3) Reactor Coolant System
(4) Auxiliary Coolant System
(5) Chemical and Volume Control System
(6) Safety Injection System
(7) Sampling System
(8) Vent and Drain Systems
(9) Steam and Feedwater Systems (steam generator, feedwater controls and valves only)
(10) Fuel Handling and Reactor Servicing Equipment
(11) Instrumentation and Control Equipment (for systems listed above)

b. (Alternate 2) Direct Cycle Nuclear Boiler (BWR), 1,250 MWt, designed for steam conditions of 1,000 psia (min) and 0.2 percent moisture (max); feedwater conditions of 270 F (min), including:

(1) Reactor Vessel System
(2) Reactor Control Rod and Drive System
(3) Recirculation System
(4) Shutdown Reactor Cooling System
(5) Standby Liquid Control System
(6) Supplemental Cooling Systems
(7) Reactor Water Cleanup System
(8) Fuel Handling and Reactor Servicing Systems
(9) Miscellaneous Nuclear Service Systems
(10) Main Steam System (steam lines up to and including isolation valves only)
(11) Condensate, Make-Up and Feedwater Systems (reactor feedwater controls and valves only)
(12) Control and Monitoring Instruments and Panels
(13) Process Radiation Monitoring Equipment

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2. Waste Disposal System

a. Radioactive Waste Collection Tank

One (1), vertical, flat bottom, dished top 1,180 ft^3 capacity, carbon steel, API code design.

b. Gravity Drain Collection Tanks

Two (2), vertical, flat bottom, dished top 650 ft^3 capacity, carbon steel, API code design.

c. Demineralizers

Three (3), mixed bed, 10 gpm/ft^2 capacity, tank material carbon steel, rubber lining, ASME code design.

d. Waste Holding Tanks

Two (2), vertical, flat bottom, dished top 5,000 ft^3 capacity, carbon steel, API code design.

e. Spent Resin Tank

One (1), vertical flat bottom, dished top 750 ft^3 capacity, stainless steel lined, API code design.

f. Compressed Gas Receivers

PWR - Three (3), vertical, dished bottom and top, 60 ft^3 capacity.
BWR - Four (4), vertical, dished bottom and top, 100 ft^3 capacity, ASME code design.

g. Gas Stripper Pumps (PWR Only)

Two (2), centrifugal, all stainless steel, tdh 150 ft, 50 gpm @ 200 F, drive motor 3 hp.

h. Evaporator and Transfer Pumps

Ten (10), centrifugal, all stainless steel, tdh 150 ft, 50 gpm @ 200 F, drive motor 3 hp.

i. Demineralizer Pumps

Three (3), centrifugal, cast iron casing, tdh 150 ft, 20 gpm @ 200 F, drive motor 2 hp.

j. Radioactive Waste Collection Tank Pumps

Two (2), centrifugal, cast iron casing, tdh 230 ft, 200 gpm @ 200 F, drive motor 20 hp.

k. Gravity Drain Tank Pumps

Four (4), centrifugal, cast iron casing, tdh 100 ft, 50 gpm @ 200 F, drive motor 2 hp.

l. Gas Compressors

Two (2) multi-stage reciprocating compressors, last stage exhaust @ 2,000 psi, drive motor 150 hp-BWR, 75 hp-PWR.

m. Ventilating Fans

Two (2), 3,000 cfm capacity exhaust fans, discharge pressure, 6 in. of water, drive motor 5 hp.

n. Hydraulic Baler

One (1), total pressure 16,000 psi, package size 1 ft^3.

o. Gas Stripper (PWR Only)

One (1), packed tower 2 ft diameter, 15 ft height, stainless steel casing, capacity 100 gpm.

p. Gas Stripper Preheater (PWR Only)

One (1), removable bundle, all stainless steel heat exchanger, temperature in-shell 230 F, tubes 60 F, temperature out-tubes 130 F, design pressure-shell 50 psig, design code TEMA.

q. Switchgear

Metal-clad, dead front, low voltage switchgear including dry type transformer, 4.16 kv/400 volt, 3-phase, 50 cycle.

r. Motor Control Center

Metal-clad, 400 volt, 3-phase, 50 cycle.

3. Steam Turbine - Generator Unit

a. (Alternate 1) Steam Turbine - Generator Unit for Use with (PWR) Reactor.

(1) 254,000 kw tandem-compound four flow, 3,000 rpm nuclear steam turbine designed for throttle steam conditions of 752.7 psia, 1,197.4 h, 0.3 percent moisture, exhausting at 26 psia (constant back-pressure), including suitable moisture separating equipment.

(2) 320,000 kva hydrogen inner-cooled generator, 0.85 PF, 0.58 SCR @ 45 psig, 50 cycles, 3,000 rpm, 3-phase.

(3) Brushless excitation system

(4) Standard Handbook Accessories

b. (Alternate 2) Steam Turbine-Generator Unit for Use with (BWR) Reactor.

(1) 253,000 kw tandem-compound two flow, 3,000 rpm nuclear steam turbine designed for throttle steam conditions of 965 psia, 1,191.2 h, 0.28 percent moisture and exhausting at 26 psia (constant back-pressure), including suitable moisture separating equipment.

(2) 320,000 kva liquid conductor-cooled generator, 0.85 PF, 0.58 SCR @ 45 psig, 50 cycles, 3,000 rpm, 3-phase.

(3) Gear-Driven Exciter

(4) Standard Handbook Accessories

4. Other Power Plant Components

a. (Alternate 1) for PWR Steam Source.

(1) Boiler Feed Pumps

Three (3) (one spare), multi-stage centrifugal, chrome steel split casing and internals, tdh 2,500 ft, 5,700 gpm @ 365 F, motor rating 4,500 hp.

(2) Booster Pumps

Three (3) (one spare), centrifugal, horizontal, split-case discharge, tdh 400 ft, 4,300 gpm @ 241 F, motor rating 600 hp.

(3) Feedwater Heater Drains Pump

One (1), pit type centrifugal, tdh 100 ft, 2,500 gpm @ 289 F, motor rating 75 hp.

(4) Hotwell Pumps

Four (4), pit-centrifugal, tdh 90 ft, 2,100 gpm @ 240 F, motor rating 60 hp.

(5) Feedwater Heaters

Two (2) vertical U-tube heaters arranged in parallel. Tube Side: temperature in 240 F, temperature out 363 F, design pressure 200 psi, flow (each) 1,940,000 lb/hr, Shell Side: temperature 368 F, design pressure 180 psi, flow (each) 323,000 lb/hr. Materials: Shell, CS(A-285-C); Channel, CS(A-285-C); Tube Sheet, CS(A-212-B); Tubes 70-30 Cu-Ni, Total heat transfer 250 x 10^6 Btu/hr per heater.

(6) Instrument Air Compressor

One (1) double-stage reciprocating compressor, discharge pressure 115 psig, capacity 150 scfm, drive motor 50 hp.

(7) Service Air Compressors

Two (2) vane-rotary compressor with water jacket, discharge pressure 115 psig, capacity 500 scfm, drive motor 100 hp.

(8) Instrument Air Receiver

One (1), vertical, dished bottom and top, capacity 120 ft^3, carbon steel, design pressure 150 psig, ASME design code.

(9) Service Air Receivers

Two (2), vertical, dished bottom and top, capacity 120 ft^3, carbon steel, design pressure 150 psig, ASME design code.

(10) Demineralizer Feed Pumps

Two (2), vertical pit, cast iron casing, tdh 150 ft, 150 gpm, motor rating 10 hp.

(11) Condensate Make-Up Pumps

Two (2), pit type centrifugal, cast iron casing, tdh 140 ft, 500 gpm, motor rating 30 hp.

(12) Sump Pumps

Four (4), vertical pit type centrifugal, cast iron casing, tdh 900 ft, 100 gpm, motor rating 5 hp.

(13) General Service Pumps

Two (2), vertical pit, cast iron casing, tdh 200 ft, 500 gpm, motor rating 40 hp.

(14) Service Cooling Pumps

Three (3) (one spare), horizontal centrifugal, cast iron casing, tdh 80 ft, 5,000 gpm, motor rating 150 hp.

(15) Service Cooling Heat Exchangers

Two (2) (one spare), single-pass double-head heat exchanger, Tube Side: temperatre in 110 F, temperature out 95 F, design pressure 150 psi, flow 10,000 gpm. Shell Side: temperature in 89 F, temperature out 99 F, design pressure 50 psia, flow 15,000 gpm. Materials: shell CS(A-285-C), channel CS(A-285-C), tube sheet Muntz metal, tubes admiralty, total heat transfer 25 x 10^6.

(16) Condensate Storage Tanks

Two (2), 4,500 ft^3 capacity, concrete, aluminum lined.

(17) Condensate Surge Tank

One (1), horizontal, dished heads, 48,000 gallon capacity, carbon steel, API code design.

(18) Treated Water Head Tank

One (1) horizontal, dished heads, 6,400 gallon capacity, carbon steel, API code design.

(19) Service Cooling Head Tank

One (1) horizontal, dished heads, 6,400 gallon capacity, carbon steel, API code design.

(20) Reactor Polar Crane

One (1), polar-gantry, 88 ft span, 100/15 ton capacity.

(21) Turbine Room Crane

One (1), travelling bridge, 80 ft span, 100/15 ton capacity.

(22) Office Air-Conditioning Unit

One (1), package unit including roof evaporator condenser 50 ton rating.

b. (Alternate 2) for BWR Steam Turbine Cycle

(1) Boiler Feed Pumps

Three (3), (one spare), multi-stage centrifugal, chrome steel split casing and internals, tdh 2,700 ft, 4,700 gpm motor rating 4,500 hp.

(2) Booster Pumps

Three (3), (one spare), centrifugal, horizontal split case, tdh 450 ft, 4,500 gpm @ 241 F, motor rating 600 hp.

(3) Feedwater Heater Drains Pump

One (1), pit-centrifugal, tdh 400 ft, 150 gpm @ 258 F, motor rating 20 hp.

(4) Hotwell Pumps

Four (4), pit-centrifugal, tdh 90 ft, 2,300 gpm @ 240 F, motor rating 75 hp.

(5) Condensate Demineralizer

One (1), preassembled "Powdex" process full flow demineralizer-filter, complete with equipment for backflushing, resin replacement, instrumentation and controls. Flow - 4,320,000 lb/hr at 240 F.

(6) Feedwater Heaters

Two (2) vertical U-tube heaters, arranged in parallel. Tube Side: temperature in 240 F, temperature out 252 F, design pressure 200 psi, flow 2,160,000 lb/hr, Shell Side: temperature out 257 F, design pressure 50 psi. Materials: shell CS (A-285-C); channel CS (A-285-C); tube sheet CS (A-212-B); tubes 70-30 Cu-Ni. Total heat transfer 27.0×10^6 Btu/hr per heater.

(7) Instrument Air Compressor

One (1) double-stage reciprocating compressor, discharge pressure 115 psig, capacity 150 scfm, drive motor 50 hp.

(8) Service Air Compressors

Two (2) vane-rotary compressor with water jacket, discharge pressure 115 psig, capacity 500 scfm, drive motor 100 hp.

(9) Instrument Air Receiver

One (1) vertical, dished bottom and top, capacity 120 ft^3, carbon steel, design pressure 150 psig, ASME design code.

(10) Service Air Receivers

Two (2) vertical, dished bottom and top, capacity 120 ft^3, carbon steel, design pressure 150 psig, ASME design code.

(11) Demineralizer Feed Pumps

Two (2) vertical pit type centrifugal, cast iron casing, tdh 150 ft, 150 gpm, motor rating 10 hp.

(12) Condensate Make-Up Pumps

Two (2) pit type centrifugal, cast iron casing, tdh 140 ft, 500 gpm, motor rating 30 hp.

(13) Sump Pumps

Four (4) vertical pit type centrifugal, cast iron casing, tdh 90 ft, 100 gpm, motor rating 5 hp.

(14) General Service Pumps

Two (2) vertical pit type centrifugal, cast iron casing, tdh 200 ft, 500 gpm, motor rating 40 hp.

(15) Service Cooling Pumps

Three (3) (one spare), horizontal centrifugal, cast iron casing, tdh 80 ft, 5,000 gpm, motor rating 150 hp.

(16) Service Cooling Heat Exchangers

Two (2) single-pass double-head heat exchangers, Tube Side: temperature in 110 F, temperature out 95 F, design pressure 150 psi, flow 10,000 gpm, Shell Side: temperature in 89 F, temperature out 99 F, design pressure 50 psi, flow 15,000 gpm, Materials: Shell CS (A-285-C), channel CS (A-285-C), tube sheet Muntz metal, tubes admiralty, total heat transfer 25×10^6.

(17) Condensate Storage Tanks

Two (2) 4,500 ft^3 capacity, concrete, aluminum lined.

(18) Condensate Surge Tank

One (1) horizontal, dished heads, 48,000 gallon capacity, carbon steel, API code design.

(19) Treated Water Head Tank

One (1) horizontal, dished heads, 6,400 gallon capacity, carbon steel, API code design.

(20) Service Cooling Head Tank

One (1) horizontal, dished heads, 6,400 gallon capacity, carbon steel, API code design.

(21) Reactor Gantry Crane

One (1). gantry, 95 ft span, 100/15 ton capacity.

(22) Turbine Room Crane

One (1) travelling bridge, 80 ft span, 100/15 ton capacity.

(23) Office Air-Conditioning Unit

One (1) package unit including roof evaporator condenser, 50 ton rating.

B. Desalting Plant

1. Equipment for Heat Reject and Recovery Stages

a. Brine Heaters

Four (4) box type construction, each 33 ft long x 17 ft-6 in. wide by 30 ft-9 in. high with 4 tube bundles, each having 2,827 - 1 in. OD x 18 BWG 90-10 Cu-Ni tubes (surface each brine heater 51,470 sq ft).

b. Flanged Expansion Joints

Eighty (80) 0.164 in. traverse.

c. Flanged Expansion Joints

Eighty (80) 0.74 in. traverse.

d. Flanged Expansion Joints

Eighty (80) 0.97 in. - traverse bellows, Monel, two corrugations, flanges - forged steel - epoxy coated (Van Stone).

e. Heat Recovery Tube Bundles

Two hundred and twenty-four (224) heat recovery tube bundles including two water boxes each. Each bundle has 3,687 - 7/8 in. OD tubes; 20 BWG 90-10 Cu-Ni tubes in the major areas and 20 BWG 90-10 Cu-Ni/stainless steel bimetallic in the air cooling areas, all tubes 44 ft-6 in. long (surface 37,612 sq ft); tube sheets: carbon steel, 90-10 Cu-Ni cladding one face at 15 percent of tube-sheet thickness; baffles and intermediate tube sheet of carbon steel. Sixteen (16) out of the 224 bundles will have the same number of tubes and material, only that the wall thickness will be 18 BWG.

f. Heat Reject Tube Bundles

Sixteen (16) heat reject tube bundles, including two water boxes each. Each bundle has 3,500 - 7/8 in. OD tubes 20 BWG 90-10 Cu-Ni tubes in the major areas and 20 BWG 90-10 Cu-Ni/stainless steel bimetallic in the air cooling areas, all tubes 41 ft long (surface 32,850 sq ft); tube sheets: carbon steel, 90-10 Cu-Ni cladding one face at 15 percent of tube-sheet thickness; baffles and intermediate tube sheet - carbon steel.

g. Heat Reject - Deaerator Tube Bundles

Sixteen (16) heat reject-deaerator tube bundles, including two water boxes each. Each bundle has 3,500 - 7/8 in. OD 20 BWG 90-10 Cu-Ni/stainless steel bimetallic tubes 20 ft-6 in. long (surface 16,425 sq ft); tube sheets: carbon steel 90-10 Cu-Ni; cladding one face at 15 percent of tube-sheet thickness, baffles and intermediate tube sheet - carbon steel.

2. Major Pumps

a. Heat Reject Pumps

Five (5) heat reject pumps, 112,000 gpm capacity, tdh 56.5 ft, motor rating 2,000 hp syn.

b. Recycle Brine Pumps

Twelve (12) recycle brine pumps, 72,500 gpm capacity, tdh 219 ft, motor rating 5,000 hp syn.

c. Make-Up Water Pumps

Four (4) make-up water pumps, 35,500 gpm capacity, tdh 31 ft, motor rating 350 hp ind.

d. Blowdown Pumps

Eight (8) blowdown pumps, 17,500 gpm capacity, tdh 46 ft, motor rating 300 hp ind.

e. Distillate Pumps

Eight (8) product water pumps, 18,250 gpm capacity, tdh 57.7 ft, motor rating 350 hp ind.

f. Chlorinator Water Pumps, Horizontal Centrifugal

Two (2) 75 gpm capacity, tdh 75 lb/sq in., motor rating 5 hp.

g. H_2SO_4 Metering Pumps

Two (2) H_2SO_4 metering pumps, 630 gph capacity, 95 percent H_2SO_4, tdh 50 psig, motor rating 1-1/2 hp.

h. Vacuum Condenser Water Booster Pumps

Four (4) vacuum condenser water booster pumps, 4,000 gpm capacity, tdh 25 psig, motor rating 75 hp ind.

i. Condensate Pumps - Vacuum Systems I

Four (4) condensate pumps - vacuum systems I, 25 gpm capacity, tdh 25 psig, motor rating 1 hp ind.

j. Condensate Pumps - Vacuum Systems II

Four (4) condensate pumps - vacuum systems II, 15 gpm capacity, tdh 25 psig, motor rating 1 hp ind.

k. Condensate Pumps - Vacuum Systems III

Four (4) condensate pumps - vacuum systems III, 25 gpm capacity, tdh 25 psig, motor rating 5 hp ind.

3. Vacuum Equipment

a. Vacuum Equipment for System I

Four (4) sets, each set - 2 precondensers, 2 jets, 2 after-condensers.

b. Vacuum Equipment for System II

Four (4) sets, each set - 2 precondensers, 2 jets, 2 inter-condensers, 2 jets, 2 aftercondensers.

c. Vacuum Equipment for System III

Four (4) sets, each set - 4 jets, 2 intercondensers, 2 jets, 2 intercondensers, 2 jets, 2 aftercondensers.

4. Electrical Equipment

a. Lightning Arrestors

Twelve (12) 161 kv.

b. Switches

Eight (8) 161 kv, 600 amp, group operated, side break.

c. Oil Circuit Breakers

Three (3) 161 kv, 1,200 amp.

d. Transformers

Two (2) 20/26.7/33.3 MVA 161/4.16 kv, 3-phase.

e. Metal-Clad Switchgear Line Up

One (1) outdoor switchgear assembly, 4,160 volts, 50 cycles, 350 MVA interrupting capacity consisting of:

- Four (4) 2,000 amp incoming breakers, one (1) 3,000 amp bus tie breaker.
- Two (2) auxiliary compartments, each consisting of three (3) PT's and three (3) lightning arrestors.
- Twelve (12) starting breakers and field equipment for 5,000 hp synchronous motors. (Motor excitation supplied by motor manufacturers.)

f. Metal-Clad Switchgear Line Up

One (1) outdoor switchgear assembly, 4,160 volts, 50 cycles, 250 MVA interrupting capacity consisting of:

- Two (2) compartments for current limiting reactors rated at 2,000 amp (to reduce the interrupting duty from 350 MVA to 250 MVA).
- Two (2) 2,000 amp incoming breakers and two (2) 2,000 amp tie breakers.
- Three (3) auxiliary compartments, two consisting of three (3) PT's and three (3) lightning arrestors and one (1) consisting of only three (3) PT's.
- Twenty-six (26) starting breakers for induction motors.
- Three feeder breakers.
- One spare compartment.

g. Battery Assembly

One (1) assembly of batteries, battery racks and chargers - for above batteries.

h. Transformers

Two (2) 500 kva, 4, 160/400 volt, 3-phase.

i. Low Voltage Switchgear Line Up

Two (2) outdoor, 400 volt to include 5 compartments for incoming line, tie and feeder circuit breakers, bus entrance and metering.

j. Motor Control Centers

Six (6) outdoor to include compartments for reversing and non-reversing motor starters, circuit breakers for lighting distribution and power receptacles and space for future units.

5. Miscellaneous Equipment

a. Gantry Crane

One (1) gantry crane, 50 ton hook, span 75 ft, 40 ft lift, hoisting speed 14 fpm on main hook, hoisting speed 60 fpm on 5 ton hook, trolley speed 100 fpm, bridge speed 100 fpm, diesel driven generator, arranged for power rotation of tracks to permit travel at 90 degrees to main runway.

b. Degassing Tower

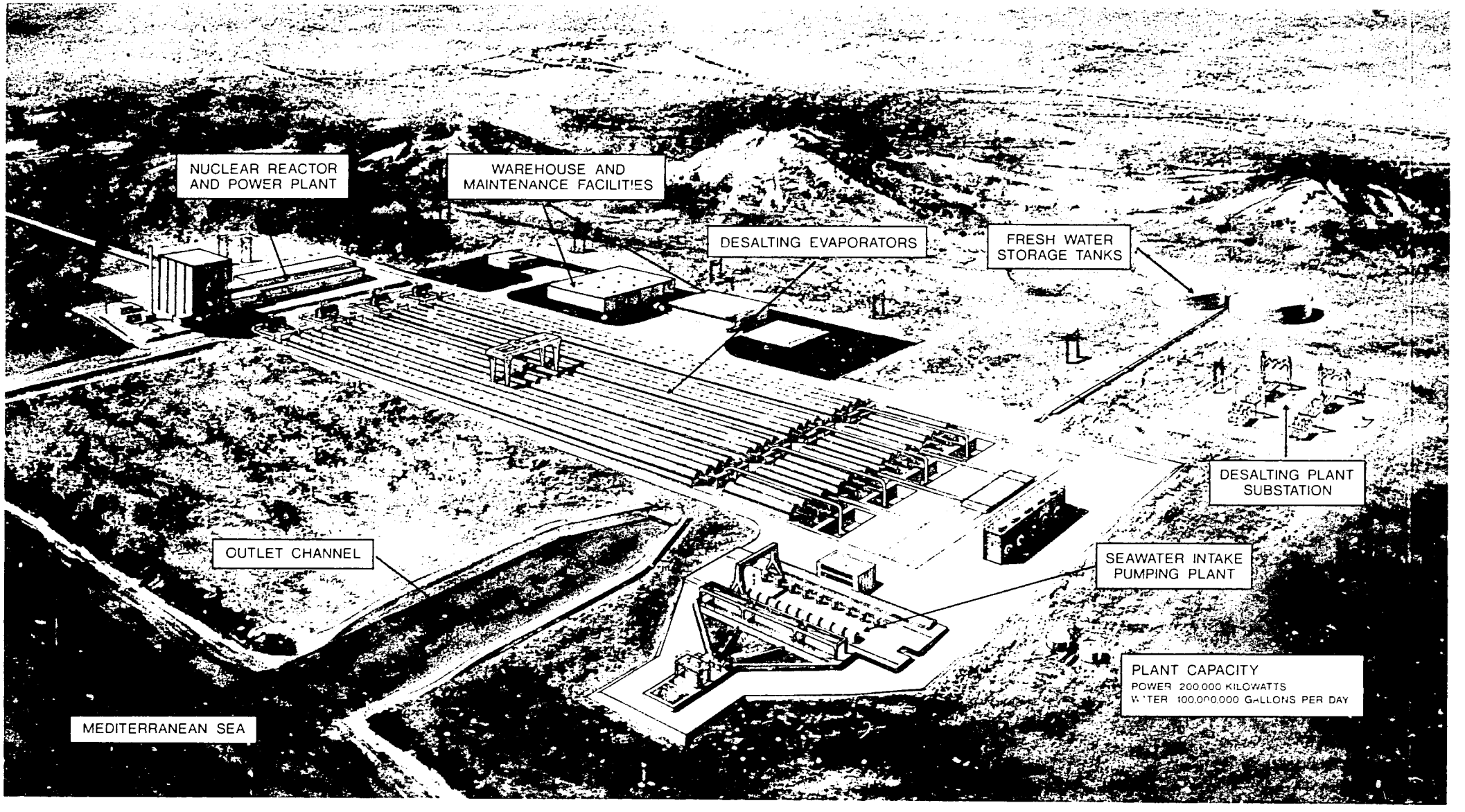
One (1) degassing tower, remove 7,800 lb/hr CO_2 from 135,000 gpm of seawater, tower approximately 150 ft long x 40 ft wide x 20 ft high, polypropylene grid packing, five motor driven fans - 20 hp motors.

c. Chlorinator Units (1 Spare)

Two (2) chlorinator units, 8,000 lb/day capacity each, including vaporizers and scales for 1 ton Cl_2 cylinders.

d. Sulphuric Acid Tanks

Two (2) 2,000 barrels, API cone roof storage tanks for 95 percent H_2SO_4. Complete with loading connections, level gages, vents, manholes and pump suction nozzles.



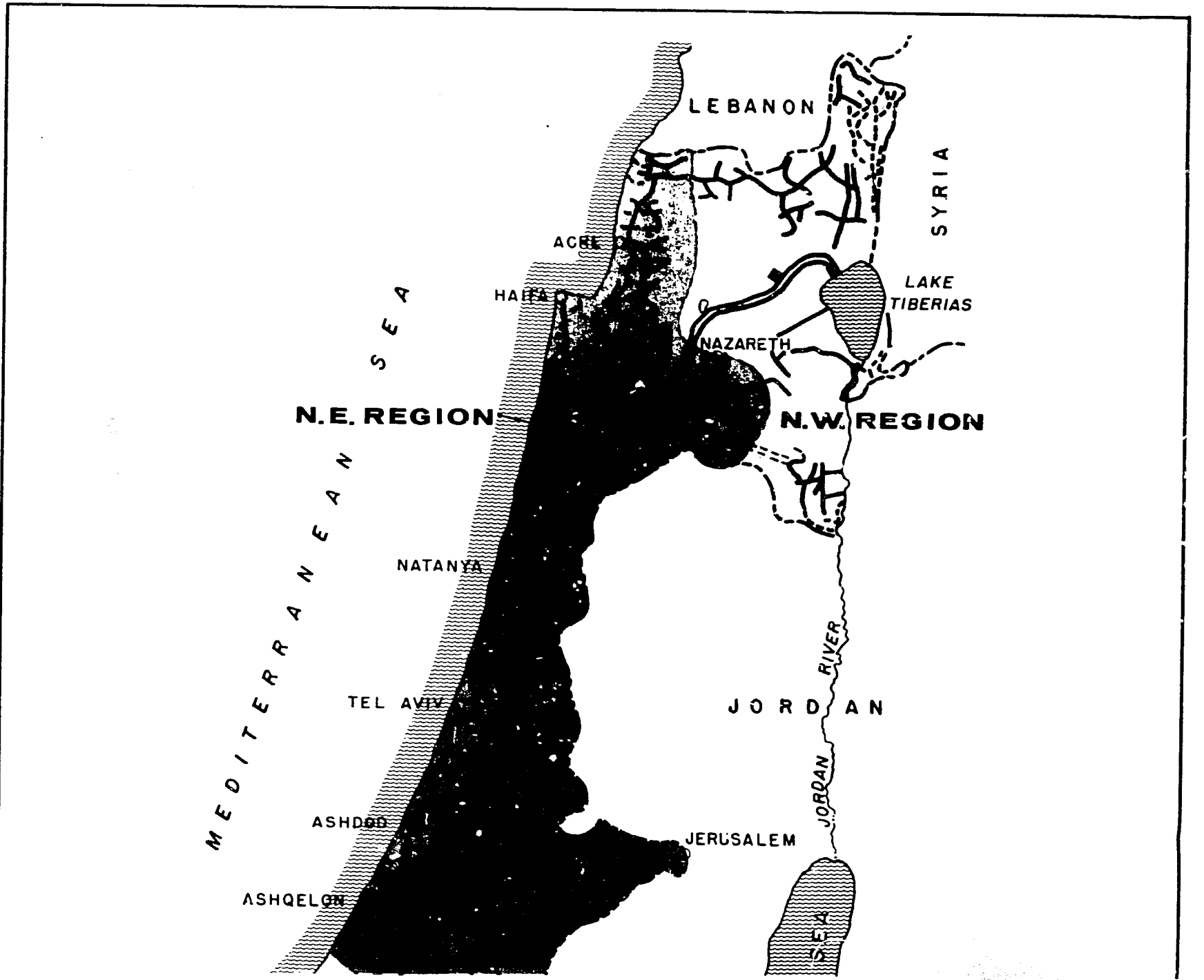
DUAL-PURPOSE ELECTRIC POWER—WATER DESALTING PLANT FOR ISRAEL

STUDY SPONSORED JOINTLY BY UNITED STATES–ISRAEL GOVERNMENTS

Prime Contractor: Kaiser Engineers Subcontractor: Catalytic Construction Company

FIGURE 1

184


LEBANON
SYRIA
ACRE
HAIFA
LAKE
TIBERIAS
NAZARETH
N.E. REGION
N.W. REGION
MEDITERRANEAN SEA
NATANYA
TEL AVIV
JORDAN
RIVER
JORDAN
ASHDOD
JERUSALEM
ASHQELON
SEA

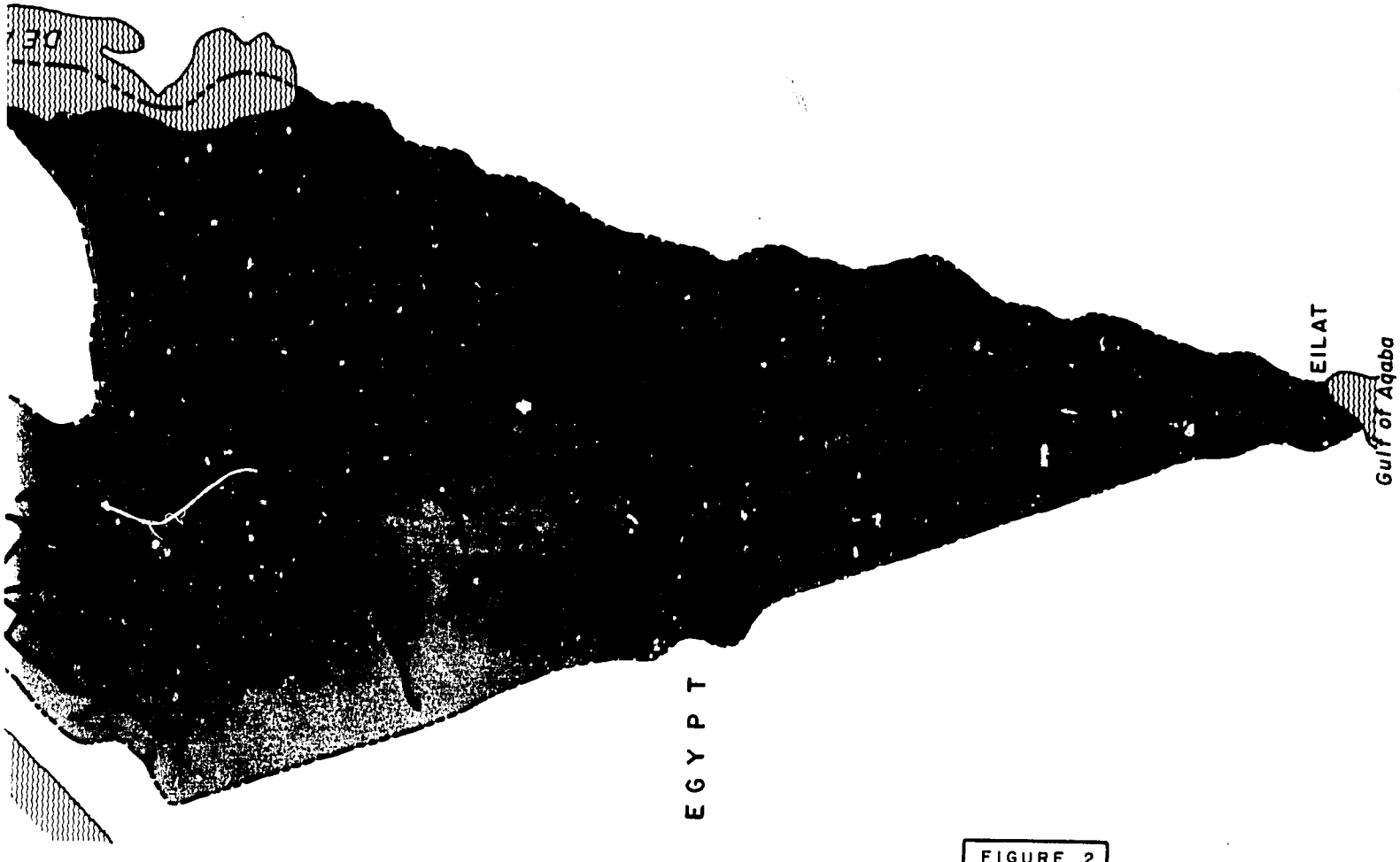
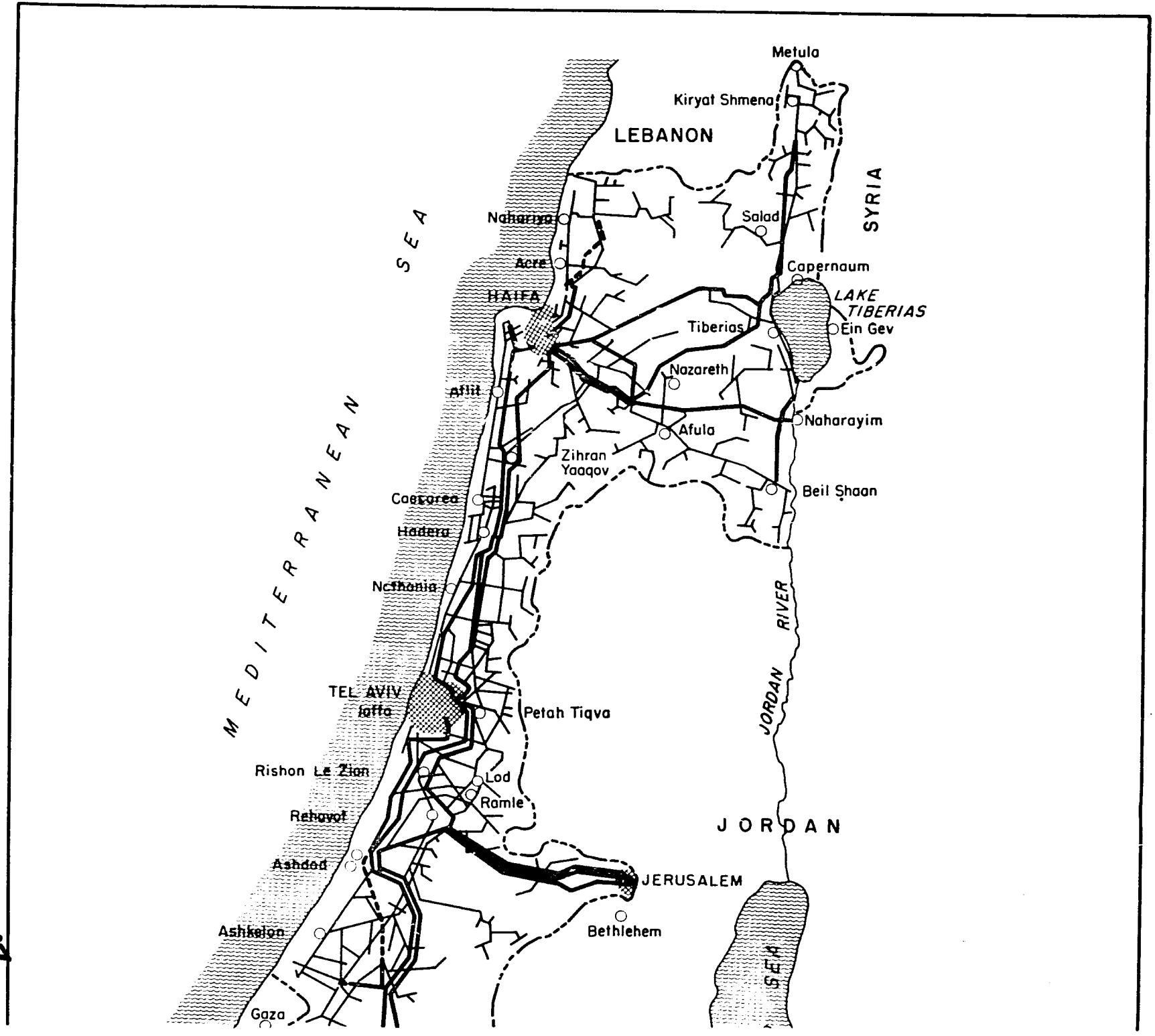


FIGURE 2

MAP OF ISRAEL

WATER DISTRIBUTION NETWORK

REF: REPORT OF THE UNITED STATES - ISRAEL DESALTING AND POWER TEAM.


Metula
Kiryat Shmona
LEBANON
SYRIA
Salad
Naharya
Acre
HAIFA
Capernaum
LAKE TIBERIAS
Ein Gev
Tiberias
Nazareth
Afula
Naharayim
Zihran Yaaqov
Beil Shaan
Caesarea
Hadera
Netanya
MEDITERRANEAN SEA
JORDAN RIVER
TEL AVIV
Jaffa
Petah Tiqva
Rishon Le Zion
Lod
Ramle
Rehovot
JORDAN
Ashdod
JERUSALEM
Ashkelon
Bethlehem
Gaza
SEA

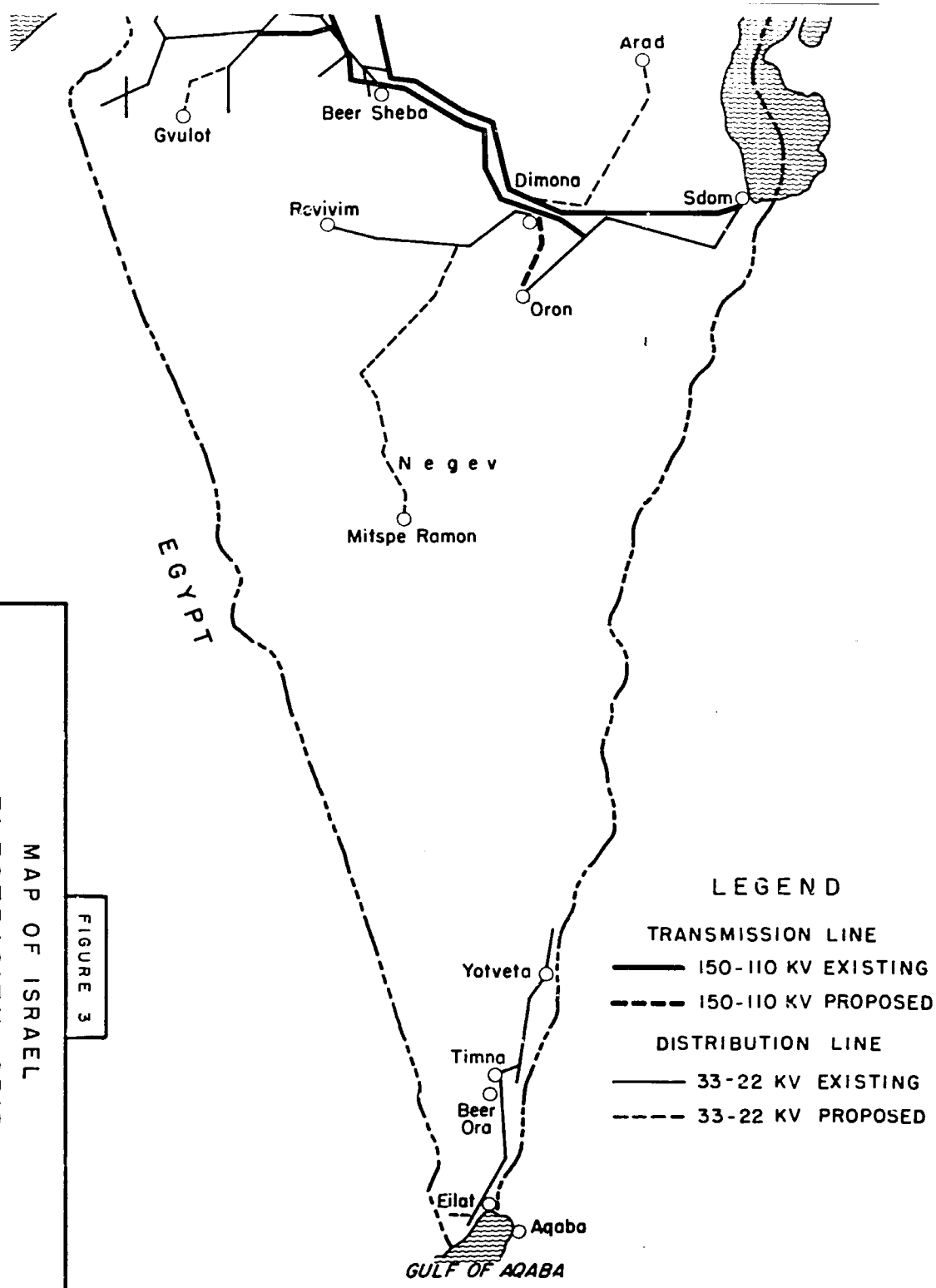
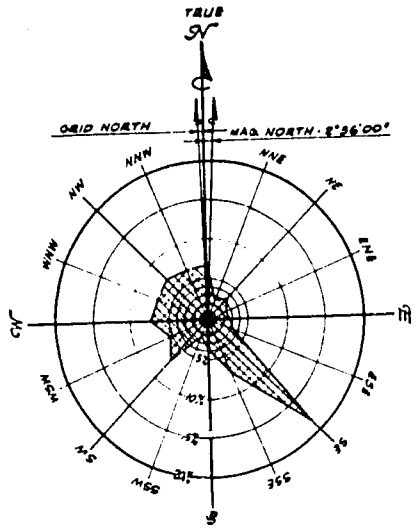


FIGURE 3

MAP OF ISRAEL

ELECTRICITY GRID

REF: REPORT OF THE UNITED STATES - ISRAEL DESALTING AND POWER TEAM.



WIND ROSE

ASHDOD STATION

ANNUAL SUMMARY OF WIND DIRECTION
VARIABLE · 37%
CALM · 5.94%

(PERCENTAGES INDICATE DIRECTION FROM WHICH WIND BLOWS)

I · 1

	0/2 KM	2/5 KM	5/10 KM	10/15 KM	15/20 KM
POPULATION · 1961	-	195	-	-	437,700
POPULATION · 1980	-	5400	-	-	880,000

I · 2

POPULATION · 1961	-	-	195	59,060	884
POPULATION · 1980	-	-	400	70,600	1000

I 3

POPULATION · 1961	-	-	568	51,410	-
POPULATION · 1980	-	-	400	48,400	-

I 4

POPULATION · 1961	-	-	7780	691	-
POPULATION · 1980	-	-	23,600	700	-

I 5

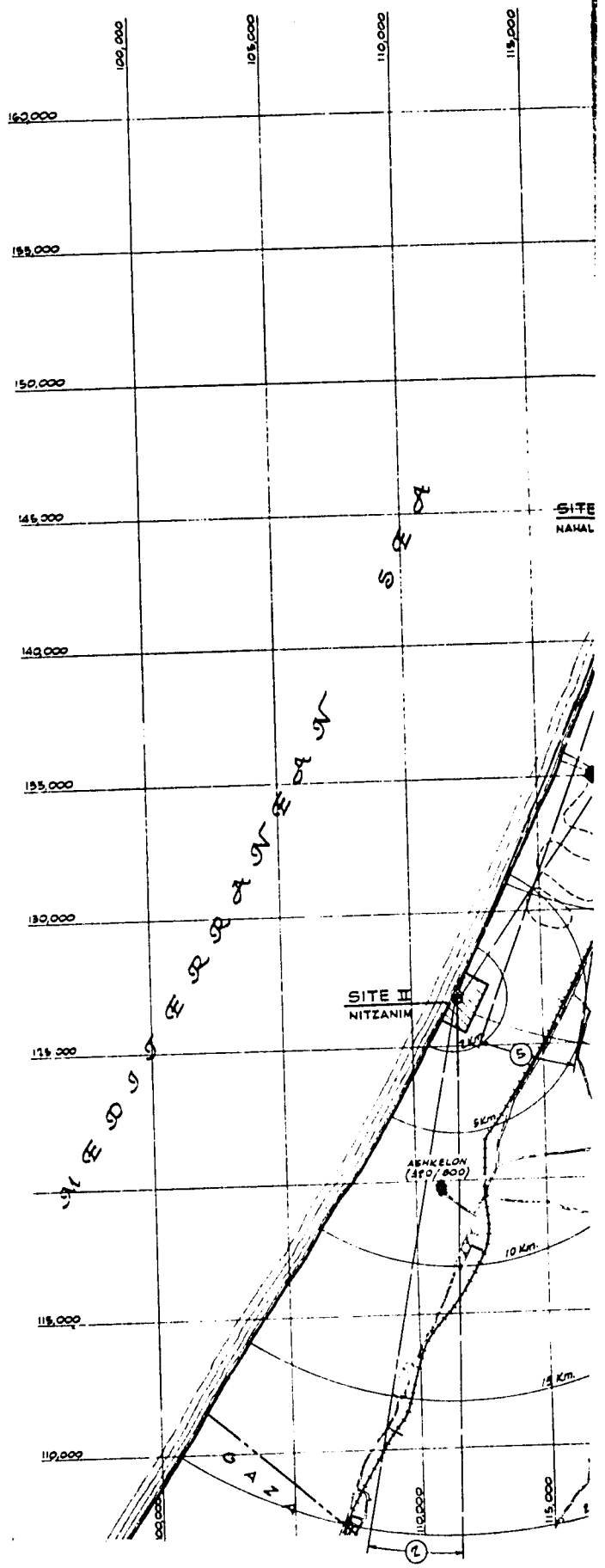
POPULATION · 1961	-	-		15,600	-
POPULATION · 1980	-	-		140,000	-

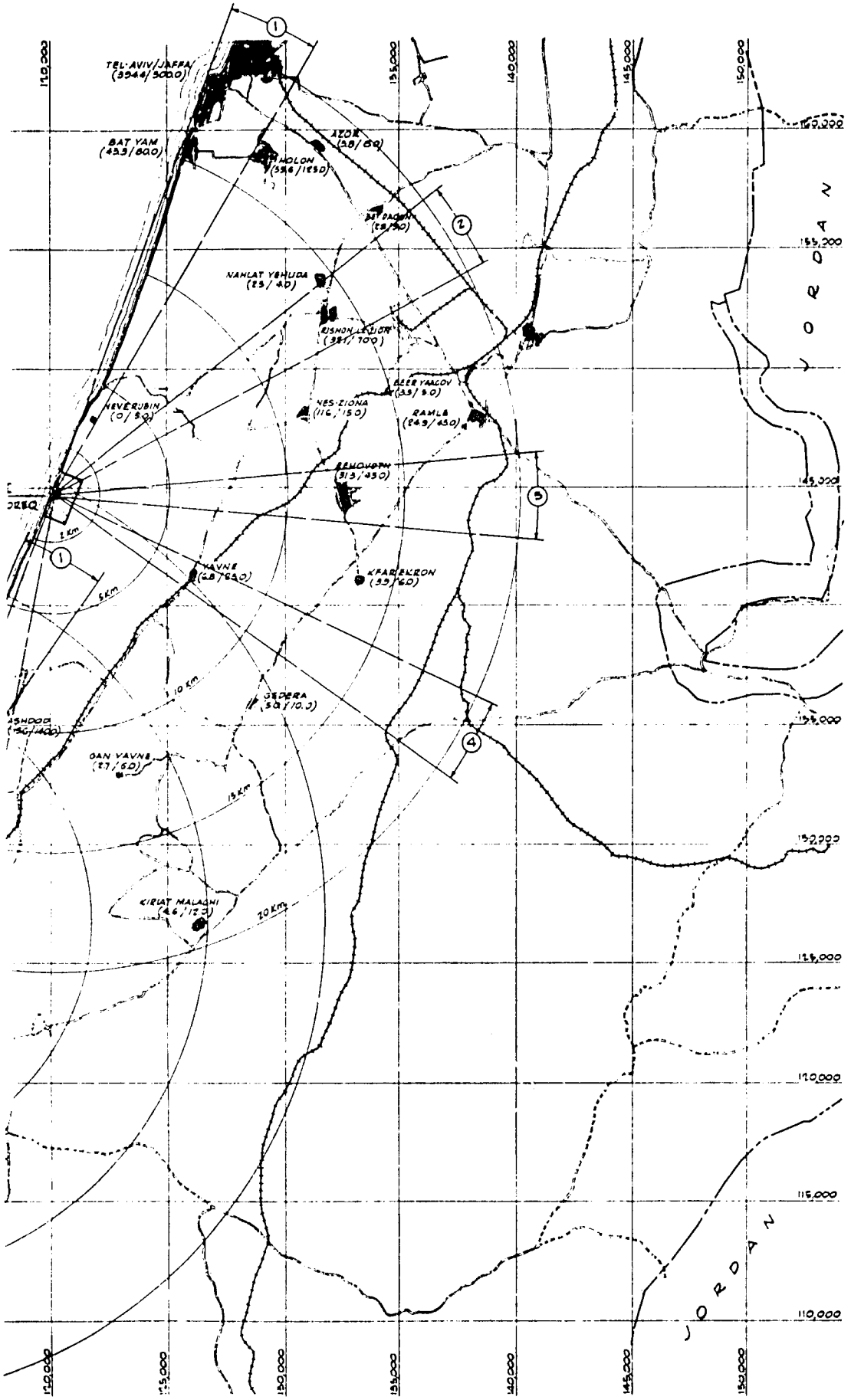
II 1

POPULATION · 1961	-	-	15,600	-	-
POPULATION · 1980	-	-	140,000	-	-

II 2

POPULATION · 1961	-	-	32,000	-	-
POPULATION · 1980	-	-	80,000	-	-





LEGEND

FIRST CLASS ROAD

SECOND CLASS ROAD

RAILROAD

INTERNATIONAL BOUNDARY

TOWN

POPULATION IN THOUSANDS-1965 (15.6/1400)

ESTIMATED POPULATION IN THOUSANDS - 1980/1981

1 0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

1 0 1 2 3 4 5 6 MILES

FIGURE 4

KAISER ENGINEERS
OAKLAND, CALIFORNIA

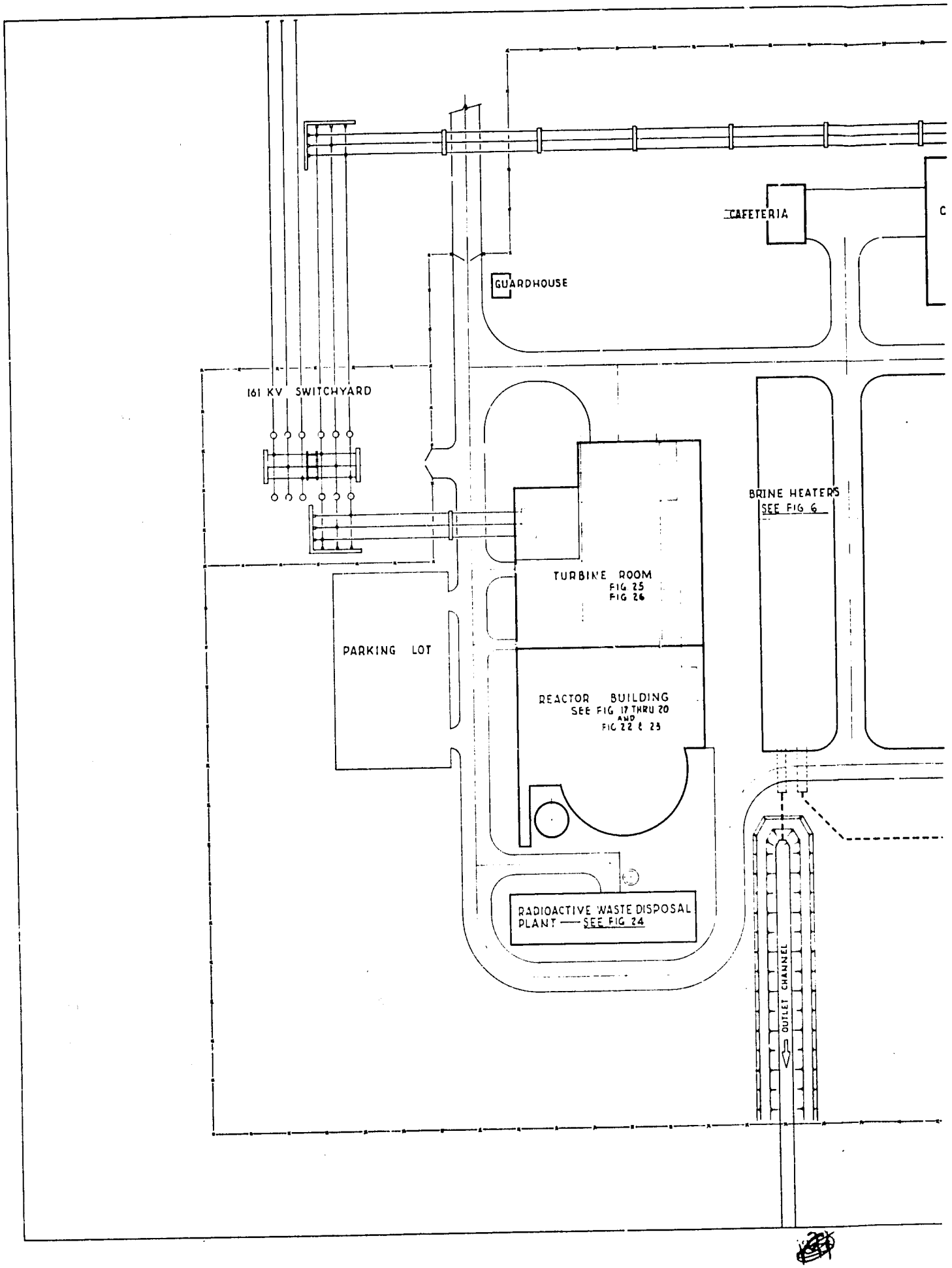
FOR

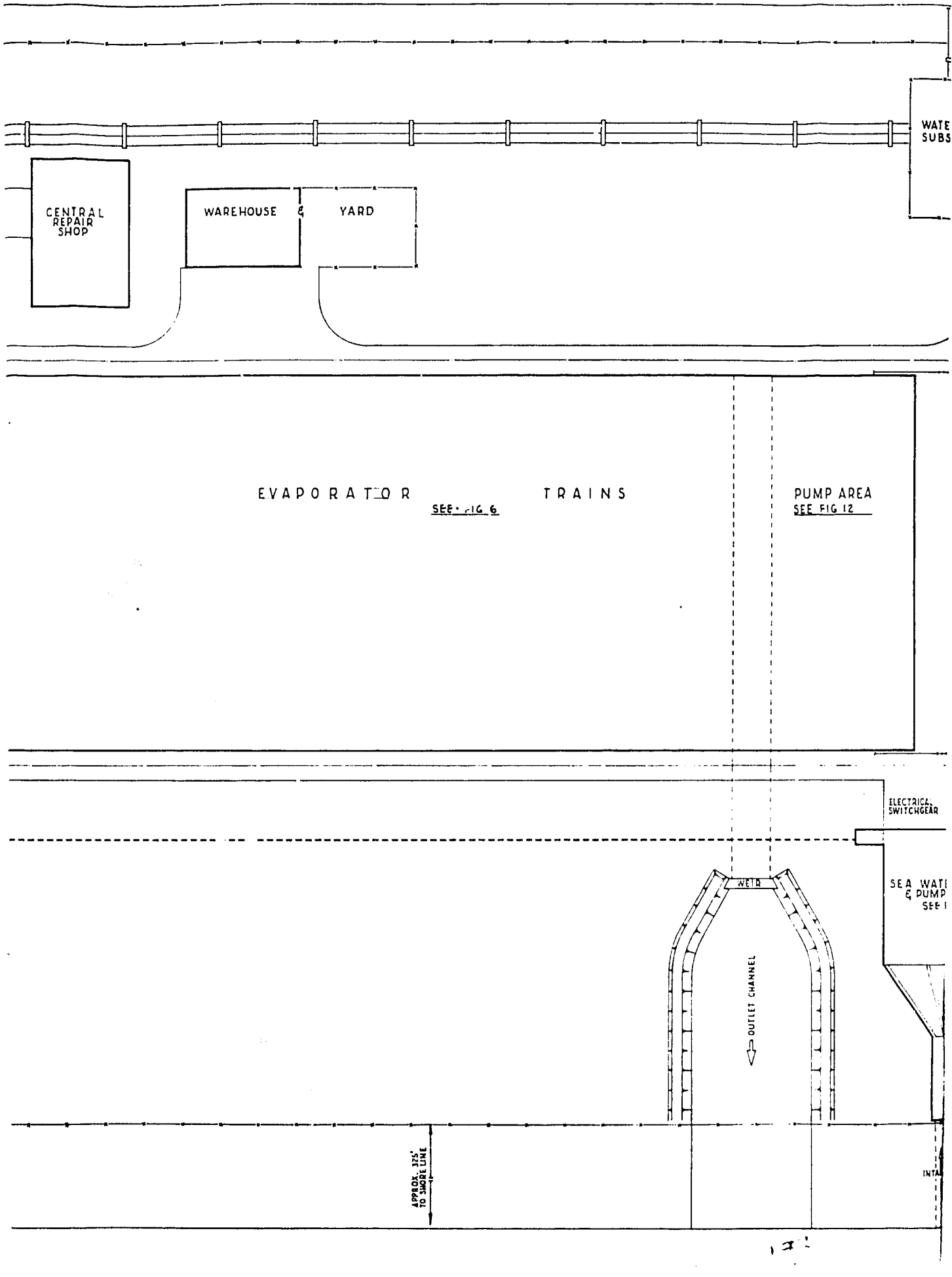
UNITED STATES - ISRAEL JOINT BOARD

SITE LOCATION MAP

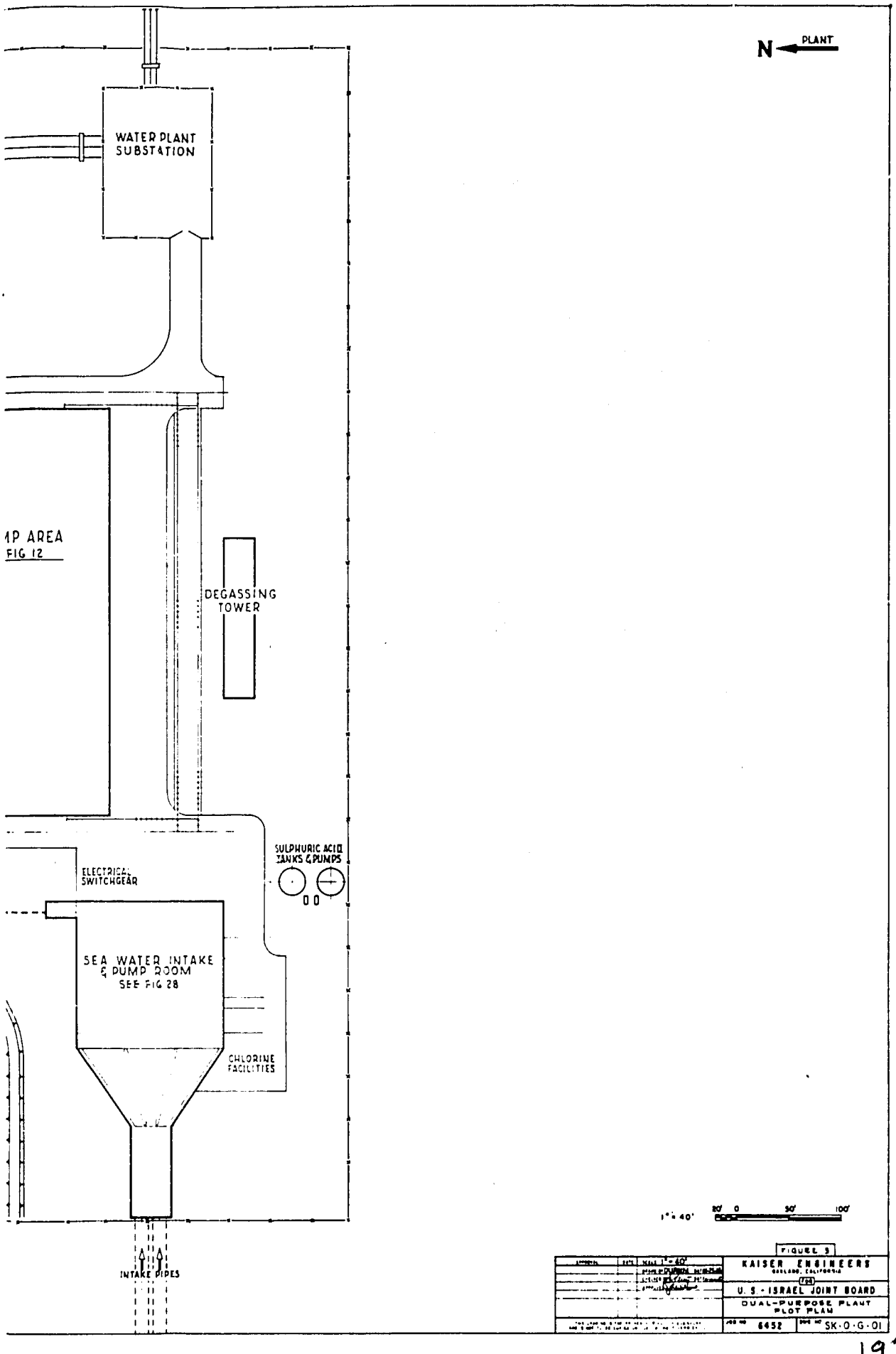
JOB NO 6452	DWG. NO. SK-0-G-02	REVISION R-0

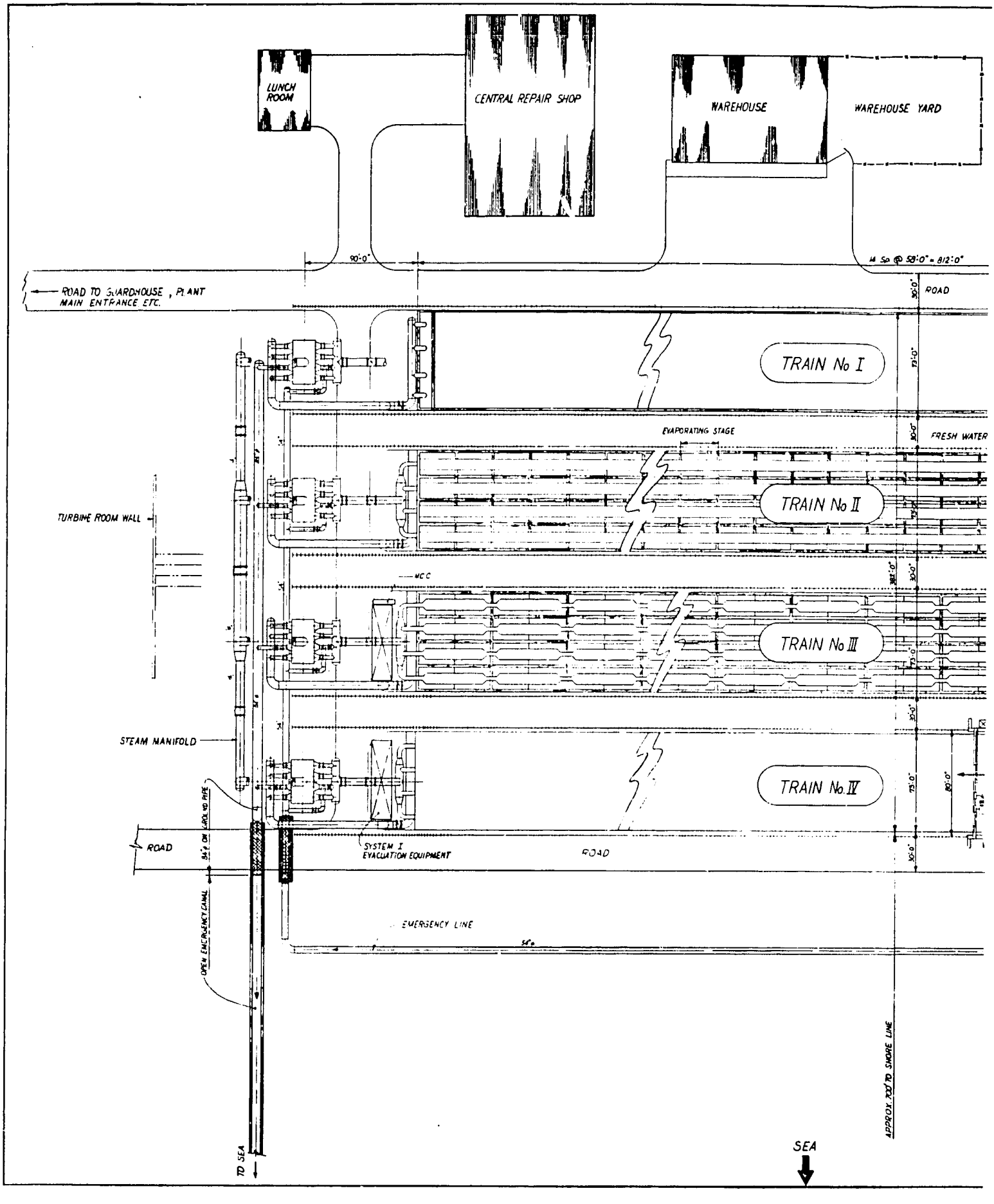
190


CAFETERIA
GUARDHOUSE
161 KV SWITCHYARD
BRINE HEATERS
SEE FIG 6
TURBINE ROOM
FIG 25
FIG 26
PARKING LOT
REACTOR BUILDING
SEE FIG 17 THRU 20
AND
FIG 22 & 23
RADIOACTIVE WASTE DISPOSAL
PLANT — SEE FIG 24
OUTLET CHANNEL

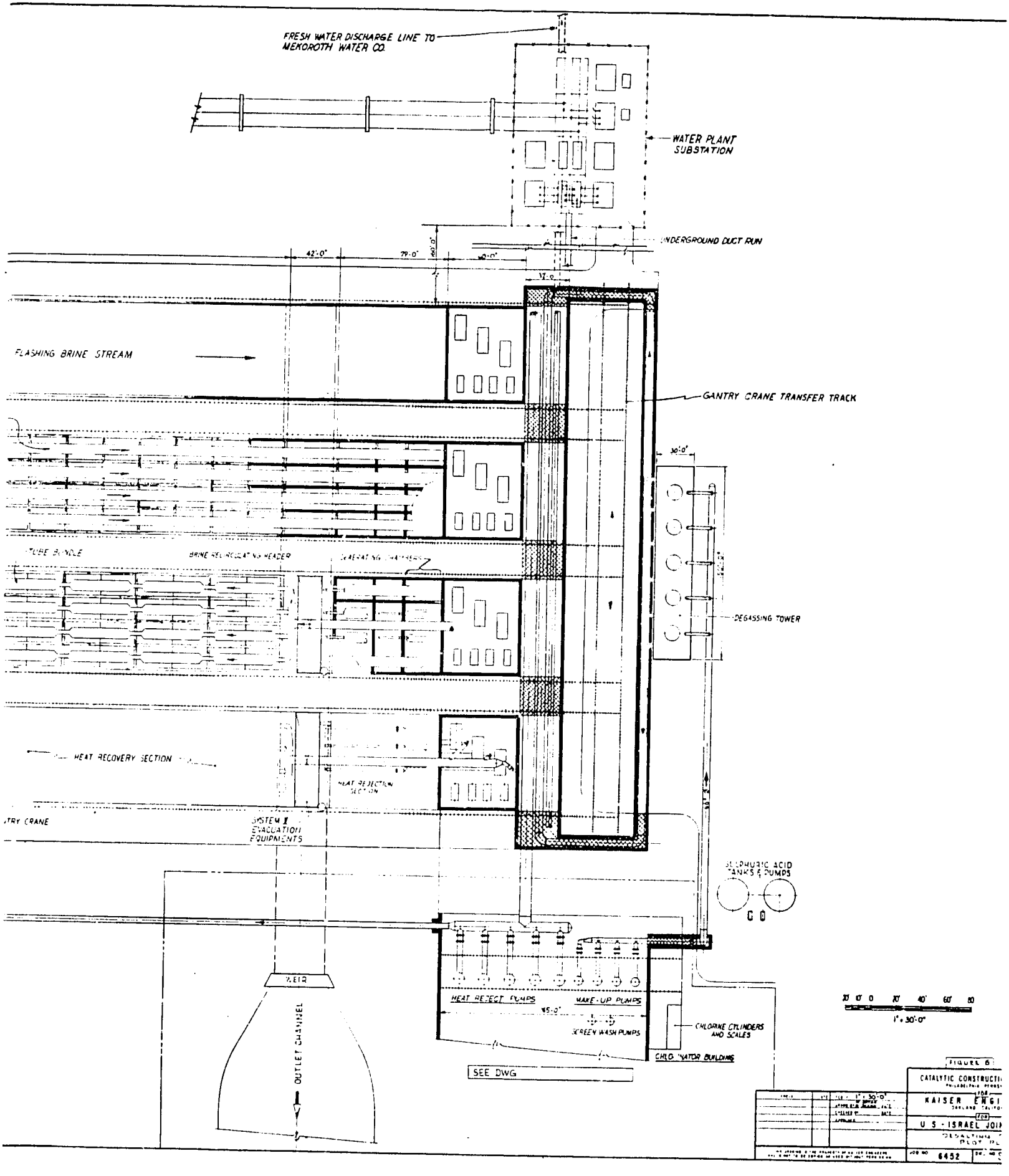

WATE
SUBS
CENTRAL REPAIR SHOP
WAREHOUSE
YARD
EVAPORATOR TRAINS
SEE FIG 6
PUMP AREA
SEE FIG 12
ELECTRICAL SWITCHGEAR
SEA WATE
& PUMP
SEE
WEIR
OUTLET CHANNEL
APPROX. 325' TO SHORE LINE
INTA

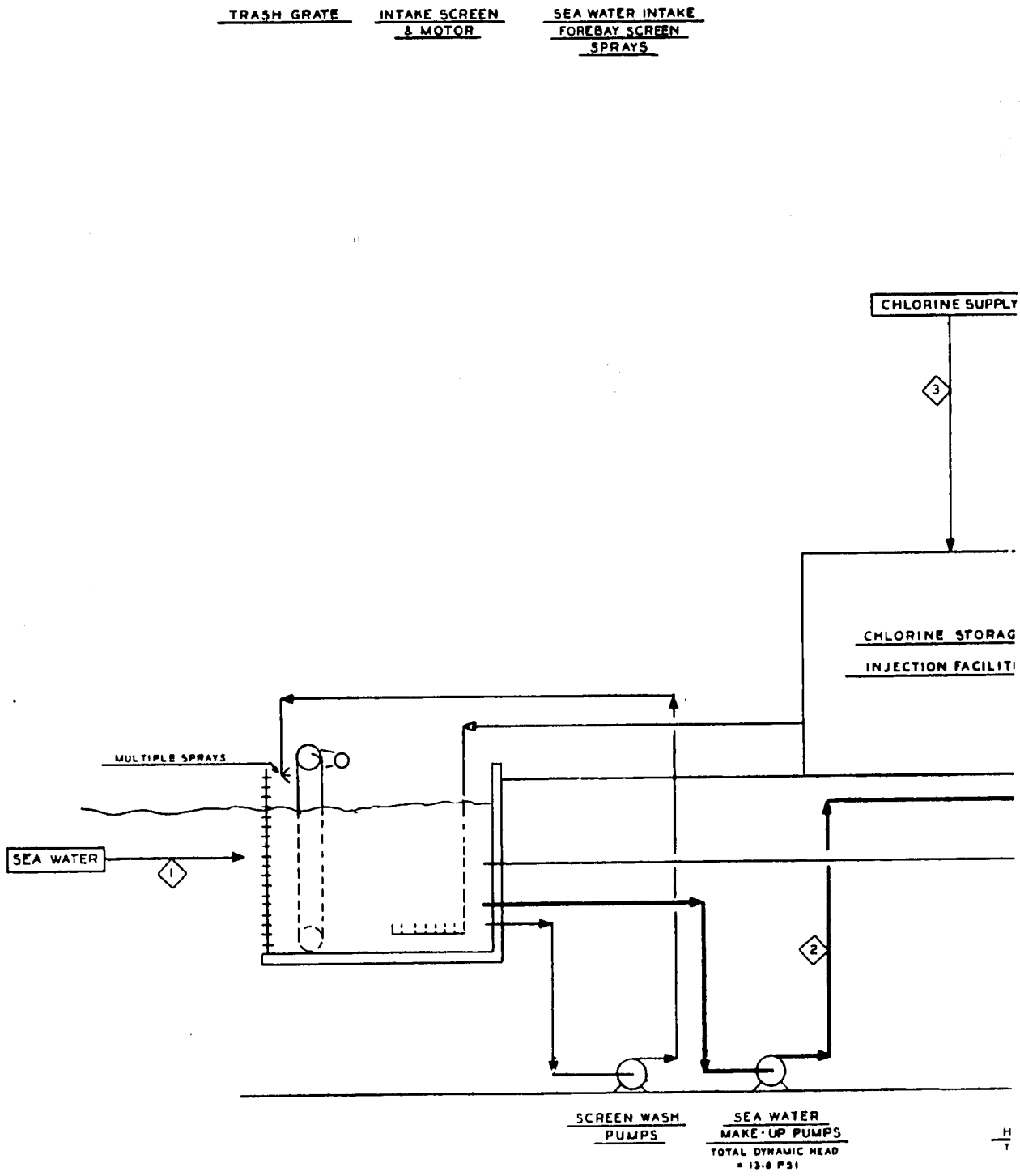
192

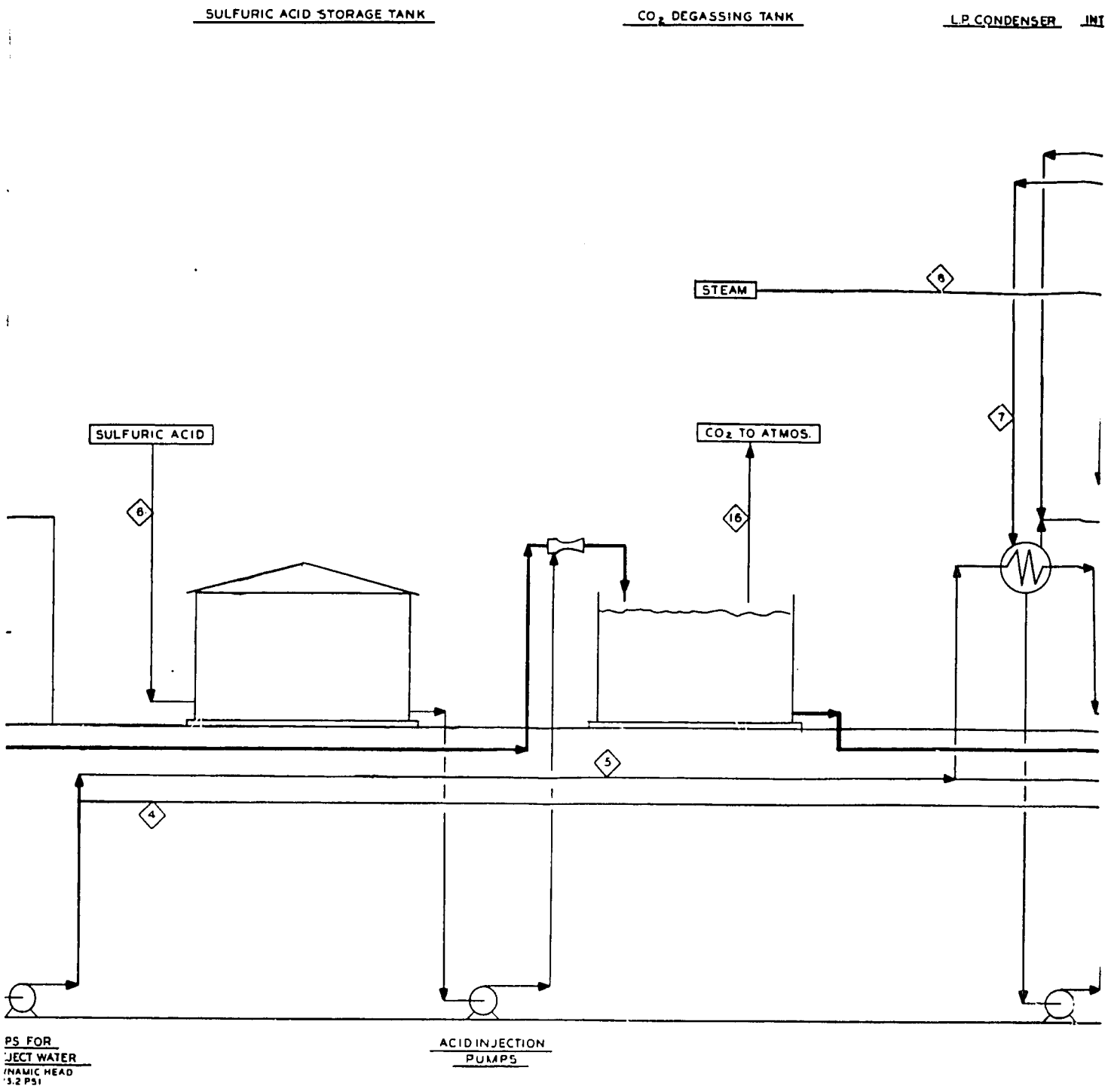

N
PLANT
WATER PLANT SUBSTATION
MP AREA
FIG 12
DEGASSING TOWER
SULPHURIC ACID TANKS & PUMPS
ELECTRICAL SWITCHGEAR
SEA WATER INTAKE & PUMP ROOM
SEE FIG 28
CHLORINE FACILITIES
INTAKE PIPES
1" = 40'
20' 0 50' 100'
FIGURE 3
KAISER ENGINEERS
OAKLAND, CALIFORNIA
U. S. - ISRAEL JOINT BOARD
DUAL-PURPOSE PLANT
PLOT PLAN
JOB NO 6452
DWG NO SK-O-G-01

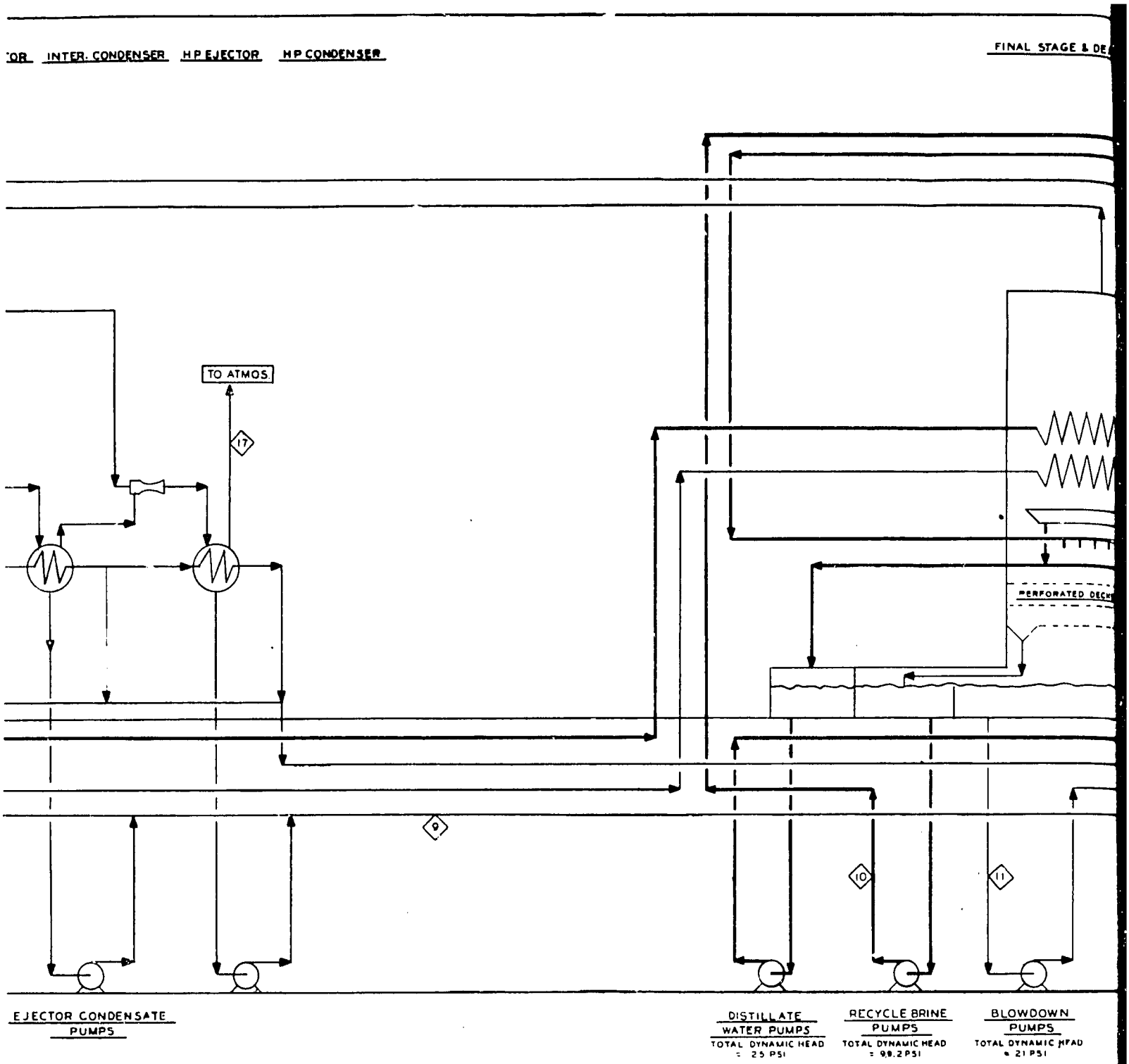

LUNCH ROOM
CENTRAL REPAIR SHOP
WAREHOUSE
WAREHOUSE YARD
90'-0"
ROAD TO GUARDHOUSE, PLANT MAIN ENTRANCE ETC.
ROAD
TRAIN No I
EVAPORATING STAGE
FRESH WATER
TRAIN No II
TURBINE ROOM WALL
MCC
TRAIN No III
STEAM MANIFOLD
TRAIN No IV
ROAD
SYSTEM I EVACUATION EQUIPMENT
ROAD
EMERGENCY LINE
OPEN EMERGENCY CANAL
APPROX. 700' TO SHORE LINE
TO SEA
SEA

194

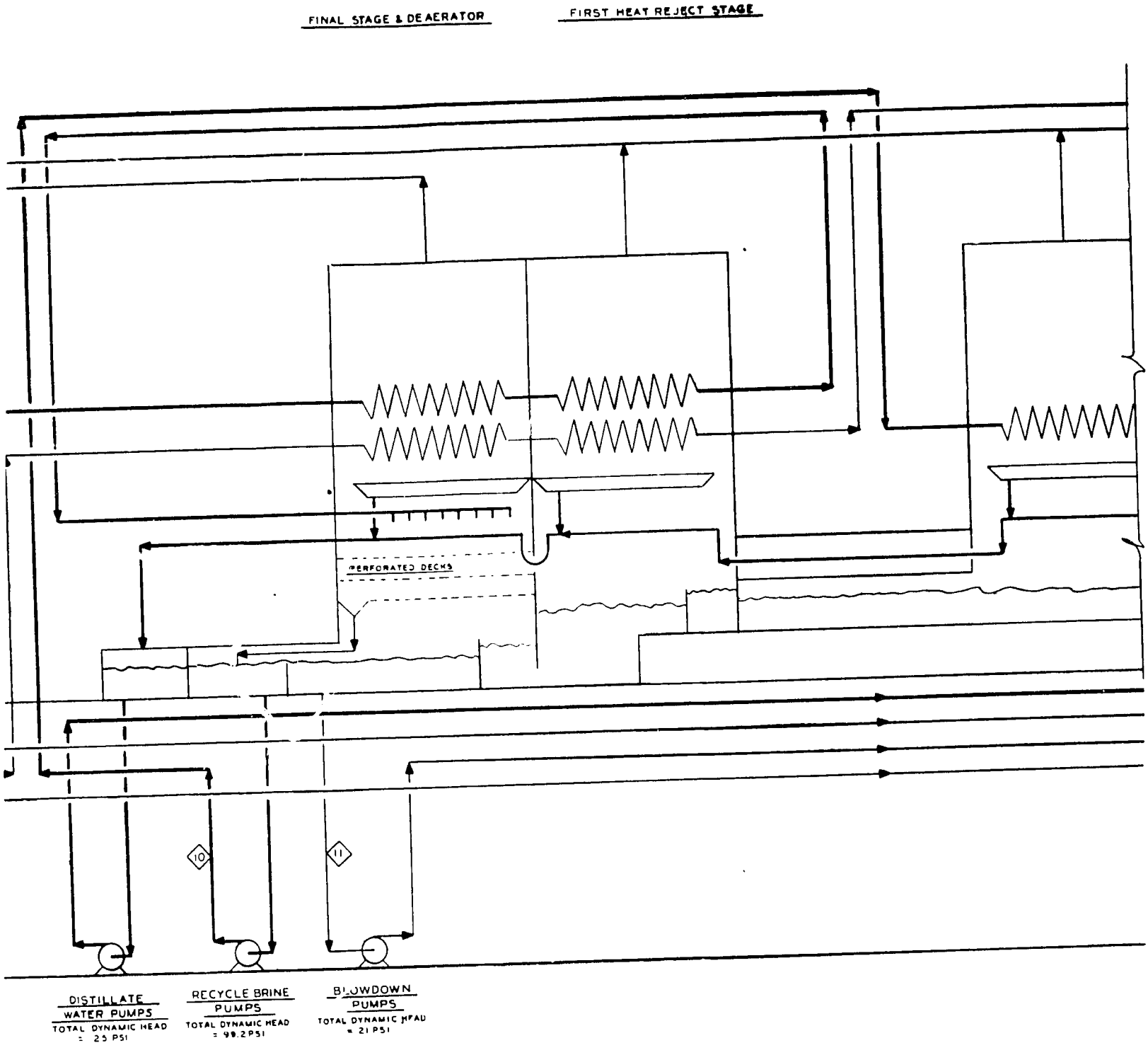

FRESH WATER DISCHARGE LINE TO MEKOROTH WATER CO.
WATER PLANT SUBSTATION
UNDERGROUND DUCT RUN
42'-0"
79'-0"
80'-0"
40'-0"
17'-0"
FLASHING BRINE STREAM
GANTRY CRANE TRANSFER TRACK
30'-0"
DEGASSING TOWER
HEAT RECOVERY SECTION
HEAT REJECTION SECTION
SYSTEM I EVACUATION EQUIPMENTS
SULPHURIC ACID TANKS & PUMPS
WEIR
OUTLET CHANNEL
HEAT REJECT PUMPS
MAKE-UP PUMPS
45'-0"
SCREEN WASH PUMPS
CHLORINE CYLINDERS AND SCALES
CHLORINATOR BUILDING
SEE DWG
30' 10' 0 10' 40' 60' 80
1" = 30'-0"
FIGURE 6
CATALYTIC CONSTRUCTI
KAISER ENGI
U.S.-ISRAEL JOI
6452


TRASH GRATE
INTAKE SCREEN & MOTOR
SEA WATER INTAKE FOREBAY SCREEN SPRAYS
CHLORINE SUPPLY
3
CHLORINE STORAG
INJECTION FACILIT
MULTIPLE SPRAYS
SEA WATER
1
2
SCREEN WASH PUMPS
SEA WATER MAKE-UP PUMPS
TOTAL DYNAMIC HEAD = 13.8 PSI

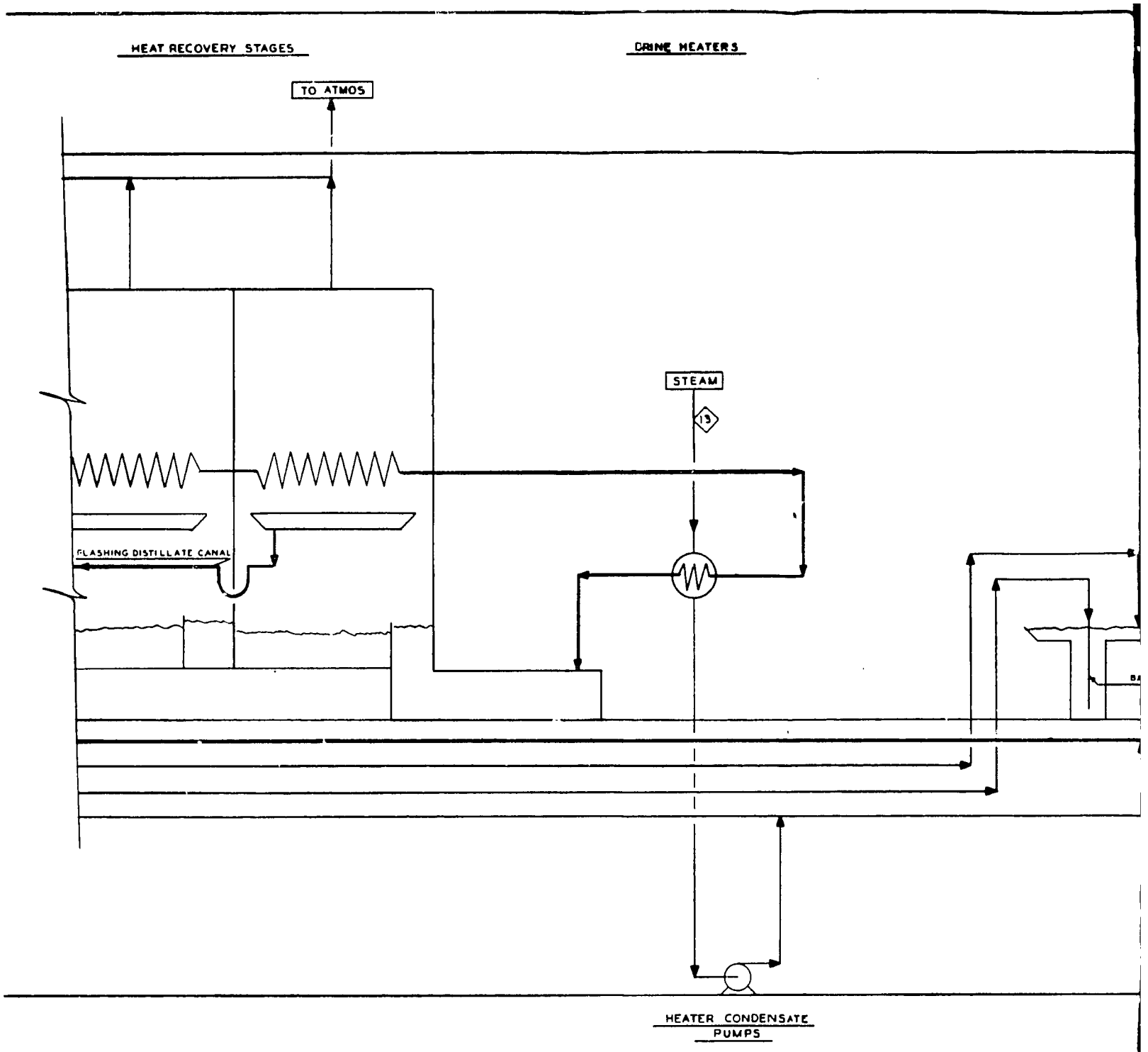

SULFURIC ACID STORAGE TANK
CO_2 DEGASSING TANK
L.P. CONDENSER
INT
STEAM
8
7
SULFURIC ACID
CO_2 TO ATMOS.
8
16
5
4
PS FOR
JECT WATER
NAMIC HEAD
3.2 PSI
ACID INJECTION
PUMPS



STREAM NO / ONENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14
W (LB/HR)	283,800,000	69,500,000	40	211,000,000	8,300,000	9,650	63,500	110,000	157,000	290,000,000	34,750,000	34,750,000	3,400,000	3,560,000
W (GPM)	562,000	135,000		411,000	16,000				314	550,000	66,000	69,500		7,100
PERATURE (°F)	70	70		70	70		80	365	120	82	82	80	240	235
SSURE (PSIA)							1" Hg	185					25	
OLVED SOLIDS (% BY WT)	3.86	3.86		3.86	3.86					6.8	7.72			
CONDENSIBLES (% BY WT)							25							



8	9	10	11	12	13	14	15	16	17	18		
110,000	157,000	290,000,000	34,750,000	34,750,000	3,400,000	3,560000	254100000	7,800	16,500	47,000		
	314	550,000	66,000	69,500		7.100	493,000			94		
365	120	82	82	80	240	235	82	70	105	120		
185					25							
		6.8	7.72				4.3					
									96			


HEAT RECOVERY STAGES
BRINE HEATERS
TO ATMOS
STEAM
13
FLASHING DISTILLATE CANAL
HEATER CONDENSATE PUMPS

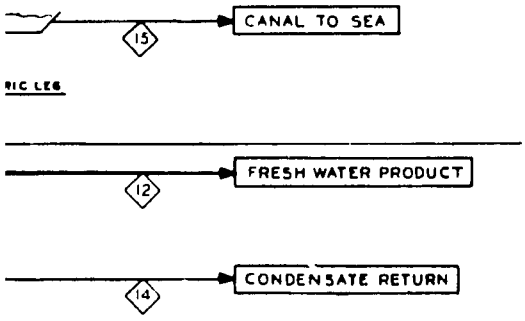


FIGURE 7

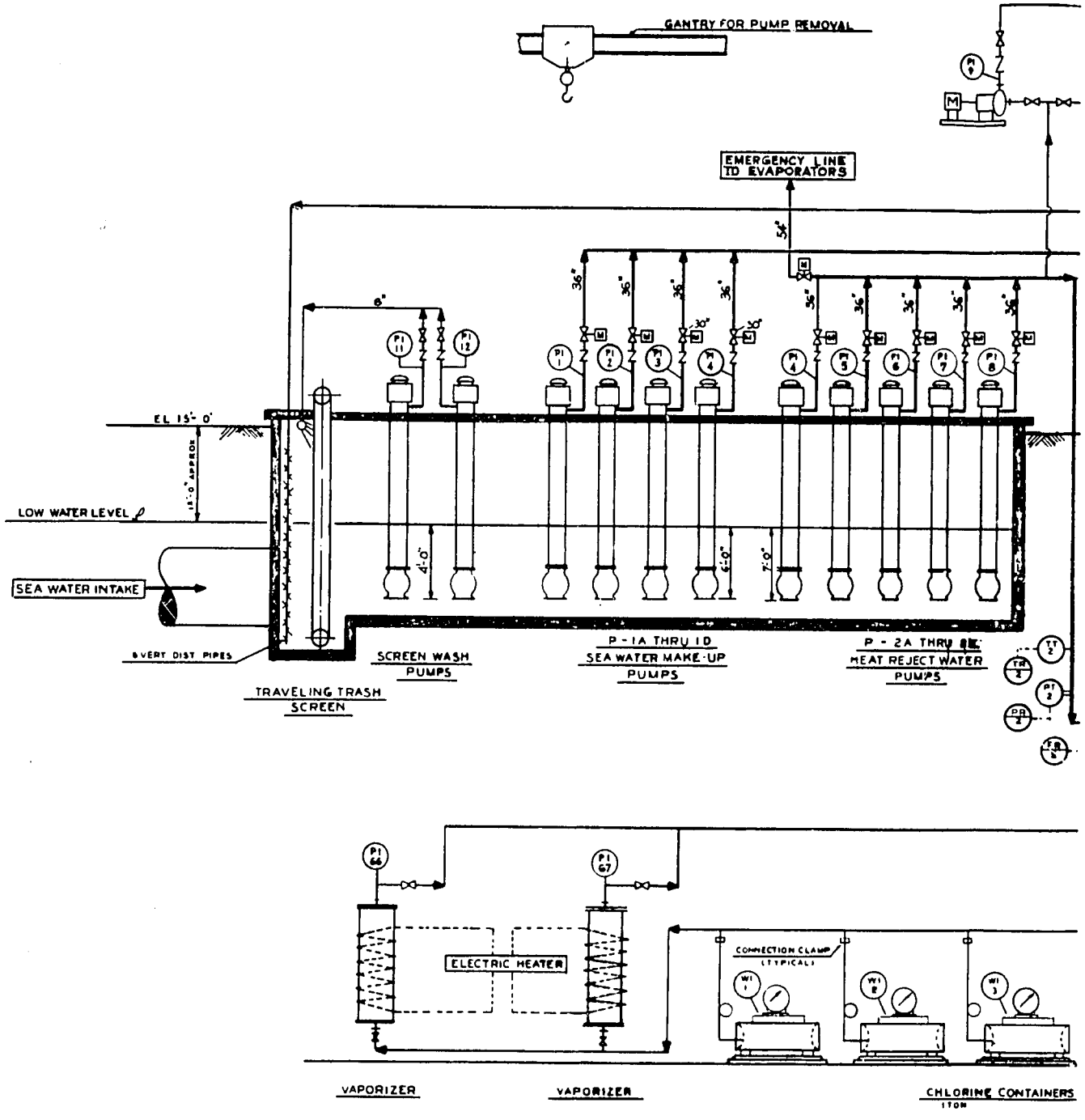
FOR

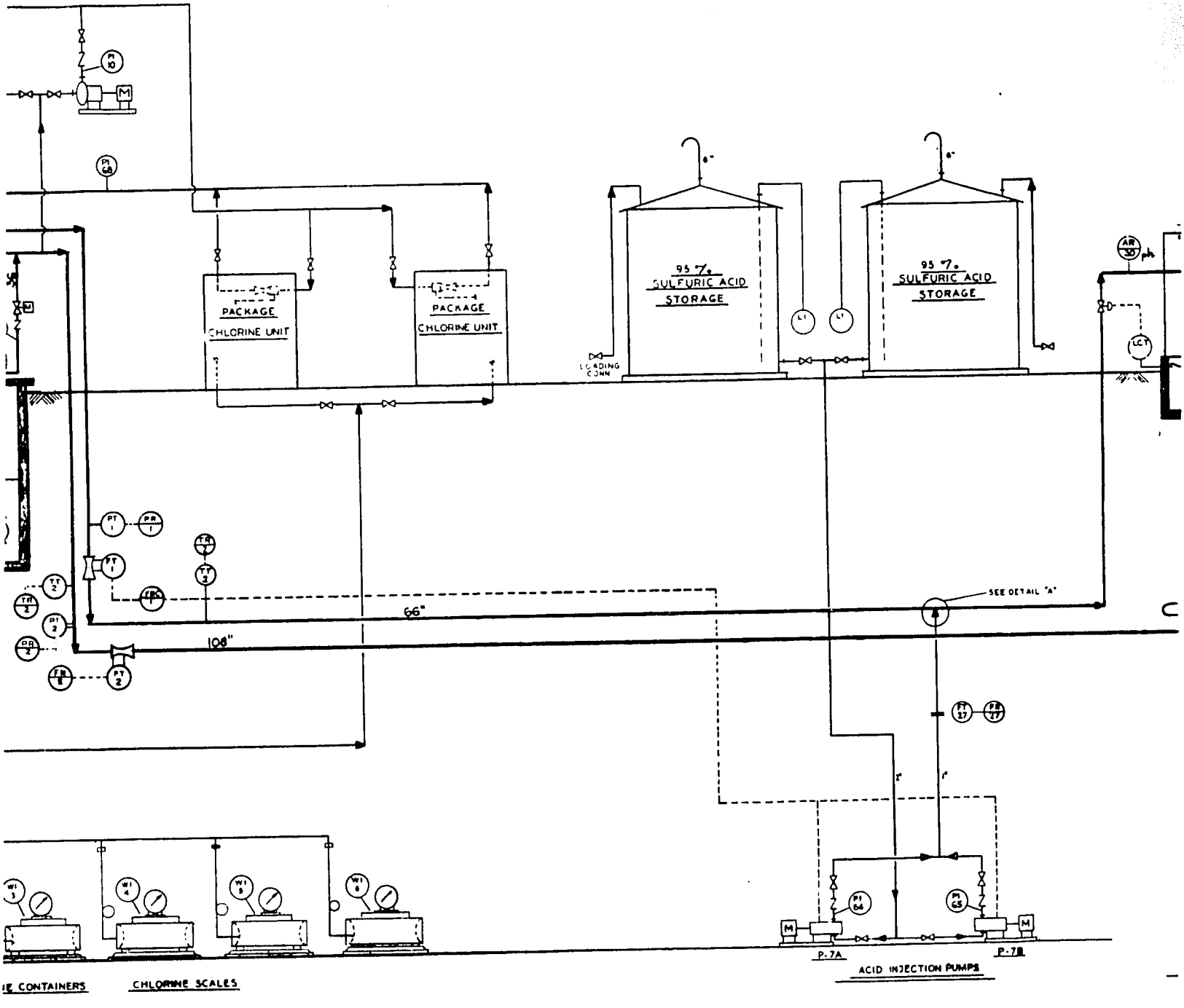
ISRAEL POWER DESALTING PLANT

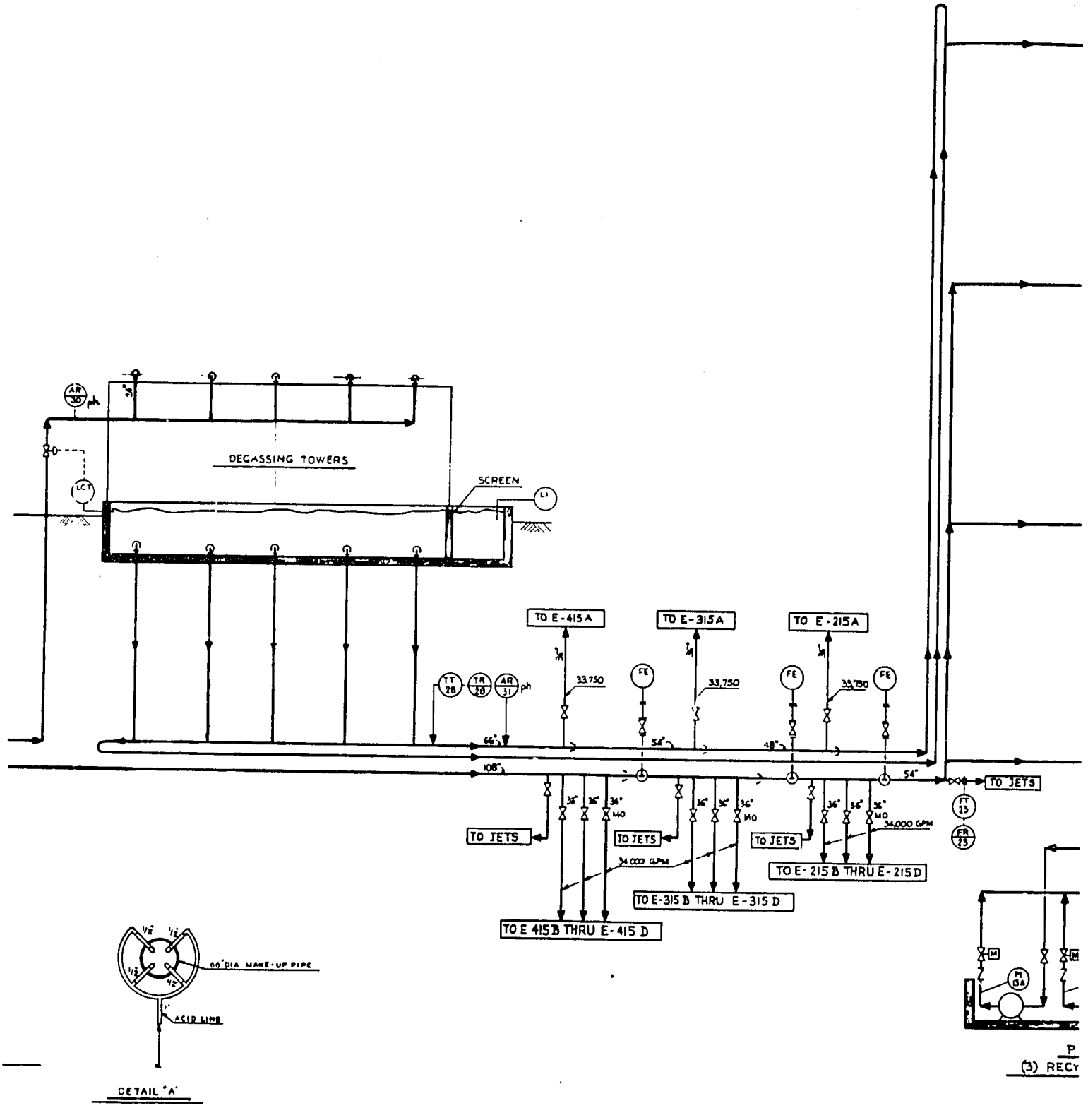
CATALYTIC CONSTRUCTION COMPANY
ENGINEERING DEPARTMENT PHILA., 2, PA

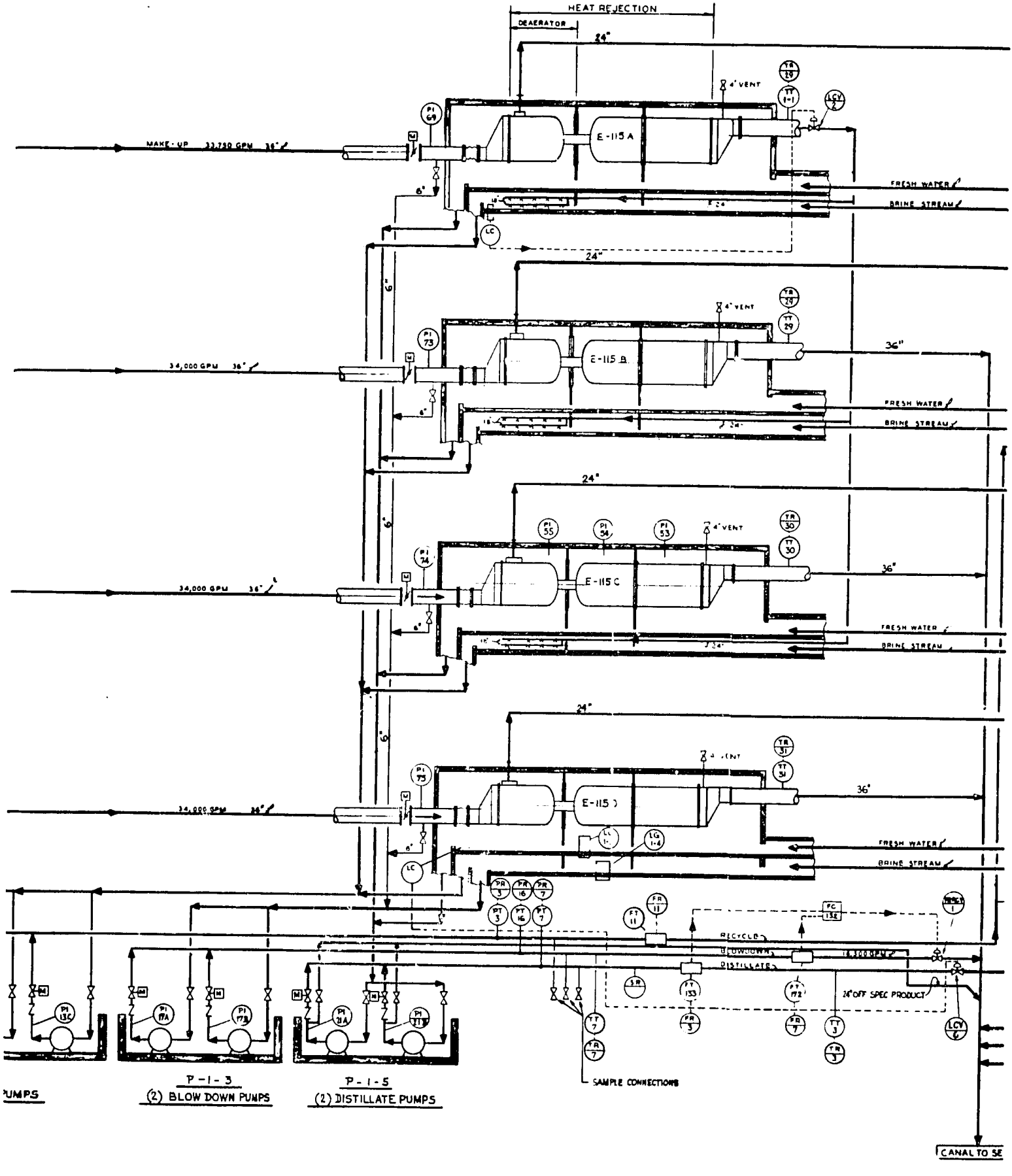
FLOW DIAGRAM
DESALTING PLANT

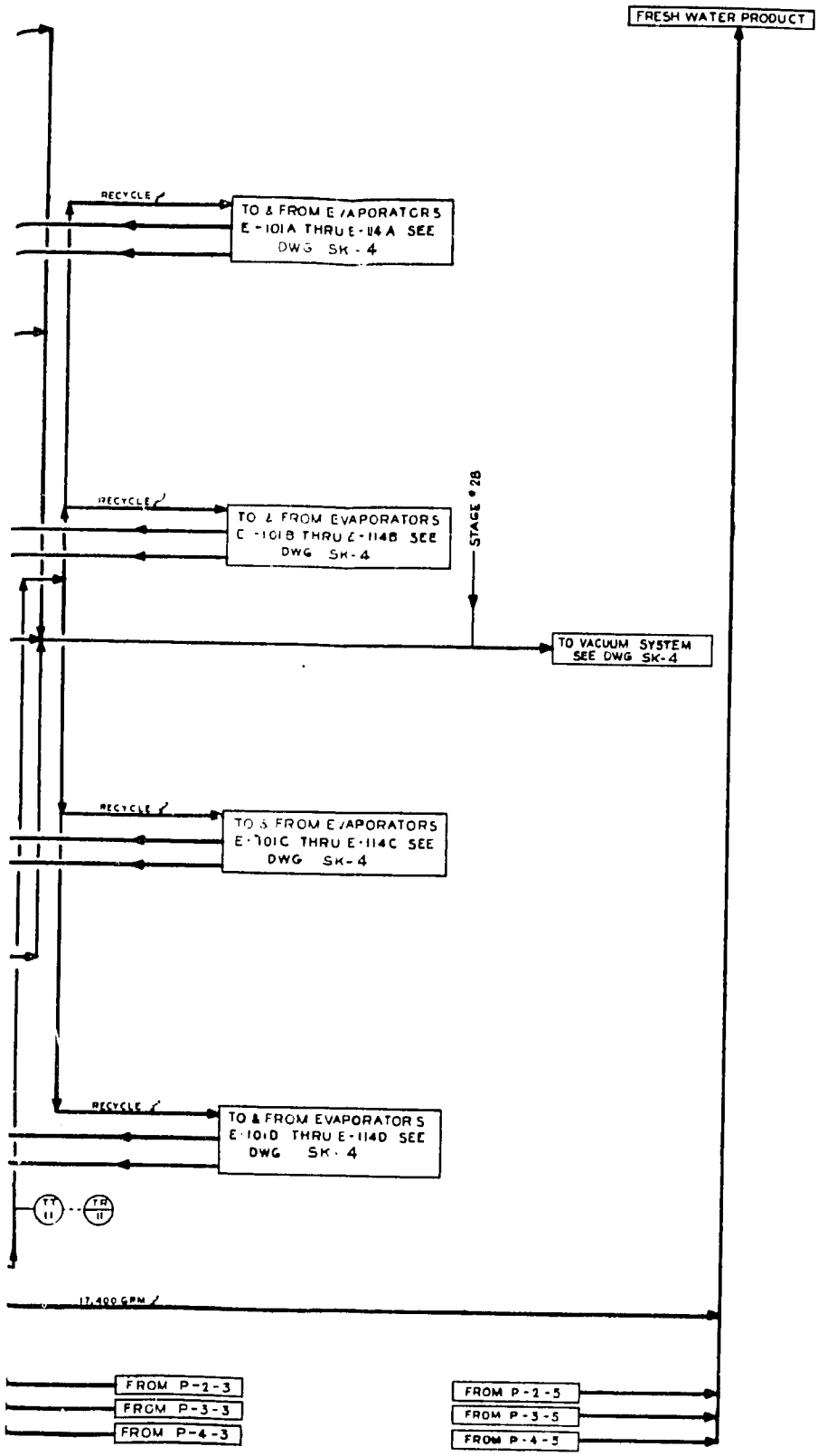
C C CO APPROVAL			CONTRACT NO	DWG NO. R-201
CLIENT APPROVAL			JOB NO 40,970	


GANTRY FOR PUMP REMOVAL
EMERGENCY LINE TO EVAPORATORS
54"
36"
30"
8"
EL 15'-0"
15'-0" APPROX
LOW WATER LEVEL
SEA WATER INTAKE
6 VERT DIST PIPES
4'-0"
6'-0"
7'-0"
TRAVELING TRASH SCREEN
SCREEN WASH PUMPS
P-1A THRU 1D
SEA WATER MAKE-UP PUMPS
P-2A THRU
HEAT REJECT WATER PUMPS
ELECTRIC HEATER
CONNECTION CLAMP (TYPICAL)
VAPORIZER
VAPORIZER
CHLORINE CONTAINERS
1 TON


PACKAGE
CHLORINE UNIT
PACKAGE
CHLORINE UNIT
95 % SULFURIC ACID STORAGE
95 % SULFURIC ACID STORAGE
LOADING CONN
66"
108"
SEE DETAIL "A"
P-7A
P-7B
ACID INJECTION PUMPS
CHLORINE SCALES


DEGASSING TOWERS
SCREEN
AR 30 pH
LCT
LI
TT 28
TR 28
AR 31 pH
TO E-415 A
TO E-315 A
TO E-215 A
FE
33,750
66"
54"
48"
108"
TO JETS
34,000 GPM
TO E-215 B THRU E-215 D
TO E-315 B THRU E-315 D
TO E 415 B THRU E-415 D
FT 23
FR 23
66" DIA MAKE-UP PIPE
ACID LINE
DETAIL "A"
(3) RECY


HEAT REJECTION
DEAERATOR
24"
4" VENT
MAKE-UP 33,730 GPM 36"
E-115 A
FRESH WATER
BRINE STREAM
34,000 GPM 36"
E-115 B
36"
E-115 C
E-115 D
RECYCLE
BLOWDOWN
DISTILLATE
16,300 GPM
24" OFF SPEC PRODUCT
SAMPLE CONNECTIONS
CANAL TO SE
P-1-3
(2) BLOW DOWN PUMPS
P-1-5
(2) DISTILLATE PUMPS
PUMPS



SEA

FIGURE 8

CATALYTIC CONSTRUCTION COMPANY
PHILADELPHIA PENNSYLVANIA

FOR

KAISER ENGINEERS
OAKLAND, CALIFORNIA

FOR

U.S.-ISRAEL JOINT BOARD

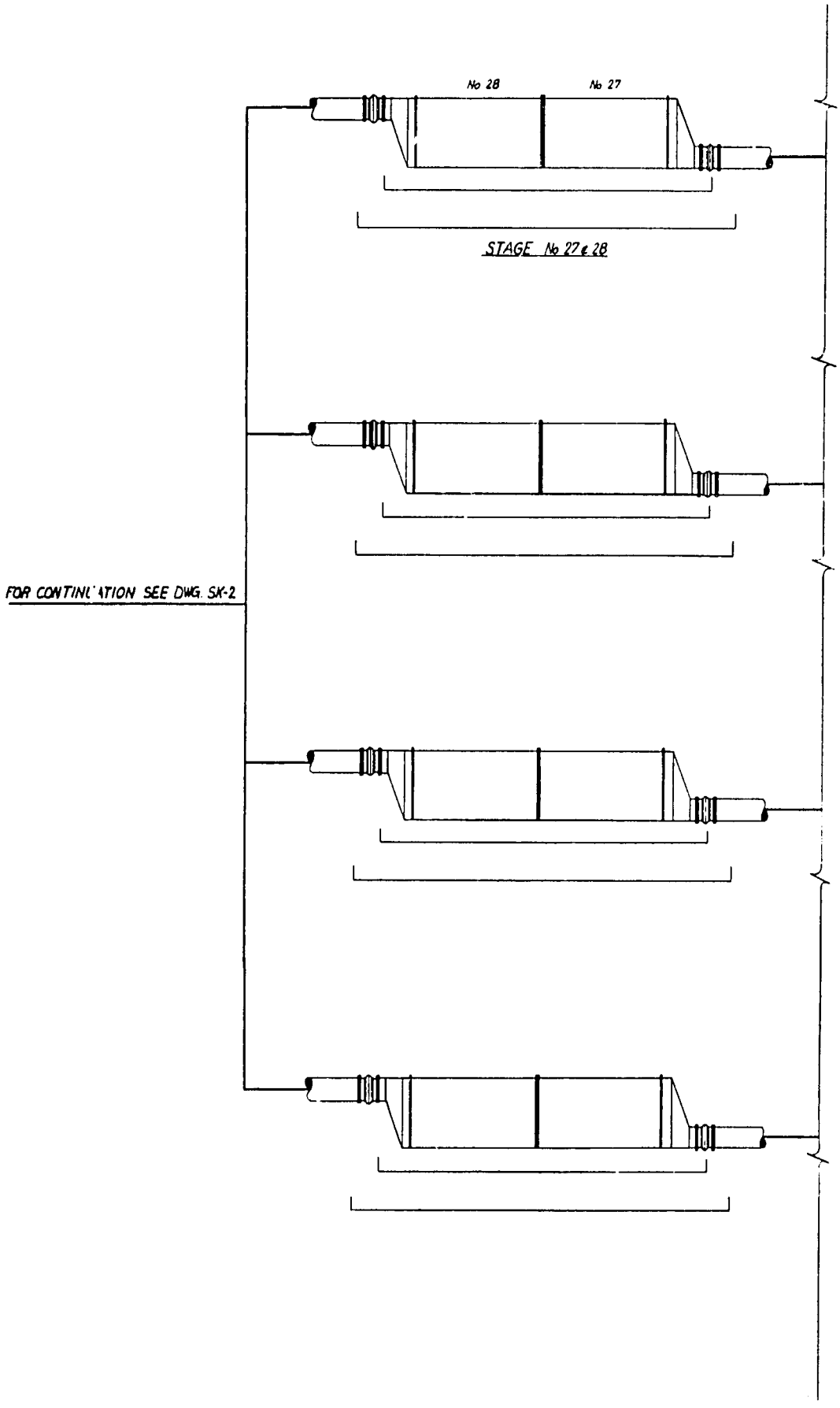
PIPING AND INSTRUMENT DIAGRAM - SHEET #1

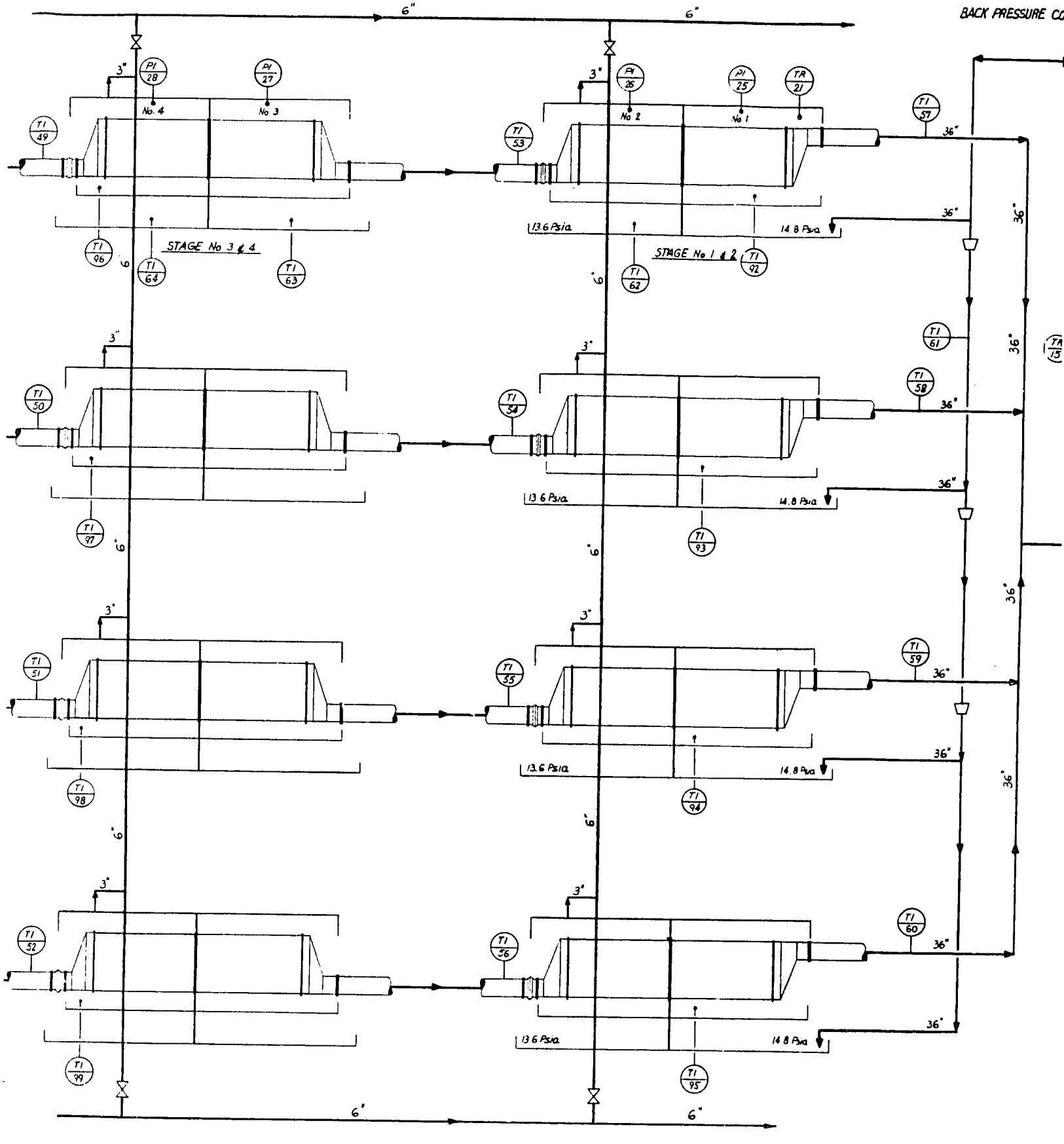
APPROVAL	DATE	SCALE NONE
		DRAWN BY H.Y. SLAVE / B. Deane DATE
		CHECKED BY DATE
		APPROVED

THIS DRAWING THE PROPERTY OF KAISER ENGINEERS AND IS NOT TO BE COPIED OR USED WITHOUT PERMISSION

JOB NO 6452 DWG NO SK-5-P-03

2086


No 28
No 27
STAGE No 27 & 28
FOR CONTINUATION SEE DWG. SK-2


BACK PRESSURE CO
6"
6"
3"
PI 28
PI 27
No. 4
No 3
PI 26
PI 25
TR 21
No 2
No 1
TI 49
TI 53
TI 57
36"
13.6 Psia
14.8 Psia
STAGE No 3 & 4
STAGE No 1 & 2
TI 96
TI 64
TI 63
TI 62
TI 92
9"
TI 61
TI 50
TI 54
TI 58
TI 97
TI 93
TI 51
TI 55
TI 59
TI 98
TI 94
TI 52
TI 56
TI 60
TI 99
TI 95

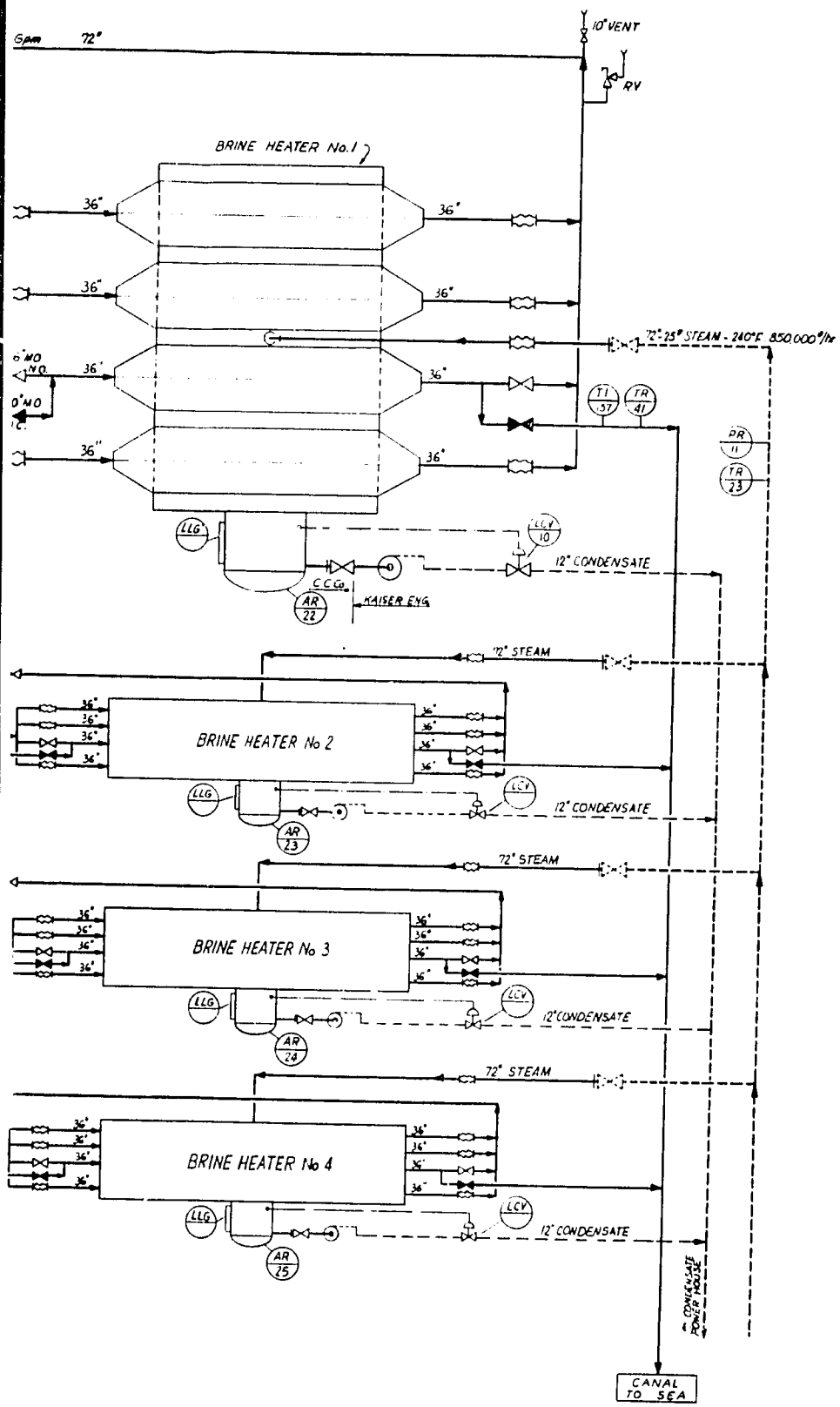


FIGURE 9

CATALYTIC CONSTRUCTION COMPANY
PHILADELPHIA, PENNSYLVANIA

FOR

KAISER ENGINEERS
OAKLAND, CALIFORNIA

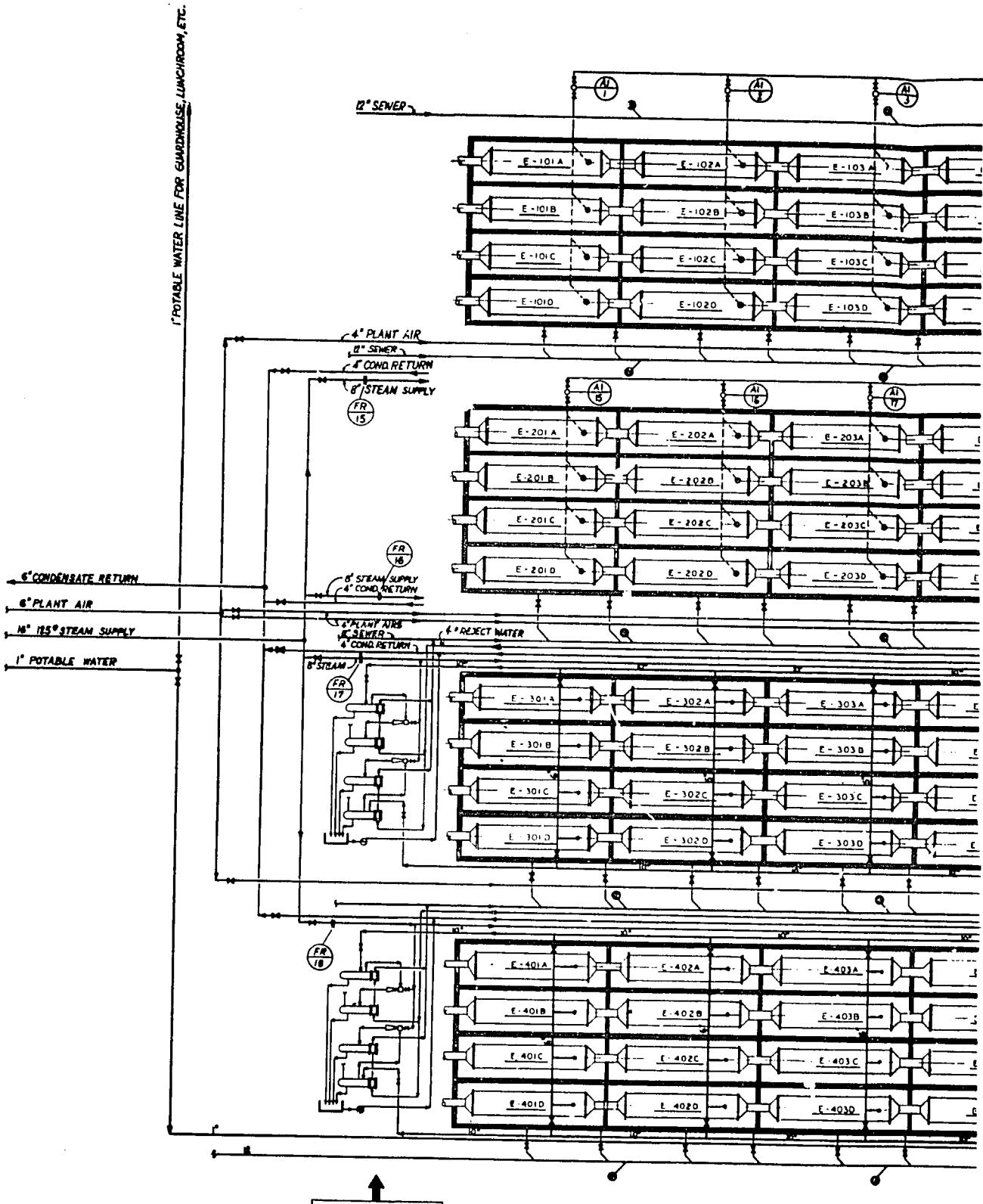
FOR

U. S. - ISRAEL JOINT BOARD

PIPING AND INSTRUMENT DIAGRAM - SHEET # 2

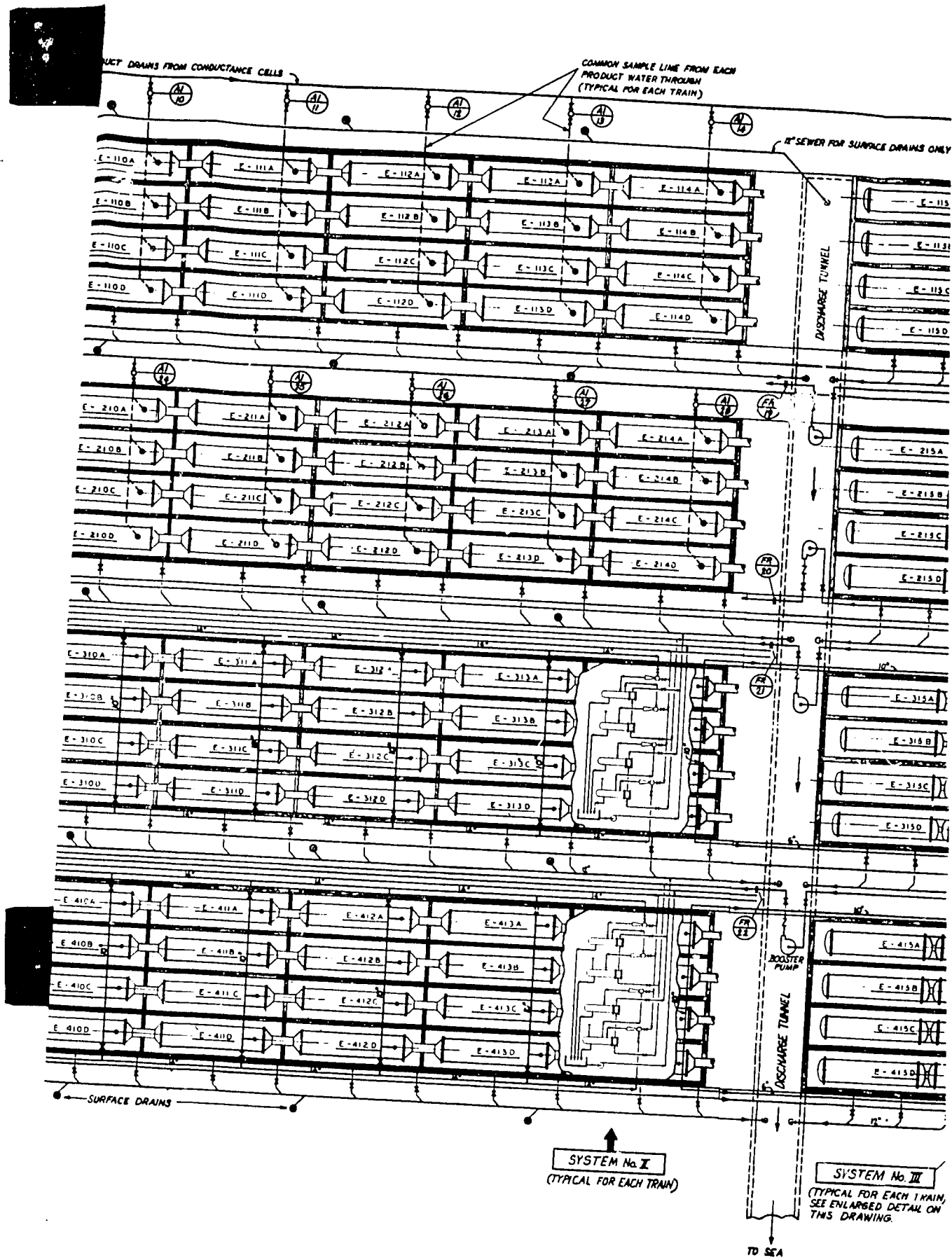
JOB NO 6452

DWG NO

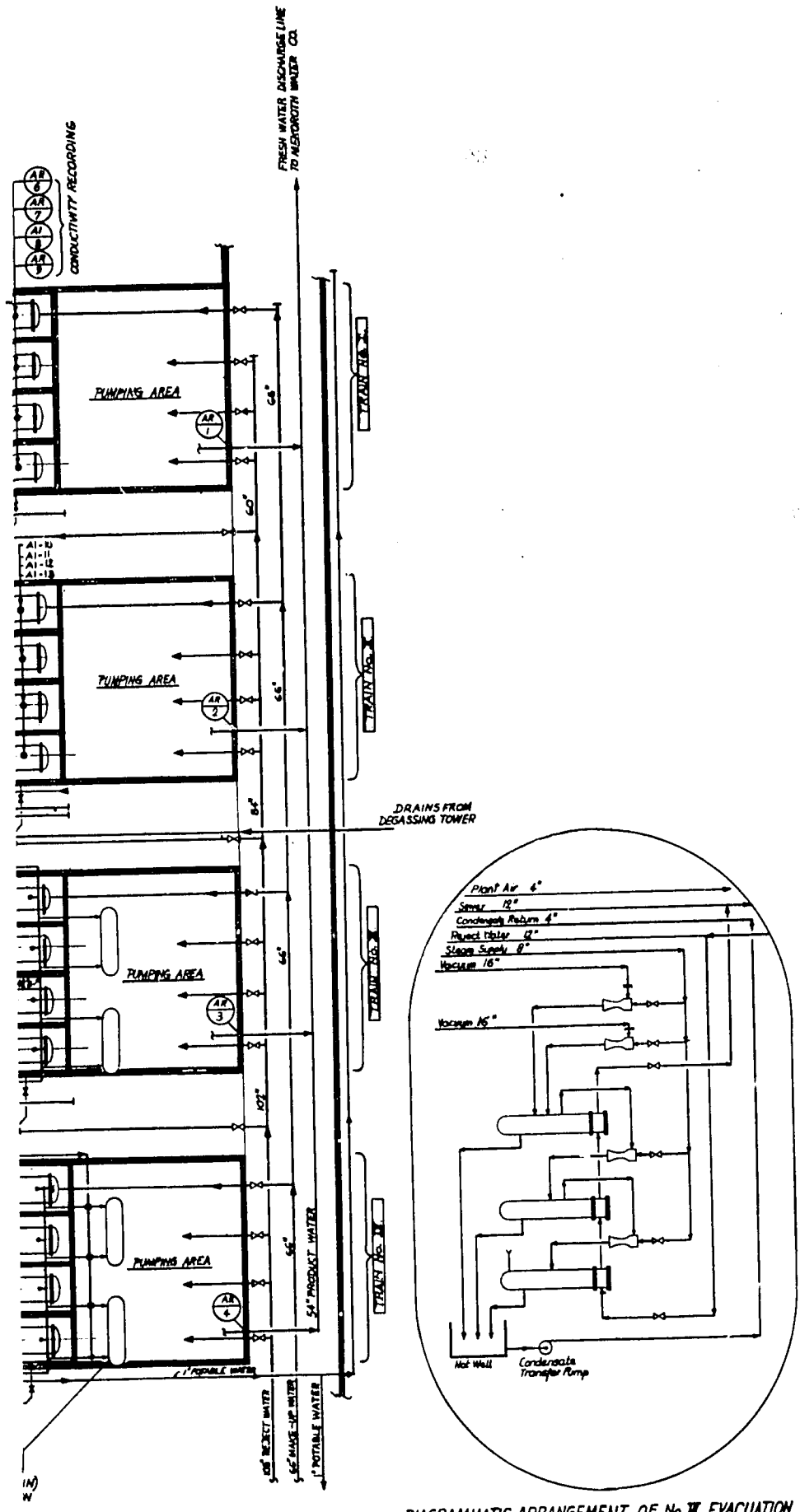

1" POTABLE WATER LINE FOR GUARDHOUSE, LUNCHROOM, ETC.
12" SEWER
4" PLANT AIR
12" SEWER
4" COND. RETURN
8" STEAM SUPPLY
FR 15
FR 16
FR 17
FR 18
6" CONDENSATE RETURN
6" PLANT AIR
16" 125# STEAM SUPPLY
1" POTABLE WATER
8" STEAM SUPPLY
4" COND. RETURN
4" PLANT AIR
12" SEWER
4" COND. RETURN
8" STEAM
4" REJECT WATER
E-101A
E-102A
E-103A
E-101B
E-102B
E-103B
E-101C
E-102C
E-103C
E-101D
E-102D
E-103D
E-201A
E-202A
E-203A
E-201B
E-202B
E-203B
E-201C
E-202C
E-203C
E-201D
E-202D
E-203D
E-301A
E-302A
E-303A
E-301B
E-302B
E-303B
E-301C
E-302C
E-303C
E-301D
E-302D
E-303D
E-401A
E-402A
E-403A
E-401B
E-402B
E-403B
E-401C
E-402C
E-403C
E-401D
E-402D
E-403D
SYSTEM No. I
(TYPICAL FOR EACH TRAIN)

PRODUCT DRAINS FROM COND
E-104A
E-105A
E-106A
E-107A
E-108A
E-109A
E-110A
E-104B
E-105B
E-106B
E-107B
E-108B
E-109B
E-110B
E-104C
E-105C
E-106C
E-107C
E-108C
E-109C
E-110C
E-104D
E-105D
E-106D
E-107D
E-108D
E-109D
E-110D
E-204A
E-205A
E-206A
E-207A
E-208A
E-209A
E-210A
E-204B
E-205B
E-206B
E-207B
E-208B
E-209B
E-210B
E-204C
E-205C
E-206C
E-207C
E-208C
E-209C
E-210C
E-204D
E-205D
E-206D
E-207D
E-208D
E-209D
E-210D
E-304A
E-305A
E-306A
E-307A
E-308A
E-309A
E-310A
E-304B
E-305B
E-306B
E-307B
E-308B
E-309B
E-310B
E-304C
E-305C
E-306C
E-307C
E-308C
E-309C
E-310C
E-304D
E-305D
E-306D
E-307D
E-308D
E-309D
E-310D
E-404A
E-405A
E-406A
E-407A
E-408A
E-410A
E-404B
E-405B
E-406B
E-407B
E-408B
E-410B
E-404C
E-405C
E-406C
E-407C
E-408C
E-410C
E-404D
E-405D
E-406D
E-407D
E-408D
E-410D
4" DRAINS
SURFACE

211


UCT DRAINS FROM CONDUCTANCE CELLS
COMMON SAMPLE LINE FROM EACH PRODUCT WATER THROUGH (TYPICAL FOR EACH TRAIN)
12" SEWER FOR SURFACE DRAINS ONLY
DISCHARGE TUNNEL
BOOSTER PUMP
SURFACE DRAINS
SYSTEM No. I
(TYPICAL FOR EACH TRAIN)
SYSTEM No. III
(TYPICAL FOR EACH TRAIN, SEE ENLARGED DETAIL ON THIS DRAWING.
TO SEA

212



DIAGRAMMATIC ARRANGEMENT OF No. VII EVACUATION SYSTEM

(ONE HALF SYSTEM SHOWN)

FIGURE 10

CATALYTIC CONSTRUCTION COMPANY
PHILADELPHIA, PENNSYLVANIA

FOR

KAISER ENGINEERS
OAKLAND, CALIFORNIA

FOR

U. S. - ISRAEL JOINT BOARD

VACUUM FLOW DIAGRAM AND MISCELLANEOUS UTILITIES

JOB NO. 6452 DWG. NO. SK-5-P-05

APPROVAL DATE SCALE 1" = 10'-0"

DRAWN BY DATE

CHECKED BY DATE

APPROVED

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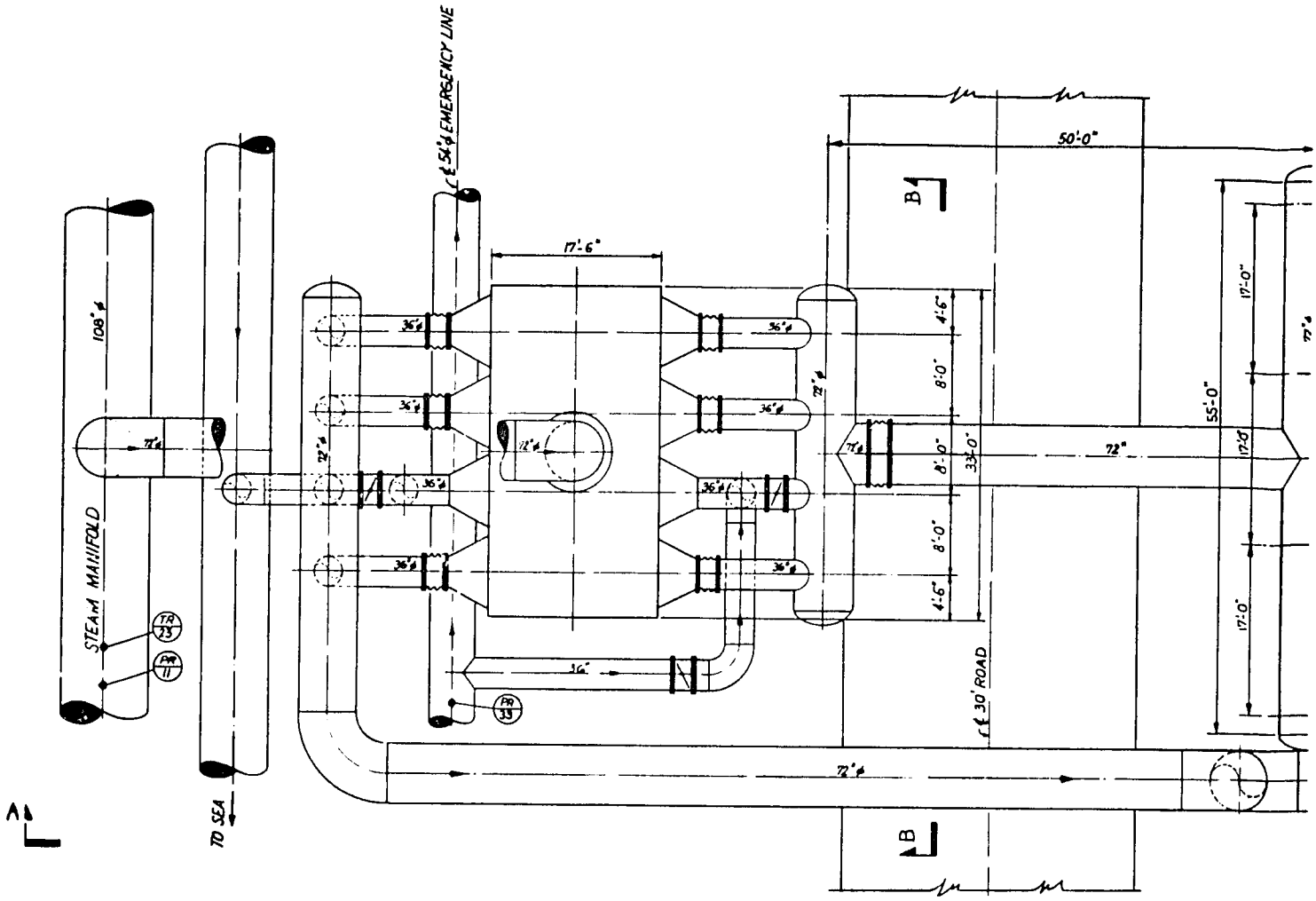
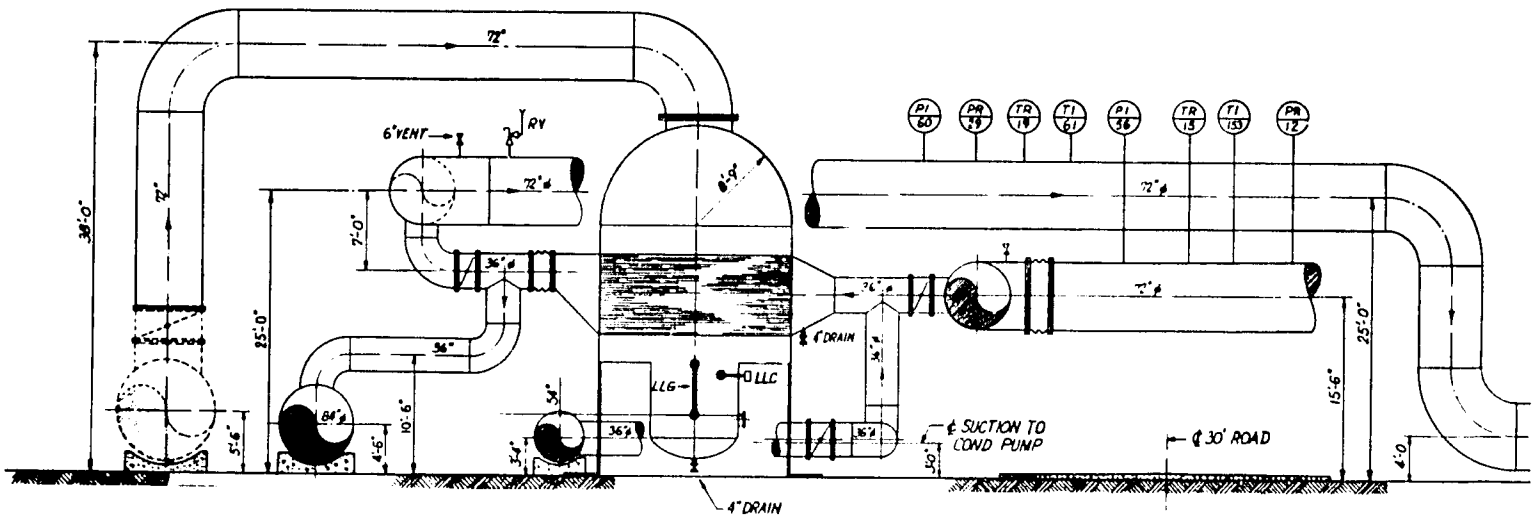
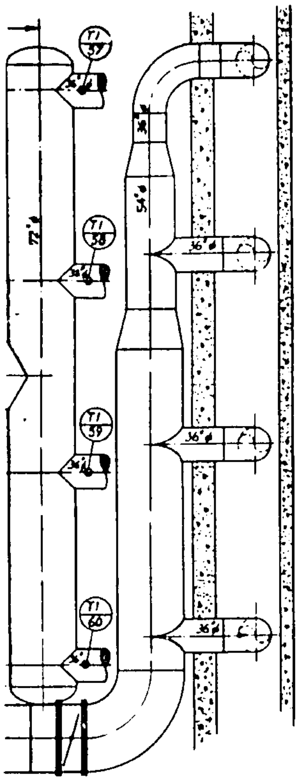
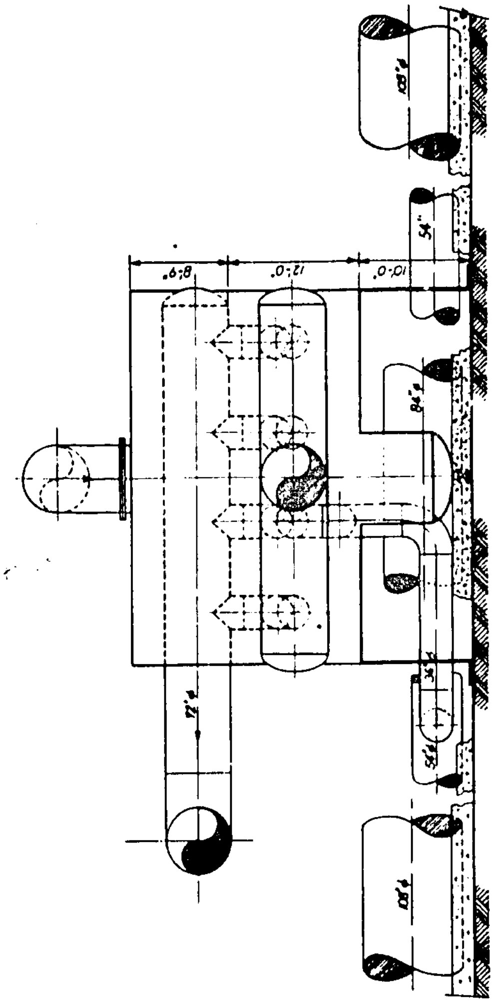


PLAN



SECTION A-A





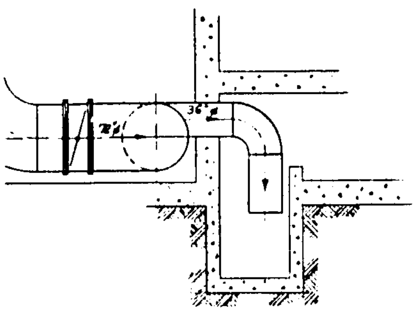
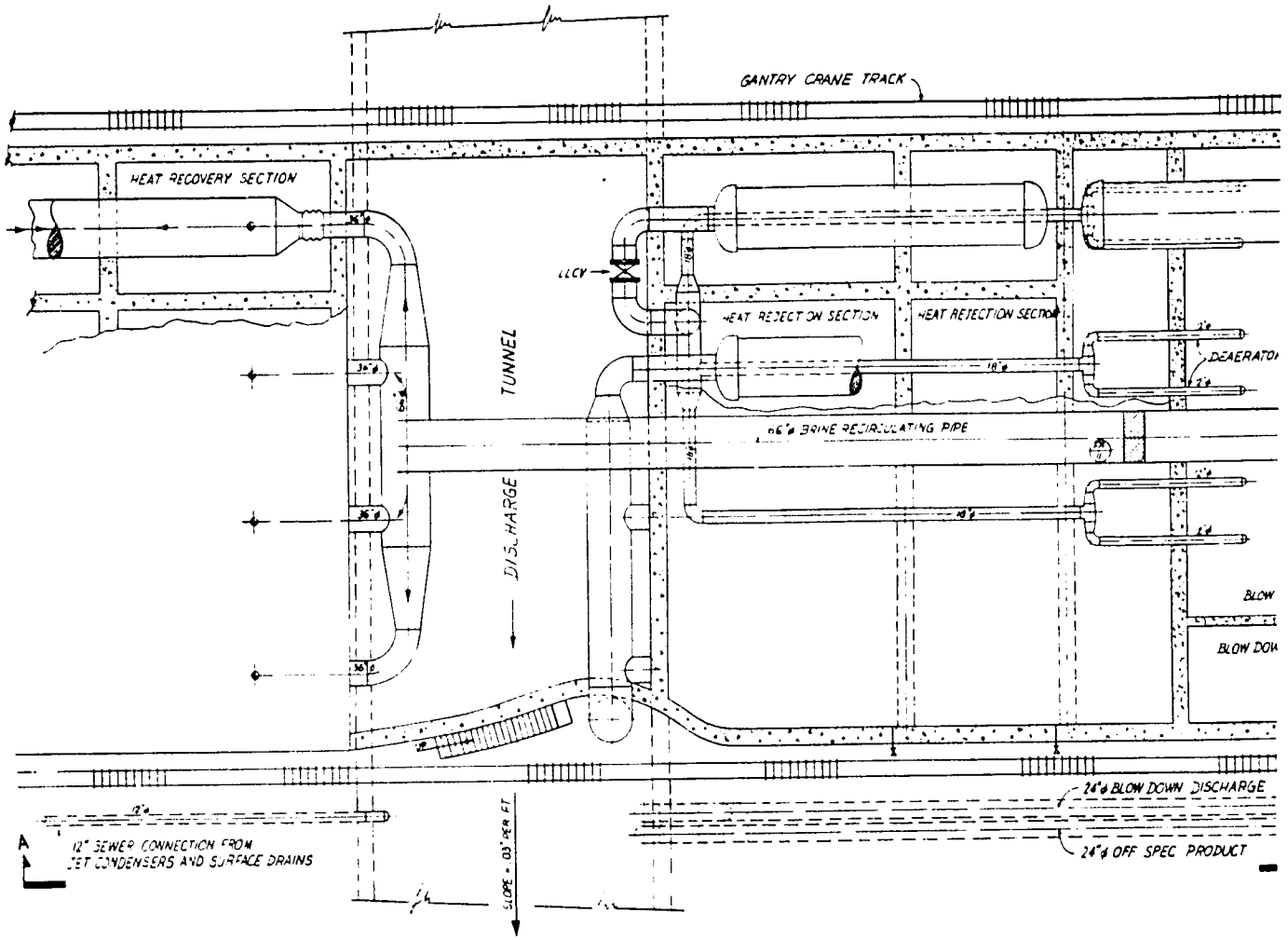
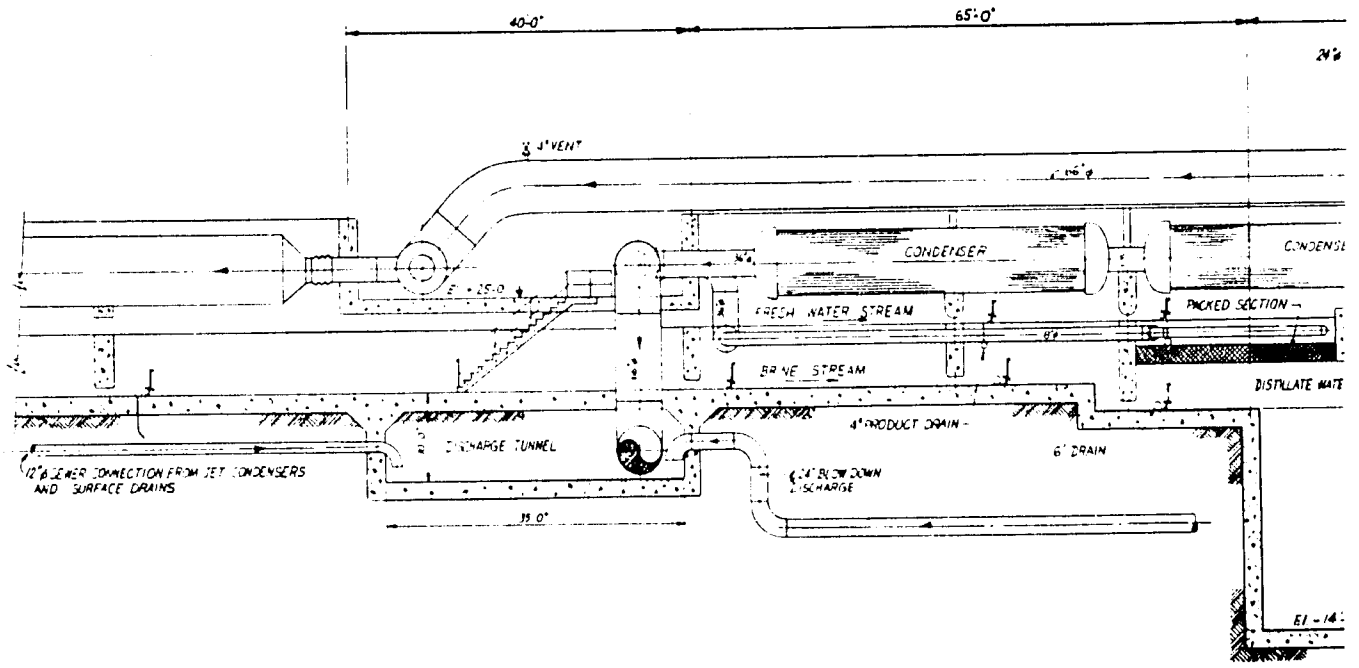


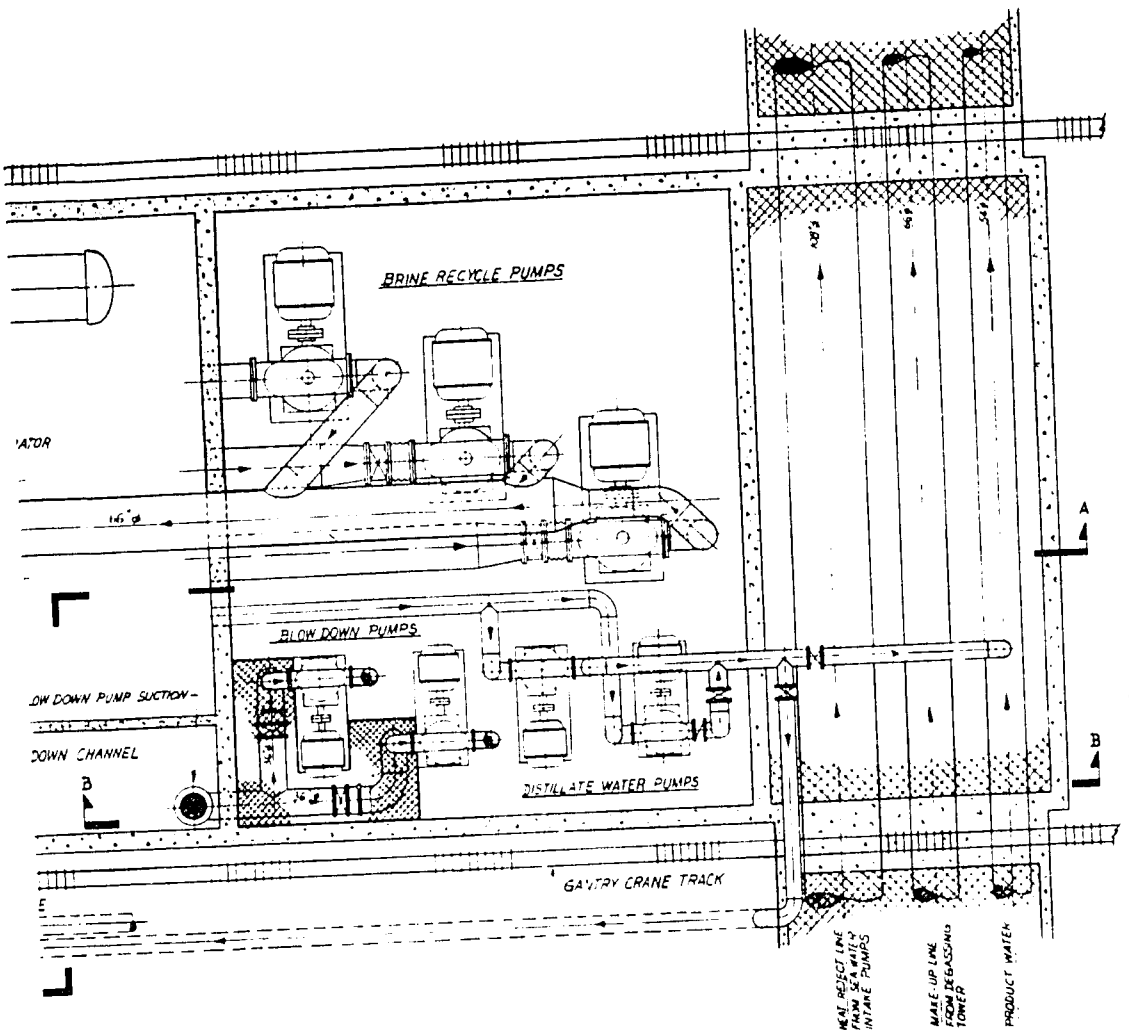
FIGURE 11

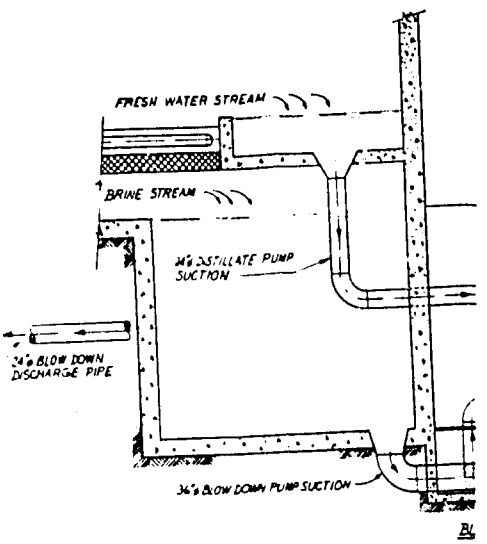
APPROVAL	DATE	SCALE 1/8" = 1'-0"
		DRAWN BY B. Szabo DATE
		CHECKED BY DATE
		APPROVED

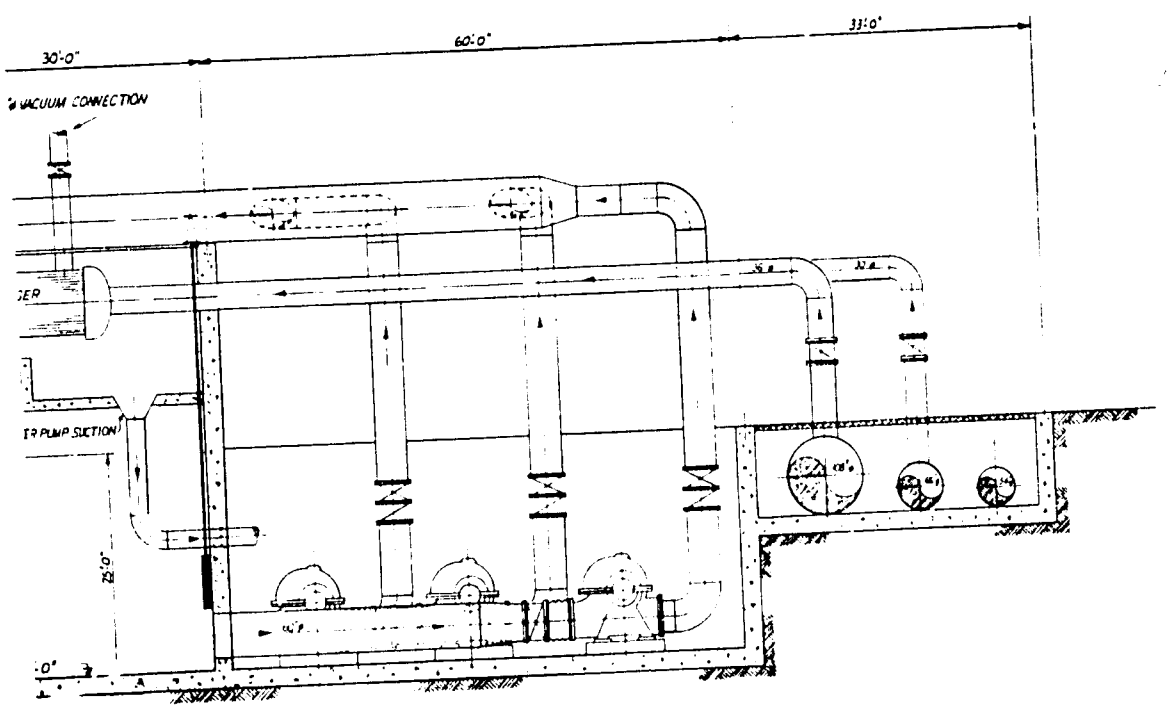
CATALYTIC CONSTRUCTION COMPANY
PHILADELPHIA PENNSYLVANIA
FOR
KAISER ENGINEERS
OAKLAND, CALIFORNIA
FOR
U. S. - ISRAEL JOINT BOARD
PIPING ARRANGEMENT AT
BRINE HEATERS
JOB NO 6452 DWG NO SK-5-P-01


GANTRY CRANE TRACK
HEAT RECOVERY SECTION
LLCV
HEAT REJECTION SECTION
HEAT REJECTION SECTION
TUNNEL
DISCHARGE
DEAERATOR
BRINE RECIRCULATING PIPE
BLOW
BLOW DOW
24"ø BLOW DOWN DISCHARGE
24"ø OFF SPEC PRODUCT
12" SEWER CONNECTION FROM
JET CONDENSERS AND SURFACE DRAINS
SLOPE = .03" PER FT

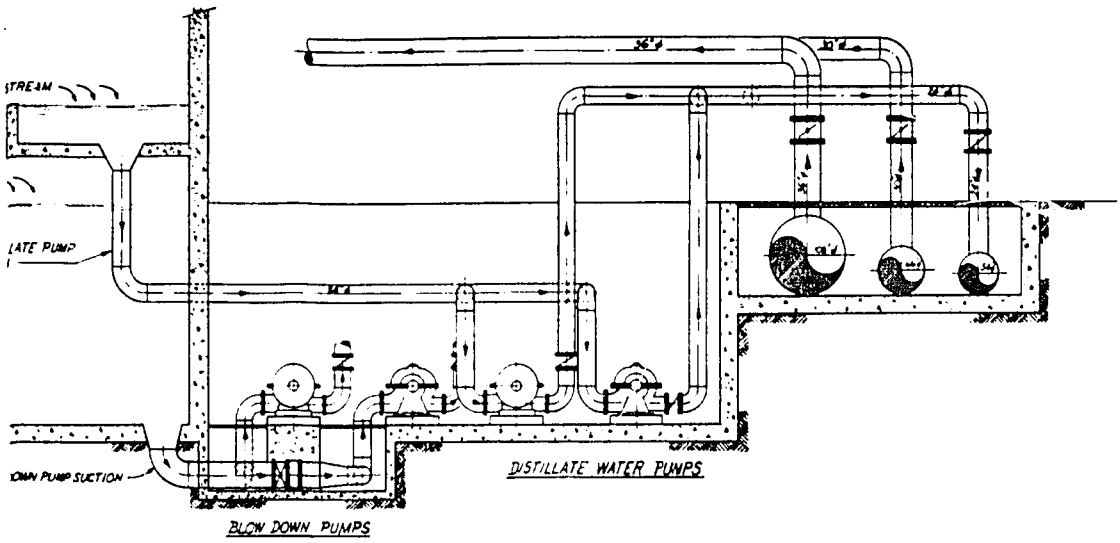

40'-0"
65'-0"
3" VENT
CONDENSER
FRESH WATER STREAM
PACKED SECTION
BRINE STREAM
DISTILLATE WATE
4" PRODUCT DRAIN
6" DRAIN
DISCHARGE TUNNEL
12"ø SEWER CONNECTION FROM JET CONDENSERS
AND SURFACE DRAINS
24" BLOW DOWN
DISCHARGE
35'-0"


BRINE RECYCLE PUMPS
BLOW DOWN PUMPS
DISTILLATE WATER PUMPS
GANTRY CRANE TRACK
DOWN CHANNEL
A
B
HEAT REJECT LINE FROM SEA WATER INTAKE PUMPS
MAKE-UP LINE FROM DEGASSING TOWER
PRODUCT WATER


FRESH WATER STREAM
BRINE STREAM
24"ø DISTILLATE PUMP SUCTION
24"ø BLOW DOWN DISCHARGE PIPE
36"ø BLOW DOWN PUMP SUCTION


30'-0"
60'-0"
33'-0"
VACUUM CONNECTION
PUMP SUCTION
29'-0"

SECTION A-A



SECTION B-B

FIGURE 12

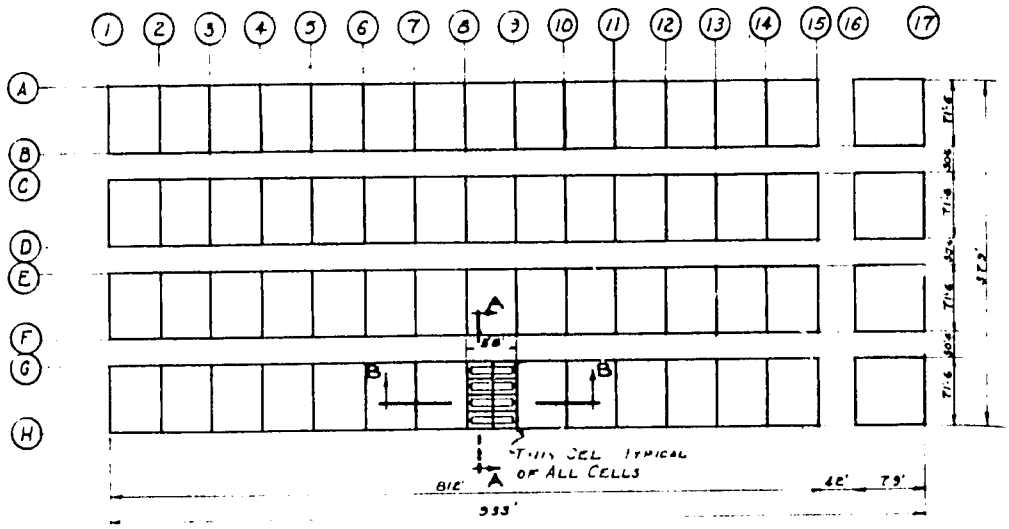
CATALYTIC CONSTRUCTION COMPANY

KAISER ENGINEERS

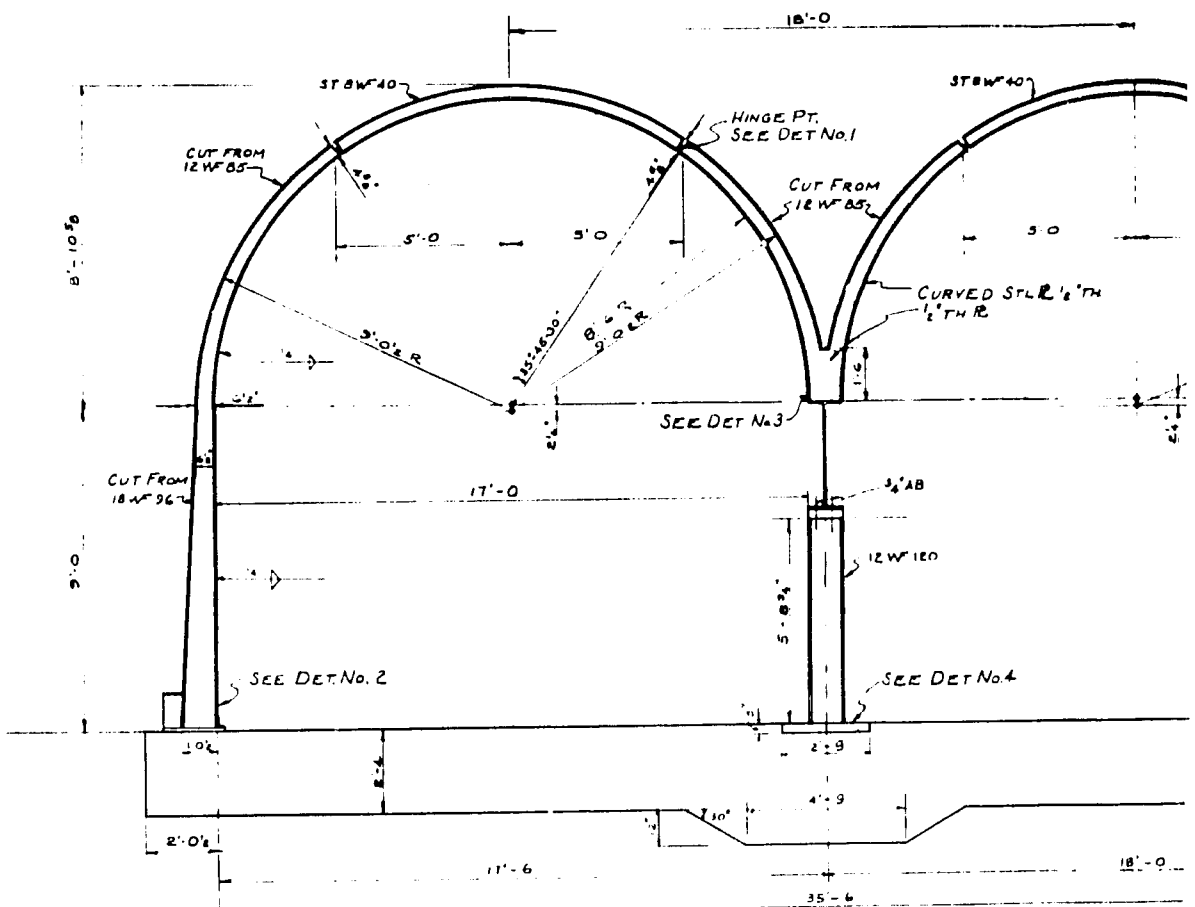
U S - ISRAEL JOINT BOARD

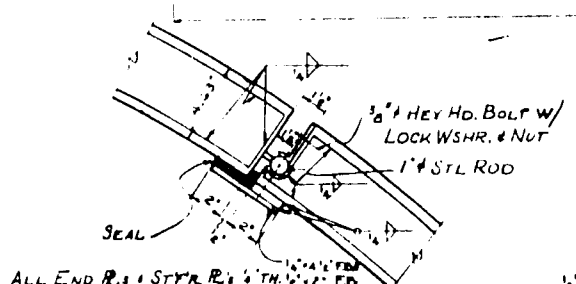
EQUIPMENT ARRANGEMENT - PUMP AREA

6452 SK-5-P-02



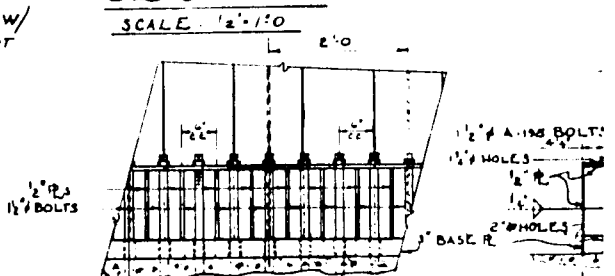
PLAN
SCALE 1" = 80'0





DET. No. 1
SCALE: 1" = 8'0"

SECT. A-A
SCALE: 1/2" = 1'0



DETAIL No. 2
SCALE: 1" = 1'0

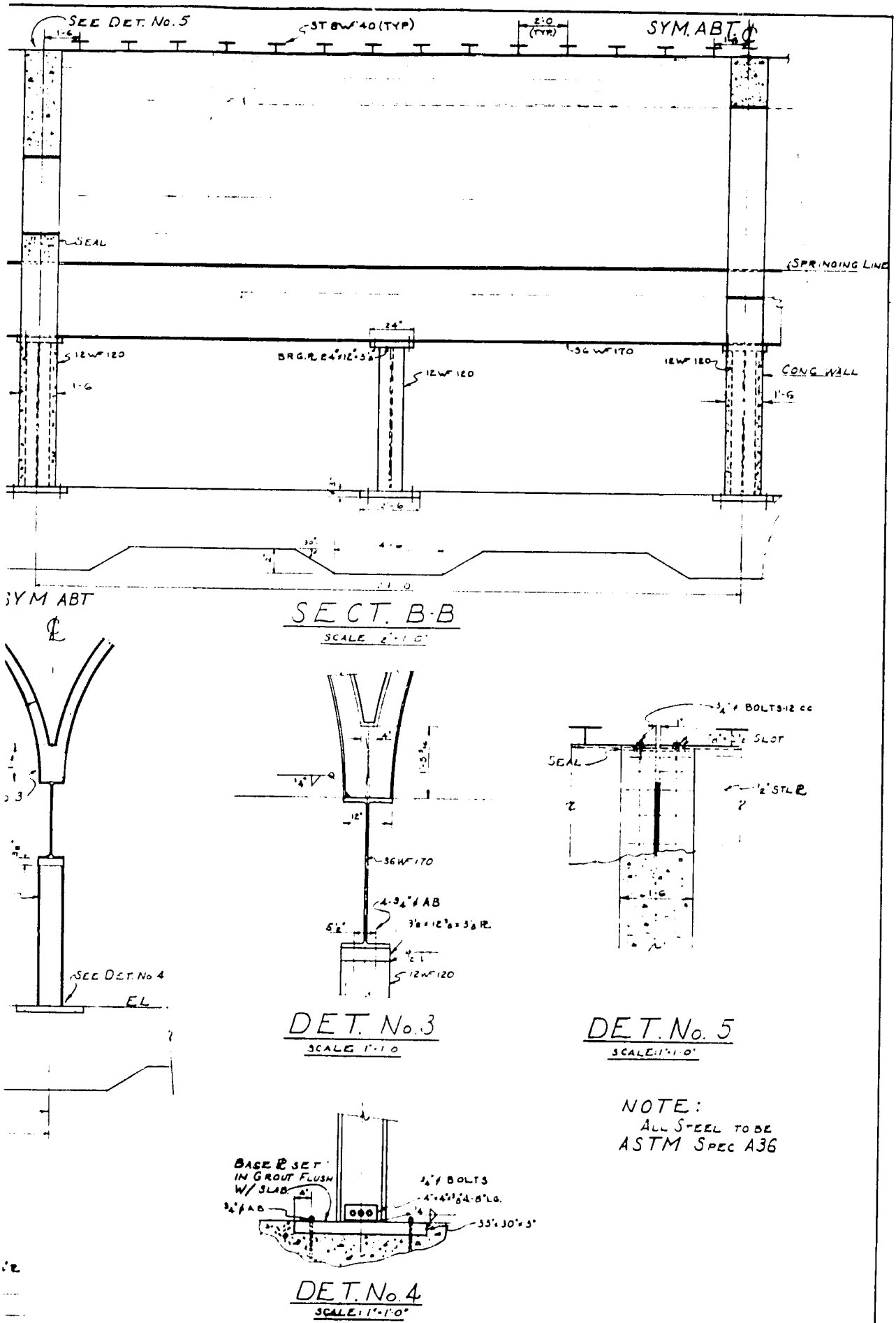


FIGURE 13

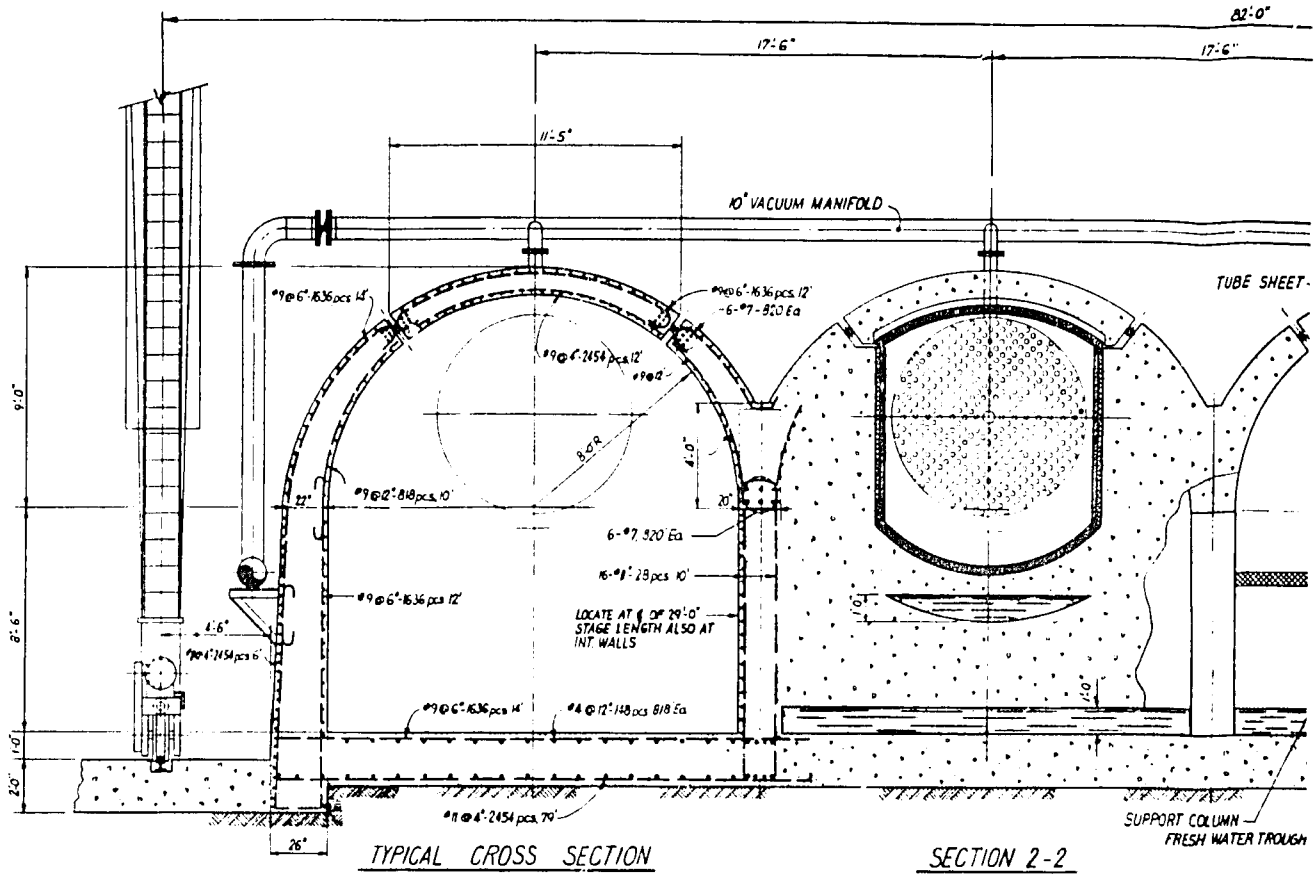
CATALYTIC CONSTRUCTION COMPANY
PHILADELPHIA PENNSYLVANIA

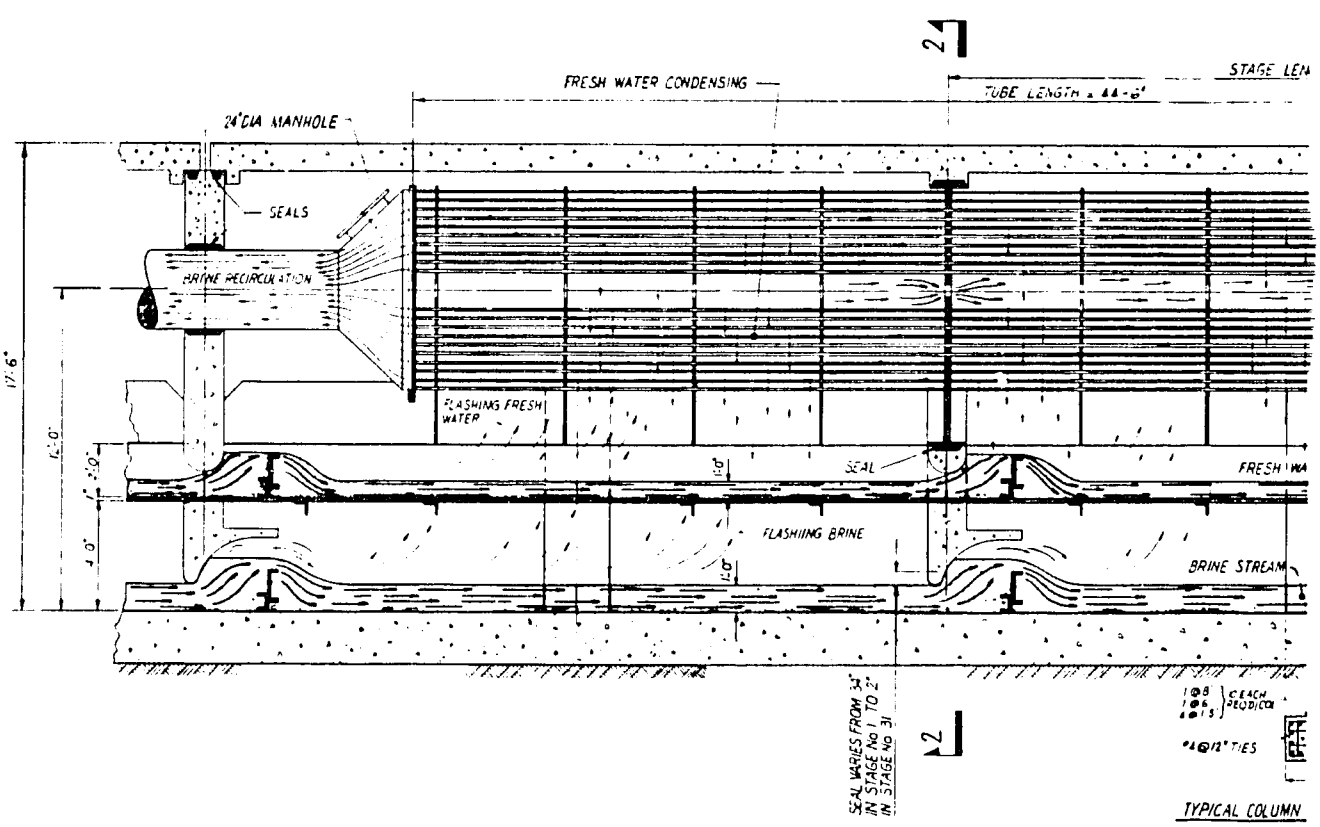
FOR
KAISER ENGINEERS
OAKLAND CALIFORNIA

FOR
U S - ISRAEL JOINT BOARD

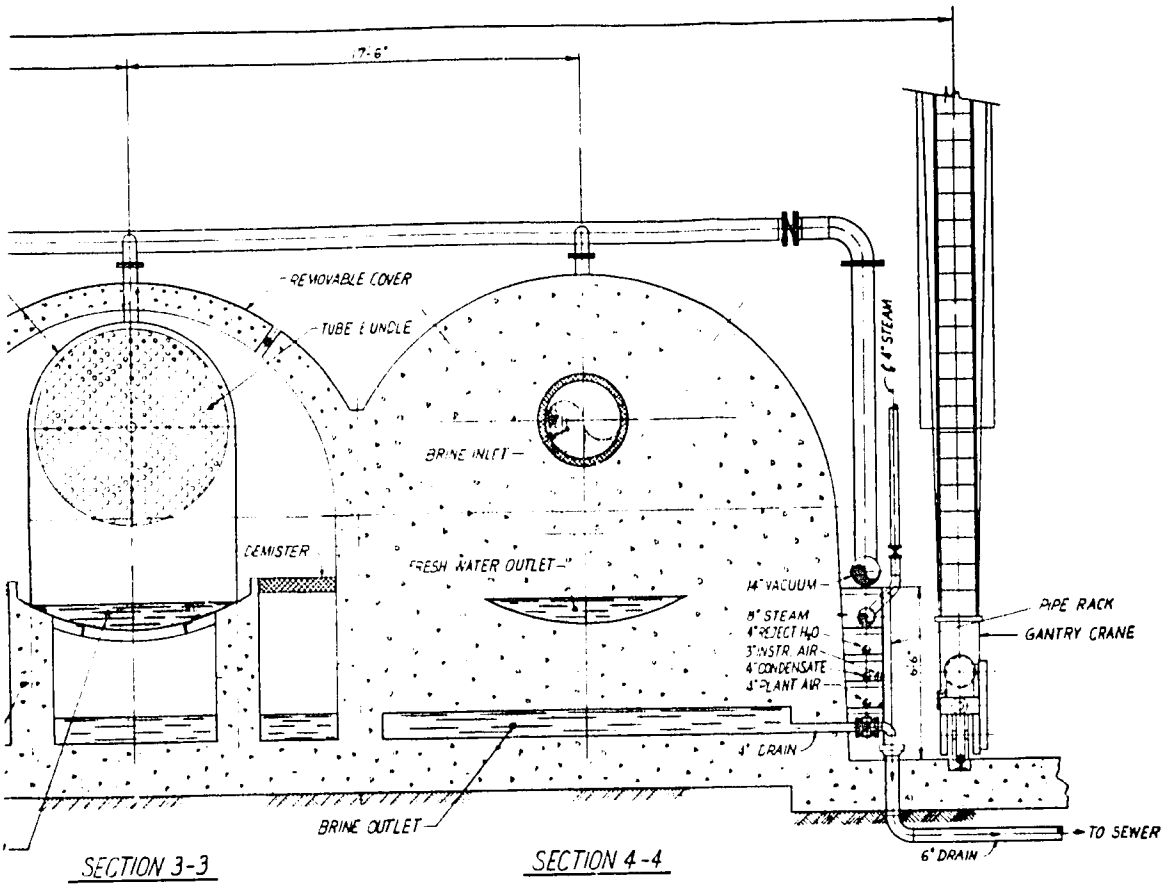
MODULE ARRANGEMENT
STRUCTURAL STEEL ENCLOSURE

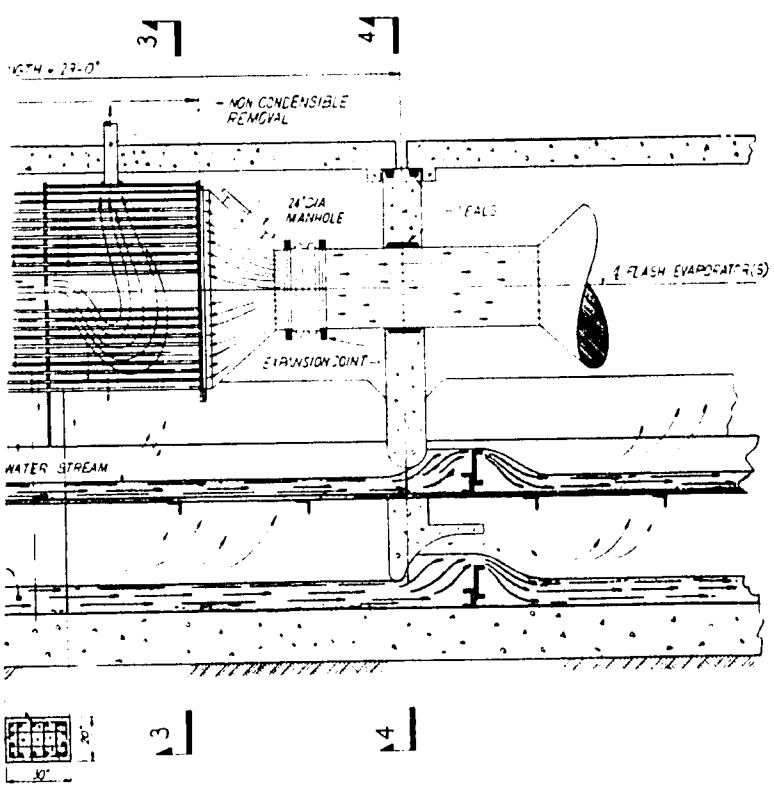
JOB NO 6452 DWG NO SK-5-A-02





NOTE: ALL INTERNAL CONCRETE SURFACES ARE TO BE PROVIDED WI



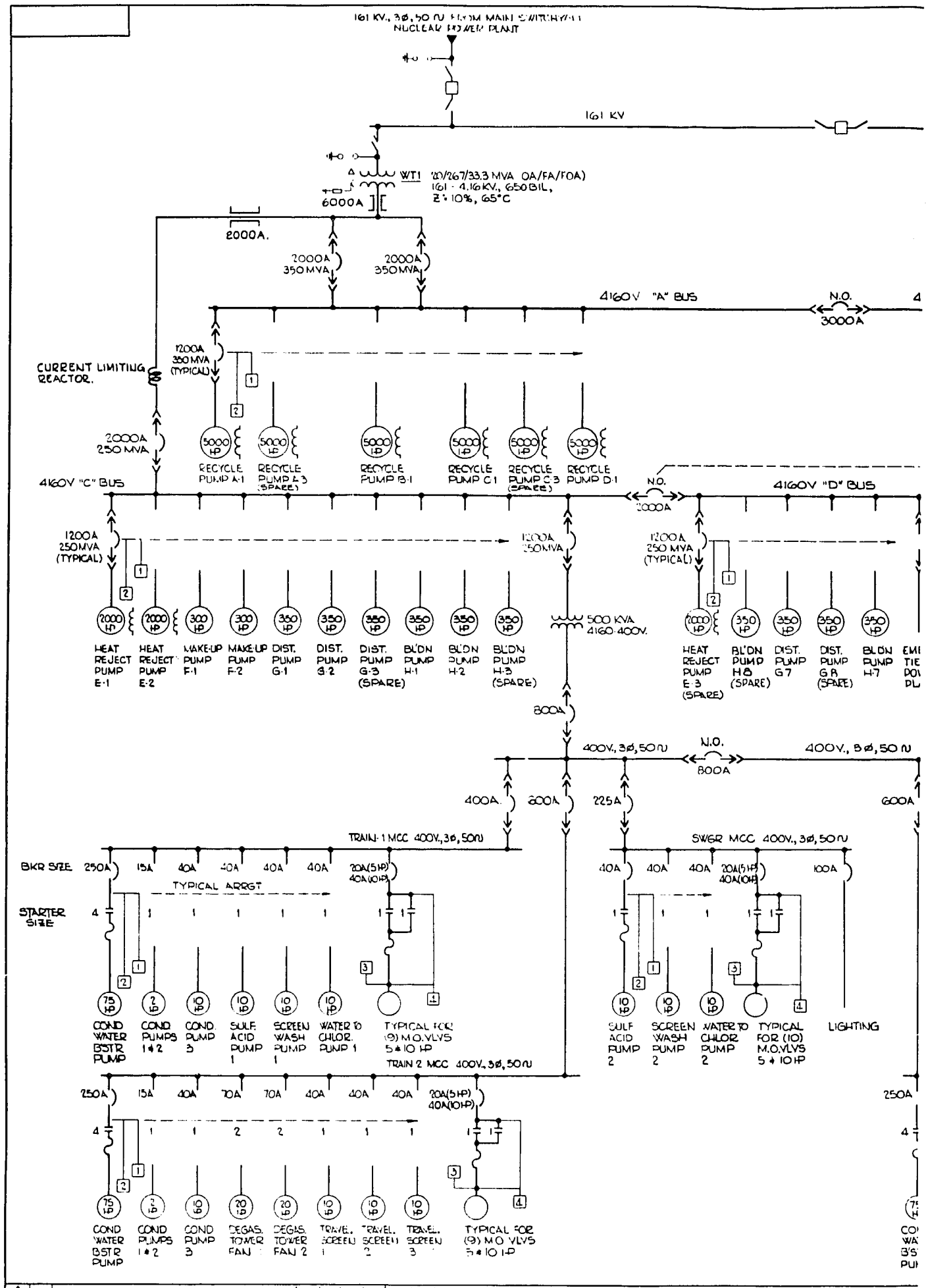


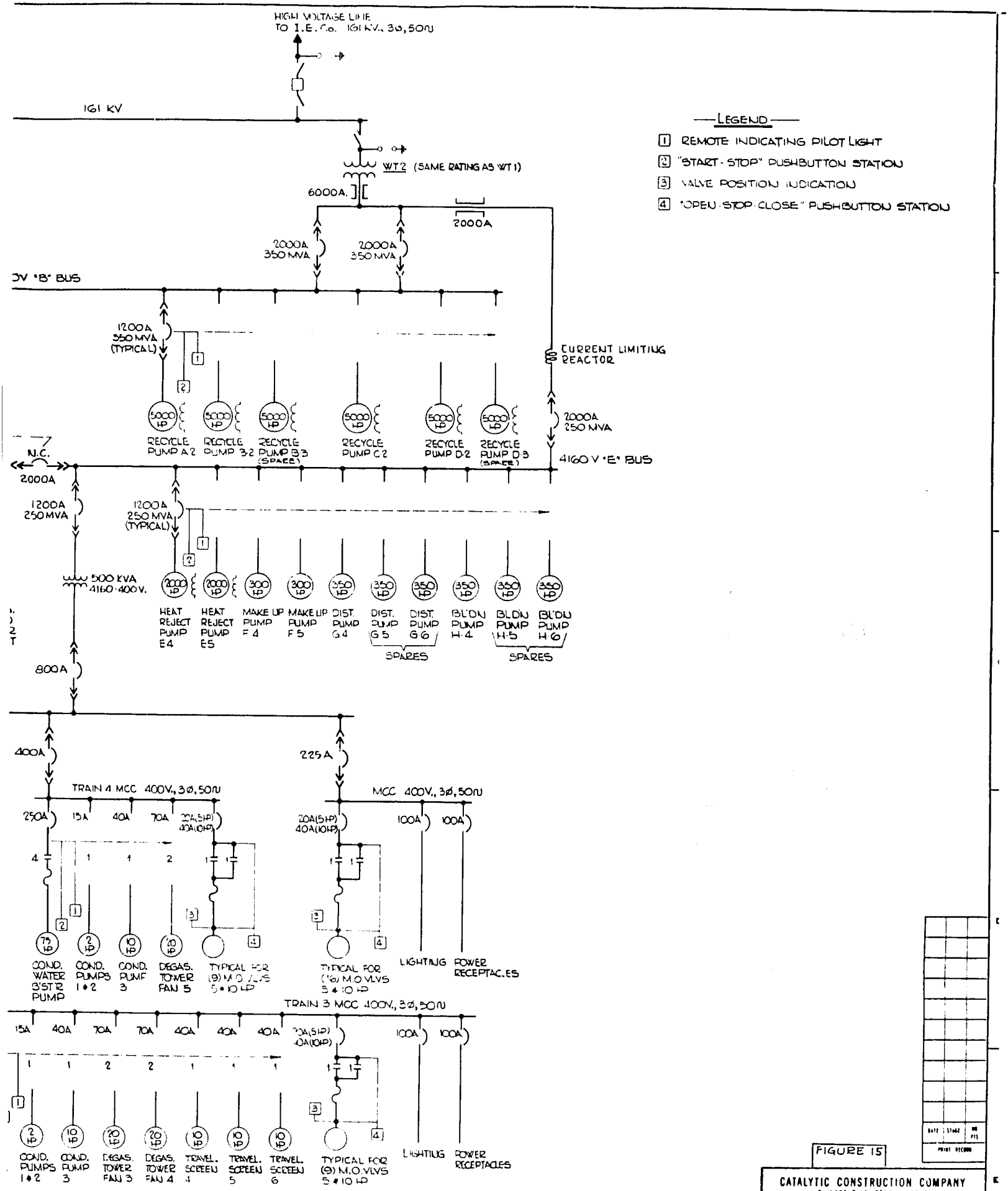
MN CROSS SECTION

WITH A PROTECTIVE LINING

FIGURE 14

CATALYTIC CONSTRUCTION COMPANY	
KAISER ENGINEERS	
U.S.-ISRAEL JOINT BOARD	
MODULE ARRANGEMENT CONCRETE ENCLOSURE	
6452	SK-5-A-01


161 KV., 3Ø, 50 ~ FROM MAIN SWITCHYARD
NUCLEAR POWER PLANT
161 KV
WT1 (20/267/33.3 MVA OA/FA/FOA)
161 - 4.16 KV., 650 BIL,
Z = 10%, 65°C
6000A
2000A.
2000A 350 MVA
2000A 350 MVA
4160V "A" BUS
N.O.
3000A
CURRENT LIMITING REACTOR.
1200A 350 MVA (TYPICAL)
2000A 250 MVA
5000 HP
RECYCLE PUMP A-1
RECYCLE PUMP A-3 (SPARE)
RECYCLE PUMP B-1
RECYCLE PUMP C-1
RECYCLE PUMP C-3 (SPARE)
RECYCLE PUMP D-1
4160V "C" BUS
N.O.
2000A
4160V "D" BUS
1200A 250 MVA (TYPICAL)
1200A 250 MVA
1200A 250 MVA (TYPICAL)
2000 HP
HEAT REJECT PUMP E-1
HEAT REJECT PUMP E-2
300 HP
MAKE-UP PUMP F-1
MAKE-UP PUMP F-2
350 HP
DIST. PUMP G-1
DIST. PUMP G-2
DIST. PUMP G-3 (SPARE)
BL'DN PUMP H-1
BL'DN PUMP H-2
BL'DN PUMP H-3 (SPARE)
500 KVA 4160-400V.
HEAT REJECT PUMP E-3 (SPARE)
BL'DN PUMP H-6 (SPARE)
DIST. PUMP G-7
DIST. PUMP G-8 (SPARE)
BL'DN PUMP H-7
800A
400V., 3Ø, 50 ~
N.O.
800A
400V., 3Ø, 50 ~
400A.
600A
225A
600A
TRAIN-1 MCC 400V., 3Ø, 50 ~
SWGR MCC 400V., 3Ø, 50 ~
BKR SIZE
250A
15A
40A
20A(5HP) 40A(10HP)
100A
TYPICAL ARRGT
STARTER SIZE
75 HP
COND WATER BSTR PUMP
COND PUMPS 1 & 2
COND PUMP 3
SULF. ACID PUMP 1
SCREEN WASH PUMP 1
WATER TO CHLOR. PUMP 1
TYPICAL FOR (9) M.O.VLVS 5 & 10 HP
SULF ACID PUMP 2
SCREEN WASH PUMP 2
WATER TO CHLOR PUMP 2
TYPICAL FOR (10) M.O.VLVS 5 & 10 HP
LIGHTING
TRAIN 2 MCC 400V., 3Ø, 50 ~
70A
20 HP
DEGAS. TOWER FAN 1
DEGAS. TOWER FAN 2
TRAVEL. SCREEN 1
TRAVEL. SCREEN 2
TRAVEL. SCREEN 3



LEGEND

1. REMOTE INDICATING PILOT LIGHT
2. "START - STOP" PUSHBUTTON STATION
3. VALVE POSITION INDICATION
4. "OPEN - STOP - CLOSE" PUSHBUTTON STATION

FIGURE 15

CATALYTIC CONSTRUCTION COMPANY
PHILADELPHIA PENNSYLVANIA

FOR

KAISER ENGINEERS
OAKLAND, CALIFORNIA

FOR

U S - ISRAEL JOINT BOARD

ELECTRICAL SINGLE LINE DIAGRAM
DESALTING PLANT

JOB NO 6432

DWG NO SK 5 E 01

NONE

DRAWN BY G.W. DATE 7/24/62

CHECKED BY H.C.M. DATE 7/26/62

APPROVED

ISSUED | APPD | DATE | APPD | DATE
CATALYTIC | CLIENT

REVISIONS | APPD | DATE
CATALYTIC

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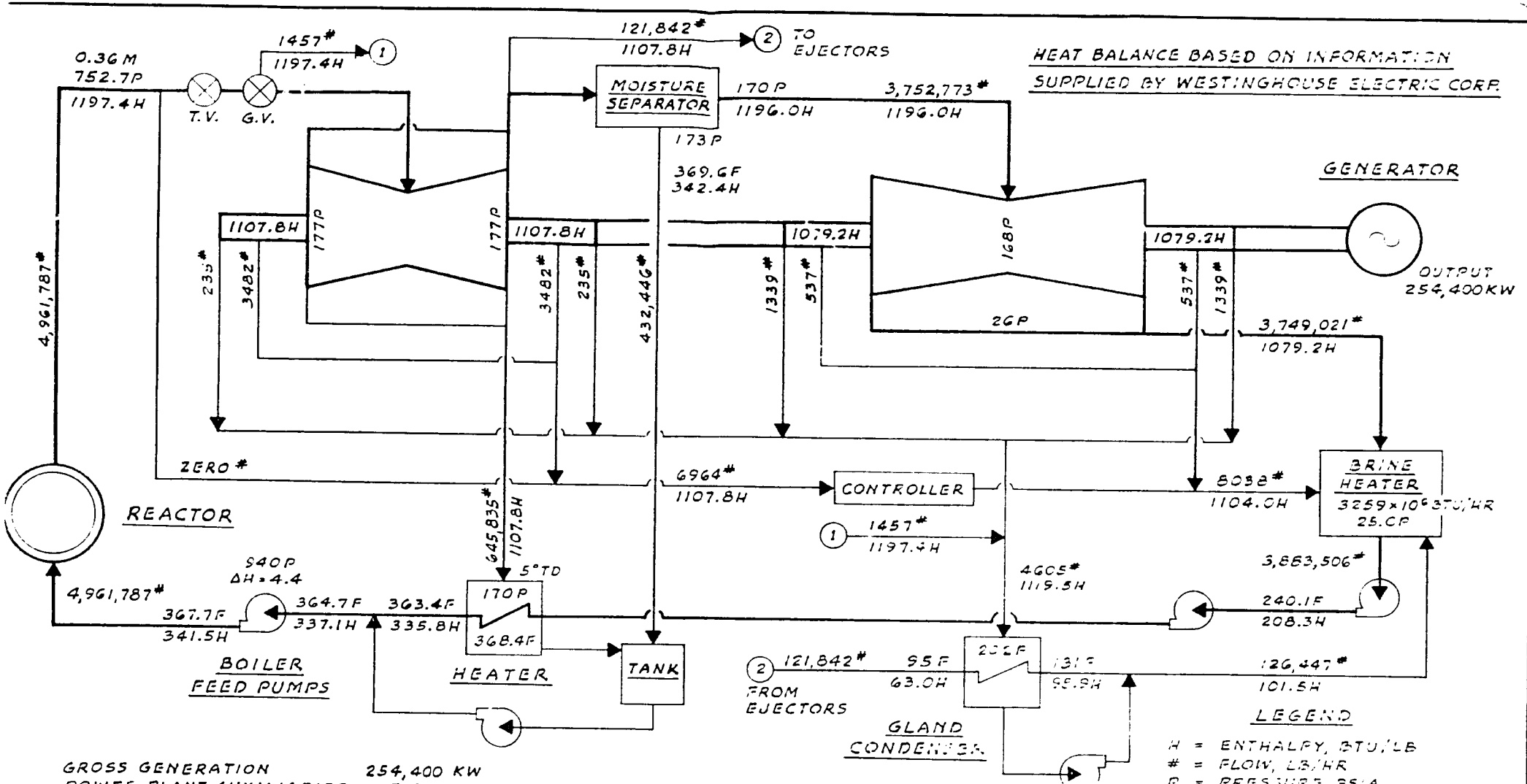

GROSS GENERATION	254,400 KW
POWER PLANT AUXILIARIES	17,300 KW
WATER PLANT AUXILIARIES	35,400 KW
ALLOWANCE FOR LIGHTING, VENTILATION, ETC.	1,700 KW
NET SALEABLE POWER	200,000 KW
REACTOR SIZE	1,244 MWt

TURBINE - GENERATOR DATA

254,400 KW @ 26.0 PSIA BACK PRESSURE
752.7 PSIA, 0.36 % MOISTURE
GEN: 320,000 KVA & 0.85 PF
TC4F 3000 RPM

FIGURE 16

APPROVAL	DATE	SCALE: NONE
		DRAWN BY M.S. DATE 1/24/66
		CHECKED BY DATE 1/26/66
		APPROVED 1/28/66

KAISER ENGINEERS
OAKLAND, CALIFORNIA

FOR

U. S. - ISRAEL JOINT BOARD

PWR HEAT BALANCE

JOB NO 6452 DWG. NO

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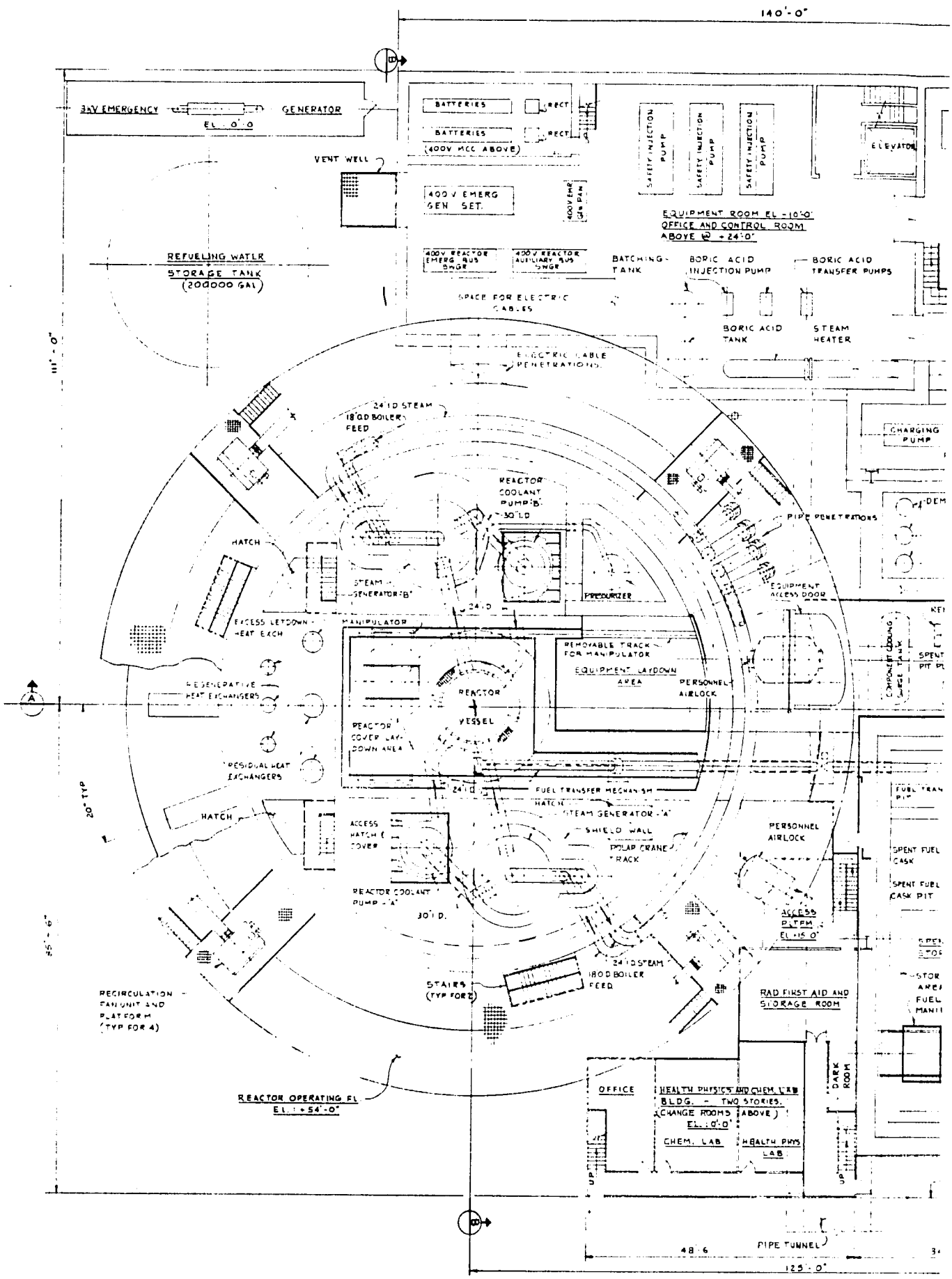
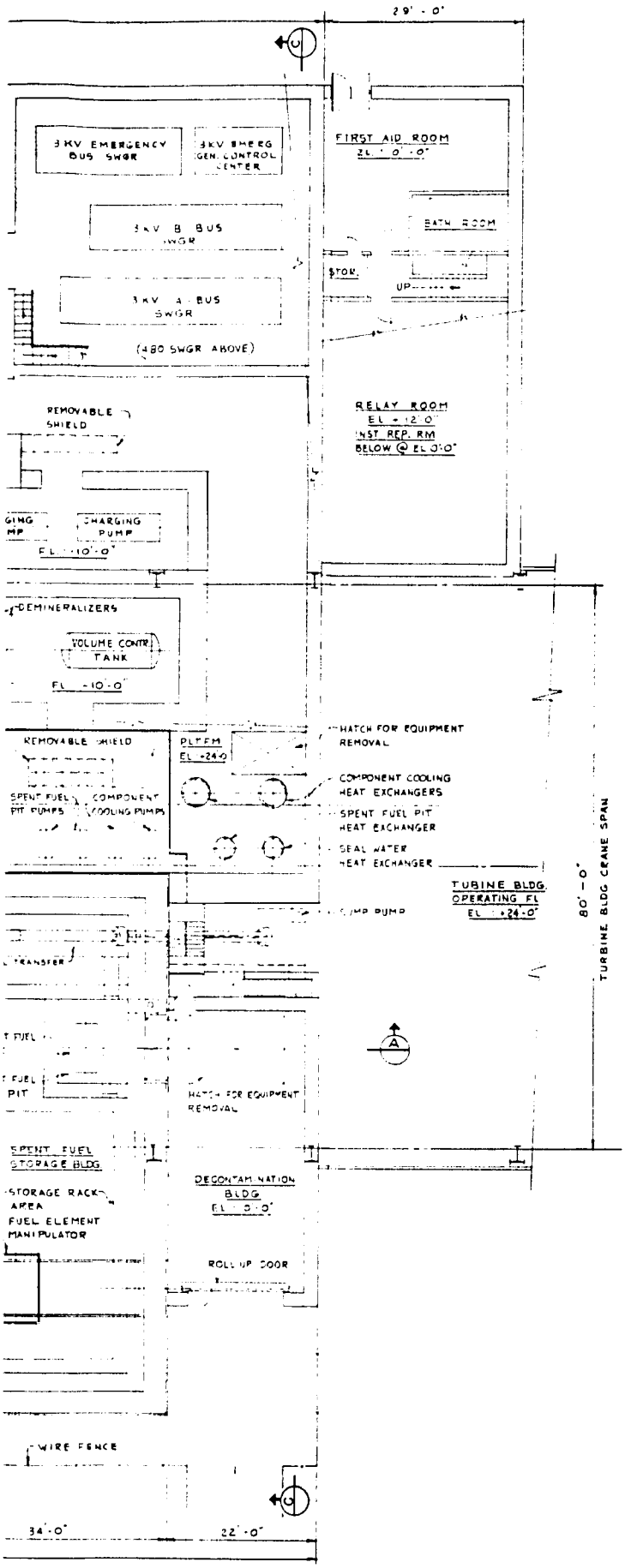
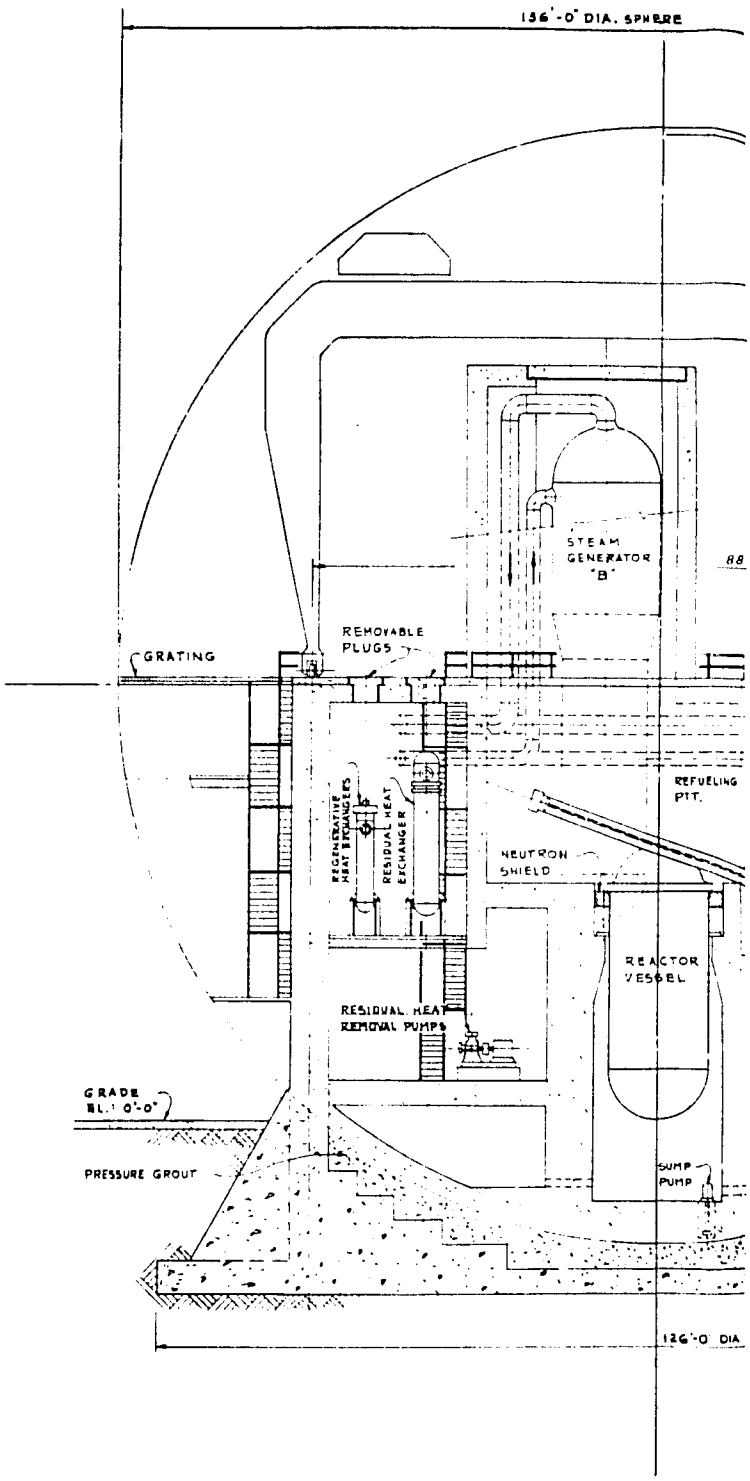
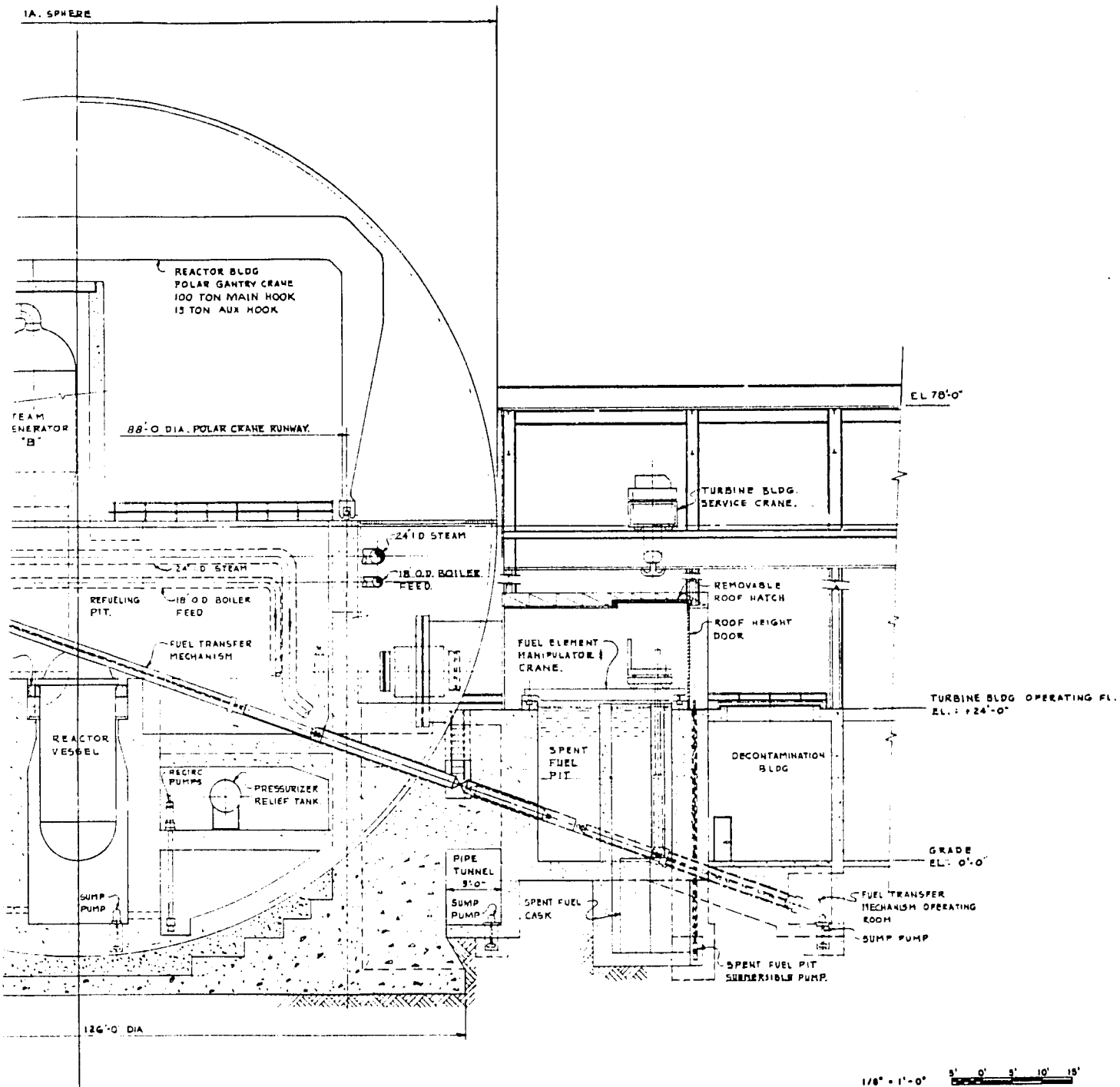


REACTOR AND AUXILIARY BLDG. COMPOSITE PLANS


29'-0"
3KV EMERGENCY BUS SWGR
3KV EMERG GEN. CONTROL CENTER
FIRST AID ROOM
EL. 0'-0"
3KV B BUS SWGR
BATH ROOM
STOR.
UP
3KV A BUS SWGR
(480 SWGR ABOVE)
REMOVABLE SHIELD
RELAY ROOM
EL. +12'-0"
INST. REP. RM
BELOW @ EL. 0'-0"
CHARGING PUMP
EL. -10'-0"
DEMINERALIZERS
VOLUME CONTR. TANK
EL. -10'-0"
REMOVABLE SHIELD
PLTFM
EL. +24'-0"
HATCH FOR EQUIPMENT REMOVAL
COMPONENT COOLING HEAT EXCHANGERS
SPENT FUEL PIT HEAT EXCHANGER
SEAL WATER HEAT EXCHANGER
SPENT FUEL PIT PUMPS
COMPONENT COOLING PUMPS
TUBINE BLDG. OPERATING FL
EL. +24'-0"
80'-0"
TURBINE BLDG CRANE SPAN
HATCH FOR EQUIPMENT REMOVAL
SPENT FUEL STORAGE BLDG.
STORAGE RACK AREA
FUEL ELEMENT MANIPULATOR
DECONTAMINATION BLDG.
EL. 0'-0"
ROLL UP DOOR
WIRE FENCE
34'-0"
22'-0"


136'-0" DIA. SPHERE
STEAM GENERATOR "B"
GRATING
REMOVABLE PLUGS
REGENERATIVE HEAT EXCHANGERS
RESIDUAL HEAT EXCHANGER
REFUELING PIT
NEUTRON SHIELD
REACTOR VESSEL
RESIDUAL HEAT REMOVAL PUMPS
GRADE
EL. 0'-0"
PRESSURE GROUT
SUMP PUMP
126'-0" DIA.

SECTION

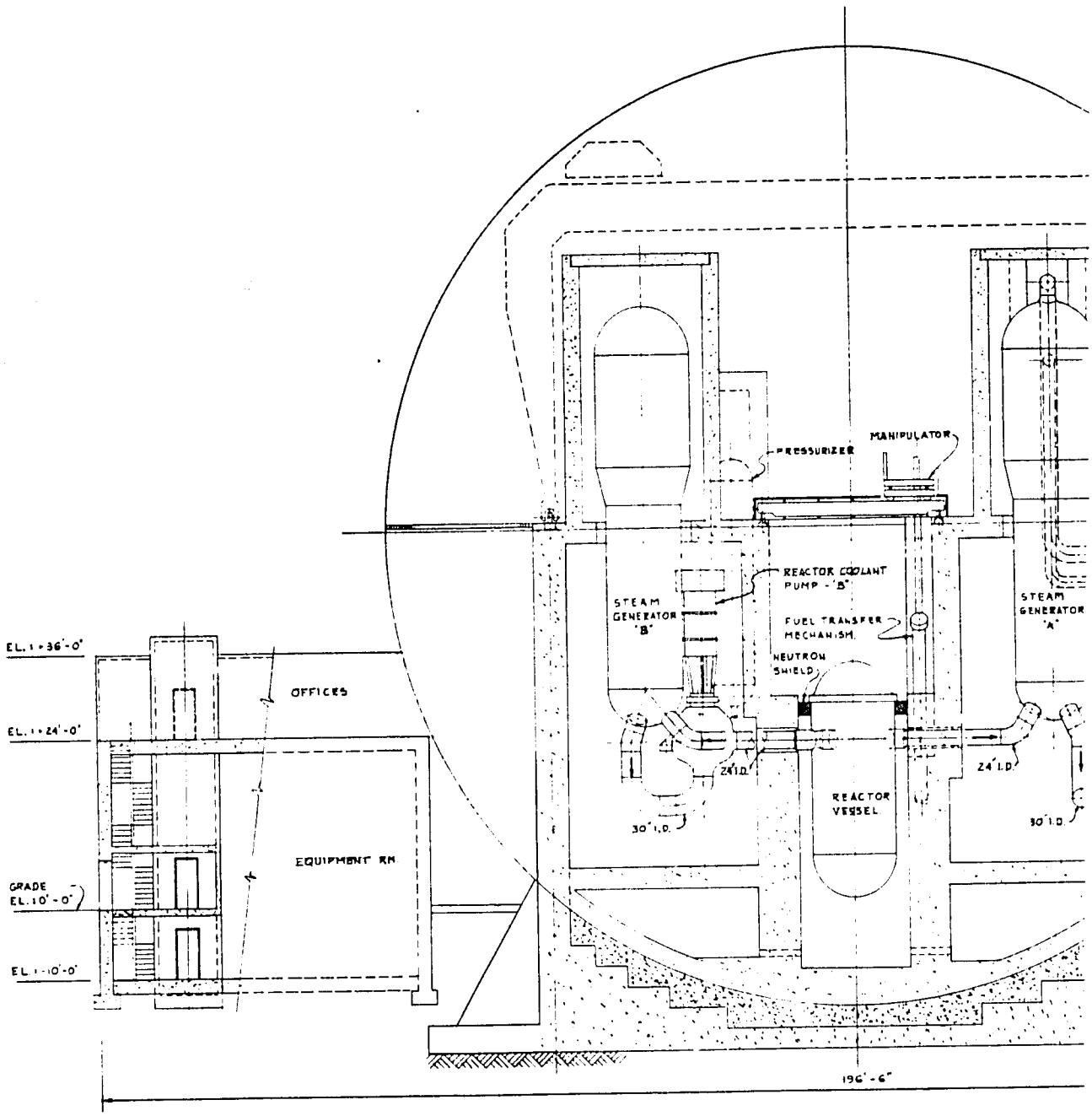


SECTION (A)

FIGURE 17

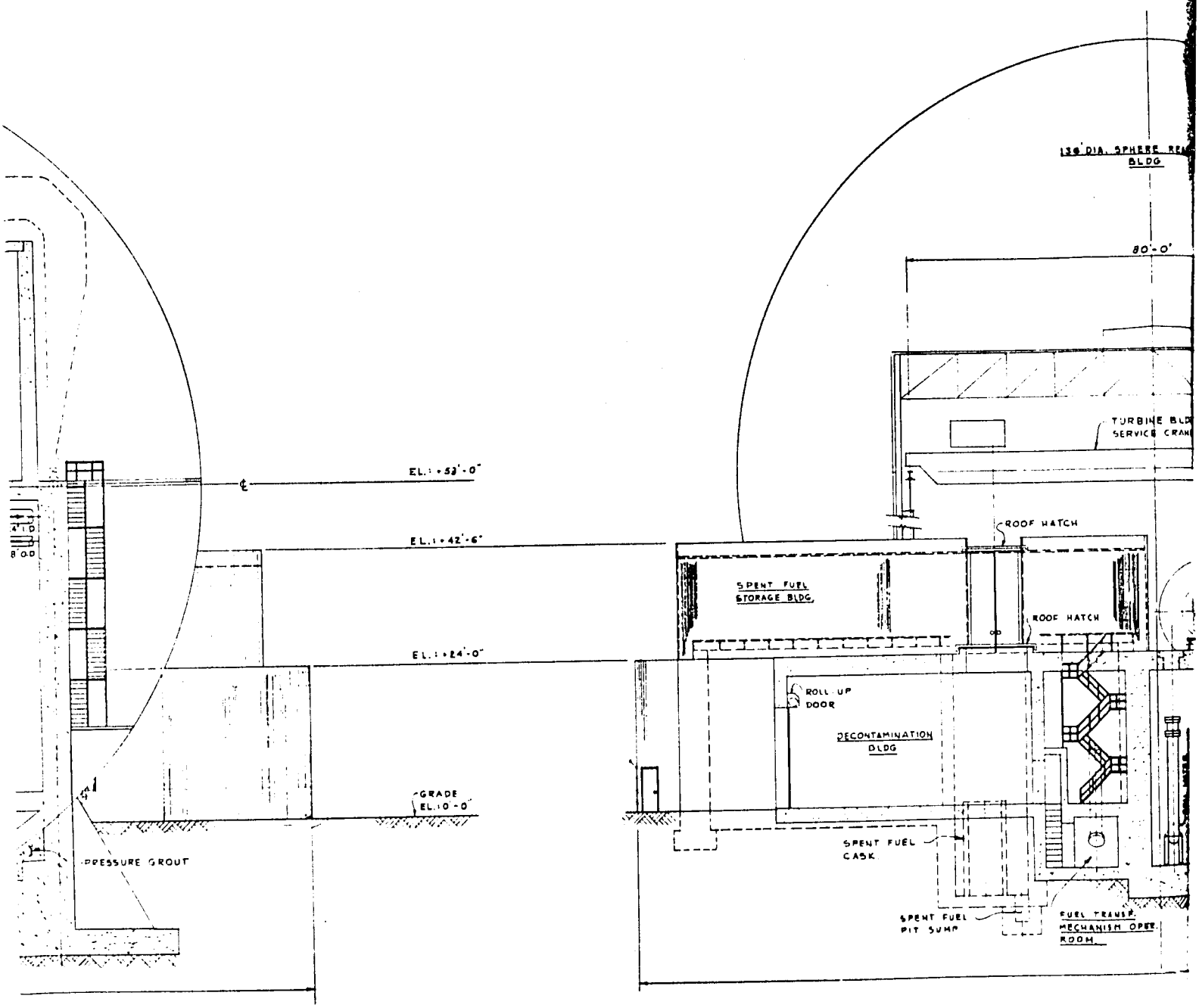
	KAISER ENGINEERS
	U.S.-ISRAEL JOINT BOARD
	PAR REACTOR BUILDING STEEL CONTAINMENT SHEET 1
	6452 SK-2 A-01

228


EL. 1+36'-0"
EL. 1+24'-0"
GRADE
EL. 10'-0"
EL. 1-10'-0"
OFFICES
EQUIPMENT RM
PRESSURIZER
MANIPULATOR
REACTOR COOLANT
PUMP - "B"
STEAM
GENERATOR
"B"
FUEL TRANSFER
MECHANISM
NEUTRON
SHIELD
REACTOR
VESSEL
24" I.D.
30" I.D.
STEAM
GENERATOR
"A"
196'-6"

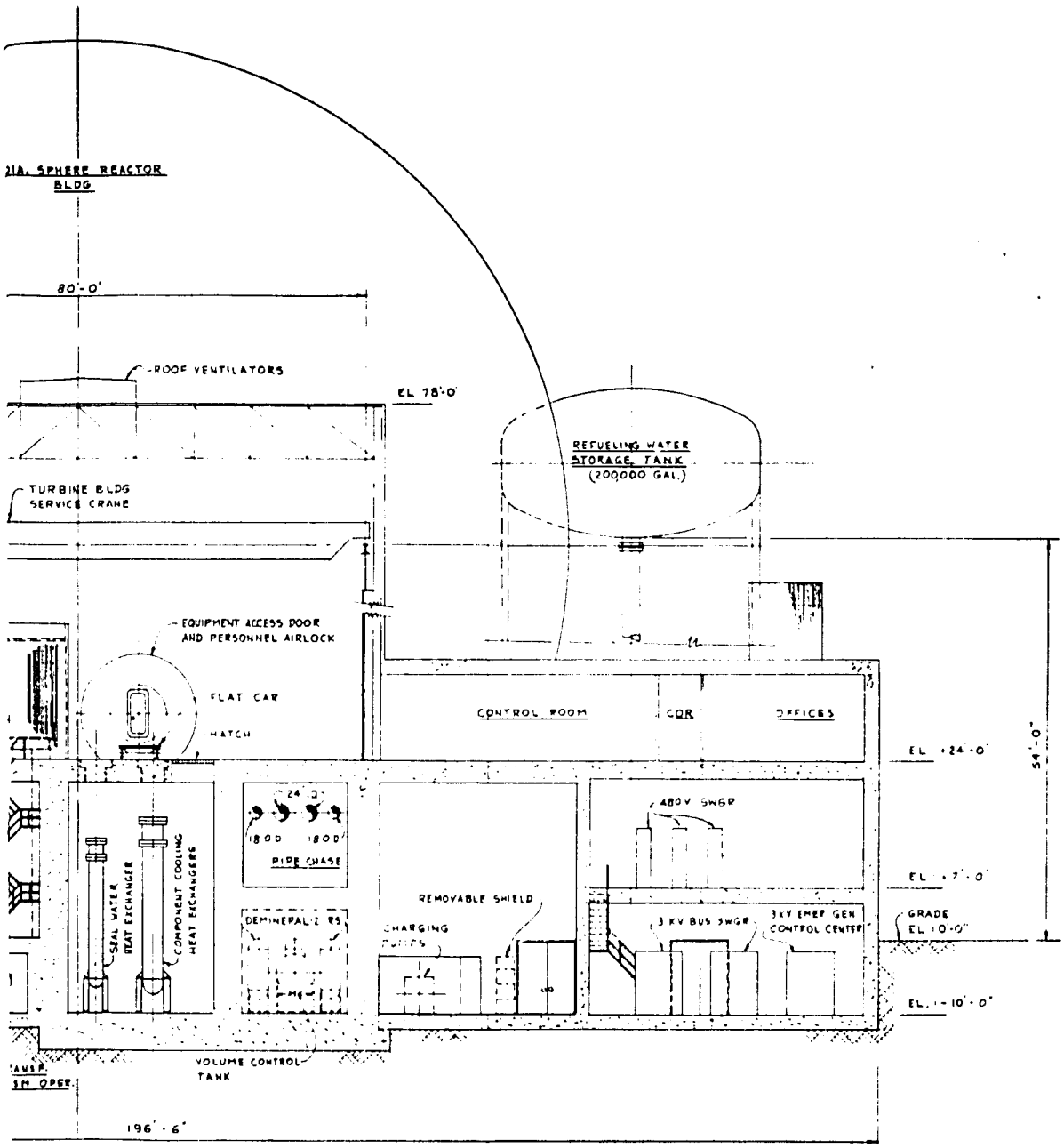
SECTION Ⓑ

229


130' DIA. SPHERE
BLDG
80'-0"
TURBINE BLD
SERVICE CRAN
EL. + 53'-0"
EL. + 42'-6"
EL. + 24'-0"
GRADE
EL. 10'-0"
ROOF HATCH
SPENT FUEL
STORAGE BLDG.
ROOF HATCH
ROLL UP
DOOR
DECONTAMINATION
BLDG
SPENT FUEL
CASK
SPENT FUEL
PIT SUMP
FUEL TRANSP.
MECHANISM OPER.
ROOM
PRESSURE GROUT

SECTIO

230



SECTION Ⓒ

1/8" = 1'-0"

FIGURE 18

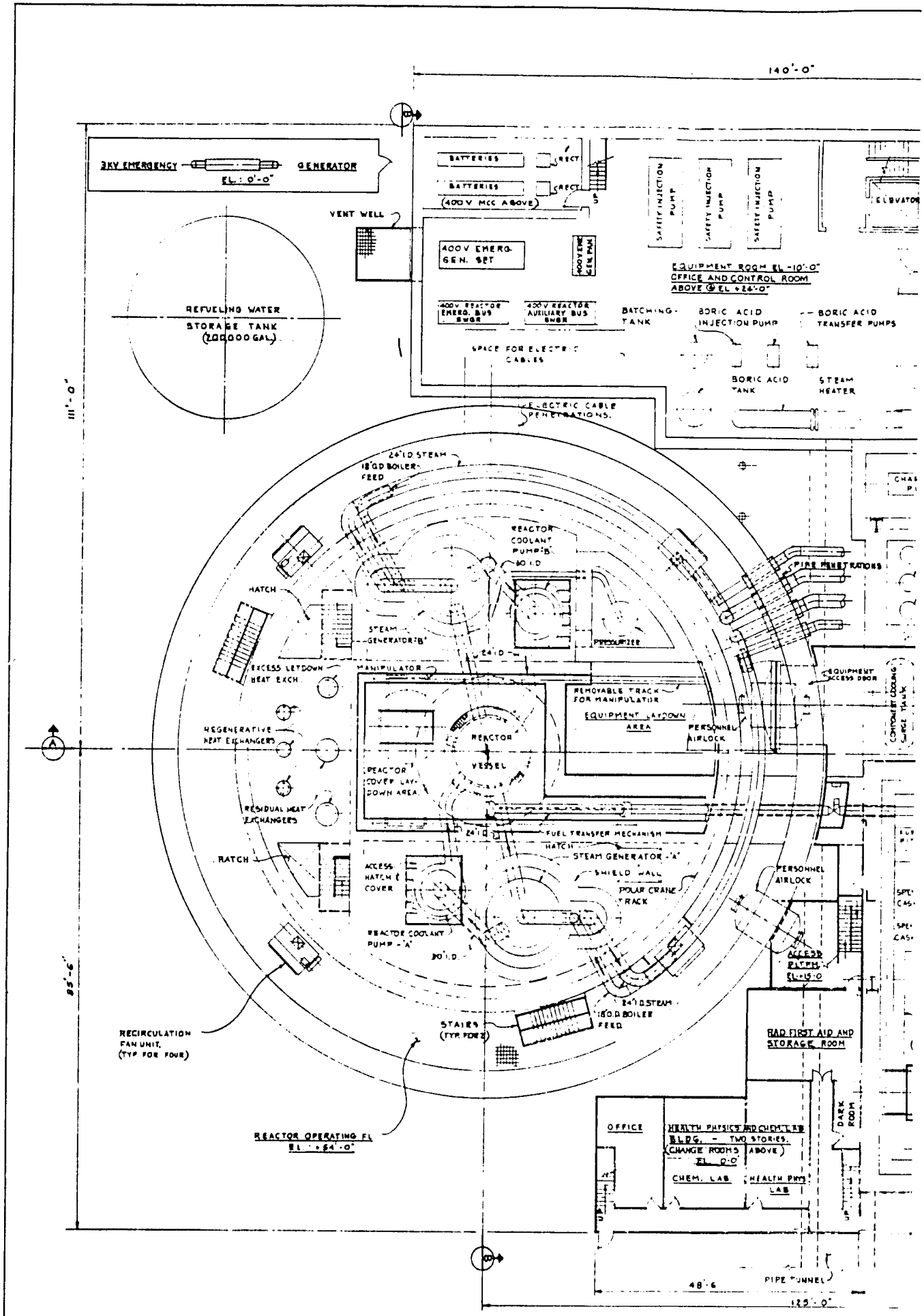
KAISER ENGINEERS
OAKLAND, CALIFORNIA

U.S.-ISRAEL JOINT BOARD

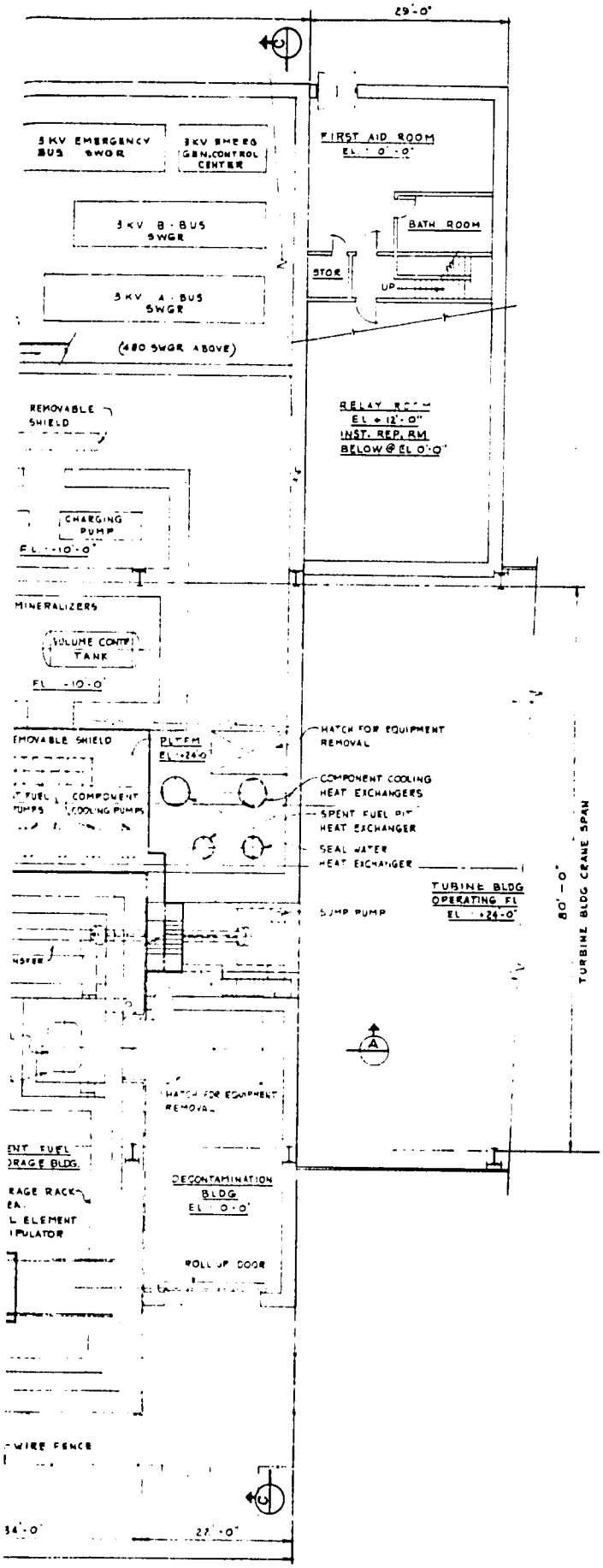
PWR REACTOR BUILDING
STEEL CONTAINMENT SHEET

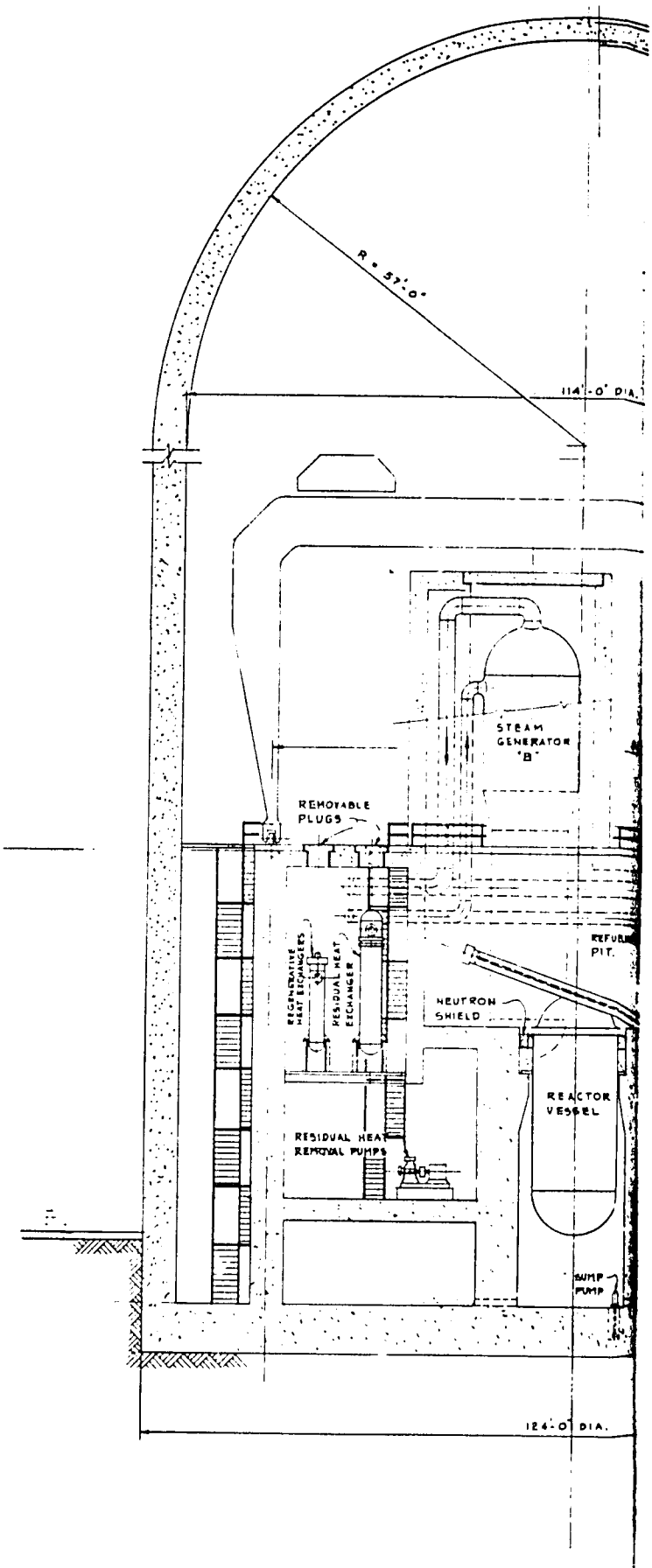
JOB NO 6452 SK-2-A-

2'31

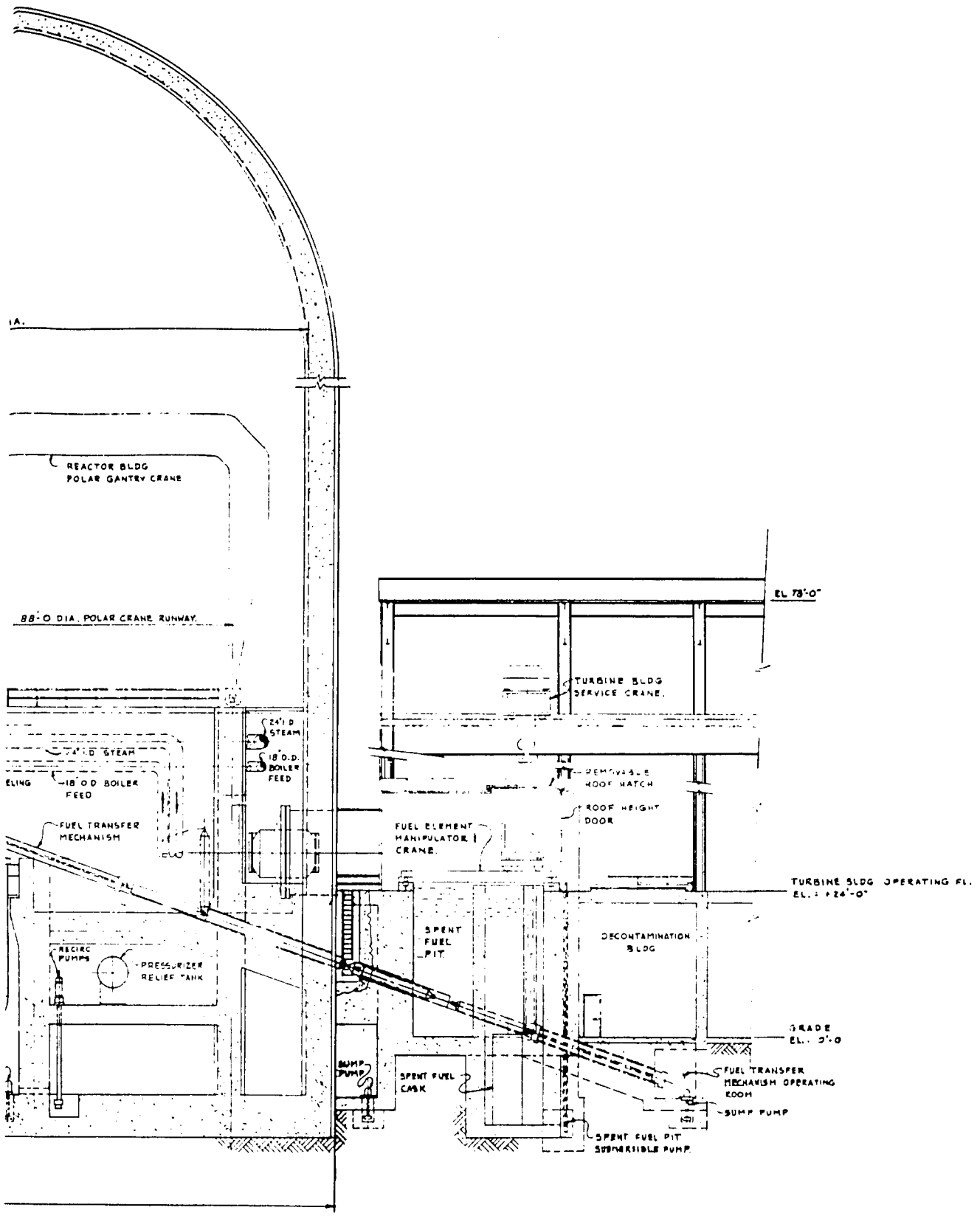


REACTOR AND AUXILIARY BLDG. COMPOSITE PLANS


29'-0"
3 KV EMERGENCY BUS SWGR
3 KV EMERG GEN. CONTROL CENTER
FIRST AID ROOM
EL. 0'-0"
3 KV B-BUS SWGR
BATH ROOM
STOR
UP
3 KV A-BUS SWGR
(480 SWGR ABOVE)
REMOVABLE SHIELD
RELAY ROOM
EL. +12'-0"
INST. REP. RM
BELOW @ EL 0'-0"
CHARGING PUMP
EL. -10'-0"
MINERALIZERS
VOLUME CONTROL TANK
EL. -10'-0"
REMOVABLE SHIELD
PLENUM
EL. +24'-0"
HATCH FOR EQUIPMENT REMOVAL
COMPONENT COOLING HEAT EXCHANGERS
SPENT FUEL PIT HEAT EXCHANGER
SEAL WATER HEAT EXCHANGER
COMPONENT COOLING PUMPS
TURBINE BLDG OPERATING FL
EL. +24'-0"
SUMP PUMP
80'-0"
TURBINE BLDG CRANE SPAN
A
HATCH FOR EQUIPMENT REMOVAL
DECONTAMINATION BLDG
EL. 0'-0"
ROLL UP DOOR
WIRE FENCE
34'-0"
27'-0"


R = 57'-0"
114'-0" DIA.
STEAM GENERATOR "B"
REMOVABLE PLUGS
REGENERATIVE HEAT EXCHANGERS
RESIDUAL HEAT EXCHANGER
NEUTRON SHIELD
REFUEL PIT.
REACTOR VESSEL
RESIDUAL HEAT REMOVAL PUMPS
SUMP PUMP
124'-0" DIA.

SECTION



N

1/8" = 1'-0"

FIGURE 19

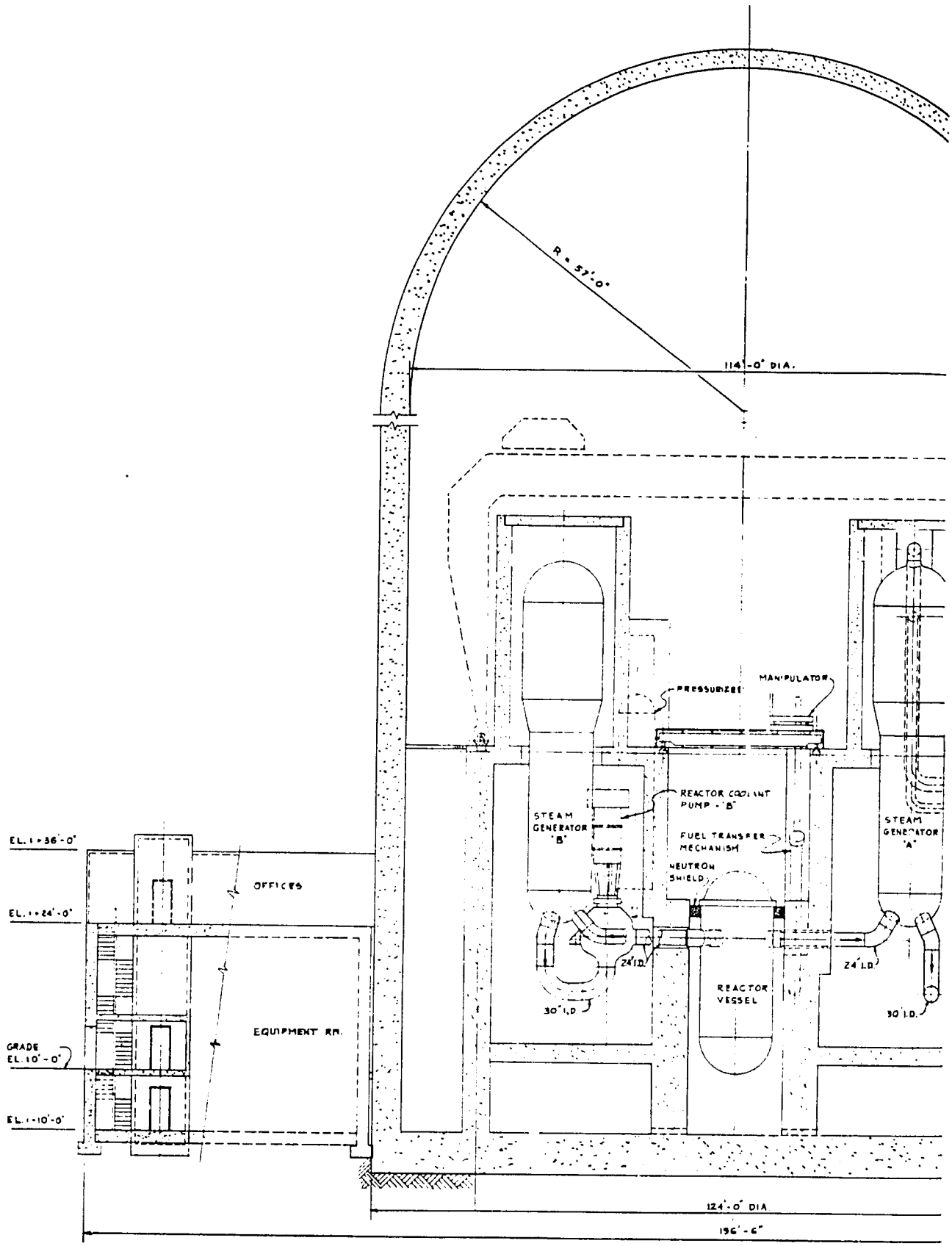
KAISER ENGINEERS

FOR

U.S.-ISRAEL JOINT BOARD

PWR REACTOR BUILDING
CONCRETE CONTAINMENT SHEET-1

6452 SK-2-A-03



SECTION B

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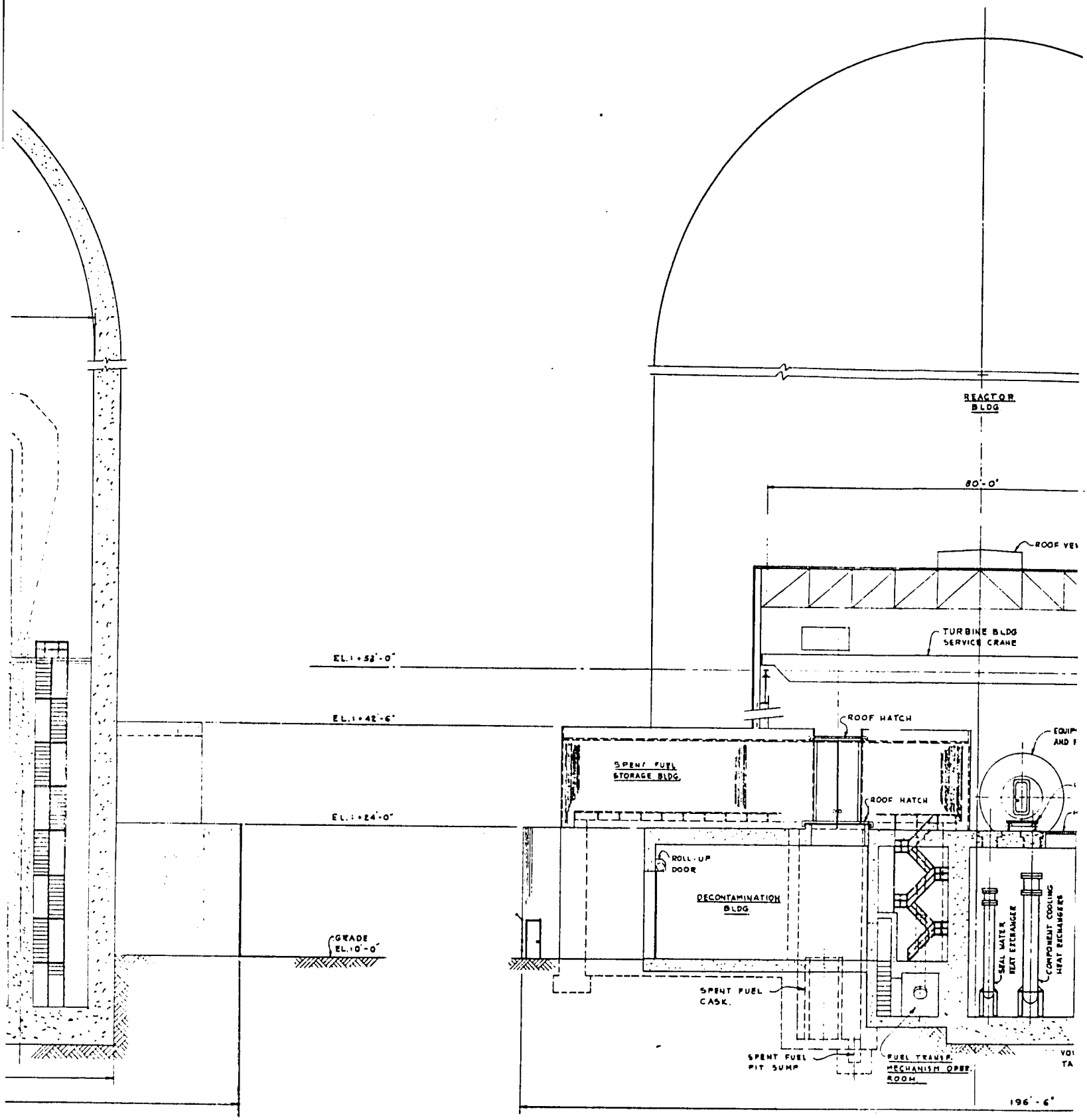
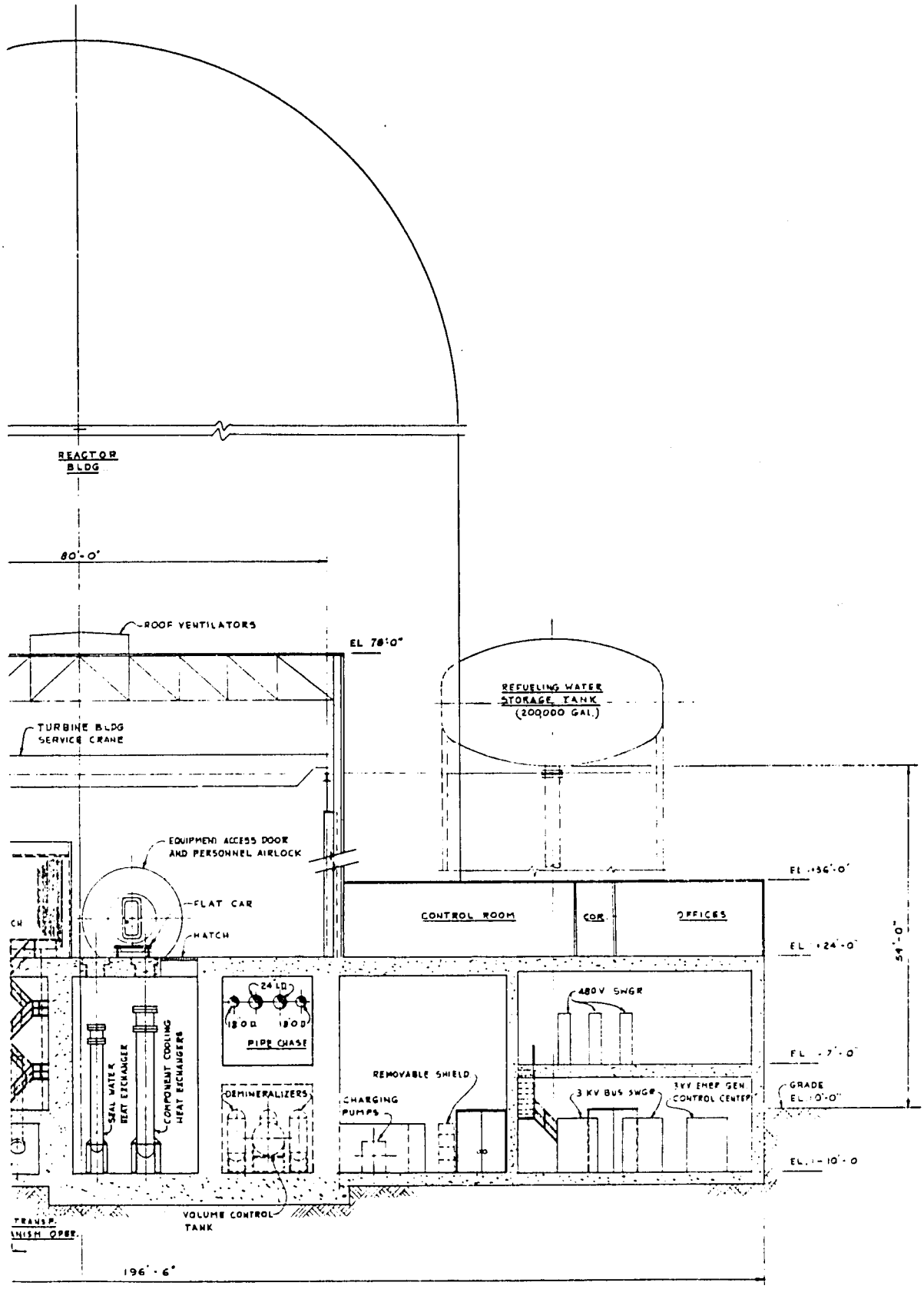

REACTOR BLDG
80'-0"
ROOF VE
TURBINE BLDG SERVICE CRANE
EL. +52'-0"
EL. +42'-6"
ROOF HATCH
EQUIP AND
SPENT FUEL STORAGE BLDG.
ROOF HATCH
EL. +24'-0"
ROLL-UP DOOR
DECONTAMINATION BLDG.
SEAL WATER HEAT EXCHANGER
COMPONENT COOLING HEAT EXCHANGERS
GRADE EL. 10'-0"
SPENT FUEL CASK.
SPENT FUEL PIT SUMP
FUEL TRANSP. MECHANISM OPER. ROOM
VO
TA
196'-6"

SECTION ⊕



SECTION Ⓒ

1/8" = 1'-0"

FIGURE 20

APPROVAL	DATE	SCALE 1/8" = 1'-0"	KAISER ENGINEERS OAKLAND, CALIFORNIA
		DRAWN BY	FOR
		CHECKED BY	U. S. - ISRAEL JOINT BOARD
		APPROVED BY	PWR REACTOR BUILDING CONCRETE CONTAINMENT SHEET 2
			JOB NO 6452 — DWG NO SK-2-A-04

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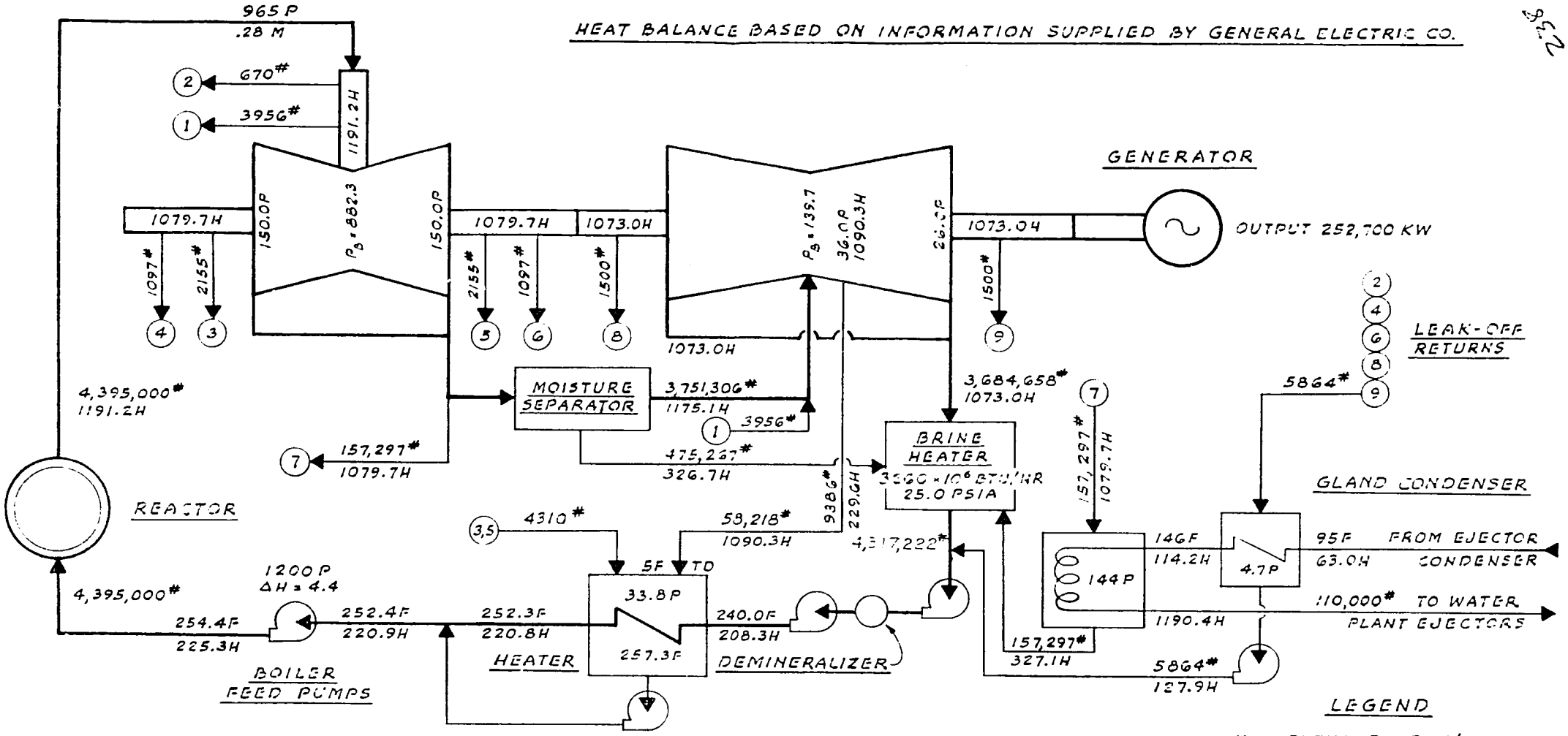
HEAT BALANCE BASED ON INFORMATION SUPPLIED BY GENERAL ELECTRIC CO.



TURBINE-GENERATOR DATA

GROSS GENERATION	252,700 KW
POWER PLANT AUXILIARIES	13,800 KW
WATER PLANT AUXILIARIES	35,400 KW
ALLOWANCE FOR LIGHTING, VENTILATION, ETC.	1,700 KW
NET SALEABLE POWER	201,800 KW
REACTOR SIZE	1244 MWt

252,700 KW @ 26.0 PSIA BACK PRESS. 0% MAKE-UP
TCDF 3600 RPM, 965 PSIA 0.28% MOISTURE
GEN: 320,000 KVA @ 45 PSIG H_2 PRESS. & 0.85 PF (LIQ)

LEGEND

H = ENTHALPY, BTU/LB
# = FLOW, LB/HR
P = PRESSURE, PSIA
F = TEMPERATURE, F DEGREE
M = MOISTURE, %

The above heat balance shows a net salable power of 201.8 MWt. To adjust the net salable power to 200 MWt while retaining the heat to the brine heater at the value shown, namely 3,260 x 10^6 BTU/hr., it is necessary to adjust the final feedwater temperature which in turn requires obtaining from the manufacturer additional information on extraction points.

FIGURE 21

APPROVAL	DATE	SCALE NONE
		DRAWN BY M.S. DATE 1/24/66
		CHECKED BY DATE 1/26/66
		APPROVED DATE 1/21/66

KAISER ENGINEERS
OAKLAND, CALIFORNIA

FOR

U. S. - ISRAEL JOINT BOARD

BWR HEAT BALANCE

JOB NO. 6452 DWG. NO

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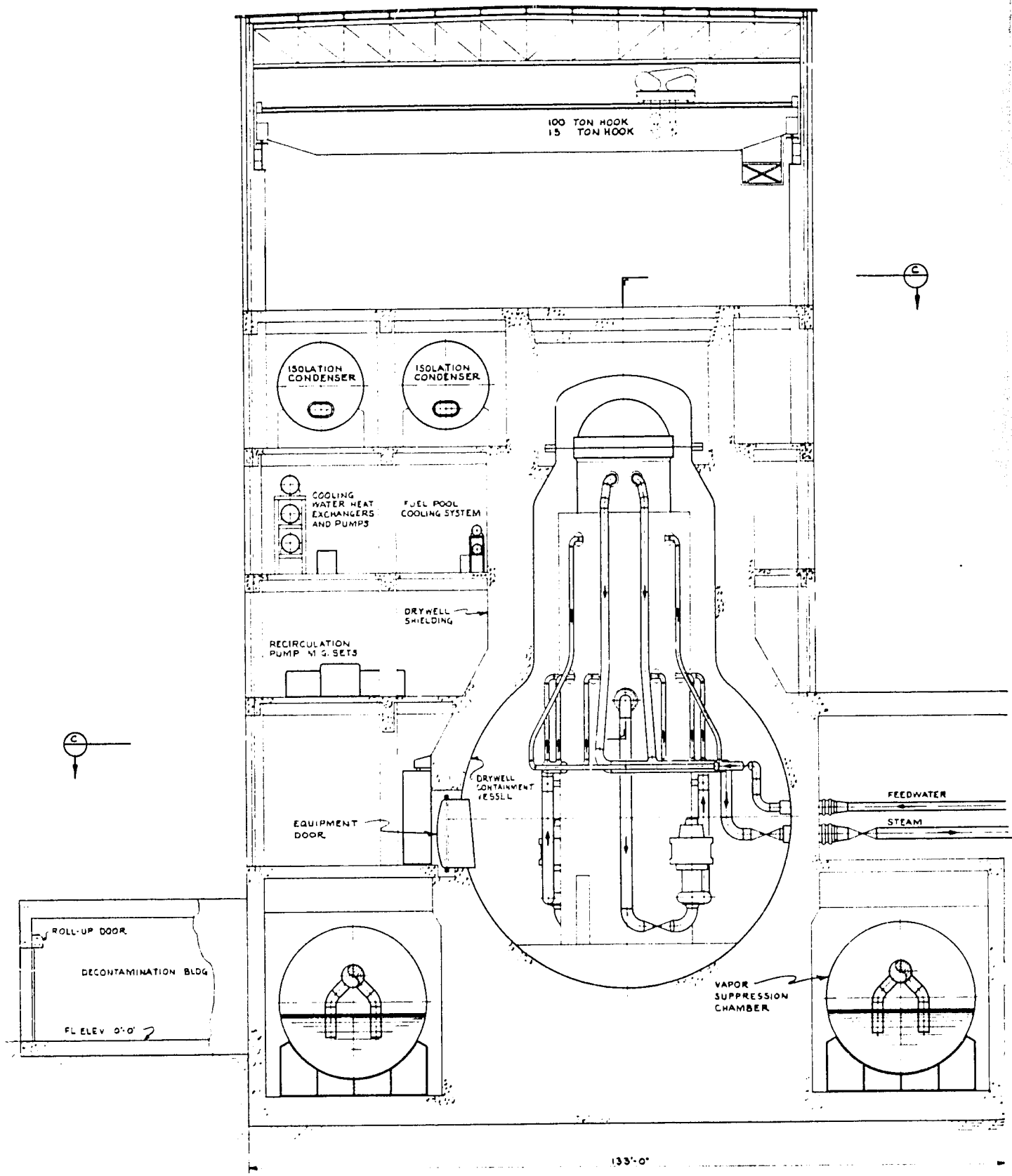
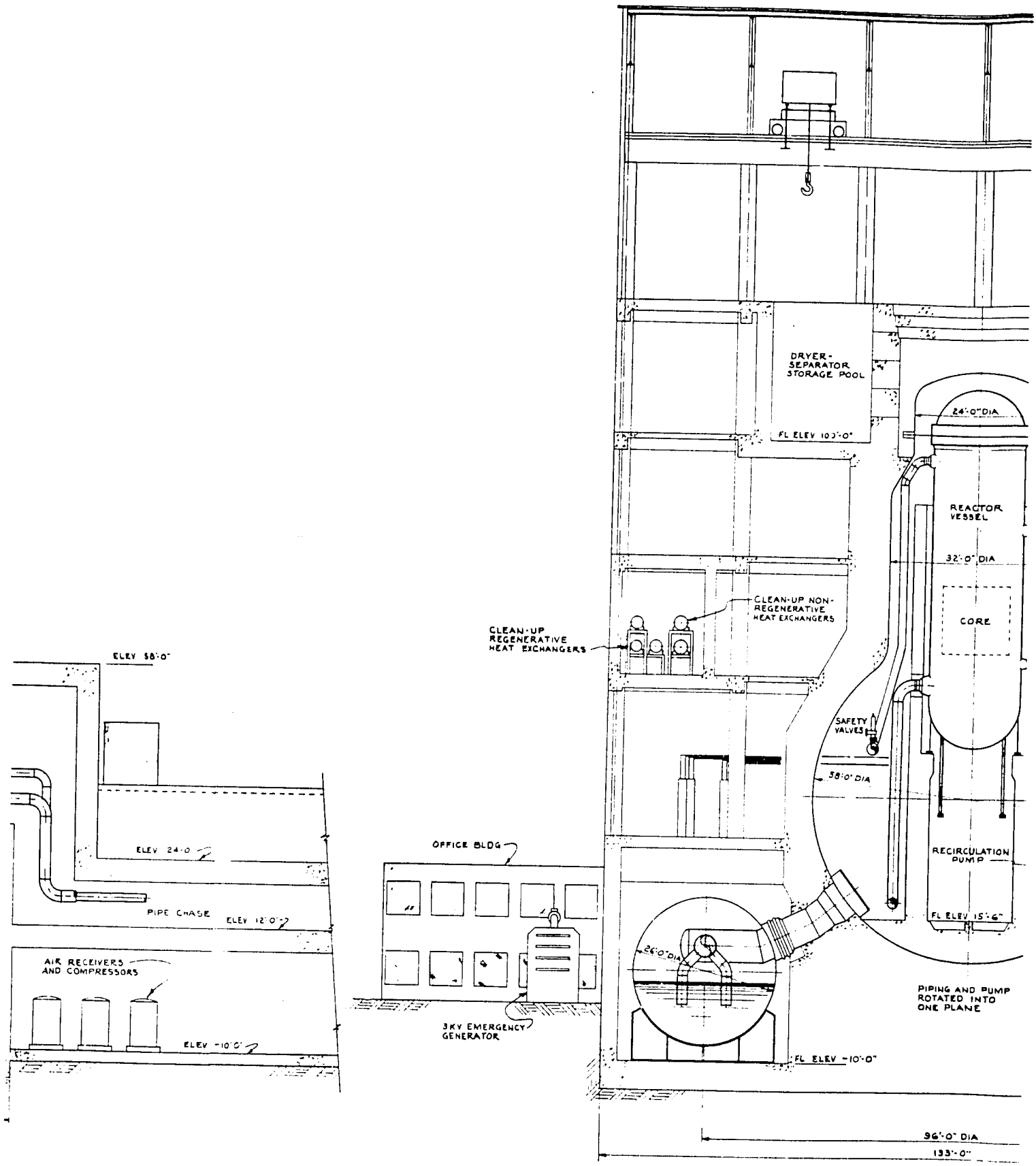


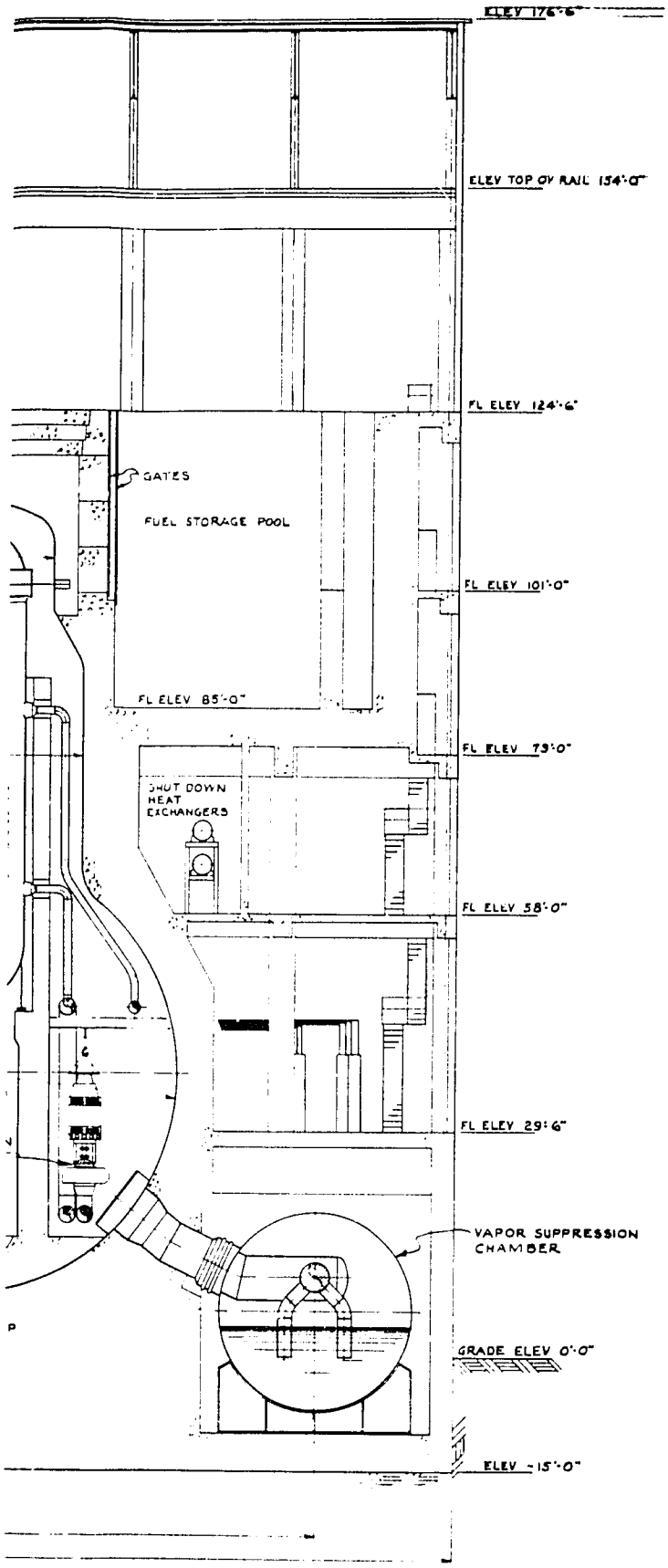
SECTION (A)

239



SECTION B

240

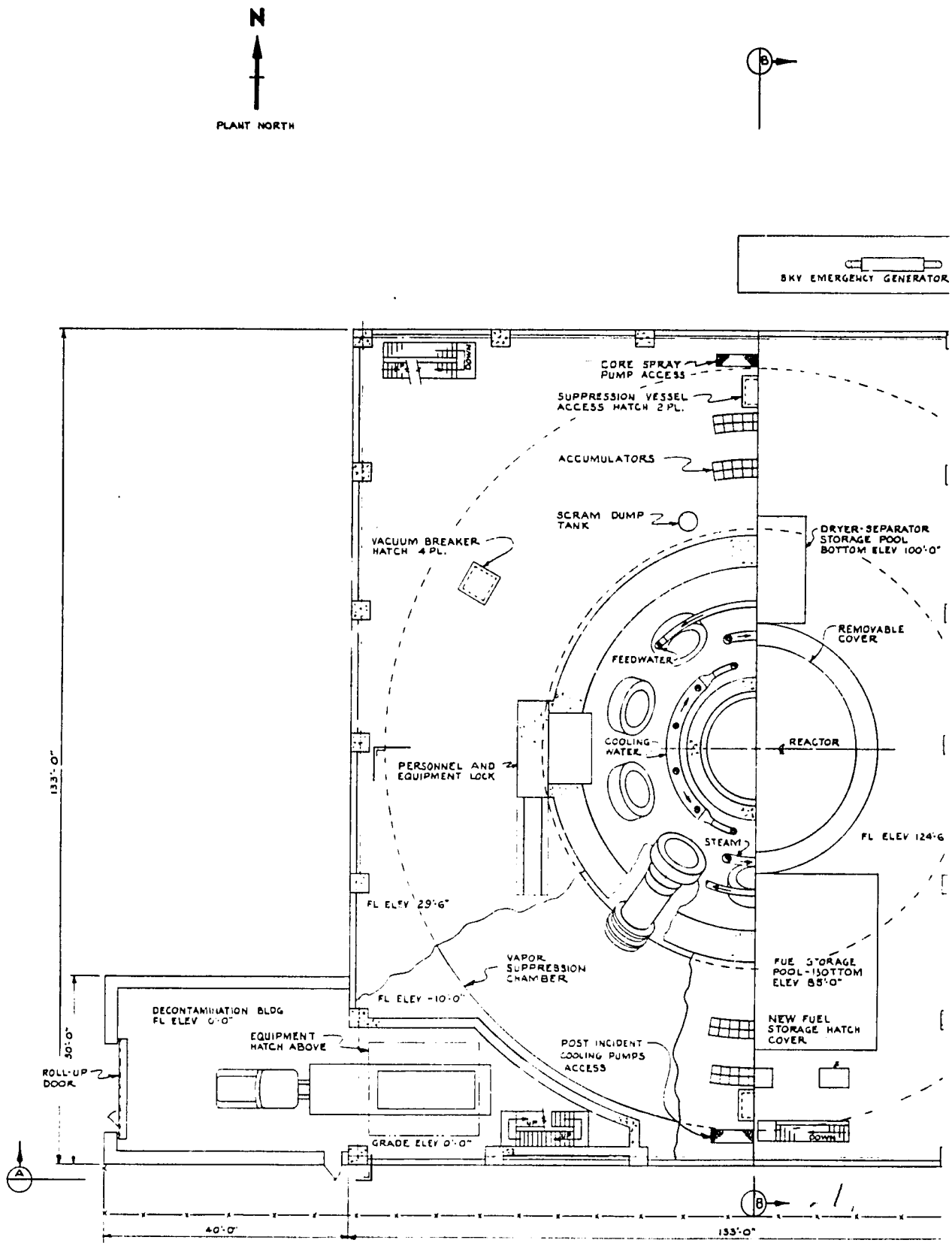


1/8" = 1'-0" 5' 0' 5' 10' 15'

B

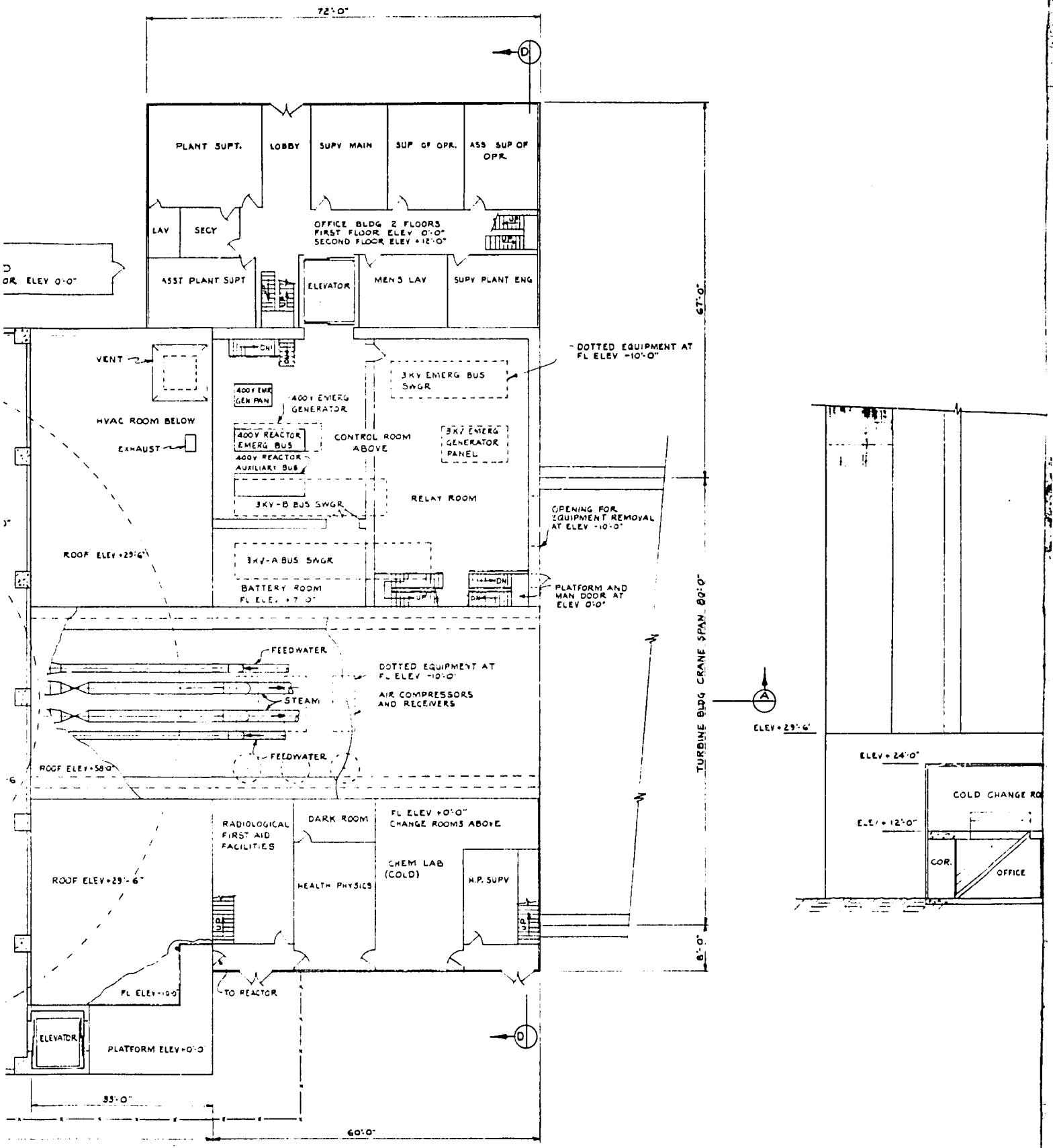
FIGURE 22

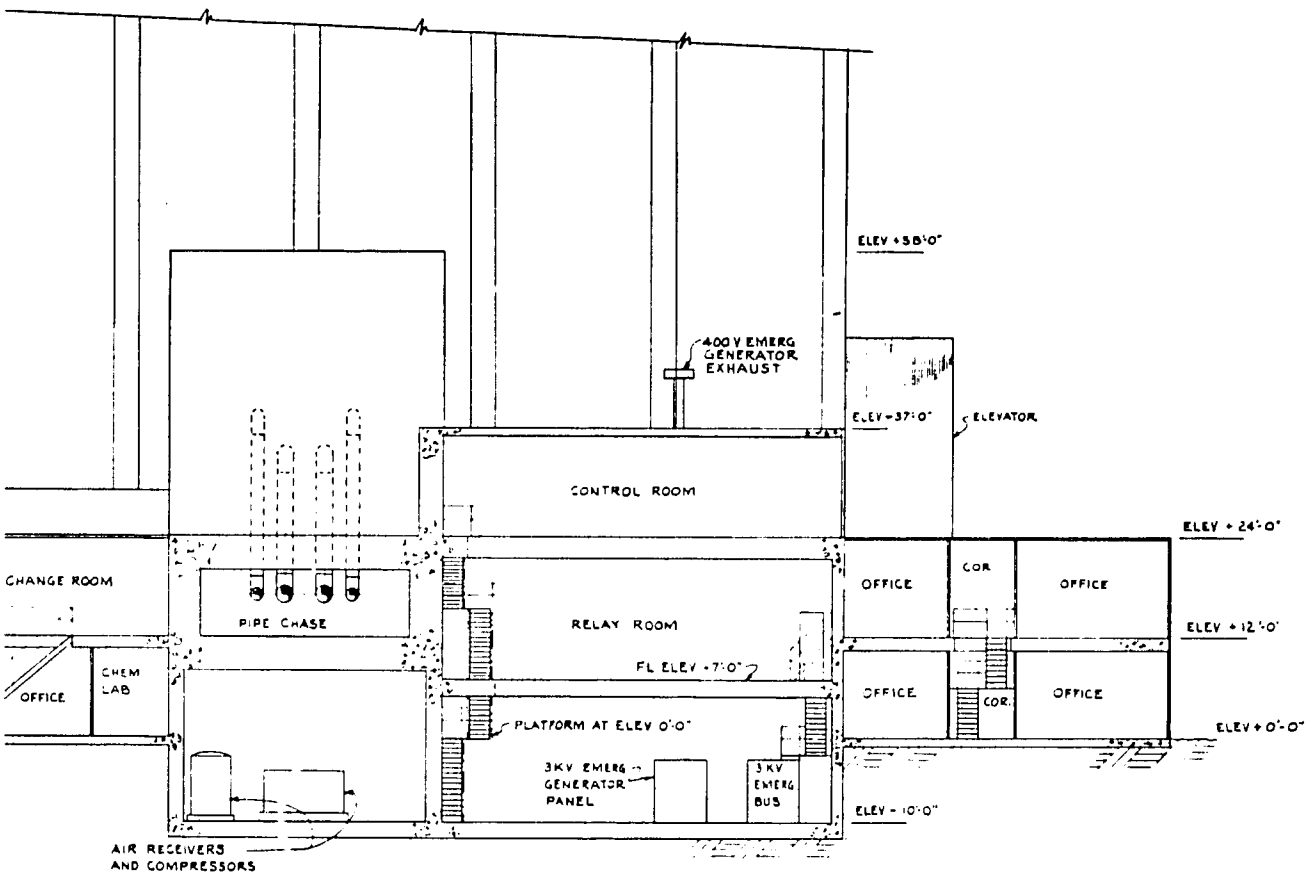
APPROVAL / DATE / SCALE 1/8" = 1'-0"	KAISER ENGINEERS OAKLAND, CALIFORNIA	
	U. S. - ISRAEL JOINT BOARD	
	BWR REACTOR BUILDING AND OFFICES - SHEET 1	
THIS DRAWING IS THE PROPERTY OF KAISER ENGINEERS AND IS NOT TO BE COPIED OR USED WITHOUT PERMISSION	JOB NO 6452	DWG NO SK-2-A-05



SECTION C

242


72'-0"
PLANT SUPT.
LOBBY
SUPV MAIN
SUP OF OPR.
ASS SUP OF OPR.
LAV
SECY
OFFICE BLDG 2 FLOORS
FIRST FLOOR ELEV 0'-0"
SECOND FLOOR ELEV +12'-0"
ASST PLANT SUPT
ELEVATOR
MEN'S LAV
SUPV PLANT ENG
67'-0"
VENT
DOTTED EQUIPMENT AT FL ELEV -10'-0"
3KV EMERG BUS SWGR
400V EMERG GEN PAN
400V EMERG GENERATOR
HVAC ROOM BELOW
EXHAUST
400V REACTOR EMERG BUS
400V REACTOR AUXILIARY BUS
CONTROL ROOM ABOVE
3KV EMERG GENERATOR PANEL
RELAY ROOM
3KV-B BUS SWGR
OPENING FOR EQUIPMENT REMOVAL AT ELEV -10'-0"
ROOF ELEV +29'-6"
3KV-A BUS SWGR
BATTERY ROOM
FL ELEV +7'-0"
PLATFORM AND MAN DOOR AT ELEV 0'-0"
FEEDWATER
DOTTED EQUIPMENT AT FL ELEV -10'-0"
STEAM
AIR COMPRESSORS AND RECEIVERS
FEEDWATER
ROOF ELEV +58'-0"
TURBINE BLDG CRANE SPAN 80'-0"
ELEV +29'-6"
ELEV +24'-0"
COLD CHANGE RO
ELEV +12'-0"
COR.
OFFICE
RADIOLOGICAL FIRST AID FACILITIES
DARK ROOM
FL ELEV +0'-0" CHANGE ROOMS ABOVE
CHEM LAB (COLD)
H.P. SUPV
HEALTH PHYSICS
ROOF ELEV +29'-6"
8'-0"
FL ELEV +10'-0"
TO REACTOR
ELEVATOR
PLATFORM ELEV +0'-0
33'-0"
60'-0"



SECTION D

1/8" = 1'-0" 5' 0' 5' 10' 15'

FIGURE 23

APPROVAL	DATE	SCALE 1/8" = 1'-0"
		DRAWN BY
		CHECKED BY
		APPROVED

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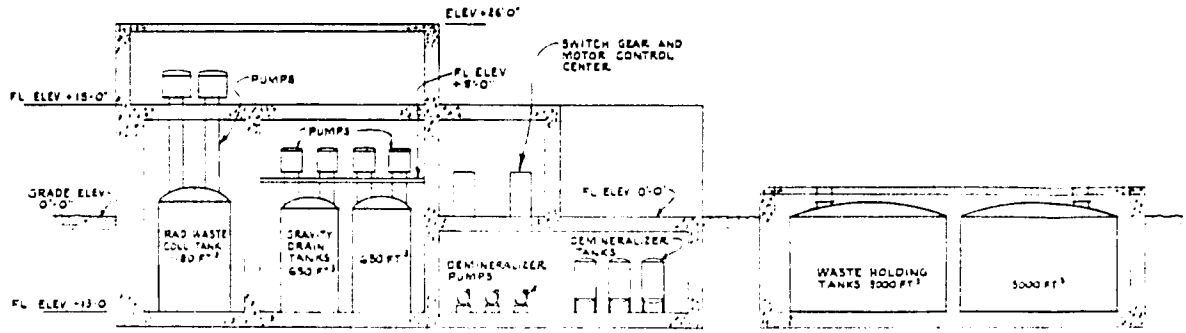
KAISER ENGINEERS
OAKLAND, CALIFORNIA

FOR

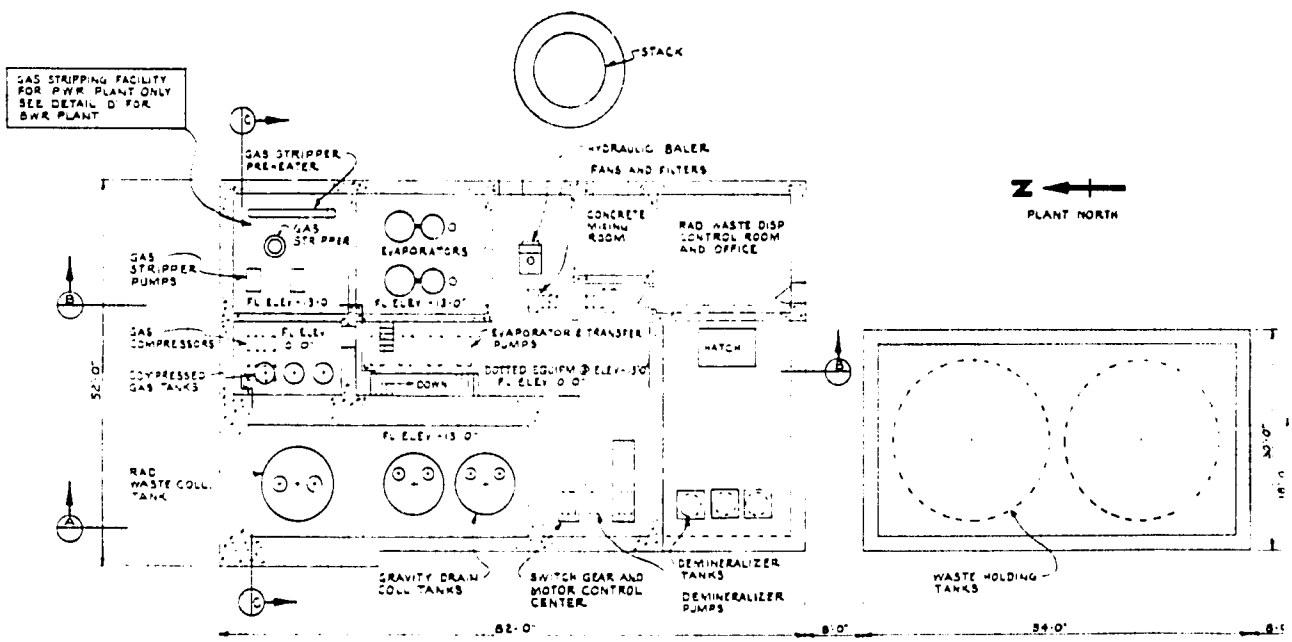
U. S. - ISRAEL JOINT BOARD

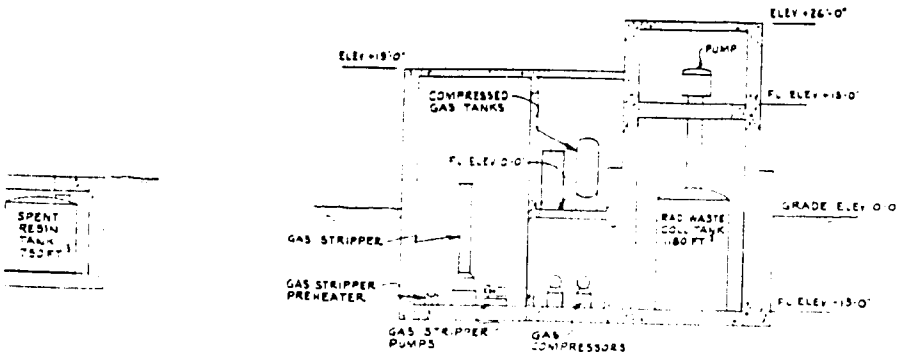
BWR REACTOR BUILDING AND OFFICES-SHEET 2

JOB NO 6452 DWG NO SK-2-A-06

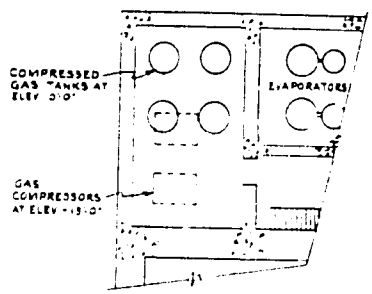

ELEV +26'-0"
SWITCH GEAR AND MOTOR CONTROL CENTER
PUMPS
FL ELEV +8'-0"
FL ELEV +15'-0"
PUMPS
GRADE ELEV 0'-0"
FL ELEV 0'-0"
RAD WASTE COLL TANK 80 FT³
GRAVITY DRAIN TANKS 650 FT³
650 FT³
DEMINERALIZER PUMPS
DEMINERALIZER TANKS
WASTE HOLDING TANKS 5000 FT³
5000 FT³
FL ELEV -13'-0

SECTION


STACK
GAS STRIPPING FACILITY FOR PWR PLANT ONLY SEE DETAIL D FOR BWR PLANT
GAS STRIPPER PRE-HEATER
HYDRAULIC BALER
FANS AND FILTERS
N
PLANT NORTH
GAS STRIPPER
EVAPORATORS
CONCRETE MIXING ROOM
RAD WASTE DISP CONTROL ROOM AND OFFICE
GAS STRIPPER PUMPS
FL ELEV -3'-0
FL ELEV -13'-0"
GAS COMPRESSORS
FL ELEV 0'-0"
EVAPORATOR & TRANSFER PUMPS
HATCH
COMPRESSED GAS TANKS
DOWN
DOTTED EQUIPM @ ELEV -30'
FL ELEV 0'-0"
52'-0"
FL ELEV -13'-0"
RAD WASTE COLL. TANK
GRAVITY DRAIN COLL TANKS
SWITCH GEAR AND MOTOR CONTROL CENTER
DEMINERALIZER TANKS
DEMINERALIZER PUMPS
WASTE HOLDING TANKS
82'-0"
8'-0"
84'-0"

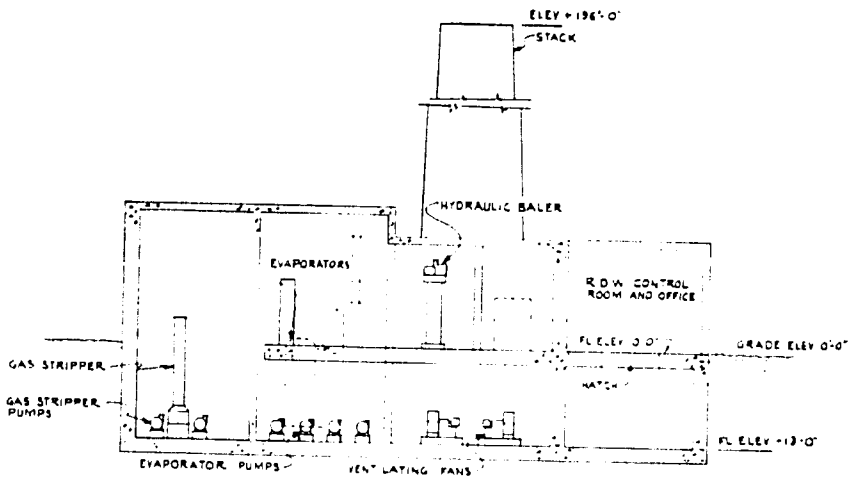


SECTION C



DETAIL D

PLAN DETAIL OF GAS COMPRESSOR AND COMPRESSED GAS TANKS FOR BWR

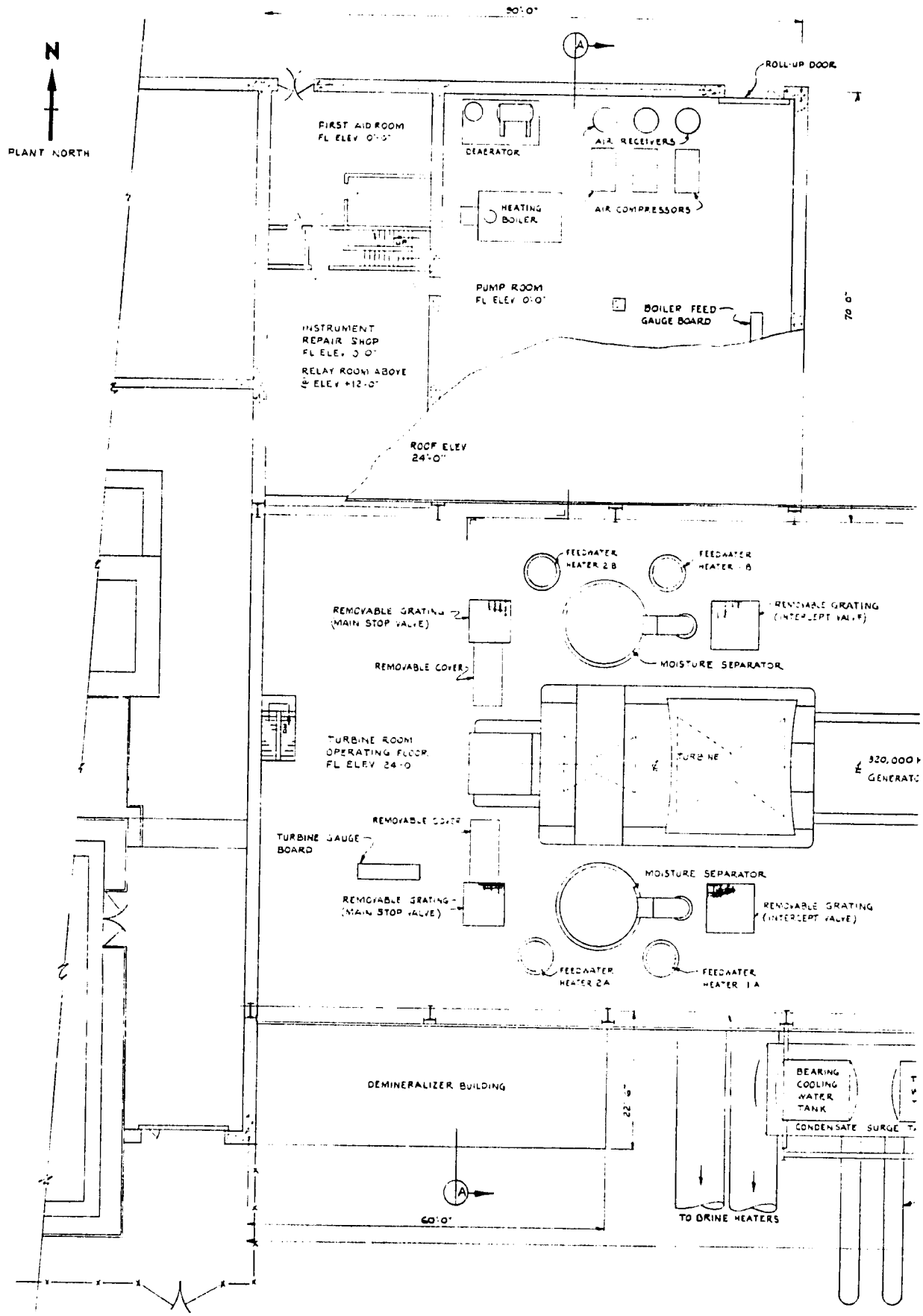


SECTION B

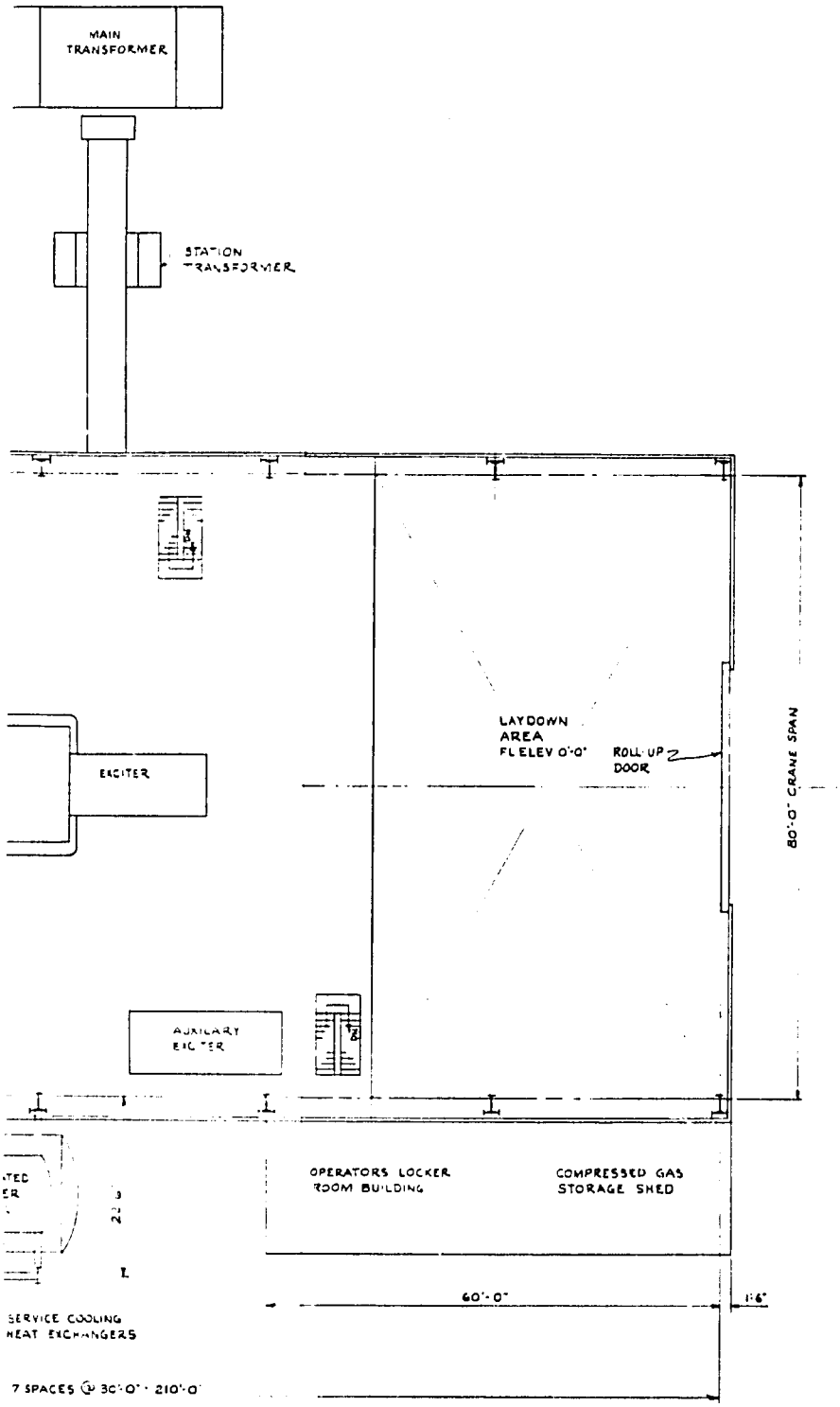
1/8" = 1'-0"

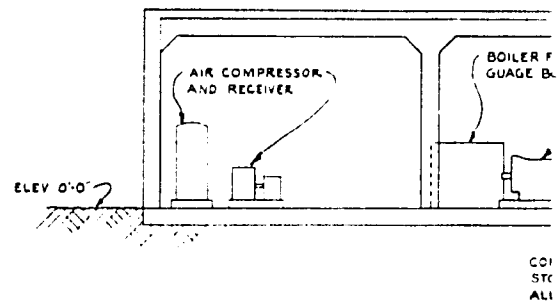
FIGURE 8.6	
KAISER ENGINEERS	
U.S.-ISRAEL JOINT BOARD	
RADIOACTIVE WASTE DISPOSAL BLDG	
8452	SK-2-A-07

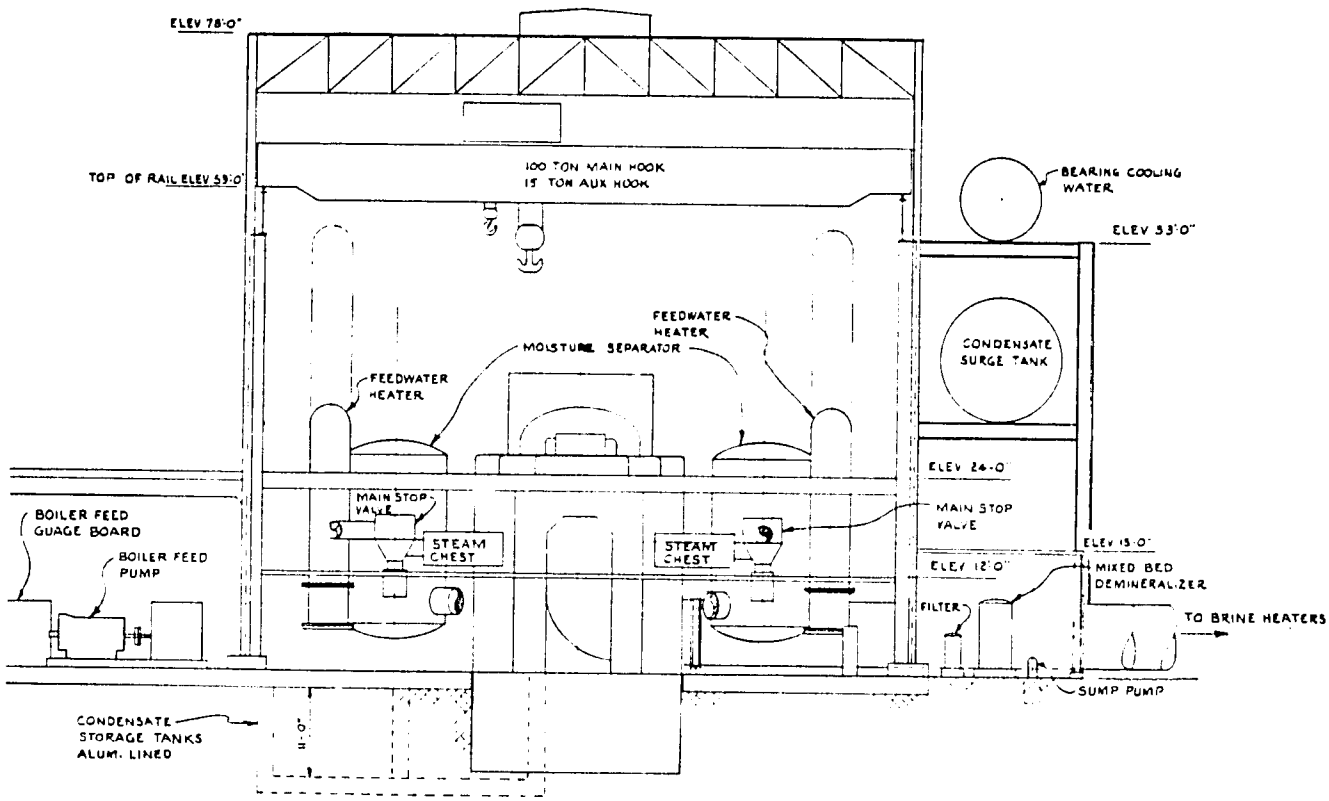
24b


N
PLANT NORTH
50'-0"
ROLL-UP DOOR
FIRST AID ROOM
FL ELEV 0'-0"
DEAERATOR
AIR RECEIVERS
HEATING BOILER
AIR COMPRESSORS
PUMP ROOM
FL ELEV 0'-0"
BOILER FEED GAUGE BOARD
70'-0"
INSTRUMENT REPAIR SHOP
FL ELEV 0'-0"
RELAY ROOM ABOVE
FL ELEV +12'-0"
ROOF ELEV
24'-0"
FEEDWATER HEATER 2B
FEEDWATER HEATER 1B
REMOVABLE GRATING (MAIN STOP VALVE)
REMOVABLE GRATING (INTERCEPT VALVE)
REMOVABLE COVER
MOISTURE SEPARATOR
TURBINE ROOM
OPERATING FLOOR
FL ELEV 24'-0"
TURBINE
320,000
GENERATO
REMOVABLE COVER
TURBINE GAUGE BOARD
MOISTURE SEPARATOR
REMOVABLE GRATING (MAIN STOP VALVE)
REMOVABLE GRATING (INTERCEPT VALVE)
FEEDWATER HEATER 2A
FEEDWATER HEATER 1A
DEMINERALIZER BUILDING
22'-9"
BEARING COOLING WATER TANK
CONDENSATE SURGE
60'-0"
TO DRINE HEATERS

247


MAIN TRANSFORMER
STATION TRANSFORMER
EXCITER
LAYDOWN AREA
FL ELEV 0'-0"
ROLL-UP DOOR
80'-0" CRANE SPAN
AUXILARY EXCITER
OPERATORS LOCKER ROOM BUILDING
COMPRESSED GAS STORAGE SHED
60'-0"
SERVICE COOLING HEAT EXCHANGERS
7 SPACES @ 30'-0" = 210'-0"


AIR COMPRESSOR AND RECEIVER
ELEV 0'-0"



SECTION (A)

1/8" = 1'-0"

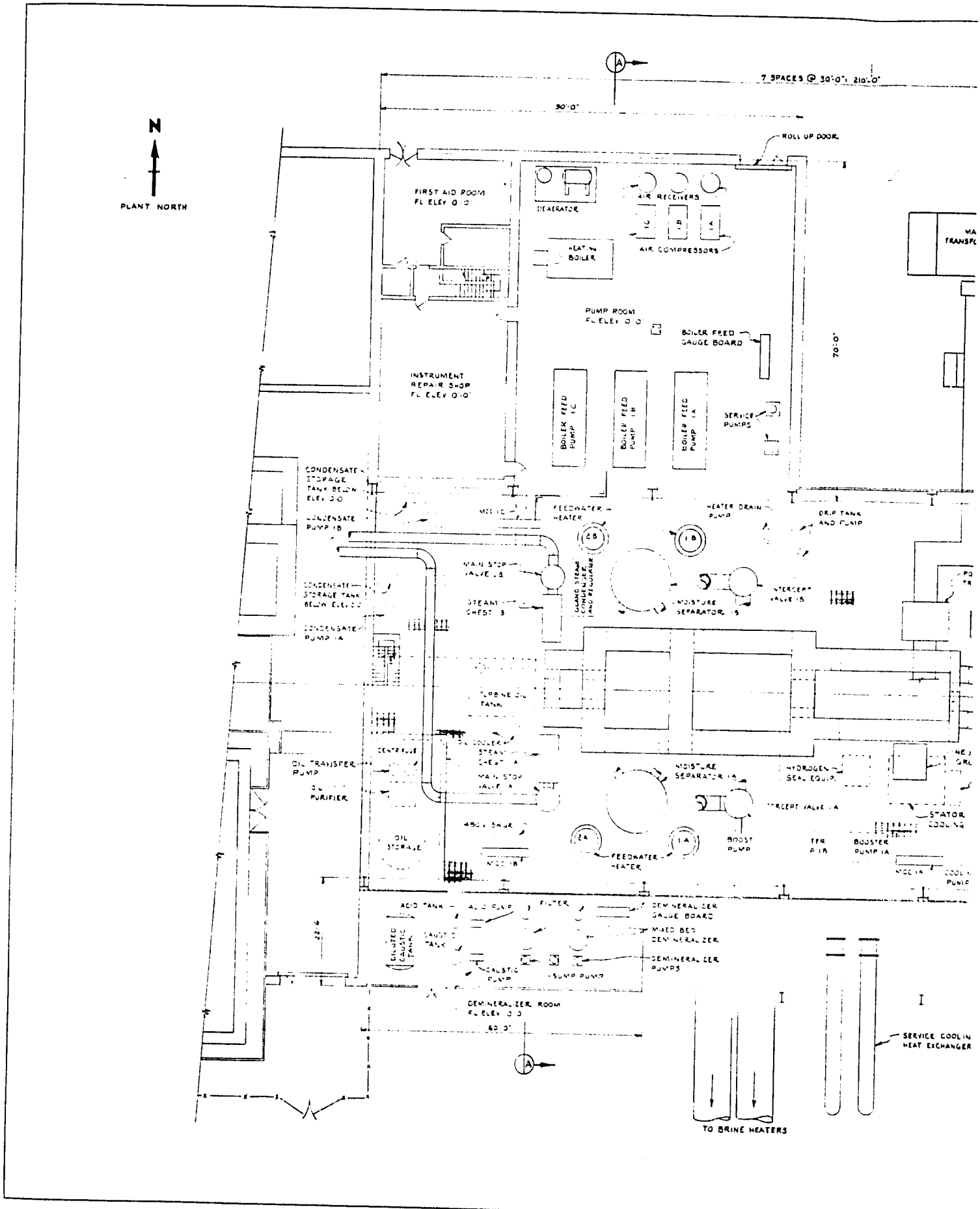
FIGURE 49

KAISER ENGINEERS

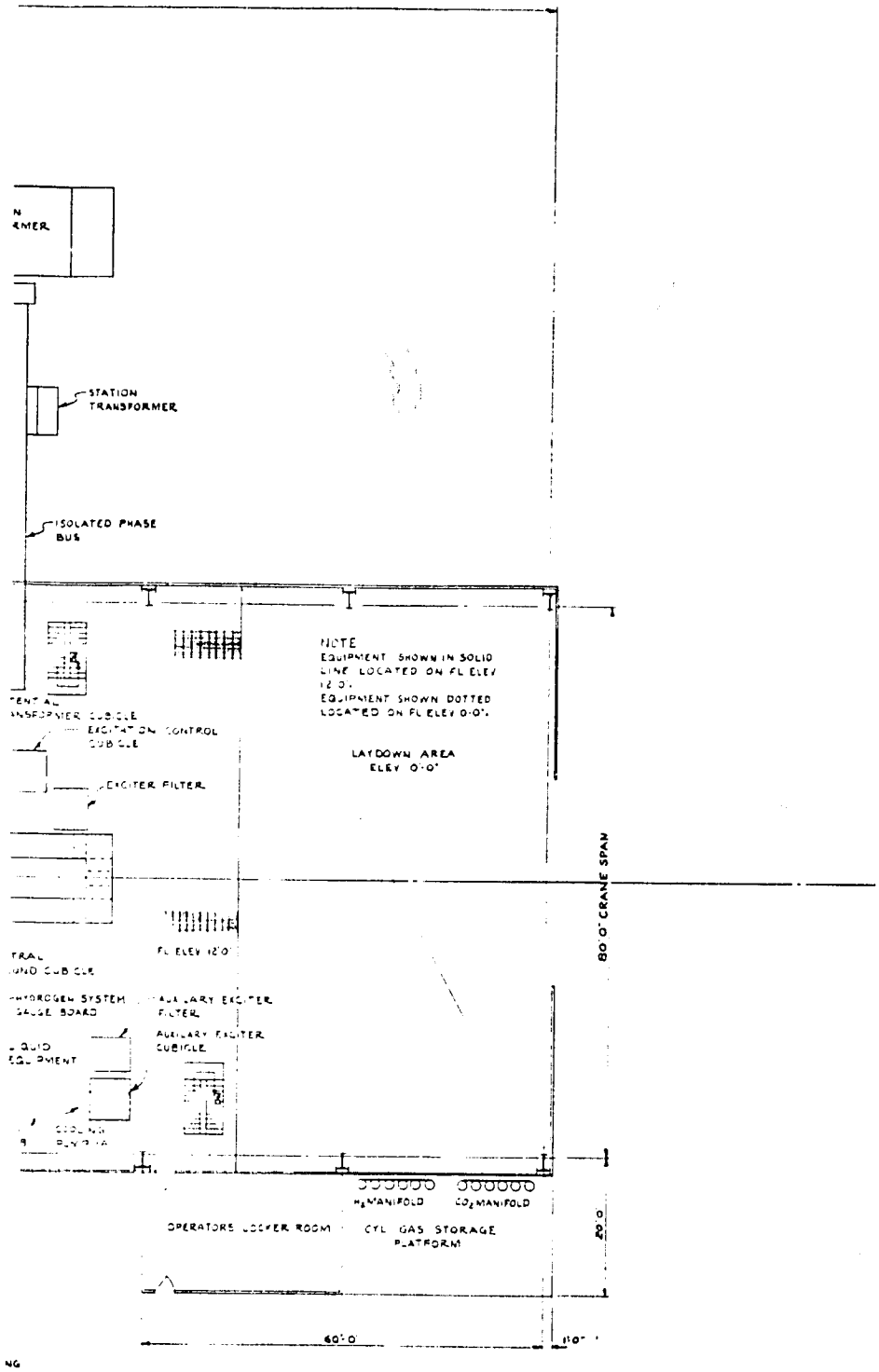
U S - ISRAEL JOINT BOARD

TURBINE ROOM PLAN AT ELEV 24'-0" AND SECTION

6452 SK-3-A-01


N
PLANT NORTH
7 SPACES @ 30'-0" = 210'-0"
90'-0"
ROLL UP DOOR
FIRST AID ROOM
FL ELEV 0'-0"
DEAERATOR
AIR RECEIVERS
AIR COMPRESSORS
HEATING BOILER
PUMP ROOM
FL ELEV 0'-0"
BOILER FEED GAUGE BOARD
70'-0"
INSTRUMENT REPAIR SHOP
FL ELEV 0'-0"
BOILER FEED PUMP 1C
BOILER FEED PUMP 1B
BOILER FEED PUMP 1A
SERVICE PUMPS
CONDENSATE STORAGE TANK BELOW ELEV 0'-0"
CONDENSATE PUMP 1B
FEEDWATER HEATER
HEATER DRAIN PUMP
DRIP TANK AND PUMP
MAIN STOP VALVE 2B
STEAM CHEST 2B
GLAND STEAM CONDENSER AND REGULATOR
MOISTURE SEPARATOR 1B
INTERCEPT VALVE 1B
CONDENSATE STORAGE TANK BELOW ELEV 0'-0"
CONDENSATE PUMP 1A
TURBINE OIL TANK
CENTRIFUGE
OIL TRANSFER PUMP
OIL PURIFIER
OIL COOLER
STEAM CHEST 1A
MAIN STOP VALVE 1A
MOISTURE SEPARATOR 1A
HYDROGEN SEAL EQUIP.
INTERCEPT VALVE 1A
STATOR COOLING
OIL STORAGE
FEEDWATER HEATER
BOOST PUMP
BOOSTER PUMP 1A
ACID TANK
ACID PUMP
FILTER
DEMINERALIZER GAUGE BOARD
MIXED BED DEMINERALIZER
DILUTED CAUSTIC TANK
CAUSTIC TANK
CAUSTIC PUMP
SUMP PUMP
DEMINERALIZER PUMPS
DEMINERALIZER ROOM
FL ELEV 0'-0"
60'-0"
SERVICE COOLING HEAT EXCHANGER
TO BRINE HEATERS

250



1/8" = 1'-0"

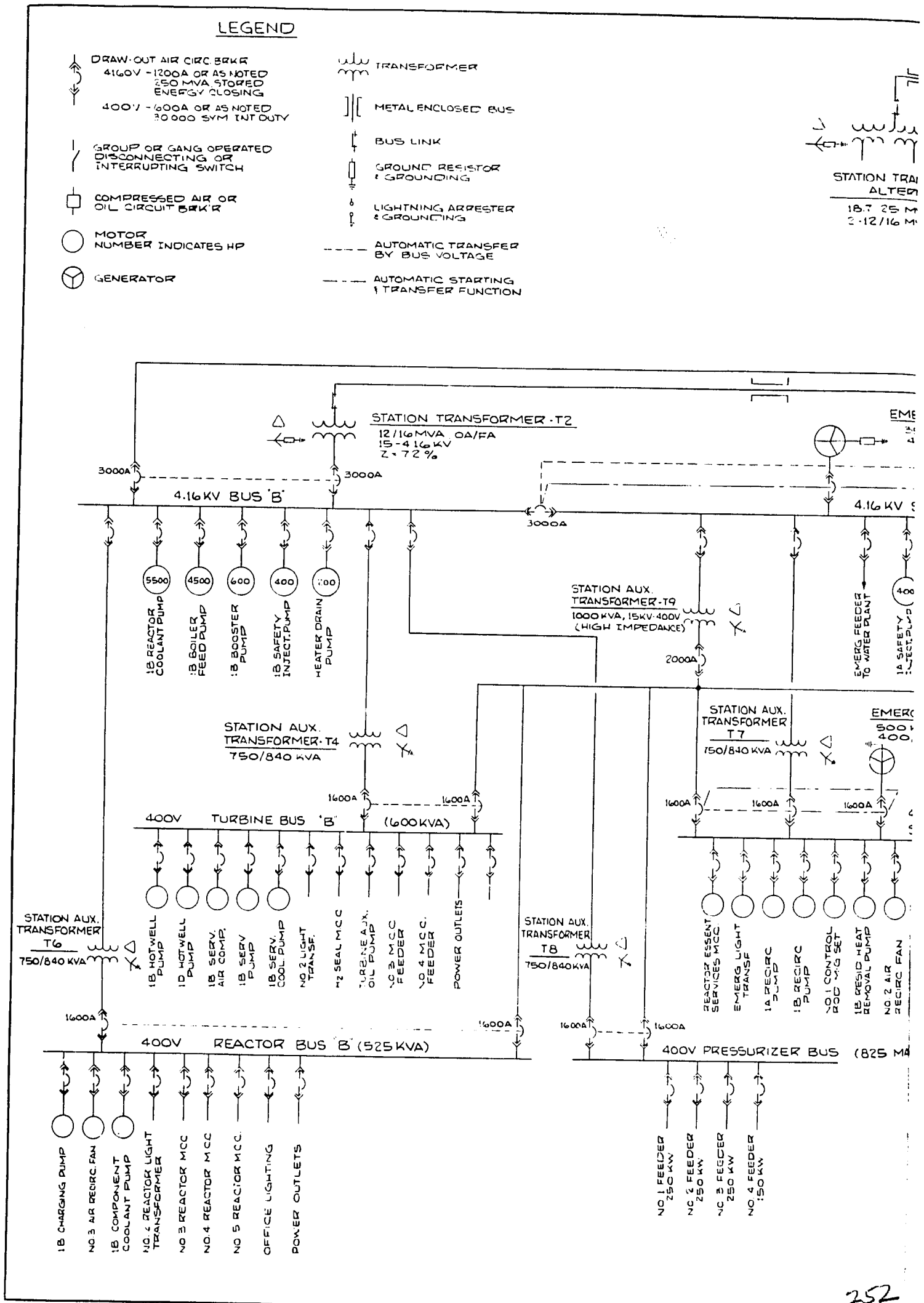
FIGURE 26

KAISER ENGINEERS

U.S.-ISRAEL JOINT BOARD

TURBINE ROOM PLAN AT ELEV 12' AND ELEV 0'

6452 SK-5-A-02


LEGEND
DRAW-OUT AIR CIRC. BRKR
4160V - 1200A OR AS NOTED
250 MVA STORED ENERGY CLOSING
400V - 600A OR AS NOTED
30 000 SYM INT DUTY
GROUP OR GANG OPERATED DISCONNECTING OR INTERRUPTING SWITCH
COMPRESSED AIR OR OIL CIRCUIT BRK'R
MOTOR
NUMBER INDICATES HP
GENERATOR
TRANSFORMER
METAL ENCLOSED BUS
BUS LINK
GROUND RESISTOR & GROUNDING
LIGHTNING ARRESTER & GROUNDING
AUTOMATIC TRANSFER BY BUS VOLTAGE
AUTOMATIC STARTING & TRANSFER FUNCTION
STATION TRANSFORMER-T2
12/16 MVA OA/FA
15-4.16 KV
Z = 7.2 %
3000A
4.16 KV BUS 'B'
5500
4500
600
400
1B REACTOR COOLANT PUMP
1B BOILER FEED PUMP
1B BOOSTER PUMP
1B SAFETY INJECT. PUMP
HEATER DRAIN PUMP
STATION AUX. TRANSFORMER-T9
1000 KVA, 15KV-400V
(HIGH IMPEDANCE)
2000A
EMERG FEEDER TO WATER PLANT
STATION AUX. TRANSFORMER-T4
750/840 KVA
1600A
400V TURBINE BUS 'B' (600 KVA)
STATION AUX. TRANSFORMER T7
750/840 KVA
STATION AUX. TRANSFORMER T6
750/840 KVA
1B HOTWELL PUMP
1D HOTWELL PUMP
1B SERV. AIR COMP.
1B SERV PUMP
1B SERV. COOL. PUMP
NO 2 LIGHT TRANSF.
H2 SEAL MCC
TURBINE AUX. OIL PUMP
NO 3 MCC FEEDER
NO 4 MCC FEEDER
POWER OUTLETS
STATION AUX. TRANSFORMER T8
750/840 KVA
REACTOR ESSENT SERVICES MCC
EMERG LIGHT TRANSF
1A RECIRC PUMP
1B RECIRC PUMP
NO 1 CONTROL ROD M-G SET
1B RESID HEAT REMOVAL PUMP
NO 2 AIR RECIRC FAN
400V REACTOR BUS 'B' (525 KVA)
400V PRESSURIZER BUS
1B CHARGING PUMP
NO 3 AIR RECIRC. FAN
1B COMPONENT COOLANT PUMP
NO. 2 REACTOR LIGHT TRANSFORMER
NO 3 REACTOR MCC
NO. 4 REACTOR MCC
NO 5 REACTOR MCC
OFFICE LIGHTING
POWER OUTLETS
NO 1 FEEDER 250 KW
NO 2 FEEDER 250 KW
NO 3 FEEDER 250 KW
NO 4 FEEDER 250 KW

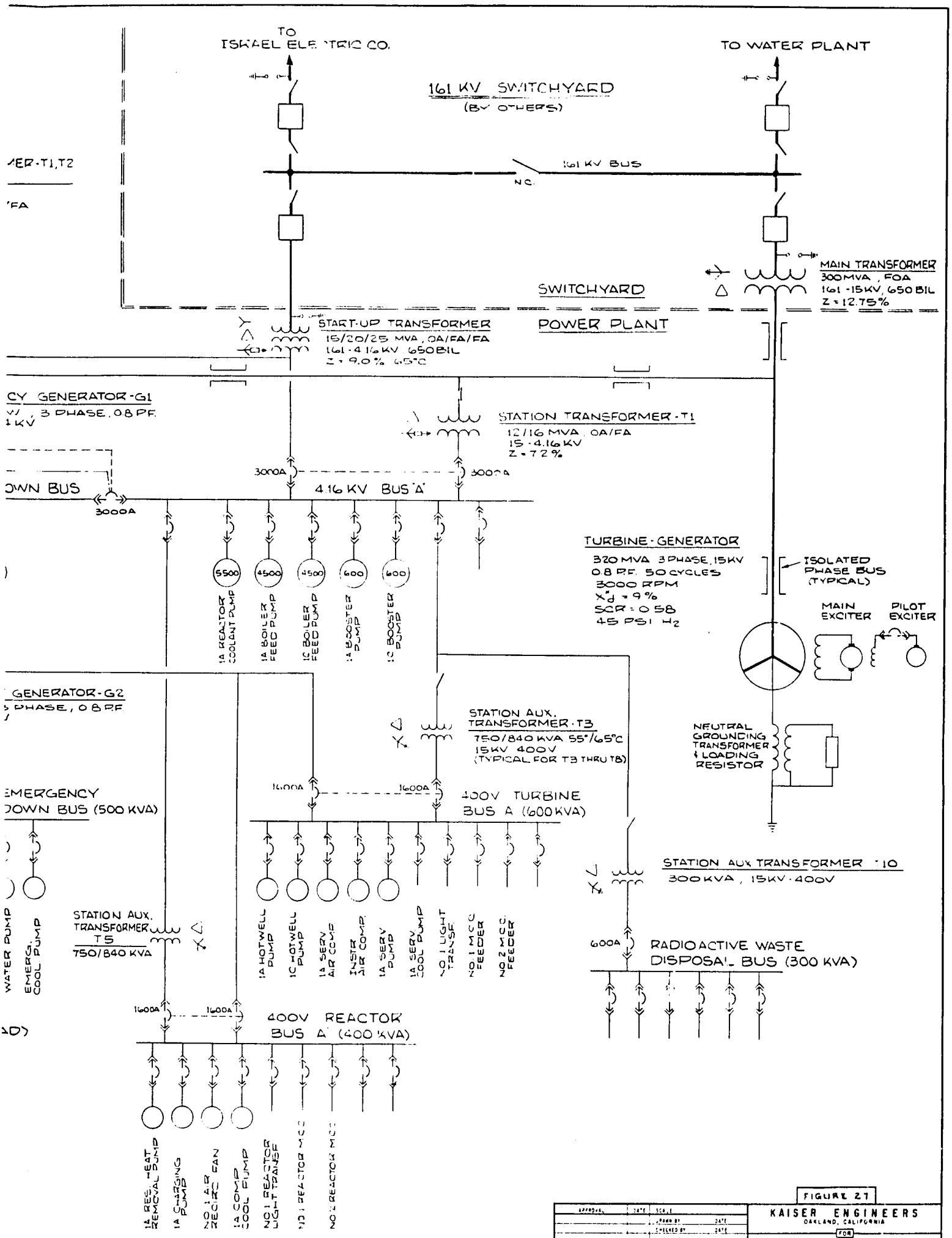
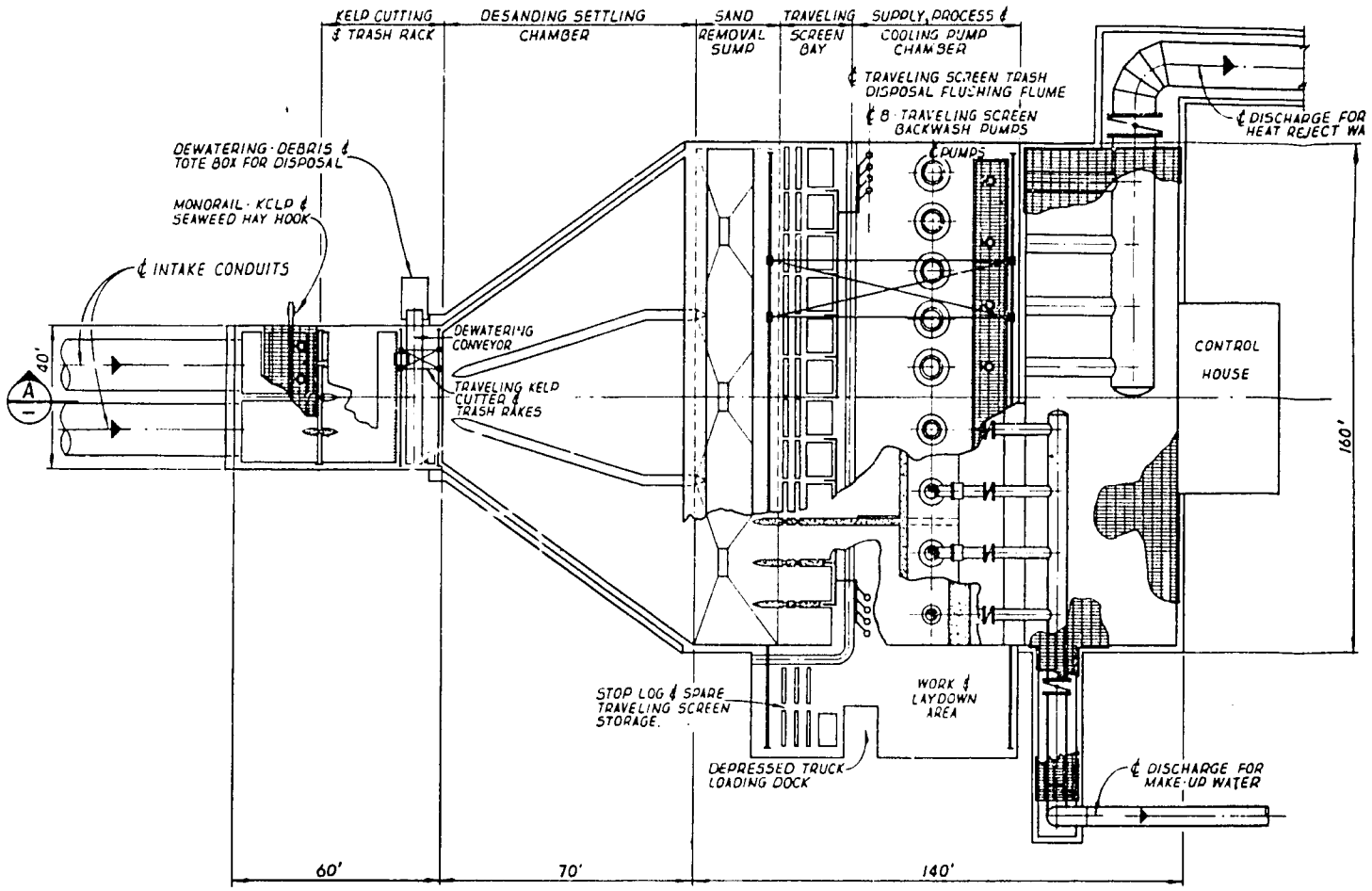


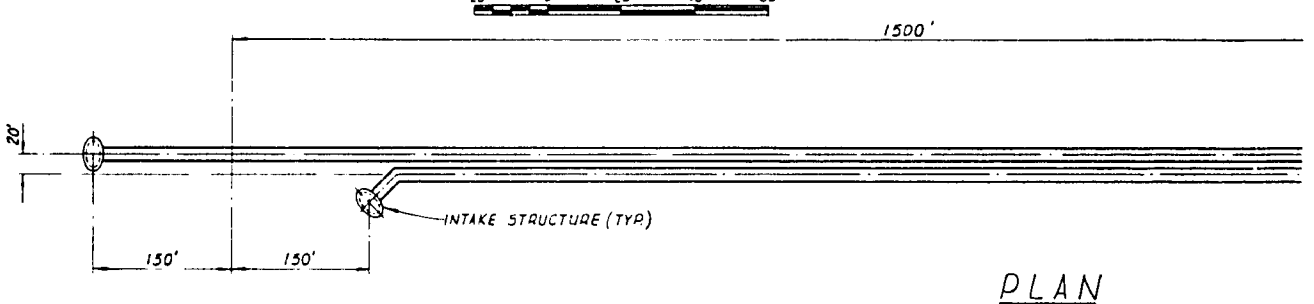
FIGURE 27

KAISER ENGINEERS OAKLAND, CALIFORNIA	
FOR U. S. - ISRAEL JOINT BOARD	
ELECTRICAL SINGLE LINE DIAGRAM NUCLEAR POWER PLANT	
JOB NO 6452	DWG NO SK-3-E-01



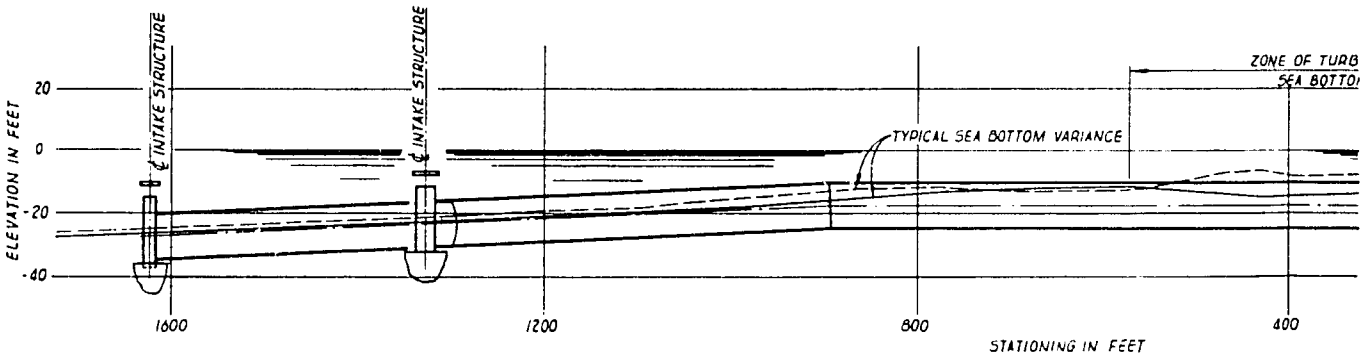
PLAN

SCALE 20' 0' 20' 40' 60'



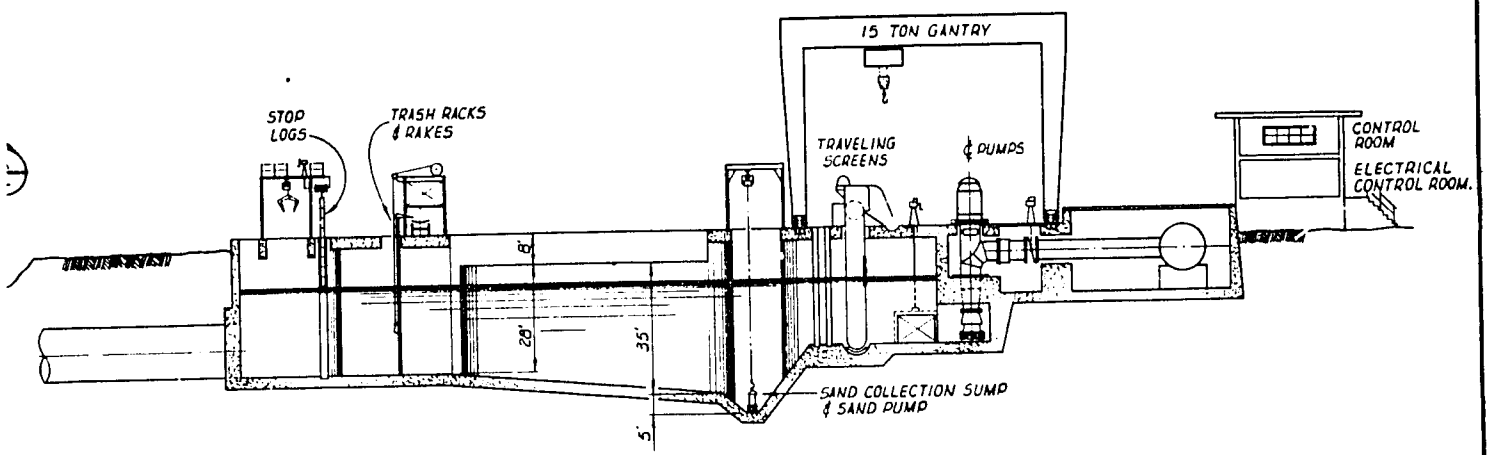
PLAN

SCALE: 100' 0 100' 200'



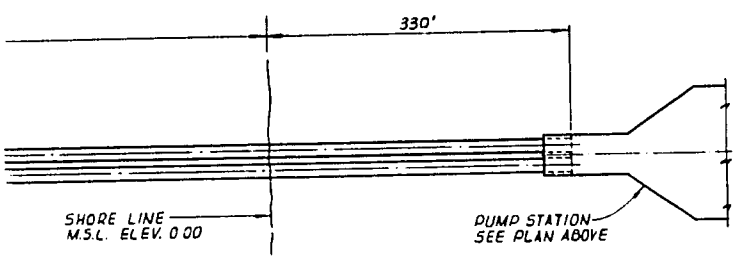
PROFILE

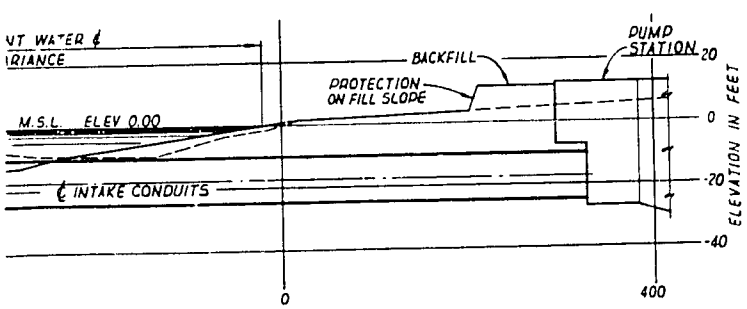
SCALES: HORIZ. 100' 0 100' 200' VERT. 20' 0 20'



SECTION (A)

SCALE:
20' 0 20' 40' 60'

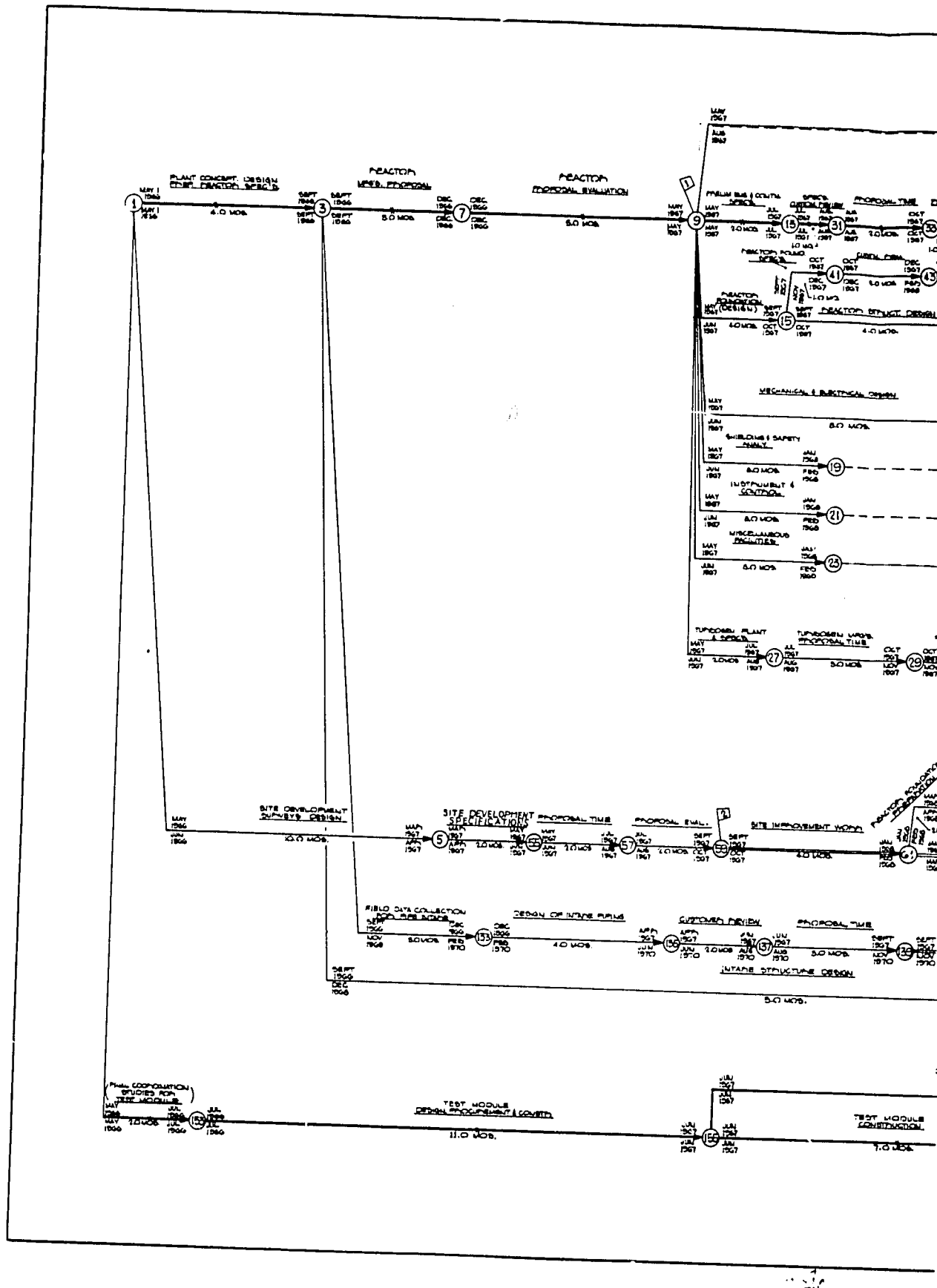




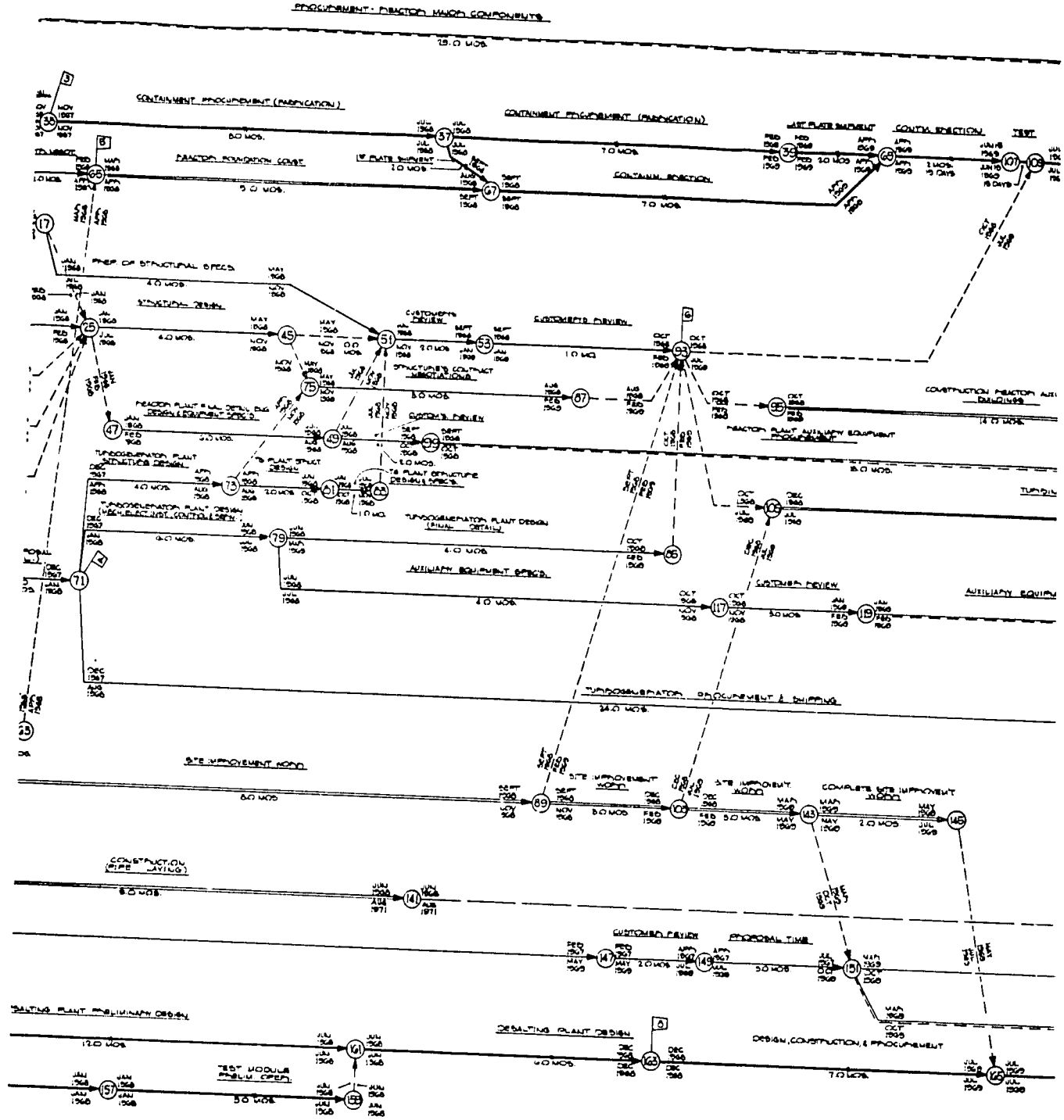
60'

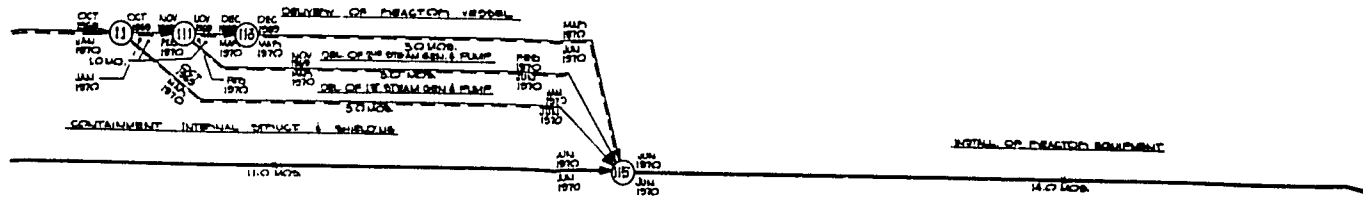
FIGURE 28

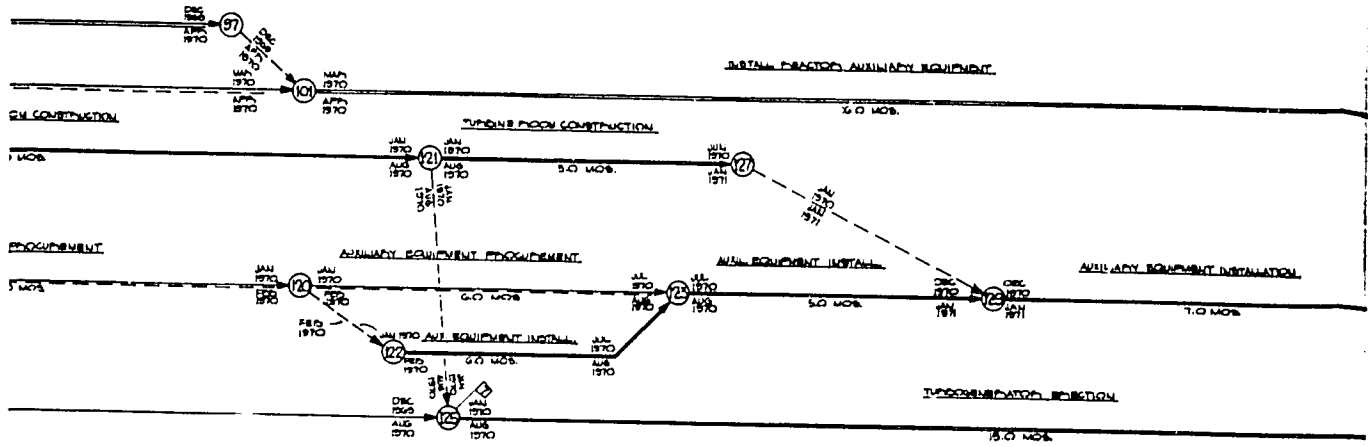
AS SHOWN	KAISER ENGINEERS OAKLAND, CALIFORNIA
DRAWN R.D.R. DATE 10-1-65	FOR
DESIGNED A.H.W. DATE 11-30-65	U. S. - ISRAEL JOINT BOARD
	INTAKE STRUCTURE & PUMPHOUSE
	JOB NO 6452 — DWG NO SK-1-A-01

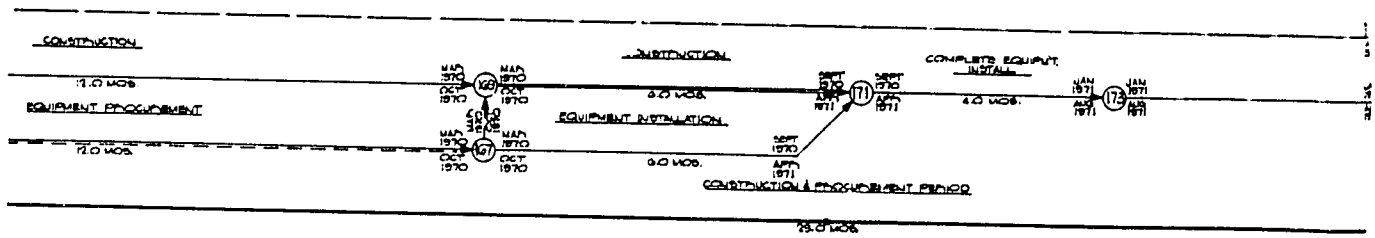

PLANT CONCEPT. DESIGN
REACTOR
REACTOR
PROPOSAL EVALUATION
MECHANICAL & ELECTRICAL DESIGN
INSTRUMENT & CONTROL
MISCELLANEOUS FACILITIES
SITE DEVELOPMENT SURVEYS, DESIGN
SITE DEVELOPMENT SPECIFICATIONS
PROPOSAL TIME
PROPOSAL EVAL.
SITE IMPROVEMENT WORK
FIELD DATA COLLECTION
DESIGN OF INTAKE PIPING
CUSTOMER REVIEW
PROPOSAL TIME
INTAKE STRUCTURE DESIGN
TEST MODULE
DESIGN, PROCUREMENT & CONSTR.
TEST MODULE
CONSTRUCTION
4.0 MOS.
5.0 MOS.
5.0 MOS.
10.0 MOS.
11.0 MOS.

256


PROCUREMENT - REACTOR MAJOR COMPONENTS
CONTAINMENT PROCUREMENT (FABRICATION)
CONTAINMENT PROCUREMENT (FABRICATION)
REACTOR FOUNDATION COMPL
CONTAINM. ERECTION
CONTAINM. ERECTION
TEST
PREP OF STRUCTURAL SPECS
STRUCTURAL DESIGN
CUSTOMER'S REVIEW
CUSTOMER'S REVIEW
STRUCTURES CONTRACT NEGOTIATIONS
REACTOR PLANT & AUX. DETAIL DWG DESIGN & EQUIPMENT SPECS
CUSTOM'S REVIEW
REACTOR PLANT AUXILIARY EQUIPMENT PROCUREMENT
TS PLANT STRUCT DESIGN
TS PLANT STRUCTURE DESIGN & SPECS
TURBOGENERATOR PLANT DETAILED DESIGN
TURBOGENERATOR PLANT DESIGN (MECHANICAL, CONTROL & ELEC)
TURBOGENERATOR PLANT DESIGN (FINAL DETAIL)
AUXILIARY EQUIPMENT SPECS.
CUSTOMER REVIEW
TURBOGENERATOR PROCUREMENT & SHIPPING
SITE IMPROVEMENT WORK
SITE IMPROVEMENT WORK
SITE IMPROVEMENT WORK
COMPLETE SITE IMPROVEMENT WORK
CONSTRUCTION (PIPE LAYING)
CUSTOMER REVIEW
PROPOSAL TIME
DESALTING PLANT PRELIMINARY DESIGN
DESALTING PLANT DESIGN
DESIGN, CONSTRUCTION, & PROCUREMENT
TEST MODULE PRELIM. DESIGN


DELIVERY OF REACTOR VESSEL
DEL. OF 2ND STEAM GEN. & PUMP
DEL. OF 1ST STEAM GEN. & PUMP
CONTAINMENT INTERNAL STRUCT. & SHIELDING
INSTALL. OF REACTOR EQUIPMENT
11.0 MOS.
14.0 MOS.


INSTALL. REACTOR AUXILIARY EQUIPMENT
CW CONSTRUCTION
TURBINE BLDG. CONSTRUCTION
AUXILIARY EQUIPMENT PROCUREMENT
AUXIL. EQUIPMENT INSTALL.
AUXILIARY EQUIPMENT INSTALLATION
TURBOGENERATOR INSPECTION
16.0 MOS.
5.0 MOS.
6.0 MOS.
7.0 MOS.
15.0 MOS.


CONSTRUCTION
INSPECTION
COMPLETE EQUIPT. INSTALL.
EQUIPMENT PROCUREMENT
EQUIPMENT INSTALLATION
CONSTRUCTION & PROCUREMENT PERIOD
12.0 MOS.
6.0 MOS.
4.0 MOS.
25.0 MOS.

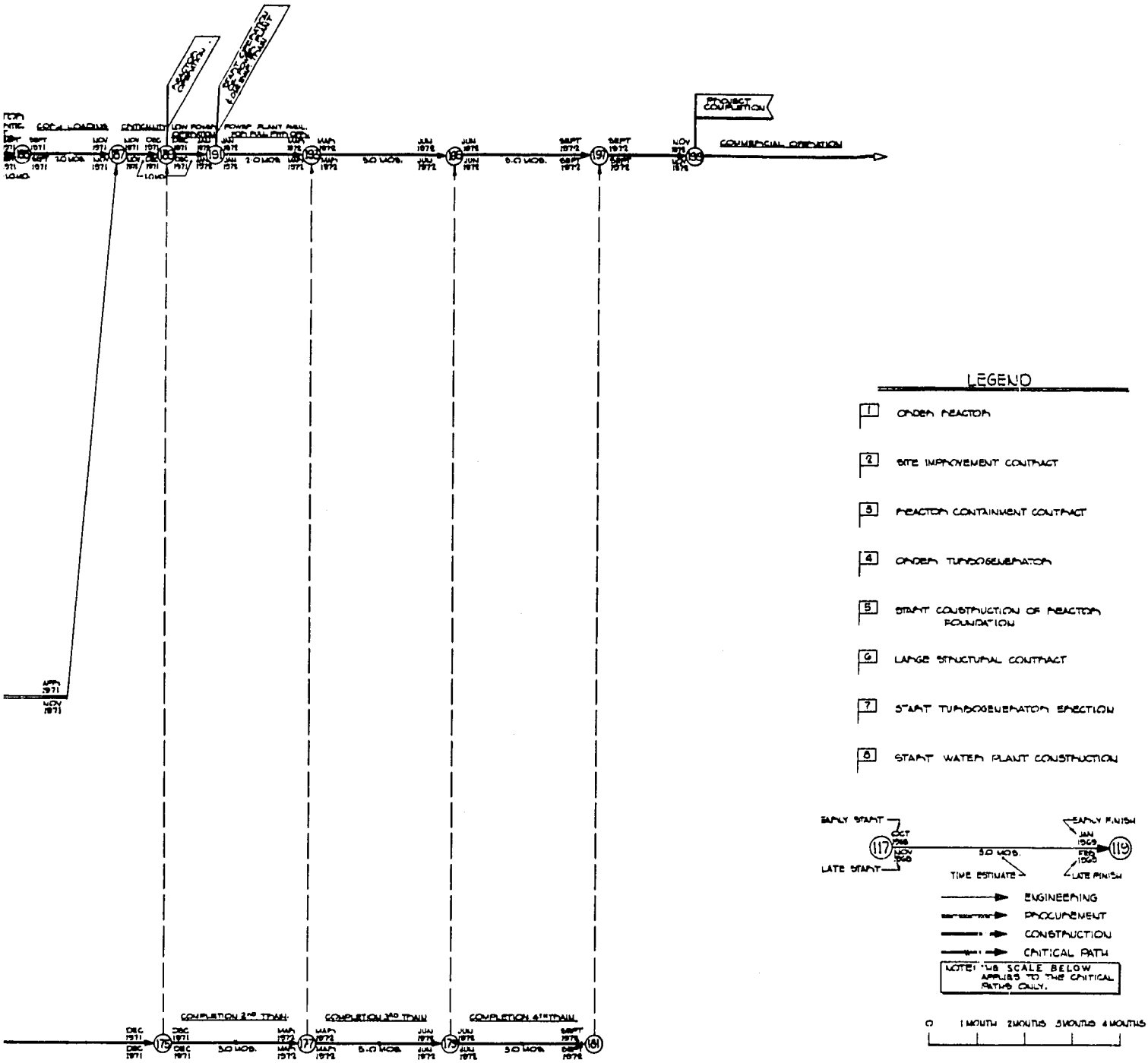
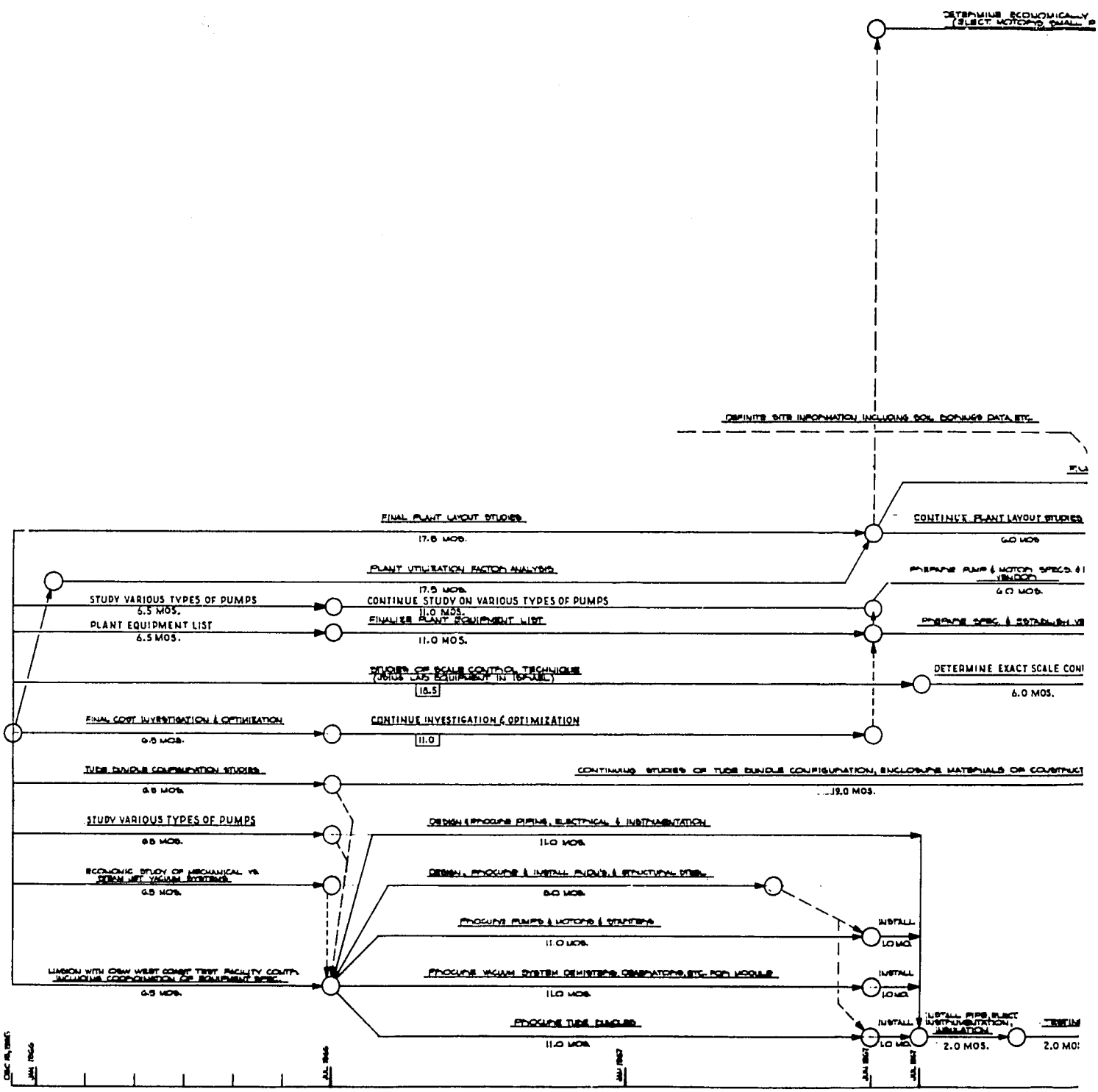
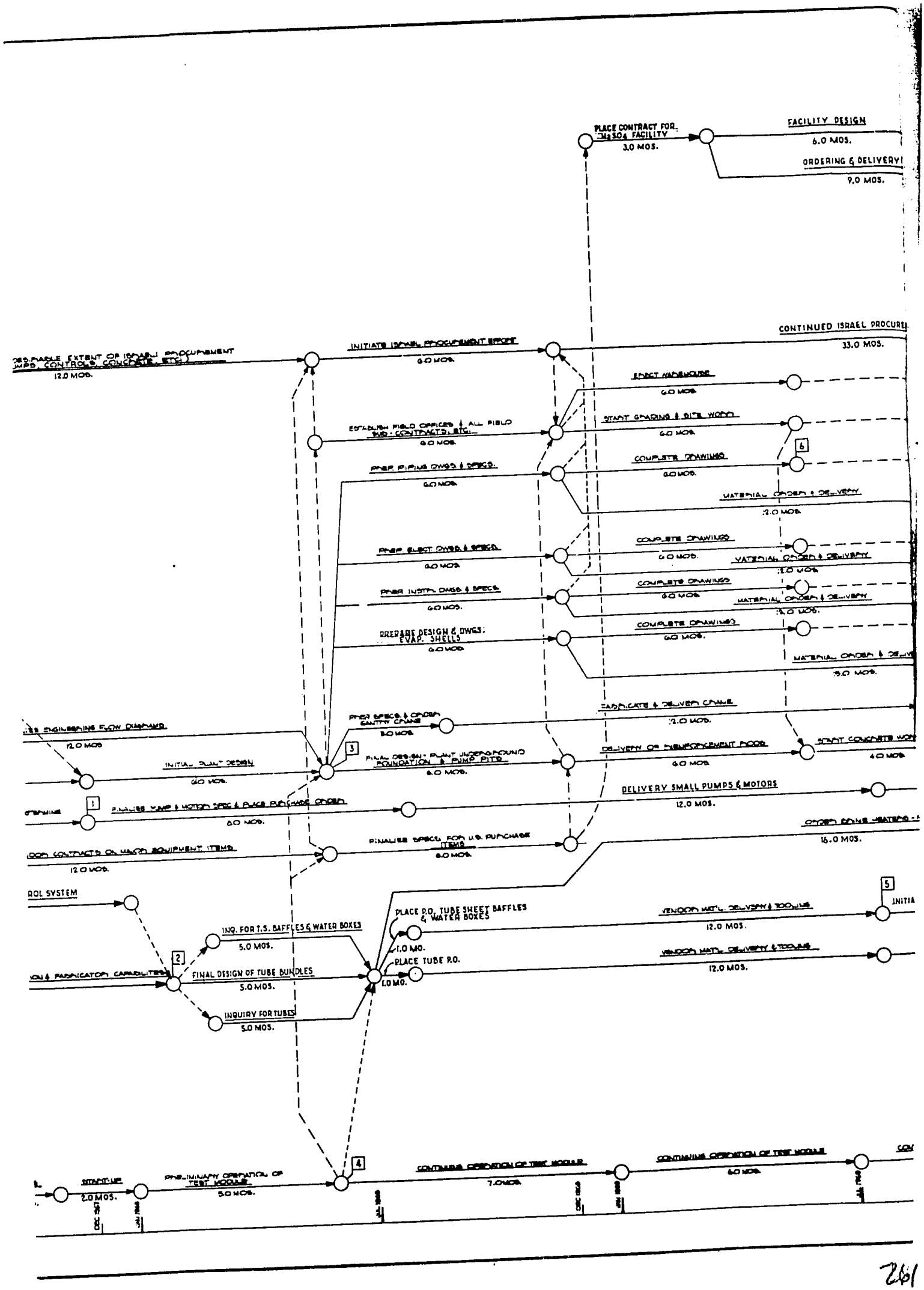
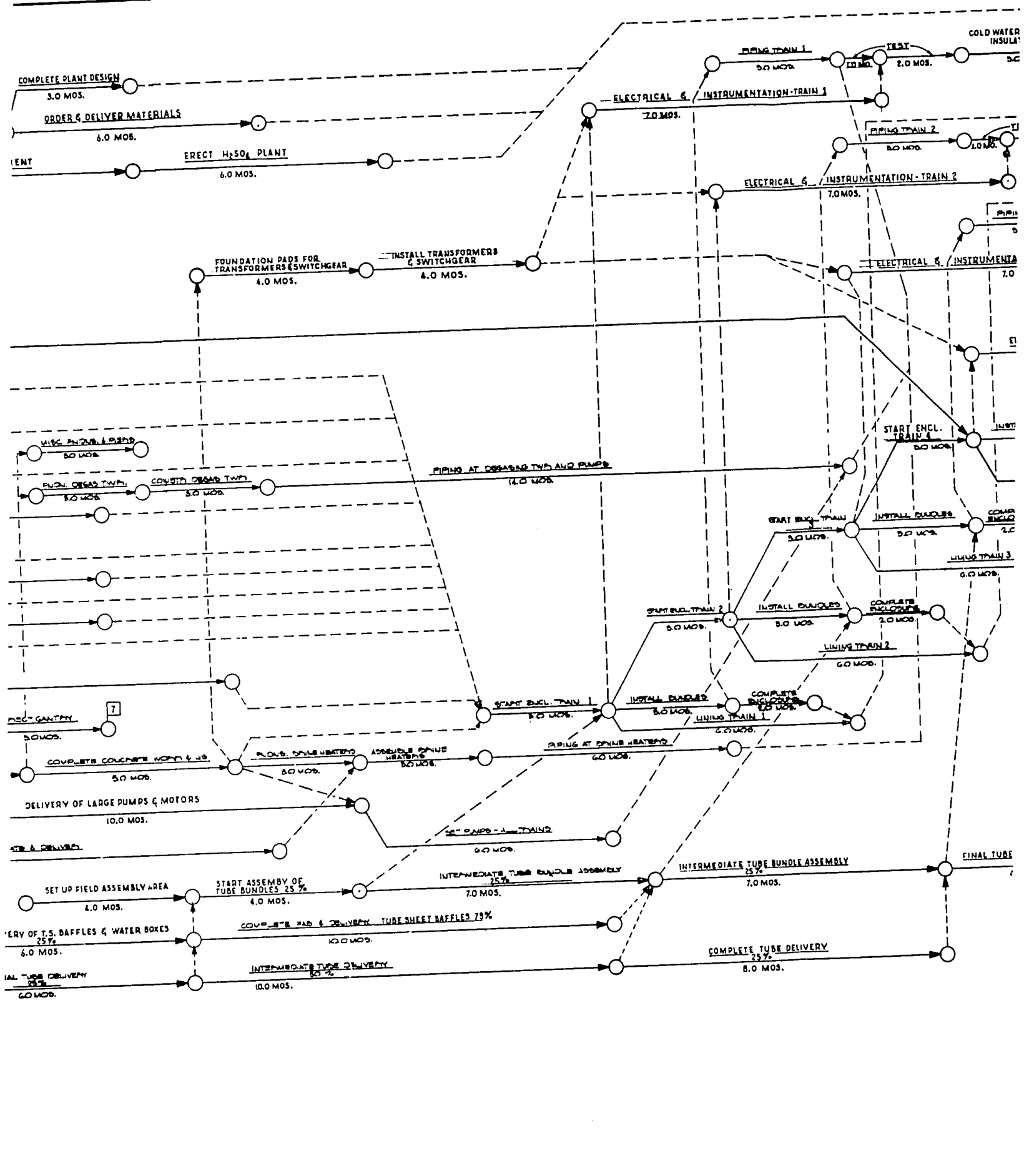


FIGURE 29

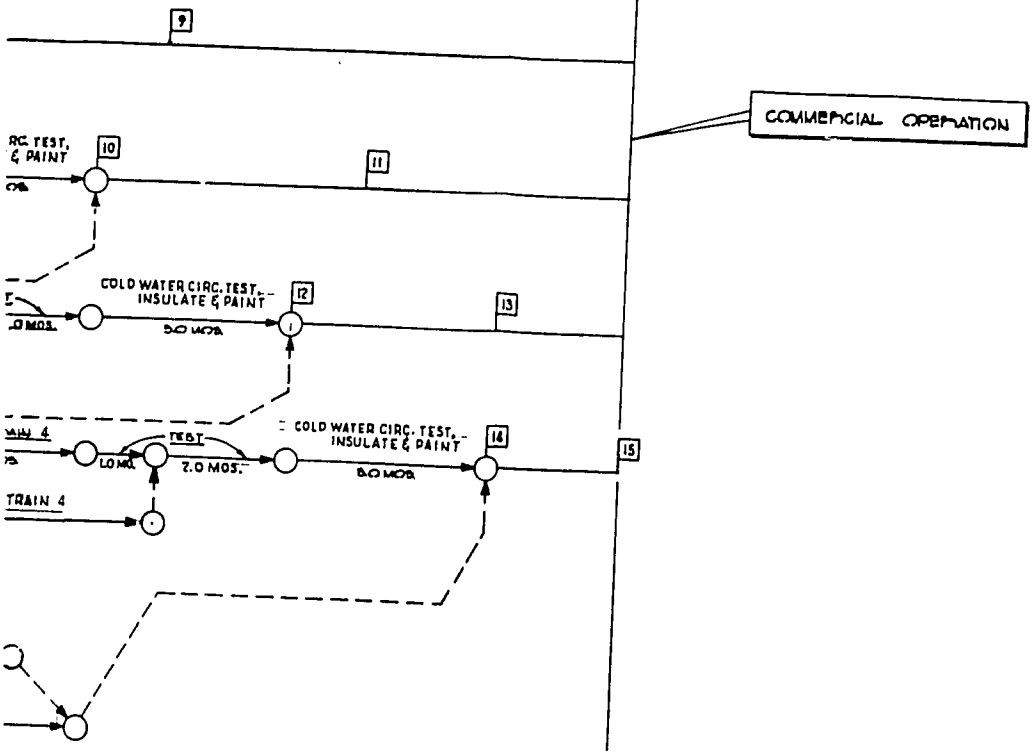
KAISER ENGINEERS OAKLAND, CALIFORNIA		
FOR U. S. - ISRAEL JOINT BOARD		
CPM. DIAGRAM FOR POWER PLAN		
JOB NO 6452	DWG NO SA-G-G-01	


DETERMINE ECONOMICALLY
DEFINITE SITE INFORMATION, INCLUDING SOIL BORINGS DATA, ETC.
FINAL PLANT LAYOUT STUDIES
17.5 MOS.
CONTINUE PLANT LAYOUT STUDIES
6.0 MOS.
PLANT UTILIZATION FACTOR ANALYSIS
17.5 MOS.
STUDY VARIOUS TYPES OF PUMPS
6.5 MOS.
CONTINUE STUDY ON VARIOUS TYPES OF PUMPS
11.0 MOS.
PLANT EQUIPMENT LIST
6.5 MOS.
FINALIZE PLANT EQUIPMENT LIST
11.0 MOS.
STUDIES OF SCALE CONTROL TECHNIQUES
(USING LAB EQUIPMENT IN TEST SUBL.)
18.5
DETERMINE EXACT SCALE CONT
6.0 MOS.
FINAL COST INVESTIGATION & OPTIMIZATION
0.5 MOS.
CONTINUE INVESTIGATION & OPTIMIZATION
11.0
TUBE BUNDLE CONFIGURATION STUDIES
0.5 MOS.
CONTINUING STUDIES OF TUBE BUNDLE CONFIGURATION, ENCLOSURE MATERIALS OR CONSTRUCT
19.0 MOS.
STUDY VARIOUS TYPES OF PUMPS
0.5 MOS.
DESIGN & PROCURE PIPING, ELECTRICAL & INSTRUMENTATION
11.0 MOS.
ECONOMIC STUDY OF MECHANICAL VS. STEAM JET VACUUM SYSTEMS
0.5 MOS.
DESIGN, PROCURE & INSTALL FLOWS & STRUCTURAL STEEL
6.0 MOS.
PROCURE PUMPS & MOTORS & STARTERS
11.0 MOS.
INSTALL
1.0 MO.
LIAISON WITH C&W WEST COAST TEST FACILITY CONTR. INCLUDING COORDINATION OF EQUIPMENT SPEC.
0.5 MOS.
PROCURE VACUUM SYSTEM DEMISTERS, CONDENSATORS, ETC. FOR MODULE
11.0 MOS.
INSTALL
1.0 MO.
PROCURE TUBE BUNDLES
11.0 MOS.
INSTALL
1.0 MO.
INSTALL PIPE, ELECT. INSTRUMENTATION, INSULATION
2.0 MOS.
2.0 MO
DEC 31, 1965
JAN 1966
JUL 1966
JAN 1967
JAN 1967
JUL 1967


PLACE CONTRACT FOR MgSO4 FACILITY
3.0 MOS.
FACILITY DESIGN
6.0 MOS.
ORDERING & DELIVERY
9.0 MOS.
CONTINUED ISRAEL PROCURE
33.0 MOS.
INITIATE ISRAEL PROCUREMENT EFFORT
6.0 MOS.
12.0 MOS.
ERECT WAREHOUSE
6.0 MOS.
START GRADING & SITE WORK
6.0 MOS.
COMPLETE DRAWINGS
6.0 MOS.
MATERIAL ORDER & DELIVERY
12.0 MOS.
COMPLETE DRAWINGS
6.0 MOS.
MATERIAL ORDER & DELIVERY
12.0 MOS.
COMPLETE DRAWINGS
6.0 MOS.
MATERIAL ORDER & DELIVERY
12.0 MOS.
COMPLETE DRAWINGS
6.0 MOS.
MATERIAL ORDER & DELIVERY
12.0 MOS.
PREPARE DESIGN & DWGS: EVAP. SHELLS
6.0 MOS.
FABRICATE & DELIVER CRANE
12.0 MOS.
DELIVERY OF REINFORCEMENT RODS
6.0 MOS.
START CONCRETE WORK
4.0 MOS.
INITIAL PLANT DESIGN
6.0 MOS.
FINALIZE SPEC. FOR U.S. PURCHASE ITEMS
6.0 MOS.
DELIVERY SMALL PUMPS & MOTORS
12.0 MOS.
16.0 MOS.
ROL SYSTEM
INQ. FOR T.S. BAFFLES & WATER BOXES
5.0 MOS.
PLACE P.O. TUBE SHEET BAFFLES & WATER BOXES
1.0 MO.
PLACE TUBE P.O.
1.0 MO.
FINAL DESIGN OF TUBE BUNDLES
5.0 MOS.
INQUIRY FOR TUBES
5.0 MOS.
VENDOR MAT'L. DELIVERY & TOOLING
12.0 MOS.
VENDOR MAT'L. DELIVERY & TOOLING
12.0 MOS.
START-UP
2.0 MOS.
PRELIMINARY OPERATION OF TEST MODULE
5.0 MOS.
CONTINUOUS OPERATION OF TEST MODULE
7.0 MOS.
CONTINUING OPERATION OF TEST MODULE
6.0 MOS.


COMPLETE PLANT DESIGN
3.0 MOS.
ORDER & DELIVER MATERIALS
6.0 MOS.
ERECT H_2SO_4 PLANT
6.0 MOS.
FOUNDATION PADS FOR TRANSFORMERS & SWITCHGEAR
4.0 MOS.
INSTALL TRANSFORMERS & SWITCHGEAR
4.0 MOS.
PIPING TRAIN 1
5.0 MOS.
TEST
1.0 MO.
2.0 MOS.
ELECTRICAL & INSTRUMENTATION-TRAIN 1
7.0 MOS.
PIPING TRAIN 2
5.0 MOS.
1.0 MO.
ELECTRICAL & INSTRUMENTATION - TRAIN 2
7.0 MOS.
PIPING AT DEGASING TWR AND PUMPS
14.0 MOS.
START ENCL. TRAIN 4
5.0 MOS.
START ENCL. TRAIN 1
5.0 MOS.
INSTALL BUNDLES
5.0 MOS.
COMPLETE ENCLOSURE
2.0 MOS.
LINING TRAIN 1
6.0 MOS.
START ENCL. TRAIN 2
5.0 MOS.
INSTALL BUNDLES
5.0 MOS.
COMPLETE ENCLOSURE
2.0 MOS.
LINING TRAIN 2
6.0 MOS.
START ENCL. TRAIN 3
5.0 MOS.
INSTALL BUNDLES
5.0 MOS.
LINING TRAIN 3
6.0 MOS.
PIPING AT DEGASING TWR
5.0 MOS.
COMPLETE COUCHER'S WORK & HD.
5.0 MOS.
PIPING AT BOILER HEATERS
6.0 MOS.
DELIVERY OF LARGE PUMPS & MOTORS
10.0 MOS.
SET UP FIELD ASSEMBLY AREA
4.0 MOS.
START ASSEMBY OF TUBE BUNDLES 25 %
4.0 MOS.
INTERMEDIATE TUBE BUNDLE ASSEMBLY 25%
7.0 MOS.
INTERMEDIATE TUBE BUNDLE ASSEMBLY 25%
7.0 MOS.
FINAL TUBE
6.0 MOS.
10.0 MOS.
COMPLETE TUBE DELIVERY 25%
8.0 MOS.
10.0 MOS.
6.0 MOS.
OPERATION OF TEST MODULE
6.0 MOS.
DEC 1969
JAN 1970
JAN 1971
JAN 1972

26-2



LEGEND

1. PLACE P.O. FOR PUMPS
2. FINAL DESIGN OF TUBE BUNDLES.
3. START DESIGN OF CONCRETE & UNDERGROUND.
4. COMPLETE PRELIMINARY OPERATION OF TEST MODULE
5. INITIAL SHIPMENT OF TUBING & TUBE SHEETS.
6. COMPLETE DESIGN
7. COMPLETE GANTRY
8. COMPLETE TRAIN 1 (READY TO RECEIVE STEAM)
9. TRAIN 1 - 100 % OUTPUT
10. COMPLETE TRAIN 2.
11. TRAIN 2 - 100 % OUTPUT
12. COMPLETE TRAIN 3
13. TRAIN 3 - 100 % OUTPUT
14. COMPLETE TRAIN 4
15. TRAIN 4 - 100 % OUTPUT & FULL COMMERCIAL OPERATION.

LEGEND

FIGURE 50

CATALYTIC CONSTRUCTION COMPANY
PHILADELPHIA, PENNSYLVANIA

KAISER ENGINEERS
OAKLAND, CALIFORNIA

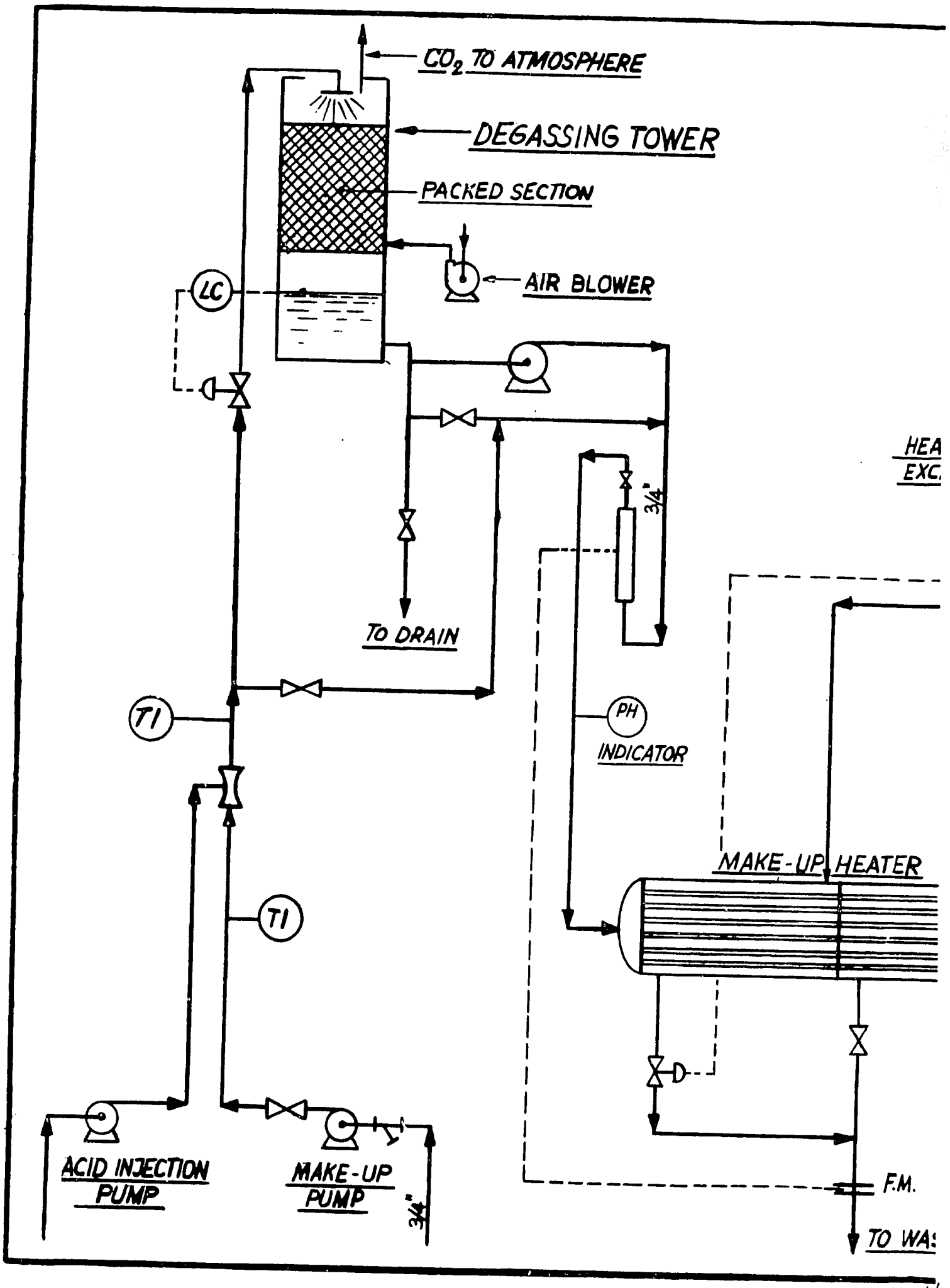
U. S. - ISRAEL JOINT BOARD

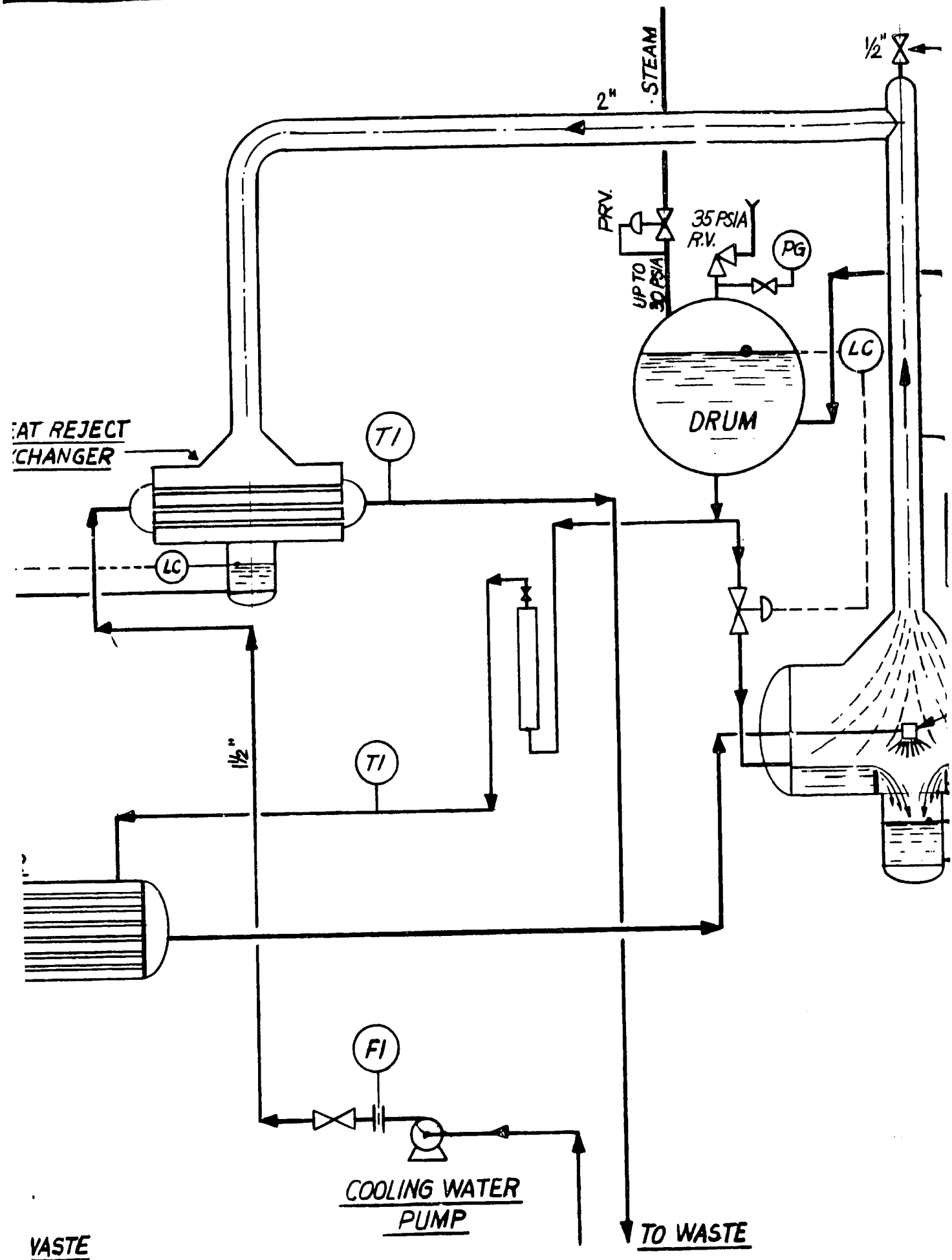
CPM DIAGRAM FOR DESALTING PLANT

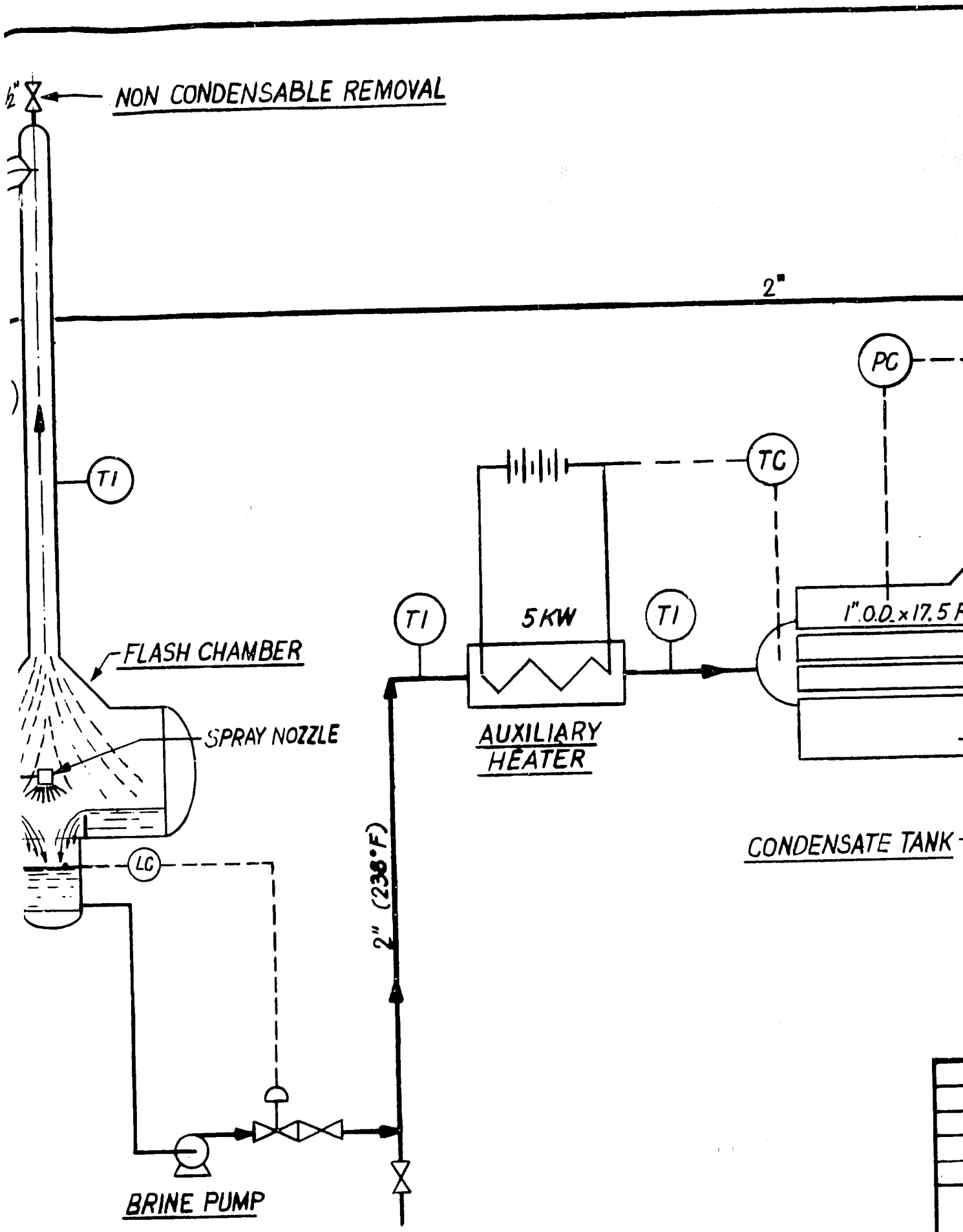
JOB NO. 6452

DWG. NO. SPI-G-6-CPM

263


CO_2 TO ATMOSPHERE
DEGASSING TOWER
PACKED SECTION
AIR BLOWER
LC
TO DRAIN
3/4"
HEA
EXC
TI
PH
INDICATOR
MAKE-UP HEATER
TI
ACID INJECTION PUMP
MAKE-UP PUMP
3/4"
F.M.
TO WA


STEAM
1/2"
2"
PRV.
35 PSIA
R.V.
PG
UP TO
30 PSIA
LC
DRUM
EAT REJECT
CHANGER
TI
LC
1 1/2"
TI
FI
COOLING WATER
PUMP
TO WASTE
VASTE


½"
NON CONDENSABLE REMOVAL
2"
PC
TC
TI
TI
5 KW
TI
1" O.D. x 17.5 F
FLASH CHAMBER
SPRAY NOZZLE
AUXILIARY HEATER
CONDENSATE TANK
LC
2" (238°F)
BRINE PUMP

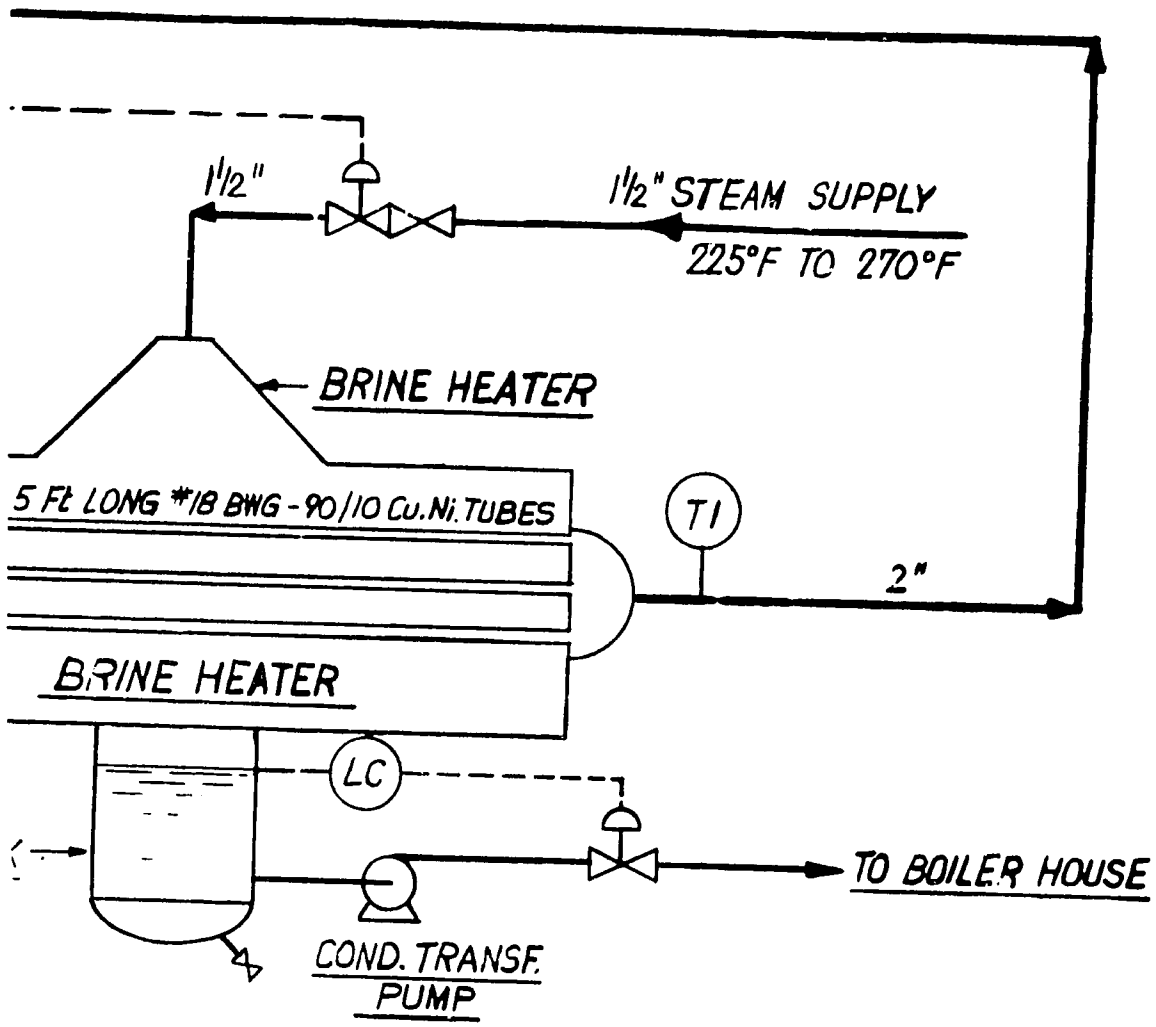


FIGURE 31

APPROVAL	DATE	SCALE NONE
		DRAWN BY B. SZABO DATE 11-7-65
		CHECKED BY DATE
		APPROVED

CATALYTIC CONSTRUCTION COMPANY
PHILADELPHIA, PENNSYLVANIA

FOR

KAISER ENGINEERS
OAKLAND, CALIFORNIA

FOR

U. S. - ISRAEL JOINT BOARD

APPARATUS FOR TESTING SCALE FORMATION

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