Design and Economic Study of a Gas Turbine Powered Vapor Compression Plant for Evaporation of Seawater

United States Department of the Interior

Office of Saline Water • Research and Development Progress Report No. 377

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Design and Economic Study of a Gas Turbine Powered Vapor Compression Plant for Evaporation of Seawater

By Struthers Energy Systems Inc., Warren, Pennsylvania and Pratt & Whitney Aircraft, East Hartford, Connecticut, for the Office of Saline Water, J.A. Hunter, Director; Everett N. Sieder, Chief, Distillation Division; S. J. Senatore, Project Manager

Contract No. 14–01–0001–1442

UNITED STATES DEPARTMENT OF THE INTERIOR • Stewart L. Udall, Secretary
Max N. Edwards, Assistant Secretary for Water Pollution Control

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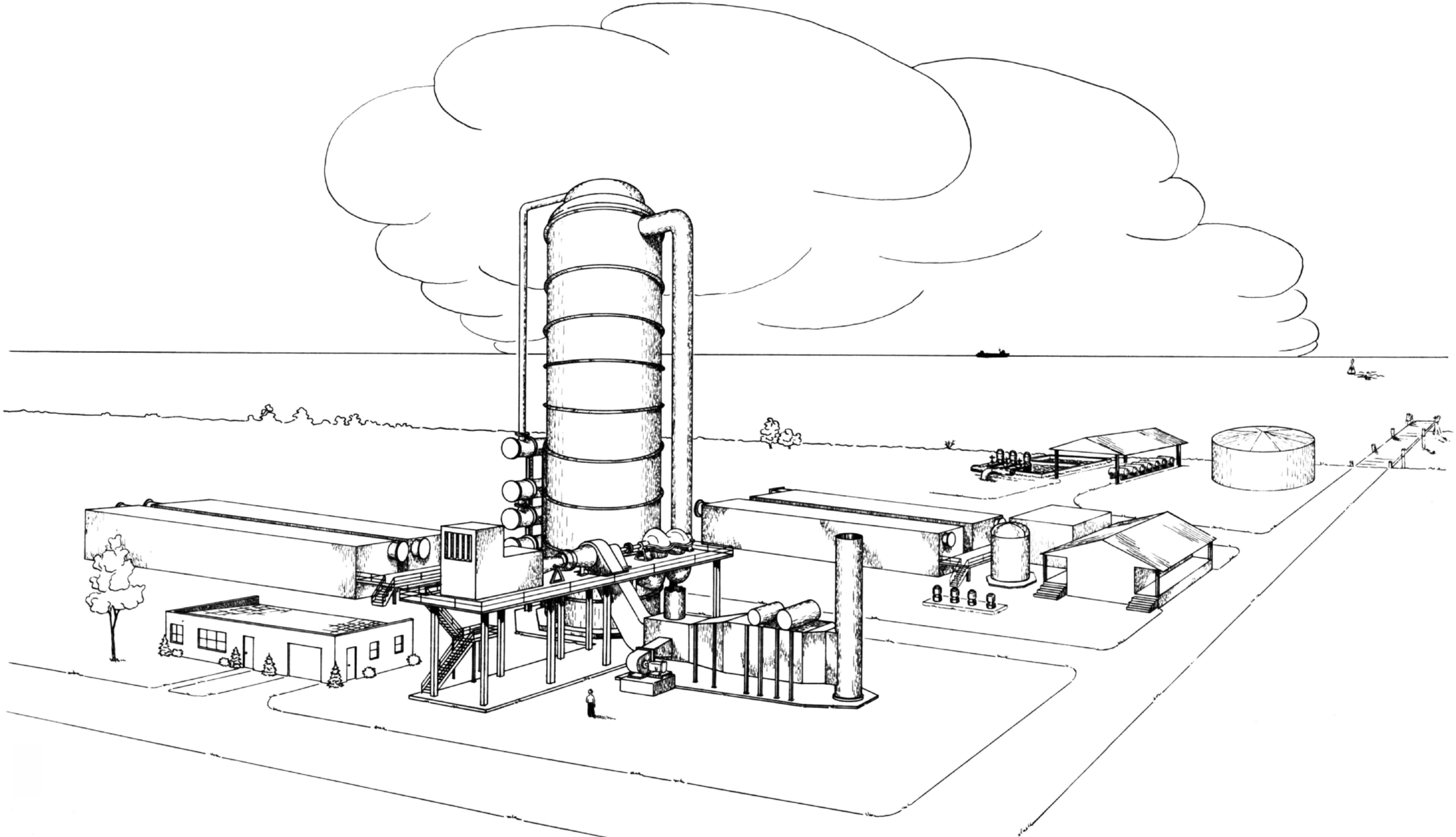
FOREWORD

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

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



8,000,000 GPD GAS TURBINE POWERED
VAPOR COMPRESSION VTE-MSF DISTILLATION PLANT

STRUTHERS ENERGY SYSTEMS, INC.
AND
PRATT & WHITNEY AIRCRAFT

ACKNOWLEDGMENT

This study was performed by Struthers Energy Systems, Inc. and Pratt & Whitney Aircraft, guided by the Office of Saline Water. The study was based on an unsolicited proposal by the two Contractors. W. L. Badger Associates, Inc., were assigned major responsibility for the water plant design under a subcontract. Other Subcontractors were Aqua-Chem, Inc., and Carco, Inc. Acknowledgment is accorded to the many other equipment manufacturers who provided design and cost information.

TABLE OF CONTENTS

I. Introduction and Scope

This report presents the results of an engineering study of the design and economics of a single purpose gas turbine powered vapor compression cycle seawater desalting plant. This work was performed under contract to the Office of Saline Water, U. S. Department of the Interior, under OSW Contract No. 14-01-0001-1442 and Struthers Energy Systems Order No. 67-50-7840.

The work performed was divided into two phases. During Phase I, the contractor was to perform an economic study of the utilization of gas turbines in a single purpose water plant to determine preliminary capital and annual cost estimates of two representative sizes of plant. A Phase I report was assembled and submitted to the Office of Saline Water. The second phase of the project was for the preparation of one specific plant design that could be carried through to the construction of a prototype or demonstration plant. The plant design that was detailed was selected by the Office of Saline Water. The basic components of the system included a gas turbine driven vapor compressor, LVT vapor compression evaporator, heat recovery boiler system, and a MSF evaporator.

II. Summary and Conclusions

1.0 Plant Design

The plant described in this report may be summarized by the following list of essential characteristics:

Process: single purpose, seawater distillation desalination plant, with a nominal capacity of 8.0 MGD product water. The process utilizes a gas turbine powered vapor compressor operating across four effects of a vertical tube evaporator. A multistage flash evaporator is used as a low temperature brine heater. Brine recirculation is not used. All site power requirements are furnished by a noncondensing steam turbo-generator. Steam is provided from a heat recovery boiler.

Capacity, MGD	8.00
Capital cost	$7,511,655
Annual operating costs	$1,039,120
Product water cost, ¢/1000 gal.	39.33
Fuel cost, ¢/MM btu HHV	20
Number of streams	1
Performance ration, # of product/ 1000 btu	19.05
Number of effects in VTE	4
Number of stages in MSF	24
Maximum brine temperature, °F	250
Steam required @ 19 psig saturated, #/hr	61,660
Electricity required. kw	1500 total
Acreage required	4
Method of scale control	H_2SO_4 continuous feed 555 #/hr
Seawater flow rate @ 75°F,gpm	11,295
Feed water flow rate @ 108.6°F, gpm.	9790
Blowdown flow rate @ 93.8°F,gpm	4195
Product water flow rate @ 92.3°F, gpm	5585
Brine Concentration Factor	
Max. from VTE design	2.0
Max. from MSF design	2.26
Number of MSF trains	4 in series
Dimensions of vessels	
VTE	36' dia. x 108' high
MSF (per train)	1-18' wide x 55'long 2-13' wide x 55'long 3-11' wide x 55'long 4-11' wide x 55'long

Vessel Material	
VTE	Carbon steel-partially clad with 90-10 Cu-Ni
MSF	Carbon Steel-waterboxes clad with 90-10 Cu-Ni
Vessel Thickness	
VTE	1" thick-except where 1/16" cladding is used
MSF	1/2" thick
Corrosion allowance	Unclad steel in contact brine 1/4", Unclad steel in contact with vapor 3/16"
Coating or lining	
VTE	90-10 Cu-Ni where applicable. Pourable silicone rubber on top of tube sheet
MSF	90-10 Cu-Ni in waterboxes.
Min. brine flow in VTE tubes,gpm	1.2
VTE tube material	90-10 Cu-Ni
MSF tube material	90-10 Cu-Ni
Assumed tube life, years	30
Tube type or configuration	
VTE	Double fluted with smooth ends
MSF	Long tube
Tube diameter, in. O.D.	
VTE	3
MSF recovery	5/8
MSF reject	5/8
Tube gage	
VTE	18 smooth tube; reduced to 20 in fluted area.
MSF recovery	20
MSF reject	18

Tube length	
VTE, ft.-in.	12-10 3/4
MSF, ft.	55
Total VTE Surface, ft^2	257,000
Total VTE Tubes	20,560
Average U, btu/ft^2 hr °F	
VTE I Effect	1482
II Effect	1473
III Effect	1463
IV Effect	1454
VTE installed cost/ft^2 surface	$6.74
Feed Heaters	4
Tube material	90-10 Cu-Ni
Tube diameter, in.	7/8
Tube gage	19
Tube length, ft.	18
Number of tubes per heater	1090
Deaerator	
Type	Vacuum, packed column
Lining	Rubber

2.0 Economic Summary

A detailed breakdown of the plant economics is presented in this report under Section VI.

2.1 Capital Costs

The capital costs of the plant are summarized below:

Special Equipment:	
VTE	
MSF	
Gas Turbine-Vapor Compressor	
Power Train	$4,903,200
Standard Engineering Equipment:	
Heat Recovery Boiler	
Electrical generating equipment	
Feed Heaters	
Pumps	652,125
Process Facilities:	
Intake Structure	
Buildings	
Site Development	
Foundation	
Piping	
Electrical	1,023,050
Subtotal Direct Costs	$6,578,375
Other Plant Costs:	
Construction Costs	
Land	
Interest During Construction	
A/E's Contingencies	828,815
Subtotal Indirect Costs	$ 828,815
GRAND TOTAL Direct and Indirect Costs	$7,511,655
Capital Cost per Gallon of Daily Capacity (8.04 MGD)	$0.934

2.2 Water Costs

The water costs of the plant are summarized below:

	$/Year	$/1000 Gal.
Fuel Costs		
@ $.20/10^6 btu	$ 229,895	0.0870
Chemical Costs	91,125	0.0345
Direct Operating Costs		
Payroll Maintenance Lube Oil	186,305	0.0705
Subtotal Direct Costs	$ 507,325	0.1920
Depreciation & Interest		
@ Cap. Recovery Factor = 5.9557%	447,370	0.1693
Other Indirect Operating Costs		
Payroll Extras General and Administration Insurance	84,425	0.0320
Subtotal Indirect Costs	$ 531,795	0.2013
Total Annual Operating Costs Based on 2642. x 10^6 Gal/Year.	$1,039,120	0.3933

The Total Annual Operating Costs based on $.25/10^6 btu fuel would be $1,096,595/year and $0.4151/1000 gallons.

III. Design Basis

1.0 General

The design criteria applicable to this particular plant design was specified in the contract document and a written communique from the Office of Saline Water. Some areas of the design were left to the judgment of the participants.

2.0 Site

The contract document specifies the plant site to be located on the lower Gulf Coast of Texas. No specific real estate was selected. The plant site elevation was specified by OSW as 50 feet above sea level. For construction cost estimates, a sandy soil, free from rocks with bearing capacity of 2000 psf was assumed. In computing the construction costs of installing the intake and brine blowdown pipes, a sandy bay bottom was assumed. Performance calculations were based on an ambient temperature of 73°F. A seawater inlet temperature of 75°F was assumed.

3.0 Seawater Analysis and Conditions

The seawater assumed in this design has a total solids concentration of 35,000 ppm. A trace of organic material is assumed to be present in the raw seawater. Animal life to be removed from the seawater includes: fish, crabs, shrimp, and jellyfish. Plant life to be removed from the seawater includes: seaweed, kelp, and leaves.

4.0 Product Water

A plant capacity of 8.0 ± 0.5 MGD of product water was specified by OSW. A maximum impurity level of 50 ppm is allowed in the product water. The product water final temperature at design conditions is 92.3°F.

5.0 Maximum Brine Concentration

The plant design is such that the maximum desirable brine concentration at the blowdown of the MSF unit is approximately 2.26. The maximum brine concentration of the VTE brine effluent is approximately 2.0.

6.0 Stream Factor and Plant Life

Planned Outages

The design of this plant is predicated on a scheduled shutdown of one week duration every year to accomplish all maintenance requiring that the plant be off-stream, cold, and open to the atmosphere. This annual turnaround frequency is dictated primarily by the needs of the power end of the system, as follows:

1. Gas generator*
    - a. hot section inspection every 4,000 hrs.
    - b. engine overhaul every 16,000 hrs.

    (the hot section inspection can be done when convenient and does not require that the plant be down for more than a few hours)
2. Power turbine
    - a. inspection once per year
    - b. overhaul every 100,000 hrs.
3. Vapor compressor
    - a. inspection and cleaning once per year
    - b. overhaul once in 30 year life
4. Waste heat boiler
    - a. inspection once per year

The one week shutdown will also permit the following work on the evaporator system:

- a. Drain and clean seawater intake pit, decarbonator sump, brine flash chambers, and heat exchanger water boxes.
- b. Clean VTE effect top tube sheets and inspect for plugged distributor orifices.
- c. Plug or replace leaking fluted tubes in VTE section.
- d. Perform any major maintenance required on piping system.

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* When a jet engine is combined with a power turbine which produces useful shaft power, the jet engine is normally referred to as a Gas Generator.

Forced Outages

All pumps will be spared and can be removed for servicing without a shutdown. Practically all of the steel piping subject to corrosion will be under vacuum and hence also can be repaired, at least temporarily, without a shutdown. Thus, tube failures constitute the major reason for forced outages. These tube failures will be most serious in the feed heating section of the plant (the MSF train and the four final feed heaters) since the seawater here is under considerably greater pressure than the distillate. To minimize the frequency of tube failures, iron modified 90-10 Cu-Ni tubing is used for all heat transfer surfaces. The number and sizes of tubes will be approximately as follows:

MSF reject - 2500 tubes-5/8" x 18 ga x 55 ft.
MSF recovery - 7500 tubes-5/8" x 20 ga x 55 ft.
Final heating - 4400 tubes-7/8" x 19 ga x 18 ft.
VTE evaporator-20560 tubes- 3" x 20 ga x 12.5 ft.

While no plants have been in service with 90-10 tubes for a period even approaching 30 years, it is possible to make a reasonable estimate of expected failures from the following references:

1. Todhurst, H.A., "Condenser Tubes in Seawater Service", Power, 57-9, March 1967.

2. Little, A.D., "Survey of Condenser Tube Life in Salt Water Service", Report to O.S.W., Contract 14-01-0001-956, Feb. 1967.

3. Int'l. Nickel Co., "A Study of Materials of Construction in Distillation Plants 1962-1963", O.S.W. Res. and Dev. Prog. Rep. No. 163, Oct. 1965.

4. Oak Ridge Nat'l. Lab., "Conceptual Design of a 250-MGD Desalination Plant", O.S.W. Res. and Dev. Prog. Rep. No. 214, Sept. 1966.

5. Kaiser Engineers and Catalytic Construction Co., "Eng'g. Feasibility and Economic Study for Dual-Purpose Electric Power-Water Desalting Plant for Israel", Jan. 1966.

Reference (1) provides sufficient information to show the probability of tube failure for 70-30 Cu-Ni tubes in contact with cool, aerated seawater in power plant condensers. These data are plotted in Fig. III-1 and are for 7/8" O.D., 18 ga tubes, 26'-3" long with about 7 ft/sec seawater velocity. Also shown is the ORNL estimate, from Ref. (4), pg 105, that 10-15% of the tubes (primarily 70-30 Cu-Ni) will have failed in 30 years in an MSF distillation plant. The data for U.S. Navy destroyers in Fig. III-1 is from Ref. (2) and shows lower failure rates, possibly as a result of their being in operation a smaller percentage of the time. Other failure rate data from Ref. (2) is in general agreement with Fig. III-1, although the scatter is wide.

References (2) and (3) show little difference in failure or corrosion rates between 70-30 and 90-10 Cu-Ni. Data from Reference (3) also indicates that the corrosion rate of 90-10 in hot deaerated seawater can be of the same magnitude as in cold aerated seawater. The data for aerated seawater is erratic, being about 0.7 mills per year at Freeport where operation was fairly continuous and chlorination was not used (Table II) and ranging from 2.1 to 11 mpy at San Diego (Table VII) where shutdowns were more frequent and chlorination was used, possibly in an excessive amount. Corrosion rate for deaerated seawater in the MSF train (Table VIII) was relatively insensitive to temperature and averaged about 0.7 mpy. The lowest corrosion rate was experienced after the seawater had been subjected to evaporation, which would have removed the last traces of dissolved oxygen. Corrosion rates in this case (Tables IV, V, IX) were only about 0.4 mpy, and would apply to the VTE tubes.

For the present case, it is assumed that the choice of tube thicknesses will offset these differences in corrosion rates. No allowance need be made for differences in tube length if it is assumed that most of the failures are a result of attack at the tube inlets, and that for the rest of the failures, the effect of tube diameter will be offset by the shorter length of the larger diameter tubes. On this basis, the solid line of Fig. III-1 is a reasonable representation of the failure rates that might be expected throughout the proposed plant. For that part of the plant where the seawater is under greater pressure than the distillate, the corresponding number of failures to be expected in each year of the plant's life is shown in Fig. III-2. In the first 10 years of plant life, an average of about three failures a year is to be expected whereas near the end of its life, failures may be occurring every three days.

The need for a shutdown to repair leaks would depend on how rapidly the leak enlarged and the pressure

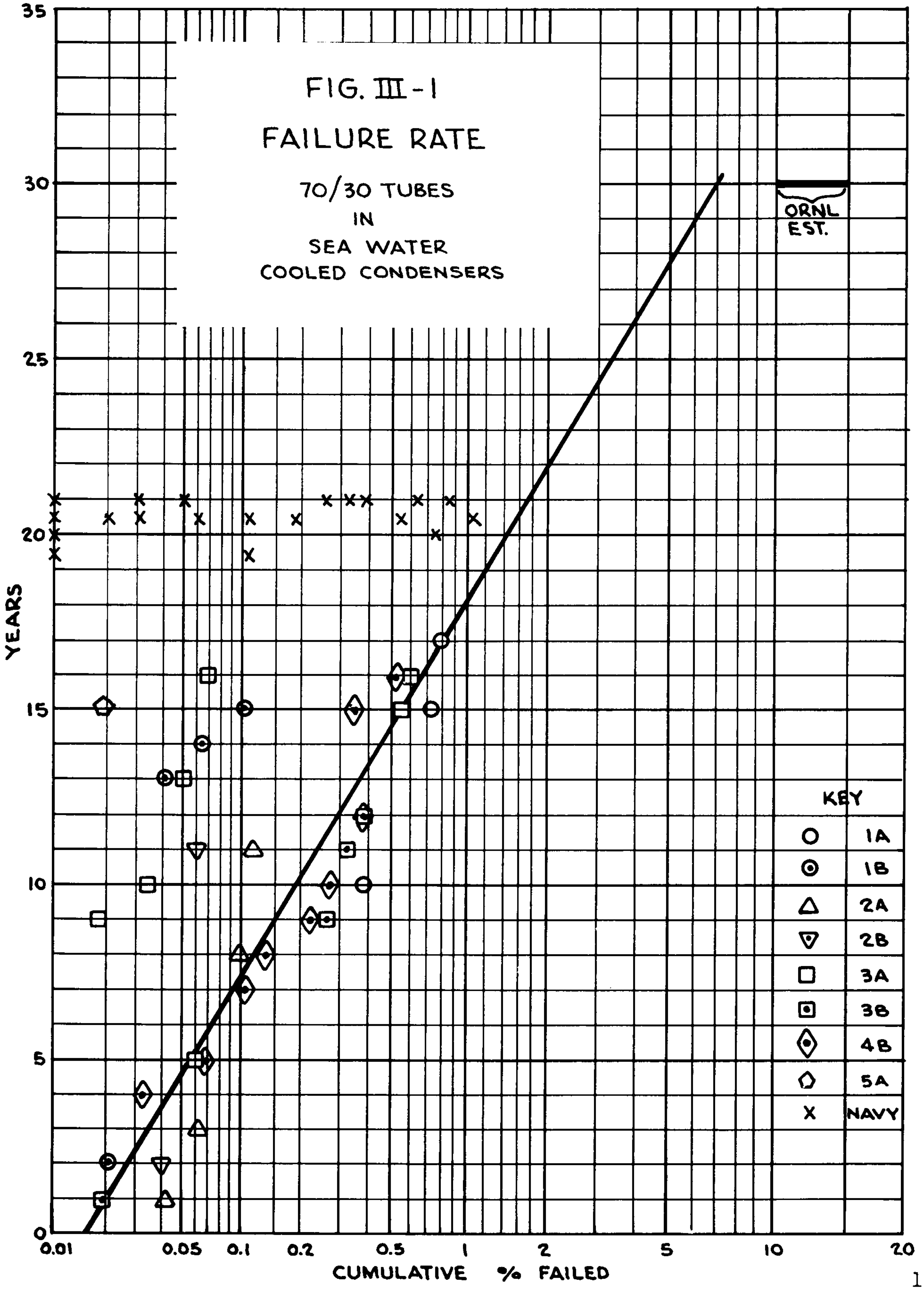


FIG. III-1

FAILURE RATE

70/30 TUBES
IN
SEA WATER
COOLED CONDENSERS

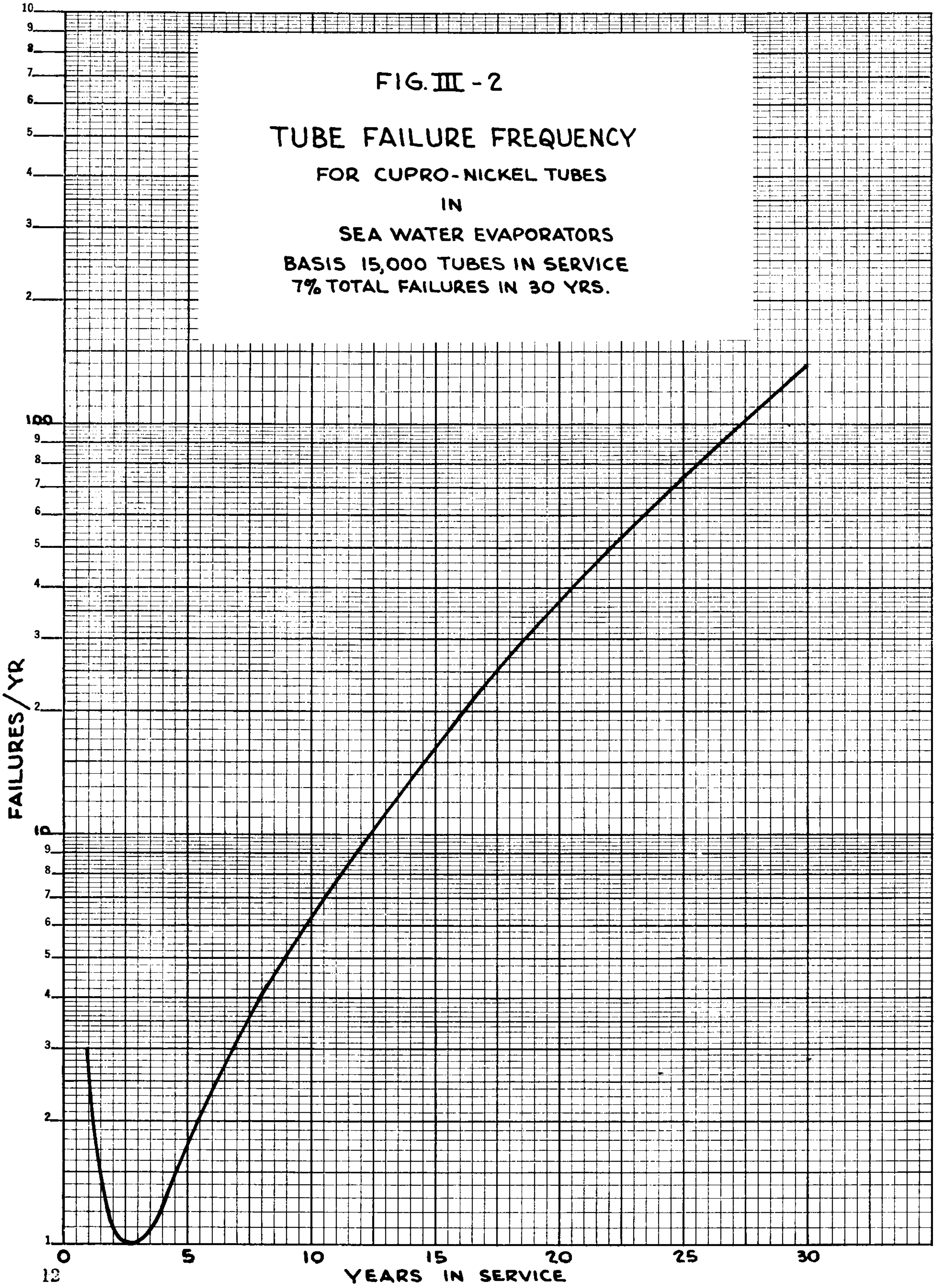


FIG. III - 2

TUBE FAILURE FREQUENCY
FOR CUPRO-NICKEL TUBES
IN
SEA WATER EVAPORATORS
BASIS 15,000 TUBES IN SERVICE
7% TOTAL FAILURES IN 30 YRS.

difference across the leak. Assuming that the leakage hole grew at the rate of 1/8" per 10 days (Reference 5), that it acted as a simple orifice, and that the pressure difference was that existing in the inlet water box of the highest temperature set of flash stages, it would take about 45 days for a single leak to contaminate the entire plant output with about 350 ppm total solids (equivalent to about 3400 ppm solids in the net output of the MSF section alone). The leak would then be about the same diameter as the tube. Thus, in the first ten years, the odds are that practically every leak would require repair before the next one developed. However, the 45 day leeway would give ample time for scheduling a shutdown and could also be arranged to permit hot end inspection of the gas generator at the same time.

In the last year of plant life, if it is assumed that a new leak started every three days after the last shutdown, it would take about 25 days for the combined leakage to contaminate the entire plant's output with 350 ppm solids (30 days to exceed 600 ppm). Thus, a plant shutdown to repair these leaks would be needed at least once a month. It is undoubtedly optimistic to assume leaks occurring at even time increments, since it is common experience that the greatest frequency occurs during a plant startup. However, it is hoped that by this time the pattern of leaks is well developed, that some preventive action can be taken (such as plugging or replacing selected portions of the tubing or installing inserts at tube inlets), and that the provisions made for dumping the most highly contaminated condensate near the end of a run will permit extending runs to at least 25 days.

The effect of tube leakage in the VTE evaporator is much less serious. Within the tubes, the steam pressure is at all points greater than the brine pressure and a leakage hole large enough to make the entire output of an MSF plant unpotable will bypass no more than a few hundred pounds of vapor to the next effect of a VTE evaporator. The fluted tubes to be used in the proposed plant require porcelain spray distributors that deliver the seawater against the porcelain wall of the distributor with a relatively strong force. Although unlikely, the nozzle could become partially plugged such that a stream of seawater was directed against the wall of the tube with enough force to cause localized damage. Erosion of the tube could occur such that a stream of brine was injected into the distillate side. Should the deflected spray be such that the entire circumference of the tube were effected, and assuming that the penetration widened at the same 1/8" per 10 day rate, it would take over two years for a tube to fail around the entire circumference. Not until this occurred, could it release to the distillate side the entire amount of brine being fed to the tube, which would contain only 34 pounds of total solids per hour, equivalent to only 12 ppm in the plant's total distillate. Thus, any tube failure starting immediately after an annual inspection should not be contributing more than 6 ppm total solids by the time of the next inspection. Not until the end of the last year of plant life, when about 170 failures would be expected, should VTE tube failures contribute more than 500 ppm solids to the product.

The only portion of the VTE where tube failure could be a problem is that section of the first effect heated by prime steam and returning its condensate to the boiler. This section has only about 530 tubes, but each month of a tube failure would increase the total solids content of the returned condensate by an additional 20 ppm. The five failures a year that would be expected at the end of 30 years would be intolerable and an allowance has therefore been made for retubing this section at the end of 15 years, when the failure frequency should be on the order of one tube every two years.

It therefore seems apparent that VTE tube failures can be dealt with during the planned week long annual shutdown and that forced outages to repair pressure tube leaks will vary in frequency from 3 to 12 times a year and average about 7 times a year over the life of the plant. There should be adequate warning available to permit careful preparation for these forced outages (at least 15 days) and their duration can therefore be kept to a minimum. Being very conservative, it should take no longer than an average of three days to shut down the plant, locate and plug the leaky tubes, and resume full production. On this basis, average annual down time should not exceed the following:

Annual turnaround	7 days
Tube plugging, 7 x 3	21 days
Subtotal	28 days

Misc. (power, fuel failure, weather, etc.) -20% of assumed outages	6 days
Total	34 days
% Availability	90.7%

For purposes of this report, a 90% plant availability was used.

7.0 Equipment Parameters

The following equipment parameters and constraints were given by the Office of Saline Water after review of the Phase I report and recommendations:

Gas Turbine Drive	Pratt & Whitney Aircraft engine FT-3 (nominal 12,500 hp)
Heat Recovery Boiler	415 psia, 650°F
Supplementary Firing	Only for start-up or trimming of plant
Back Pressure Steam Turbine	Auxiliary generator drive on separate shaft from gas turbine
Vertical Tube Evaporator	No brine recirculation
No. of effects	4
ΔT per effect	6°F ± 0.5°F
Tubing Material	90% Cu, 10% Ni
Tubing Configuration	Double Fluted
Wall Thickness	0.049 inch smooth, 0.035 inch fluted
Tube Length	12.5 feet
Tube Life	30 years
MSF Unit	
Tubing Material	90% Cu, 10% Ni
Tubing Wall Thickness	0.035 inch
Tube Life	30 years with 2% surface added for tube plugging

The flow passages of the VTE and MSF units are designed to pass the maximum expected flows, even though these flows may exist at off design conditions. The pumps were specified on the same basis.

The number of pumps installed for each particular service was based on the premise that full plant output could be maintained with one pump out of service. In most cases three half capacity pumps are provided. The Deaerated Seawater pumps are an exception to this rule. It was decided to use four, one-third capacity pumps in this application. Due to the combination of a large flow and a relatively high head (261 feet TDH) if a three pump scheme were used, the motor horsepowers would be 450 hp each. The starting of a motor of this size produces undesirable electrical problems relative to voltage dips, voltage recovery, and increased generator standby capability.

The H.P. boiler feed pumps are specified to be full capacity pumps. Due to the high head (1080 TDH) and relatively small flow (64 gpm), the use of half capacity pumps created further problems. Due to the infrequency of operation, the use of three half capacity screen wash pumps was considered impractical and two full capacity pumps were selected.

8.0 Capital Charges

To develop plant costs, the capital costs of the major components had to be determined. Specifications were written and estimating prices obtained for the following pieces of equipment:

a. Steam turbo-generator
b. MSF evaporator and components
c. Vertical pumps
d. Forced draft fan and gas engine driver
e. Auxiliary generator and gas engine driver

The capital costs of the power train, which include the turbine and vapor compressor were developed by Pratt & Whitney Aircraft.

The capital costs of the heat recovery boiler and the VTE unit were developed by Struthers Energy Systems, Inc.

An interest rate of 4.25% was specified as the cost of capital for a municipal water plant by the Office of Saline Water.

9.0 Cost Basis

9.1 Construction

The construction costs of the VTE and the Heat Recovery Boiler were developed by Struthers Energy Systems, Inc. The price of erection of the main power train was developed by Pratt & Whitney Aircraft. The MSF erection cost was quoted by Aqua-Chem. The erection costs for the smaller components were estimated by Struthers Energy Systems, Inc. The piping erection costs were estimated by Carco, Inc. of Denver, Colorado, as well as the construction equipment rental requirements. The intake structure cost estimate was performed by ORNL of Oak Ridge, Tennessee.

The design of the foundations for the various pieces of equipment was performed by Carco, Inc., as well as the foundation construction costs.

9.2 Operation and Maintenance

The costs of operation were based on a cost of natural gas of 20¢/MM btu provided by the Office of Saline Water. A cost of the synthetic type lubricating oil used in the main power train was provided by Pratt & Whitney Aircraft. This is approximately $8.00/gallon.

The manpower requirements were developed by W. L. Badger Associates. The manning schedule is based on major maintenance operations being performed by outside contractors. The salaries and payroll extras are typical of those paid in the utility field in the Texas Gulf Coast area. A check of payroll extras in the area indicated the costs to be 24% of the direct salaries. A general and administrative burden of 30% was assumed.

A maintenance contract for the main power train was developed by Pratt & Whitney Aircraft. Other plant maintenance was allowed for in the cost estimate by assuming the maintenance on the plant equipment would cost 0.5% of the total direct capital cost of the plant excluding the main power train cost.

10.0 Chemical Cost

The operating cost applicable to chemical treatment was calculated by W. L. Badger Associates. Included are costs attributable to treating the product water pipeline, although the pipeline leaves the plant property. Quotations were received from a chemical supplier in the Texas Gulf Coast area to determine present chemical costs. Acid represents the major chemical cost,and its price was based on delivering the acid to the plant site by 2000 ton barges from Corpus Christi, Texas. Chlorine price is based on delivery in one (1) ton cylinders.

11.0 Plant Grounds and Building Costs

Landscaping of the plant grounds is not included in the plant costs developed in this study. The costs of a property fence 400 feet square and one half mile of hard surface roadways are included.

The control building costs was developed by W. L. Badger Associates and is based on OSW's Report #72 with prices escalated to 1968. The costs of the chemical storage building and of the switchgear and generator house are based on quotations received by Carco, Inc.

IV. Plant Description

1.0 Process Description

1.1 General

The process consists of a gas turbine powering a vapor compressor which operates across a four-effect vertical tube evaporator. (Refer to Figure IV-1, Heat and Material Balance, and Section V, Item 2.3 for calculations) A heat recovery boiler is employed which recovers the heat from gas turbine exhaust. Steam at two energy levels is generated in the heat recovery boiler; one level is approximately 260°F saturated, and the other is 650°F, 400 psig, superheated steam which is used to power a back pressure steam turbine. The back pressure steam turbine is coupled to an electric generator which produces all the required auxiliary power for this facility. The exhaust steam at 257°F from the back pressure turbine is combined with the steam from the low pressure boiler. This steam is used as the heat input to the first effect of the vertical tube evaporator. The vapor compressor receives the low pressure steam from the fourth VTE effect at 227.7°F and increases its temperature to 343.4°F superheated steam which is then desuperheated to 256.6°F. The boiler steam is held separate from the process steam.

A multistage flash plant is used for feed heating the incoming seawater at a rate of 5.0 x 10^6 lbs/hr. This process is a once-through system without recirculation. The makeup feed is first preheated in several MSF stages to 89°F. At this temperature, sulfuric acid is injected for scale control and then the feed is decarbonated and deaerated. The makeup feed is then further preheated through the MSF train to a temperature of 208.8°F. This feed stream then proceeds through four feed heaters, one between each VTE effect. The feed is thus further heated by a portion of the steam from each of the VTE effects.

A vertical tube evaporator consists of nominal 3-inch O.D., double fluted, 90-10 copper-nickel tubes which have an effective tube length of 12'-6". The feed brine to the first effect is sprayed through distribution nozzles to the inside of the fluted tubes. The steam from the low pressure boiler and from the vapor compressor outlet is used to heat this incoming brine to a point where evaporation occurs. Essentially all heat of vaporization from the steam is transferred to the incoming brine, consequently generating an equivalent amount of product from the brine. The reject brine from the first effect is used as the feed for the second effect, and the steam generated from the evaporating brine in the first effect is used as the heat input to the second effect. The steam produced in the first effect, thus becomes the product from the second effect. This process is repeated through all four vertical tube effects. The blowdown brine from the fourth effect then enters into the flash stages of the MSF train. Similarly, the product from the vertical tube evaporator is flashed down through the MSF train in order to recover its sensible heat.

The MSF train is a conventional, commercially available system; however, it has the unique feature of having a product stream enter at the high temperature end which is approximately equal to the flashing brine stream flow rate. The duty of the MSF is approximately double that required by a simple MSF train producing product in a conventional manner from a brine stream.

This plant, as described herein, is designed to produce 8.0 MGD of distilled water when:

a. using 12,500 hp power input to the vapor compressor

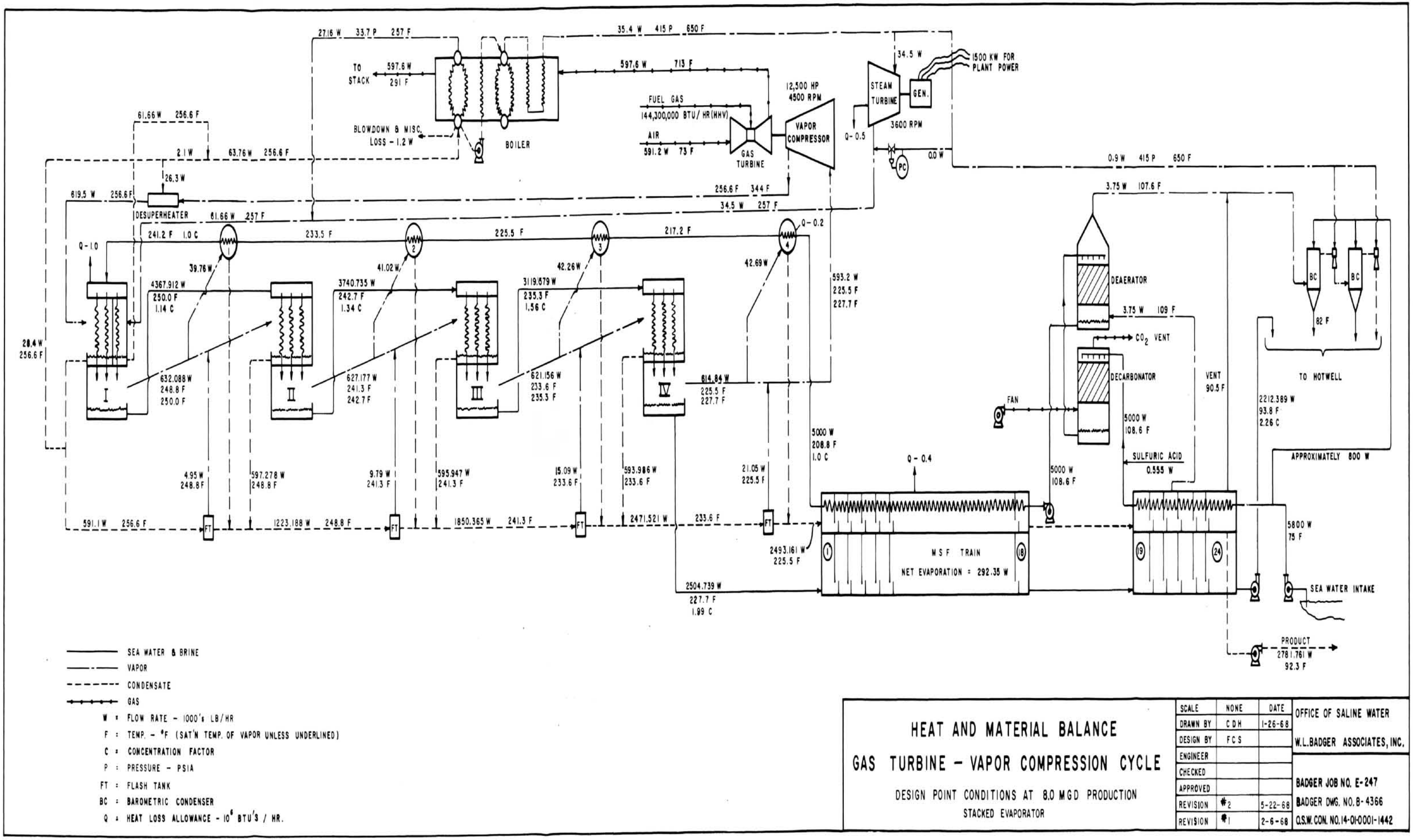
b. using no supplementary firing

c. ambient air temperature is 73°F

d. ambient seawater temperature is 75°F

e. VTE and MSF heating surfaces have the degree of cleanliness allowed for in the design.

However, the plant is capable of operating efficiently at any desired production rate for any reasonable departure from the above assumptions.



HEAT AND MATERIAL BALANCE
GAS TURBINE - VAPOR COMPRESSION CYCLE

DESIGN POINT CONDITIONS AT 8.0 MGD PRODUCTION
STACKED EVAPORATOR

SCALE	NONE	DATE	OFFICE OF SALINE WATER
DRAWN BY	CDH	1-26-68	W.L.BADGER ASSOCIATES, INC.
DESIGN BY	FCS		
ENGINEER			
CHECKED			BADGER JOB NO. E-247
APPROVED			
REVISION	#2	5-22-68	BADGER DWG. NO. B-4366
REVISION	#1	2-6-68	O.S.W. CON. NO. 14-01-0001-1442

FIGURE IV-1

FIG. IV-1

1.2 Seawater Intake System

Seawater enters into a concrete structure located on the bay bottom approximately 1000 feet off shore. A small 2" polyvinyl chloride pipeline is buried in the bay bottom with the large 30" O.D. intake line to provide chlorinated water to the incoming seawater at the intake structure. The addition of chlorine to the stream flow at this point will inhibit marine growth in the intake pipeline. The chlorine feed system is installed adjacent to the intake structure located at the plant site. Water for the chlorine feed system will be provided from the discharge of raw seawater feed pumps.

Seawater flows from the 30" O.D. line into the concrete intake structure located at the plant site. The water passes through the bar screen and then through the traveling screen. Large fish and sunken debris will be stopped by the bar screen. Smaller fish, crabs, kelp, seaweed jellyfish will be caught on the traveling screen. When the traveling screen becomes partially blocked, a difference in the upstream and downstream water level will be detected and one screen wash pump will automatically start. The traveling screen drive will then start and the debris will be washed from the screen into a trash flume. Upon restoration of an acceptable differential water level between the traveling screen, the screen drive and the screen wash pump will automatically be secured.

The screened seawater flows from the traveling water screen to the suction of the raw seawater pumps where it is pumped into a common above-grade manifold. The discharge piping of each pump has a check valve and a butterfly shut-off valve. A common line extends from the pump manifold to the inlet of a duplex strainer. This strainer is a manually operated unit designed to prevent sand from entering the MSF unit. The outlet of the strainer is connected to the inlet waterbox of the first MSF train.

1.3 Makeup Feed Pretreatment

Four chemicals are used for treatment of the seawater in this plant. Chlorine,as described above in Item 1.2, is used for marine growth control in the intake line and structure.

Ninety-eight percent (98%) sulfuric acid is used for continuous feed treatment to maintain the desired pH in the feed stream leaving the deaerator. The continuous acid pretreatment aids in controlling scaling in the evaporator for brine temperatures up to 250°F. The acid is fed into the seawater stream prior to the decarbonator. Hagan C-1 anti-foam treatment is injected into the feed stream at the MSF seawater inlet waterbox. The anti-foam compound is used to control the tendency of seawater to foam when organics are present. A solution of sodium metasilicate is injected into the product water stream to inhibit corrosion of the steel pipeline.

1.4 Air and Noncondensibles Removal

A hogging ejector is used for initial evacuation of the VTE-MSF train. The ejector is operated with steam at 400 psig and takes suction from the last stage of the MSF unit. It exhausts steam and air to the atmosphere. It is designed to evacuate the evaporator within an hour to the final operating vacuum.

A vacuum operated, packed column type deaerator is designed to remove all but 20 ppb of dissolved oxygen and all but 4 ppm of carbon dioxide from the seawater feed. These noncondensible gases are removed from the deaerator by the main steam jet air ejectors operated with 400 psig steam. These gases are passed to a built-in precondenser located in the shell of the first MSF train where they are cooled with cold seawater. These gases are removed with the first stage air ejector and discharged into the inter condenser. The gases are then removed into the second stage inter condenser by the second stage air ejectors. The gases are then liberated to atmosphere from the second stage inter condenser.

Air leakage through manholes and other flanged connections in the MSF is vented from stage to stage and is removed by the air ejector system.

Because the incoming feed water is decarbonated and deaerated, the quantity of noncondensibles liberated in the VTE unit is expected to be small. The majority of these noncondensibles will be found in the vapor space of the second VTE effect. Vapor and noncondensibles exiting from the tubes of the first effect sweep across the disengaging area of the brine cone of the second effect and down into the second effect tube bundle. Large "windows" in the 30" O.D. center pipe provide an exit for approximately 6% of the tube bundle vapor inlet flow. This vapor flow is used in the seawater feed heater as a heat source. The vapor flow design through the tube bundles is such that efficient, thorough scavenging of the noncondensibles will be maintained. These noncondensibles are vented to atmosphere from the shell side of the highest pressure feed heater.

The noncondensibles from the remaining VTE effects are swept into the respective feed heaters. A series of vents with orifice plates cascade the heater vents into the MSF evaporator for final removal by the steam jet air ejectors.

1.5 Multistage Flash Evaporator

Raw seawater is pumped into the waterbox of the lowest stage of the MSF (Stage #24) by the raw seawater feed pumps. The seawater is then heated through the lower six stages before being piped to the atmospheric decarbonator. The liberated CO_2 is removed from the decarbonator by exhaust fans. The seawater is then fed into the deaerator by vacuum drag through a level control valve. The seawater is pumped through the remaining 18 stages of heating by three of the four deaerated seawater pumps, emerging from the last MSF effect at a temperature of 208.8°F.

Hot concentrated brine enters the first stage of the MSF unit from the fourth effect of the VTE unit. The hot brine cascades from stage to stage through brine gates, flashing enroute to a final concentration factor of 2.26. As in typical MSF units, the heat of vaporization of the flashed vapor is given up to the seawater flowing in the tubes. The concentrated brine is pumped to the brine blowdown pipeline that extends 2000 feet into the bay. Hot distilled water from the fourth VTE effect is also cascaded from stage to stage in the MSF unit. Part of this distilled water is flashed in each stage and the heat of vaporization of the flashed vapor is given up to the seawater flowing in the tubes. Final product water is removed from the last stage of the MSF by two of the three distillate pumps and pumped into a product pipeline. No product water storage facilities are included in this plant design.

Should the MSF surfaces become abnormally fouled, or if the seawater temperature dropped lower than design, the MSF train will reject more heat than is normally available to the high temperature end of the system. If not compensated for, the temperatures in the VTE section would decline and production rate would be reduced. Compensation is provided by a small amount of supplementary firing, controlled by the pressure at the discharge of the vapor compressor. If the need for firing is a result merely of low seawater temperature, the flashing range in the MSF train will be wider, resulting in more MSF water production. The incremental cost of fuel for the incremental production will closely approximate the average water cost, resulting in no penalty on overall water cost.

If the MSF train is more efficient than design, or if the seawater is warmer than design, temperatures in the VTE section would tend to increase. This can be compensated for in either or both of two ways. Increasing the seawater feed rate to the system will allow the MSF train to reject more heat and will increase production by the MSF, but will require more acid. Bypassing a small amount of seawater around a part of the MSF train will reduce its effectiveness and allow more heat rejection, without requiring more acid. The instrumentation is arranged to permit the feed rate to be manually set as desired, depending on whether or not the increased production is wanted, with a bypass around the top MSF stages for either trimming purposes or for full control.

These "heat balance closure" controls of the MSF train are also needed when the plant is operated at reduced output. The control mode used at any time will depend on the above factors, the ambient air temperature, the plant power requirements, and the ratio of compressor power input to turbine exhaust heat recovered.

1.6 Feed Heater Flow

The feed heaters are single pass shell and tube type heat exchangers. Hot seawater is fed into the inlet of the lowest feed heater from the MSF unit. The seawater flows on the tube or channel side through the first heater and enters the second heater. The flow continues through all the heaters in series. The seawater is heated from 208.8°F to 241.2°F at design conditions by the feed heaters. No valving is used in the piping between the feed heaters.

Vapor entering the shell side of the feed heaters is condensed and flows from the heater at the opposite end from the vapor inlet. There are no desuperheating sections or drain cooling sections in the heaters. The drains from each feed heater may be diverted to either the product water stream or the brine stream of the next lower VTE effect depending on the purity of the condensed vapor.

1.7 Vertical Tube Evaporator

The heated seawater enters the elliptical waterbox on the top of the VTE vessel. The feed is distributed to each tube by a porcelain distribution nozzle. The nozzle sprays in the shape of a hollow cone against the nozzle wall and subsequently wets the periphery of each tube. A mixture of water vapor (steam) and heated brine discharges from the bottom of each vertical tube in the first effect tube bundle. The evaporation takes place due to the addition of heat to the outside surface of each tube from either the vapor compressor discharge or the low pressure steam from the boiler. The brine leaving the first effect tube bundle is collected in a cone-shaped basin constructed over the inlet tube sheet of the second effect. The vapor produced from the discharge of the first effect tube bundle is condensed on the outside of the tubes of the second effect. The heat of vaporization of this vapor is given up to the brine being sprayed through the inside of the second effect tubes. A 5 psi pressure drop occurs across the distributor nozzles of each effect and thus, reduces the saturation temperature of the flowing brine to the extent that evaporation occurs. The evaporation is augmented due to the addition of heat from condensing vapors on the outside of the tube.

The brine and distillate flow from the fourth effect of the VTE to the first stage of the MSF evaporator for further evaporation and heat extraction.

The vapor produced in the fourth effect does not have a heat sink on which to condense. The vapor is removed from the steam space through moisture separators or demisters and flows into the suction of the vapor compressor.

The vapor velocities at various sections of the VTE are shown in Table IV-1. The velocities shown in this table are applicable to the vessel configuration as designed for this plant.

Although the performance map of the compressor selected in this phase of the study is not as anticipated in Phase I, the plant will still be able to operate at any desired production rate, with reasonable fouling of the VTE surfaces. The fairly high suction volume at the surging limit of the compressor dictates that major decreases in production be handled by reducing the top brine temperature rather than simply by reducing the compressor speed. In Fig. IV-2, the performance map of the evaporator is superimposed on the compressor map. In the upper portion of Fig. IV-2, are shown the compression ratios required by the evaporator with both fouled and clean heating surfaces, as a function of saturated vapor pressure at the compressor intake and compressor suction parameter $(V/V_o)((T_o + 460.)/(T + 460))^{\frac{1}{2}}$. The "design" curve for 225.5°F suction temperature includes the approximate 0.00018 fouling factor allowed for in the plant design. The "dirty" curves correspond to twice this degree of fouling and the "clean" curves are for the case of no fouling. The lower set of curves of Fig. IV-2 show the relationship between the compressor suction parameter, the suction temperature, and the plant production rate. The production rate is based on the assumption of a constant blowdown concentration factor; somewhat higher concentration factors could be tolerated at the lower suction temperatures, resulting in a slightly lower total production rate but a saving in acid.

At the design 225.5° suction temperature, the compressor suction parameter is identical to the fraction of design output. At this temperature, Fig. IV-2 shows that the plant would

TABLE IV-1 VTE VAPOR VELOCITIES

A. Velocities between tubes in steam side of heating elements (FPS)

% OF HEATING SURFACE TRAVERSED	EFFECT NO. I	II	III	IV
0	20.5	21.7	24.6	28.0
25	17.6	19.1	21.6	24.7
50	14.5	16.4	18.6	21.2
75	10.6	12.8	14.5	16.7
100	2.1*	9.2	10.8	12.7

* No flow from Effect I to preheater - above assumes 1.5% vent rate.

B. Horizontal velocity through curtain of brine leaving tubes (FPS) with orifices sized for 5 psi ΔP at design feed rate.

CONDITION	EFFECT NO. I	II	III	IV
Design Feed Rate	3.7	4.4	5.2	8.6*
Maximum Feed Rate (5.5×10^6 #/hr)	6.2	7.0	9.7	8.6*
Normal Design Limit	10.0	10.6	11.4	12.2

* Assuming 4' liquid depth in IV effect sump to feed MSF train.

C. Rising velocity at maximum free horizontal area (FPS)

CONDITION	EFFECT NO. I	II	III	IV
Actual Velocity (FPS)	4.75	5.28	5.97	5.63
Normal Design Limit	5.0	5.3	5.7	6.1

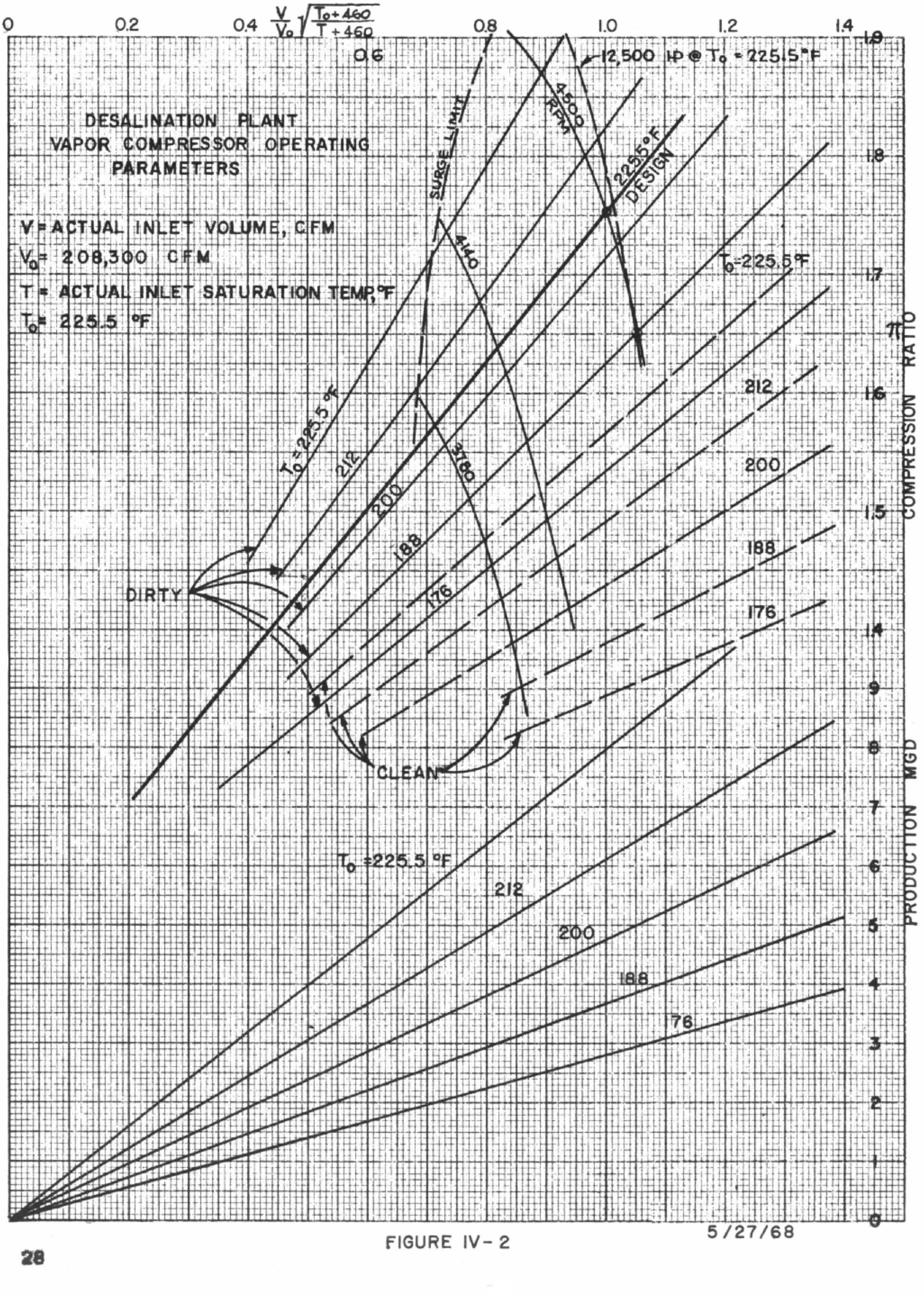


FIGURE IV- 2

5/27/68

produce about 6% more than design when clean. When dirty, it would produce about 89% of design if compressor speed were held constant but will produce 94% of design, at slightly over 4500 RPM design speed, by holding power input constant as planned.

If it were desired to reduce production while holding the suction temperature constant at the design values, Fig. IV-2 shows that production could be reduced to only about 5.7 MGD if the heating surfaces were "dirty" and only slightly less if they were clean. The figure also shows that, by dropping to a suction temperature of 176°F, production could be reduced to 2 MGD without going below a suction parameter of 0.7. It should be noted that the power input to the compressor will be substantially less than normal at any suction temperature below design.

In the other direction, it is possible to increase production to somewhat more than the design 8.0 MGD. One method is by going to a higher power output by the gas turbine, with a penalty of increased fuel cost and maintenance charges. The other method is by feeding additional seawater to the system in order to make more water by flashing the blowdown. This incurs additional costs for supplementary fuel and acid but, again, incremental costs for the incremental production are of the same magnitude as the average cost. The plant has been sized to permit feeding seawater at 10% over the rate at the design point. This is equivalent to about 3% incremental production at design 12,500 hp power input, or about 10% incremental production if the power input is increased. In the latter case, the production limit is set by the need to keep the VTE blowdown concentration factor below 2.0.

1.8 Vapor Compressor Flow

The vapor compressor receives low pressure steam from the fourth effect of the VTE at 19.0 psia, 227.7°F and compresses it to 33.4 psia, 343.4°F. The temperature of the compressed vapor entering the VTE first effect steam space is controlled by spraying with condensate. There are no control valves in the vapor compressor vapor ducts; the flow is controlled by the firing rate of the gas turbine.

The vapor compressor is intended to operate normally with less than a ± 5% variation in speed. The design of the vapor compressor is such that a 15% reduction in flow rate and a corresponding decrease in head should not result in surging while maintaining design speed.

1.9 Gas Turbine Flow

The gas turbine combustion air enters through an inlet silencer designed to attenuate compressor noise. This air is compressed and enters the gas generator combustion chamber where 144.3×10^6 btu/hr of natural gas is burned. The high temperature, high pressure gases pass through the turbine stages and are exhausted to the heat recovery boiler. The gas turbine provides 12,500 shaft horsepower to drive the vapor compressor and supplies 597,600 #/hr of exhaust gas at 713°F to the heat recovery boiler.

1.10 Heat Recovery Boiler

Exhaust gases from the gas turbine are ducted to the heat recovery boiler through a rectangular, insulated duct. These high temperature gases enter a plenum that serves to convert some of the dynamic head of the gas to static head, thus reducing the draft losses through the boiler. This plenum also accommodates a dump stack and the inlet duct from the forced draft fan. The dump stack has a conical-shaped valve in its base that will open to allow hot exhaust gases to bypass the boiler and be dumped to atmosphere during periods of low steam demands. The primary superheater is mounted in the boiler casing between the inlet plenum and the supplementary firing combustion chamber to serve also as a gas flow smoothing screen before the velocity sensitive burners. The hot gases flow through the primary superheater of the boiler where part of the exhaust gas heat is given up to the steam. The gas then passes through the burner grid and into the combustion chamber. During normal conditions, supplementary firing of the burner is not required. The gases next pass through the second superheating section and into the main high pressure steam generating section. As the gases exit from the H.P. generating section, they pass into the economizer section and on through the low pressure steam generating section, being cooled to approximately 45°F of the L.P. boiler water temperature. Refer to Figure IV-3 for a temperature profile for the heat recovery boiler.

During startup of the boiler, no high temperature exhaust gases will be available from the gas turbine. A natural gas engine driven forced draft fan is provided to furnish fresh air for combustion. The air enters the boiler inlet plenum and passes through the initial superheater section to the burner grid. Natural gas is burned in the combustion chamber to provide the heat for the production of steam. Because this entering fresh air is at ambient temperatures, the initial superheater must be taken out of service, since any steam entering it would be condensed. During boiler operation with the gas turbine not in service, the secondary superheating section is used exclusively. To prevent fresh air from being discharged into the gas turbine during boiler startup, a check damper is provided at the inlet plenum which closes off the duct leading to the gas turbine exhaust. When operating on forced draft fan air, boiler output is restricted to approximately 50% of design.

The feed water for the low pressure boiler comes from the condensate produced in the first effect of the VTE. Sufficient static head exists to feed this section of the boiler without the aid of a pump. For startup and emergency conditions, a small pump is provided to feed the L.P. boiler, taking suction from a 6000 gallon tank.

The steam produced in the low pressure boiler is used in the first effect of the VTE as explained in Item 1.7 of this section.

The H.P. boiler feed pumps take suction from the lower drum of the L.P. boiler and pump the feed water to the high pressure boiler drum through the economizer. The steam produced is removed from the H.P. drum through moisture separators and sent to the initial superheater. The steam is then routed to the final superheater where it is heated to a final temperature of 650°F. The H.P. steam is used for the turbo generator and the steam jet air ejectors. Valving and piping is provided for H.P. boiler blowdown for the control of solids.

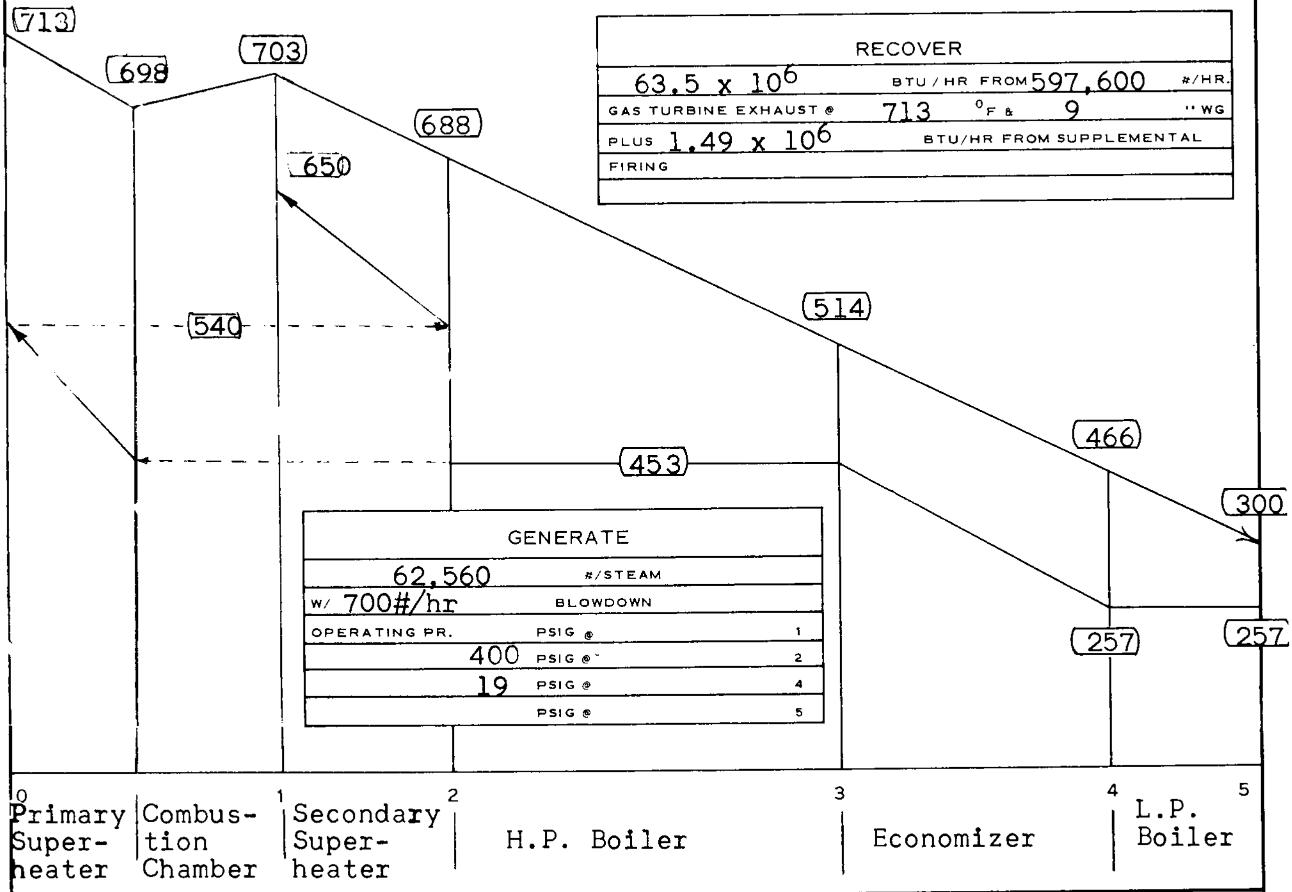
HEAT RECOVERY SPECIFICATION SHEET

CUSTOMER OFFICE OF SALINE WATER Contract No. 14-01-0001-1442

ADDRESS PROPOSAL NO.

PLANT LOCATION Texas Gulf Coast DATE June 20, 1968

TEMPERATURE PROFILE



RECOVER

63.5×10^6 BTU/HR FROM 597,600 #/HR.

GAS TURBINE EXHAUST @ 713 °F & 9 " WG

PLUS 1.49×10^6 BTU/HR FROM SUPPLEMENTAL FIRING

GENERATE

62,560 #/STEAM

W/ 700#/hr BLOWDOWN

OPERATING PR. PSIG @ 1

400 PSIG @ 2

19 PSIG @ 4

PSIG @ 5

THERMAL DESIGN

	SUPERHEATER	HIGH PRESSURE GENERATOR	ECONOMIZER	
DUTY, MM BTU/HR				
MTD, CORRECTED				
TRANSFER RATE				
(W.R.T. EXTERNAL SURF)				
(W.R.T. EXTERNAL SURF)				
FOULING FACTOR				
EXTERNAL				
INTERNAL				
STEAM PURITY, PPM				

FIGURE IV-3

1.11 Steam Turbo Generator

The steam turbo generator uses high pressure boiler steam to generate all the electrical power required on site. No tie to an outside utility is contemplated for back-up power. The turbine throttle valves are self-regulating and admit enough steam to produce the electrical load demanded. The turbine exhausts at 19 psig to the shell side of the first effect of the VTE.

1.12 Pumps

The various pumps used in this plant are described on an individual basis in the following section of this report.

1.13 Process Control

The process control of the plant is designed to be fully automatic with remote control of the various parameters available from the control room. An alarm monitoring panel is provided in the control room.

The raw seawater feed rate is controlled by a butterfly valve, pneumatically operated, located near the MSF seawater inlet waterbox. The valve position is adjustable remotely from the control room. The seawater stream flow rate is measured upstream from the control valve and the signal transmitted to the control room.

The seawater level in the decarbonator is controlled by a level controller. A signal from the level controller positions a control valve in the line to the vacuum deaerator and increases or decreases the flow rate out of the decarbonator accordingly.

The brine and distillate levels in the 24th stage of the MSF unit are each maintained by a level controller that regulates the position of the butterfly control valve downstream of the respective pumps. Both the effluent brine and product stream flow rates are monitored and recorded.

The effluent product water is monitored for salinity. Should the salinity be above acceptable limits, an alarm will be annunciated and the effluent diverted to the brine blowdown line through a 3-way diverting valve.

The necessary alarms and indicators are provided in the control room for safe monitoring of the process.

The makeup to the low pressure boiler is controlled by a level controller mounted on the low pressure boiler drum. The water level in the high pressure boiler is controlled by a level controller mounted on the high pressure boiler drum. The superheated steam temperature from the high pressure boiler is controlled by bypassing a portion of the steam flow around the superheaters. The pressure of the low pressure steam header is monitored and if it falls below a given set point, steam from the high pressure boiler is used to supplement it.

1.14 Startup

In starting the plant from a cold condition, care must be taken to proceed in an orderly manner. The plant is provided with an auxiliary gas engine driven generator, rated at 150 kw, to operate lights, control valves, air compressor and miscellaneous small pumps as required. If an orderly startup procedure is abandoned, the auxiliary generator could become overloaded and trip off the line.

The startup of this plant is facilitated because the main source of electrical power, a back pressure steam turbo generator, is not connected or dependent of the main power train, and may thus be started independently.

In the startup procedure which follows, it is assumed that the plant is cold and at atmospheric pressure with all the water valves closed. The gas engine generator, started from its storage battery, is assumed running as it will be whenever the main plant is down.

1. Open the drum vent valves on both the H.P. and the L.P. boiler drums and close the isolating valves for the section of superheater located in the ductwork between the forced draft fan and the gas turbine. Close the main superheater outlet valve. Close boiler isolating damper between heat recovery boiler inlet plenum and gas turbine. Fill both the high pressure and the low pressure boiler with water to the light-off level in the drums using water

from the 6000 gallon condensate storage tank and the auxiliary condensate pump. Establish minimum recirculation from the auxiliary condensate pump discharge back to condensate storage tank and energize boiler level controls.

2. Open forced draft fan discharge damper and start gas engine driven forced draft fan. After engine is warmed up, increase speed until 3 1/2" W.G. static pressure is available in the inlet plenum. Purge for 5 minutes. Check out boiler fuel lines and light-off burner pilots. Using manual fuel valve, light-off burners and establish a stable flame front. After vapor forms in the H.P. boiler vents, secure H.P. boiler vents and increase boiler pressure to approximately 50 psig.

3. Line up hogging ejectors for the deaerator and the first effect of the VTE and cut in the H.P. steam from the superheater. Line up and start the H.P. boiler feed pumps and put in automatic operation. Increase the firing rate of the boiler until approximately 150 psig drum pressure is attained. The L.P. boiler vents should be closed and the L.P. boiler main steam valve opened into the L.P. steam header. This header should be exhausted to atmosphere.

4. Open the H.P. main steam valve at the superheater and begin warming up the steam turbo generator. When the steam lines are warm, bring the steam turbine up to speed and energize the plant's main electrical system. The exhaust of the steam turbine is exhausting to atmosphere at the time. Continue to run the auxiliary generator with the electrical system divided until the steam turbo generator is operating at full pressure.

5. Set the seawater feed controller for a minimum flow rate and start one of the raw seawater feed pumps. As soon as a water level is established in the atmospheric degasifier, energize the level controller and establish a flow to the vacuum deaerator. Once the water level is to the normal operating level in the deaerator, energize the deaerator level controls and start a deaerated seawater pump. Seawater will fill

the feed heaters and will flow into the VTE first effect. The seawater will cascade through the VTE and through the brine side of the MSF unit by gravity. When a water level is established in the brine chamber of the MSF 24th stage, energize the level controller and start one of the brine blowdown pumps. Both stages of the steam jet air ejector should be lined up and cut in at the time. The deaerator hogging ejector should be secured at this time.

6. The low pressure steam header flow is diverted from an atmospheric discharge to the steam chamber of the first VTE effect. The H.P. boiler pressure should be brought up to 400 psig and maintained at this pressure level. After the condensate drains in the steam chamber of the first VTE effect have reached operating level, cut them in as the feed for the low pressure boiler. The auxiliary condensate pump should be secured at this time.

7. Due to the addition of heat and the reduction in absolute pressure in the vessels, evaporation begins. Distillate cascades through the VTE and MSF and into the distillate chamber of the 24th MSF stage. When a distillate level is established, energize the level controls and start one distillate pump.

8. After inspection of the main power train lube oil system, the gas turbine is ready to be started. The controls, once initiated, bring the gas turbine up to idle speed automatically. At initiation of the start procedure, the isolating damper between the gas turbine exhaust and the heat recovery boiler inlet plenum should be opened. Once the vapor compressor flow is established and in equilibrium, the forced draft fan may be secured. The primary superheater section should be placed in service after the gas turbine is started.

9. After the seawater flow rate has been increased to the capacity of one deaerated seawater pump, the second pump should be started. The other pumps should be started as the flow increases. Gas generator speed is incrementally increased as plant load increases and temperatures rise.

10. During periods of low steam demand when the gas turbine is running, an excessive amount of steam may be generated in the heat recovery boiler. The dump stack will automatically open to divert exhaust gases away from the H.P. boiler if drum pressure exceeds normal. The plant will be on full stream when the temperatures and pressures in the VTE unit and at vapor compressor discharge have reached design values.

2.0 Equipment Descriptions and Material

2.1 General

The intent of this portion of the report is to describe the physical components of the plant including design and operating conditions as well as the materials of construction. Specifications for each major piece of equipment can be found in Section X, Appendix of this report.

2.2 Vertical Tube Evaporator (VTE)

The vertical tube evaporator, hereafter called the VTE, is a large, cylindrically shaped steel vessel that contains four effects or stages of evaporation. (Refer to Dwg. 4.2 in Appendix) Each stage consists of approximately 5140 3" O.D. tubes arranged vertically between horizontal tube sheets. The stages are arranged one under the other to form a "stacked" concept. The tubes can be pulled and replaced from inside the structure without additional disassembly.

The design conditions of the VTE are as follows:

Design Code: ASME Boiler and Pressure Vessel Code, 1965; Section VIII, Unfired Pressure Vessels
Design Pressure: Vacuum and 20 psig
Hydrostatic Test Pressure: (a) 20 psig at top of vessel
(b) 66 psig at bottom of vessel
M.A.W.P.: 35 psig
Corrosion Allowances: (a) 3/16" for steel in contact with vapors
(b) 3/8" for steel in contact with brine
(c) 0" for 90-10 Cu-Ni surfaces and monel

The material used for construction of the top elliptical head, where the brine inlet is located, is steel with a 1/16" thick cladding of 90-10 Cu-Ni. Over the top tube sheet of each of the second, third and fourth effects is a large conical shaped reservoir for collecting the unflashed brine prior to admission into the next set of vertical tubes. The sides of these conical reservoirs are fabricated of plate steel with a 90-10 Cu-Ni cladding. The top tube sheets are protected from the brine solution by the use of ceramic distribution nozzles inserted into the top of each tube and held in place by silicone rubber. The aggregation of these nozzles form a barrier between the steel tube sheet and the brine solution. The bottom tube sheet of each effect is plain steel. The tubes protrude about one and a half inches below the tube sheet and consequently are not in constant contact with the brine solution. The bottom course of plates in the VTE are fabricated of 90-10 Cu-Ni clad steel, since this area acts as a reservoir for brine prior to discharge to the MSF.

The materials in contact with the vapor and with the product water is unclad steel. No special corrosion protection is required for these areas.

The designed minimum flow rate through each tube is approximately 1.2 gpm. The flow rates through the tubes in the VTE at the Design Point rating vary up to approximately 1.97 gpm. The distribution nozzles are designed for a pressure drop of approximately 5 psi. These nozzles are made of porcelain and have a hexagon-shaped body. These nozzles are held in place by the use of a pourable silicone rubber. The tubes are allowed to protrude 1/8 to 1/4" above the top of the top tube sheet of each effect. (Refer to Dwg. 4.6 in the Appendix) A pourable silicone rubber, similar to General Electric Company type RTV-112,is applied on the top of the tube sheet, 1/4" thick and allowed to cure. Silicone rubber is then applied to the lower shoulder of the porcelain nozzle and the nozzle inserted into the tube. After the rubber is again cured, rubber is applied to the gaps between the nozzles, thus isolating the steel tube sheet from the brine solution.

The VTE has a tubular surface area of approximately 257,000 square feet. The tubes specified in this design are of the same profile as manufactured by the General Electric Company. That is, they consist of a 3 inch O.D. smooth wall tube with a wall thickness of .049" that has been doubly fluted except for the ends. During the fluting process, the wall thickness is reduced to approximately .035" and the surface area is increased some 25%, such that the heat transfer area is 1.0 sq. ft./ft. of tube length. The tube length of this design is 12'-10 3/4" overall with an active fluted length of 12'-6". The tube material is 90-10 Cu-Ni.

The VTE is designed for an inlet seawater flow of 5,000,000 #/hr into the first effect. The inlet temperature of the seawater is 241.2°F. The design flow of the compressed vapor inlet to the first effect is 619,500 #/hr at a temperature of 256.6°F. The design flow of low pressure steam into the first effect is 61,660 #/hr at a temperature and pressure of 257°F and 19 psig.

The VTE is designed to provide approximately 62,560#/hr feed water from the product stream of the first effect for makeup to the heat recovery boiler. The temperature of this stream is approximately 256.6°F. The product water design flow from the 4th effect is approximately 2,493,160 #/hr at a temperature of 225.5°F. The design flow of the concentrated brine effluent from the 4th effect of the VTE is approximately 2,504,740 #/hr at a temperature of 227.7°F. This represents a brine concentration of 1.99.

2.3 Feed Heaters

The four feed heaters in this plant are of the single pass, shell and tube design. Although the duties of each heater vary slightly, for simplicity of design, each heater is identical. The design requires that the four heaters heat 5,000,000 #/hr seawater from 208.8°F using steam vented together with noncondensibles from the 4 VTE effects. (Refer to Figures IV-4 through IV-7 for the heater specification sheets).

The design conditions of the feed heaters are as follows:

Design Code: (a) ASME Boiler and Pressure Vessel Code, 1965; Section VIII, Unfired Pressure Vessels
(b) Tubular Exchanger Manufacturers Association
Maximum Working Pressure: (a) Shell side 35 psig and full vacuum
(b) Tube side 75 psig and full vacuum
Test Pressure: (a) Shell side 53 psig
(b) Tube side 112 psig
Design Temperature: 300° F
Corrosion Allowance: (a) Shell side 3/16"
(b) Tube side 0"

These feed heaters have a non-removable tube bundle with fixed tube sheets. The channel heads are integral type with removable covers. The channels and the brine side of the tube sheets are made of steel and clad with 90-10 Cu-Ni. The shell is made of steel. Each feed heater incorporates approximately 1090 7/8" O.D. x .042" wall x 18'-0" long tubes. Steam is admitted into the shell side of the feed heater through a distribution ring designed to increase the window of steam flow and thus, decrease the entrance pressure drop.

EXCHANGER SPECIFICATION SHEET

CUSTOMER	Office of Saline Water			JOB NO. REFERENCE NO.	
ADDRESS				PROPOSAL NO.	
PLANT LOCATION				DATE	
SERVICE OF UNIT	Seawater Feed Heater			ITEM No.	1
SIZE		TYPE		CONNECTED IN	Series
SURFACE PER UNIT		SHELLS PER UNIT		SURFACE PER SHELL	

PERFORMANCE OF ONE UNIT

		SHELL SIDE		TUBE SIDE	
FLUID CIRCULATED		Steam		Seawater (3.50% T.S.)	
TOTAL FLUID ENTERING	lbs/hr	39,760		5,000,000	
VAPOR					
LIQUID	lbs/hr			5,000,000	
STEAM	lbs/hr	39,760			
NON-CONDENSABLES	lbs/hr	20			
FLUID VAPORIZED OR CONDENSED					
STEAM CONDENSED		39,760			
GRAVITY—LIQUID		1.0		1.028	
VISCOSITY—LIQUID					
MOLECULAR WEIGHT—VAPORS		18.0			
SPECIFIC HEAT—LIQUIDS			B.T.U./#	0.978	B.T.U./#
LATENT HEAT—VAPORS		946.3	B.T.U./#		B.T.U./#
TEMPERATURE IN		250.0	°F	233.5	°F
TEMPERATURE OUT		248.8	°F	241.2	°F
OPERATING PRESSURE	GAGE	14.5	#/SQ. IN.	52	#/SQ. IN.
NUMBER OF PASSES		1		1	
VELOCITY			FT./SEC.	Approx. 6	FT./SEC.
PRESSURE DROP			#/SQ. IN.	Approx. 2	#/SQ. IN.

HEAT EXCHANGED—B.T.U./HR.	37,653,000	M.T.D. (CORRECTED)	
TRANSFER RATE—SERVICE	(0.0005) Fouling Factor)	CLEAN	

CONSTRUCTION OF ONE SHELL

DESIGN PRESSURE	35 & Full Vac.	#/SQ. IN.	75 & Full Vac.	#/SQ. IN.
TEST PRESSURE	53	#/SQ. IN.	112	#/SQ. IN.
DESIGN TEMPERATURE	300	°F	300	°F

TUBES 90-10 Cu-Ni	NO.	O.D. 7/8 BWG. 19	LENGTH	PITCH
SHELL Carbon Steel		I.D. O.D.	THICKNESS	
SHELL COVER			FLOATING HEAD COVER	
CHANNEL 90-10 Cu-Ni Clad			CHANNEL COVER 90-10 Cu-Ni Clad	
TUBE SHEETS—STATIONARY 2-1/8" incl. 3/8" Cu-Ni Clad				
BAFFLES—CROSS Carbon Steel		TYPE	THICKNESS	
BAFFLE—LONG		TYPE	THICKNESS	
TUBE SUPPORTS			THICKNESS	
GASKETS				
CONNECTIONS—SHELL—IN 28"		OUT 8"	SERIES 150	
CHANNEL—IN 24"		OUT 24"	SERIES 150	
CORROSION ALLOWANCE—SHELL SIZE 3/16			TUBE SIDE 0	
CODE REQUIREMENTS ASME Sect. VIII				
WEIGHTS—EACH SHELL		BUNDLE	FULL OF WATER	

NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)

REMARKS: See dwg 4.10 in Appendix

Figure IV-4

EXCHANGER SPECIFICATION SHEET

CUSTOMER	Office of Saline Water			JOB NO. REFERENCE NO.	
ADDRESS				PROPOSAL NO.	
PLANT LOCATION				DATE	
SERVICE OF UNIT	Seawater Feed Heater			ITEM No.	2
SIZE		TYPE		CONNECTED IN	Series
SURFACE PER UNIT		SHELLS PER UNIT		SURFACE PER SHELL	

PERFORMANCE OF ONE UNIT

		SHELL SIDE		TUBE SIDE	
FLUID CIRCULATED		Steam		Seawater (3.50% T.S.)	
TOTAL FLUID ENTERING	lbs/hr	41,020		5,000,000	
VAPOR					
LIQUID	lbs/hr			5,000,000	
STEAM	lbs/hr	41,020			
NON-CONDENSABLES	lbs/hr	5			
FLUID VAPORIZED OR CONDENSED					
STEAM CONDENSED		41,020			
GRAVITY—LIQUID		1.0		1.028	
VISCOSITY—LIQUID					
MOLECULAR WEIGHT—VAPORS		18.0			
SPECIFIC HEAT—LIQUIDS			B.T.U./#	0.976	B.T.U./#
LATENT HEAT—VAPORS		951.3	B.T.U./#		B.T.U./#
TEMPERATURE IN		241.3	°F	225.5	°F
TEMPERATURE OUT		241.3	°F	233.5	°F
OPERATING PRESSURE	GAGE	10.9	#/SQ. IN.	60	#/SQ. IN.
NUMBER OF PASSES		1		1	
VELOCITY			FT./SEC.	Approx. 6	FT./SEC.
PRESSURE DROP			#/SQ. IN.	Approx. 2	#/SQ. IN.

HEAT EXCHANGED—B.T.U./HR.	39,022,000	M.T.D. (CORRECTED)	
TRANSFER RATE—SERVICE	(0.0005) Fouling Factor)	CLEAN	

CONSTRUCTION OF ONE SHELL

DESIGN PRESSURE	35 & Full Vac.	#/SQ. IN.	75 & Full Vac.	#/SQ. IN.
TEST PRESSURE	53	#/SQ. IN.	112	#/SQ. IN.
DESIGN TEMPERATURE	300	°F	300	°F

TUBES	90-10 Cu-Ni	NO.	O.D. 7/8 BWG. 19	LENGTH	PITCH
SHELL	Carbon Steel		I.D. O.D.	THICKNESS	
SHELL COVER				FLOATING HEAD COVER	
CHANNEL	90-10 Cu-Ni Clad			CHANNEL COVER	90-10 Cu-Ni Clad
TUBE SHEETS—STATIONARY	2-1/8" incl. 3/8" Cu-Ni Clad				
BAFFLES—CROSS	Carbon Steel	TYPE		THICKNESS	
BAFFLE—LONG		TYPE		THICKNESS	
TUBE SUPPORTS				THICKNESS	
GASKETS					
CONNECTIONS—SHELL—IN	28"	OUT	3"	SERIES	150
CHANNEL—IN	24"	OUT	24"	SERIES	150
CORROSION ALLOWANCE—SHELL SIZE	3/16			TUBE SIDE	0
CODE REQUIREMENTS	ASME Sect. VIII				
WEIGHTS—EACH SHELL		BUNDLE		FULL OF WATER	

NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)

REMARKS: See Dwg 4.10 in Appendix

Figure IV-5

EXCHANGER SPECIFICATION SHEET

CUSTOMER	Office of Saline Water	JOB NO.	
		REFERENCE NO.	
ADDRESS		PROPOSAL NO.	
PLANT LOCATION		DATE	
SERVICE OF UNIT	Seawater Feed Heater	ITEM No.	3
SIZE	TYPE	CONNECTED IN	Series
SURFACE PER UNIT	SHELLS PER UNIT	SURFACE PER SHELL	

PERFORMANCE OF ONE UNIT

		SHELL SIDE		TUBE SIDE	
FLUID CIRCULATED		Steam		Seawater (3.50% T.S.)	
TOTAL FLUID ENTERING	lbs/hr	42,260		5,000,000	
VAPOR					
LIQUID	lbs/hr			5,000,000	
STEAM	lbs/hr	42,260			
NON-CONDENSABLES	lbs/hr	10			
FLUID VAPORIZED OR CONDENSED					
STEAM CONDENSED		42,260			
GRAVITY—LIQUID		1.0		1.028	
VISCOSITY—LIQUID					
MOLECULAR WEIGHT—VAPORS		18			
SPECIFIC HEAT—LIQUIDS			B.T.U./#	.974	B.T.U./#
LATENT HEAT—VAPORS		956.4	B.T.U./#		B.T.U./#
TEMPERATURE IN		233.6	°F	217.2	°F
TEMPERATURE OUT		233.6	°F	225.5	°F
OPERATING PRESSURE	GAGE	7.5	#/SQ. IN.	66	#/SQ. IN.
NUMBER OF PASSES		1		1	
VELOCITY			FT./SEC.	Approx. 6	FT./SEC.
PRESSURE DROP			#/SQ. IN.	Approx. 2	#/SQ. IN.

HEAT EXCHANGED—B.T.U./HR. 40,417,000 M.T.D. (CORRECTED)

TRANSFER RATE—SERVICE (0.0005 Fouling Factor) CLEAN

CONSTRUCTION OF ONE SHELL

DESIGN PRESSURE	35 & Full Vac.	#/SQ. IN.	75 & Full Vac.	#/SQ. IN.
TEST PRESSURE	53	#/SQ. IN.	112	#/SQ. IN.
DESIGN TEMPERATURE	300	°F	3000	°F

TUBES	90-10 Cu-Ni	NO.		O.D. 7/8	BWG. 19	LENGTH	PITCH
SHELL	Carbon Steel	I.D.		O.D.		THICKNESS	
SHELL COVER						FLOATING HEAD COVER	
CHANNEL	90-10 Cu-Ni Clad					CHANNEL COVER	90-10-Cu-Ni Clad
TUBE SHEETS—STATIONARY	2-1/8" incl. 3/8" Cu-Ni Clad						
BAFFLES—CROSS	Carbon Steel	TYPE				THICKNESS	
BAFFLE—LONG		TYPE				THICKNESS	
TUBE SUPPORTS						THICKNESS	
GASKETS							
CONNECTIONS—SHELL—IN	28	OUT	3			SERIES	150
CHANNEL—IN	24	OUT	24			SERIES	150
CORROSION ALLOWANCE—SHELL SIZE	3/16					TUBE SIDE	0
CODE REQUIREMENTS	ASME Sect. VIII						
WEIGHTS—EACH SHELL		BUNDLE				FULL OF WATER	

NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)

REMARKS: See Dwg 4.10 in Appendix

Figure IV-6

EXCHANGER SPECIFICATION SHEET

CUSTOMER Office of Saline Water	JOB NO. REFERENCE NO.
ADDRESS	PROPOSAL NO.
PLANT LOCATION	DATE
SERVICE OF UNIT Seawater Feed Heater	ITEM No. 4

SIZE	TYPE	CONNECTED IN Series
SURFACE PER UNIT	SHELLS PER UNIT	SURFACE PER SHELL

PERFORMANCE OF ONE UNIT

		SHELL SIDE		TUBE SIDE	
FLUID CIRCULATED		Steam		Seawater (3.50% T.S.)	
TOTAL FLUID ENTERING	lbs/hr	42,690		5,000,000	
VAPOR					
LIQUID	lbs/hr			5,000,000	
STEAM	lbs/hr	42,690			
NON-CONDENSABLES	lbs/hr	15			
FLUID VAPORIZED OR CONDENSED					
STEAM CONDENSED		42,690			
GRAVITY—LIQUID		1.0		1.028	
VISCOSITY—LIQUID					
MOLECULAR WEIGHT—VAPORS		18			
SPECIFIC HEAT—LIQUIDS			B.T.U./#	.977	B.T.U./#
LATENT HEAT—VAPORS		961.6	B.T.U./#		B.T.U./#
TEMPERATURE IN		225.5	°F	208.8	°F
TEMPERATURE OUT		225.5	°F	217.2	°F
OPERATING PRESSURE	GAGE	4.4	#/SQ. IN.	72	#/SQ. IN.
NUMBER OF PASSES		1		1	
VELOCITY			FT./SEC.	Approx. 6	FT./SEC.
PRESSURE DROP			#/SQ. IN.	Approx. 2	#/SQ. IN.

HEAT EXCHANGED—B.T.U./HR 41,051,000	M.T.D. (CORRECTED)
TRANSFER RATE—SERVICE (0.0005 Fouling Factor)	CLEAN

CONSTRUCTION OF ONE SHELL

DESIGN PRESSURE	35 & Full Vac.	#/SQ. IN.	75 & Full Vac.	#/SQ. IN.
TEST PRESSURE	53	#/SQ. IN.	112	#/SQ. IN.
DESIGN TEMPERATURE	300	°F	300	°F

TUBES 90-10 Cu-Ni	NO.	O.D. 7/8 BWG. 19	LENGTH	PITCH
SHELL Carbon Steel		I.D. O.D.	THICKNESS	
SHELL COVER			FLOATING HEAD COVER	
CHANNEL 90-10 Cu-Ni Clad			CHANNEL COVER 90-10 Cu-Ni Clad	
TUBE SHEETS—STATIONARY 2-1/8" incl. 3/8" Cu-Ni Clad				
BAFFLES—CROSS Carbon Steel		TYPE	THICKNESS	
BAFFLE—LONG		TYPE	THICKNESS	
TUBE SUPPORTS			THICKNESS	
GASKETS				
CONNECTIONS—SHELL—IN 28"		OUT 3"	SERIES 150	
CHANNEL—IN 24"		OUT 24"	SERIES 150	
CORROSION ALLOWANCE—SHELL SIZE 3/16			TUBE SIDE 0	
CODE REQUIREMENTS ASME Sect. VIII				
WEIGHTS—EACH SHELL		BUNDLE	FULL OF WATER	

NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)

REMARKS: See Dwg. 4.10 in Appendix

Figure IV-7

2.4 Multistage Flash Evaporator (MSF)

The MSF evaporator is comprised of four trains arranged in series. These trains are each approximately 55 feet in overall length and vary in width from 8 to 15 feet. Incorporated into the shell of the lowest pressure train is the vacuum equipment. The MSF evaporator design is similar to others in service today and involves no new unproven features.

The shell of each MSF evaporator is fabricated of steel with a 3/16" corrosion allowance. The shells are designed for full vacuum and 15 psig and a temperature of 250°F. Interstage dividers within the shells are also steel with a 3/16" corrosion allowance. The waterboxes in the deaerated seawater feed sections are fabricated steel with a 1/8" 90-10 Cu-Ni cladding. The evaporator tube sheets are also clad with 90-10 Cu-Ni on the deaerated seawater side.

The tubing material used for the seawater feed is 90-10 Cu-Ni. In the undeaerated section, 18 gage tubing is used while in the deaerated section, 20 gage tubing is used. A minimum velocity of 5 ft/sec is specified while the plant is operating at a feed rate of 5,000,000 #/hr and a maximum velocity of 7 ft/sec while operating at a feed rate of 5,500,000 #/hr. The tube side of the evaporator is designed for 75 psig and 250°F.

The piping specified for blowdown brine and distillate service is carbon steel with a 1/4" corrosion allowance. Material for the vent lines is 316 stainless steel. For temperatures up to 160°F, the pipe material for the deaerated seawater feed is epoxy lined steel. For temperatures above 160°F, fiberglass reinforced epoxy pipe is specified for the deaerated seawater feed system.

The makeup feed water vacuum deaerator is of the packed column type and is designed to operate as follows:

Oxygen concentration in effluent 20 ppb
Carbon Dioxide concentration in effluent
Less than 4.0 ppm.

Deaerator materials of construction are as follows:

Shell Fabricated carbon steel, rubber lined
Spray Nozzles Bronze
Deaerator Packing Plastic pall rings.

The atmospheric decarbonator is of wood slat construction and includes an electric driven fan for air circulation.

The air ejectors are of conventional power plant design complete with strainers. Twin ejector elements are provided, each to handle full 100% ejecting capacity.

The complete specification for this MSF unit is found in the Appendix. The specification as written is for the furnishing of a complete unit that will operate in conjunction with a VTE thermo-compression evaporator.

The specification includes the furnishing of pumps and motors, chemical feed equipment, electrical equipment and instrumentation and controls. The performance of the MSF unit under normal conditions shall be as follows:

(a) Heat 5,000,000 #/hr of standard seawater (3.50% T.S.) from 75°F to 208.8°F.

(b) Utilize heat from 2,493,000 #/hr of distillate from the VTE entering at 225.5°F and flashing to 92.4°F.

(c) Utilize heat from 2,504,000 #/hr of brine blowdown (7.0% T.S.) from the VTE entering at 227.7°F and flashing down to 93.9°F.

2.5 Heat Recovery Boiler (Refer to Dwg. 4.1 in Appendix)

The heat recovery boiler is designed to operate on high temperature exhaust gases from the gas turbine. Under normal conditions, the gas turbine exhausts approximately 597,600 #/hr exhaust gas at a temperature of 713°F. The heat recovery boiler actually consists of two interconnected boilers designed to operate at two different pressure levels. The high pressure boiler is rated to produce 35,400 #/hr steam at 400 psig and 650°F. The low pressure is designed to produce 27,160 #/hr at 19 psig saturated. The design pressure drop through the gas side of the boiler is 9" H_2O. The design pressures and temperature of the boiler are as follows:

SERVICE	PRESSURE, PSIG	TEMPERATURE, °F
(a) Superheater	500	750
(b) H.P. Boiler	500	500
(c) Economizer	625	500
(d) L.P. Boiler	100	400

The boiler is designed in accordance with the ASME Boiler and Pressure Vessel Code, 1965; Section I.

The heat exchange tubing in the boiler is of the spirally-wound fin type, with the exception of the downcomers which are smooth wall, insulated pipe. Schedule 40 pipe is used throughout, fabricated of A-106B material. The superheaters, H.P. and L.P. boiler generating surfaces, as well as the economizer, utilize 2 3/8" O.D. tubes. The superheater sections use a fin size of 3/4" x .06" thick x 5 per in. The remaining sections use a fin size of 1 1/8" x .06" x 5 per in.

The use of a low pressure boiler allows lower stack temperatures and consequently a higher thermal efficiency. An economizer and two superheating sections are used in conjunction with the high pressure boiler. A burner grid is incorporated for the combustion of fuel when required.

The boiler casing is fabricated of 3/16" thick carbon steel plate with the necessary stiffeners welded to the exterior to reduce vibration and buckling. The insulation is installed internally and covered with a 16 gage carbon steel liner. In the combustion area, the liner is 22 gage type 302 stainless steel. The thickness of the block insulation used in the boiler varies from 2 inches up to approximately 5 inches. The exhaust gas stack is fabricated of rolled carbon steel plate and is uninsulated. A 40 foot stack height is sufficient.

Other equipment furnished with the heat recovery boiler includes a dump stack and diverting valve, a gas engine driven forced draft fan for startup, two full capacity H.P. boiler feed pumps, the exhaust gas stack, instruments and controls, and check damper to prevent air flow back into the gas turbine during operation with the forced draft fan.

2.6 Gas Turbine-Vapor Compressor Power Train

The equipment selected for the power train in this study consists of a Pratt & Whitney Aircraft Model GG3C-4 Gas Generator, a Cooper-Bessemer RT-48 free turbine, and a Sulzer Brothers' AC-8-75 axial flow vapor compressor.

Figure IV-8 shows the arrangement of equipment.

Gas Turbine

The GG3C/RT-48 Gas Turbine was selected on the basis of its considerable service as a gas compressor prime mover for the natural gas transmission lines and is a proven base load machine. The GG3C is an industrialized version of the JT-3 turbo-jet aircraft engine. The engine is a two spool design. The first or low pressure compressor has nine axial flow stages of compression and is driven by a two-stage axial flow turbine. The second or high pressure compressor has seven axial flow stages of compression and is driven by a single-stage axial flow turbine. The RT-48 power turbine is a two-stage axial flow free turbine with an overhung rotor design. Figure lV-9 is a schematic section of the gas turbine.

The free turbine design has no mechanical link between gas generator and power turbine. This feature has several advantages over the single-shaft turbine design. The starting power requirement is substantially less since there is no need to start and accelerate the load. A 25 horsepower natural gas expander is used to start and accelerate the GG3C to a self-sustaining speed. The free turbine design characteristically provides a torque speed characteristic better suited to compressor drive applicators than single-shaft turbines. The gas generator can be repaired or removed without disturbing the power turbine or load, thus simplifying maintenance.

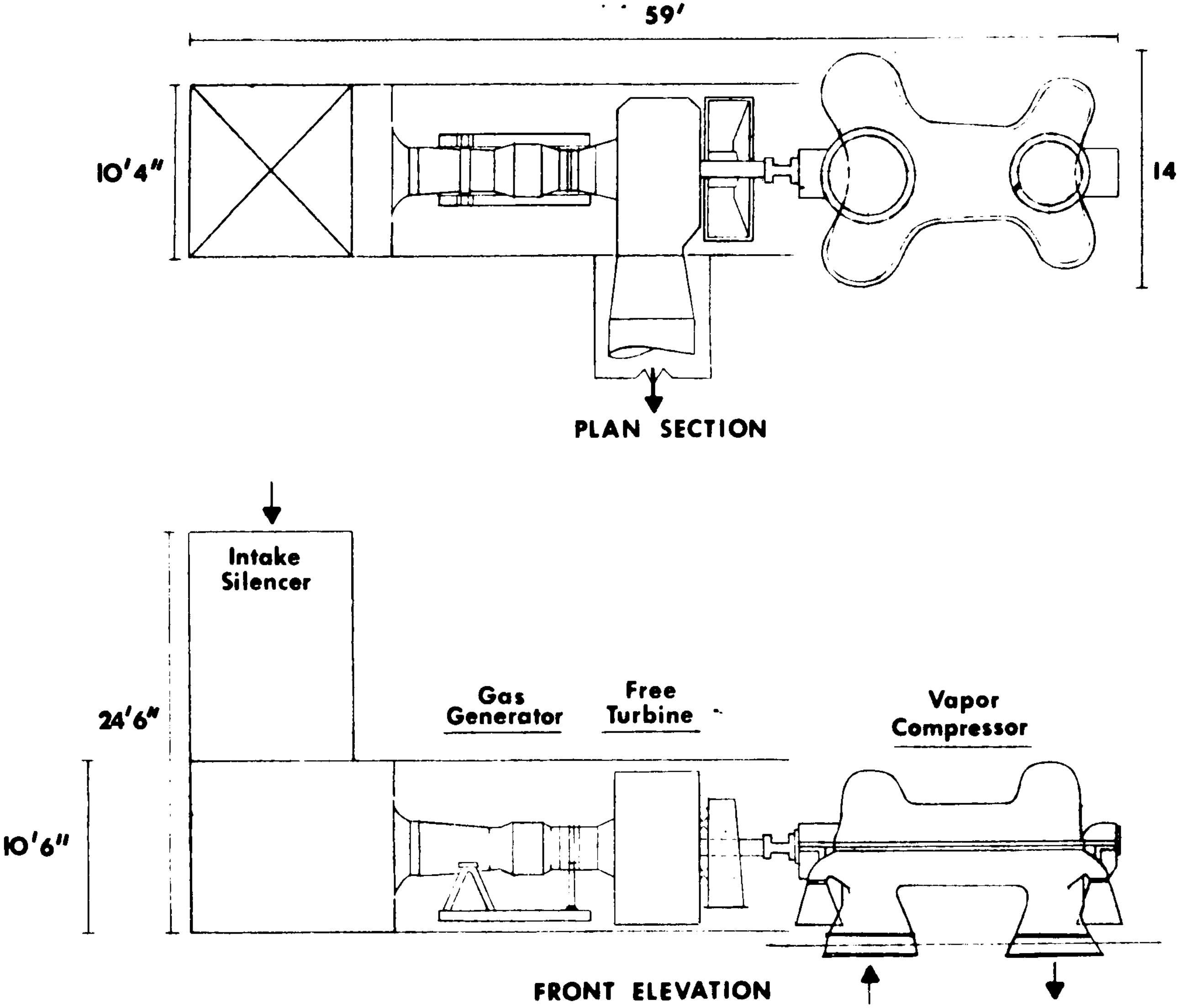
The gas turbine is rated at 12,500 horsepower up to 90°F at sea level with silencing adequate for an industrial area in the inlet stack and 9 inches water gage back pressure at the exhaust outlet. Figure IV-10 shows the estimated gas turbine performance. While operating at this continuous rating, it is expected that the gas generator will be overhauled after 16,000 hours (2 years) of operation and the hot section will be inspected after every 4,000 hours of operation or 6 months. The free turbine will be overhauled after 100,000 hours of operation and inspected annually. The gas generator, free turbine, auxiliaries and controls, are all readily accessible for routine inspection and service. The gas generator can be removed and another substituted in approximately eight hours. Thus, the engine can be repaired or overhauled without curtailing plant operation for extended periods. The engine change out for the scheduled overhaul will be accomplished during the annual plant shutdown every second year. The overhauled engine will be reinstalled when returned from the overhaul shop.

Vapor Compressor

The Sulzer Brothers' AC-8-75 compressor is an eight-stage axial flow fixed geometry machine. It is essentially the same machine that has been used as an industrial air compressor. The machine has been modified from the standard by installing water wash nozzles at three points in the vapor flow path to clean deposits off the blades and stators and by using materials suitable for the intended duty. It is expected that the vapor compressor will have to be completely rebuilt once in the 30 year life and inspected annually. However, a complete rotor, stators, bearings and seals will be stored at the site against the eventuality of unforeseen difficulties.

The vapor compressor at the design point will compress 593,000 pounds per hour of vapor, 208,300 cfm inlet volume, to a pressure ratio of 1.75. The adiabatic efficiency is 84%. The compressor power input and speed at the design point is 12,500 hp and 4,500 rpm. The map of the compressor performance is shown on Figure IV-11.

GAS TURBINE–VAPOR COMPRESSOR POWER TRAIN

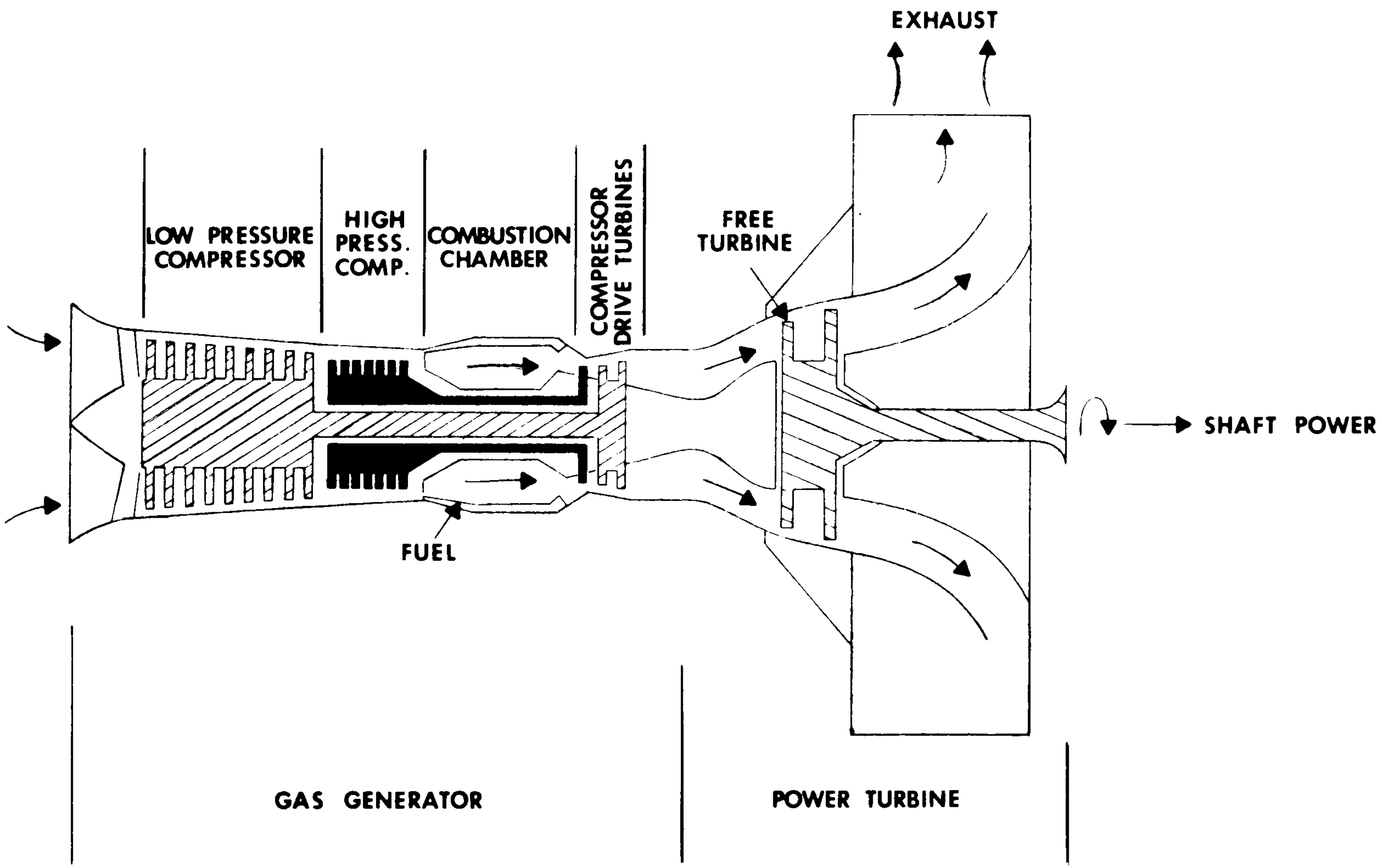


PLAN SECTION

FRONT ELEVATION

FIGURE IV-8

Scale $\frac{1}{16}$"=1'
EGR/jh
4-2-68



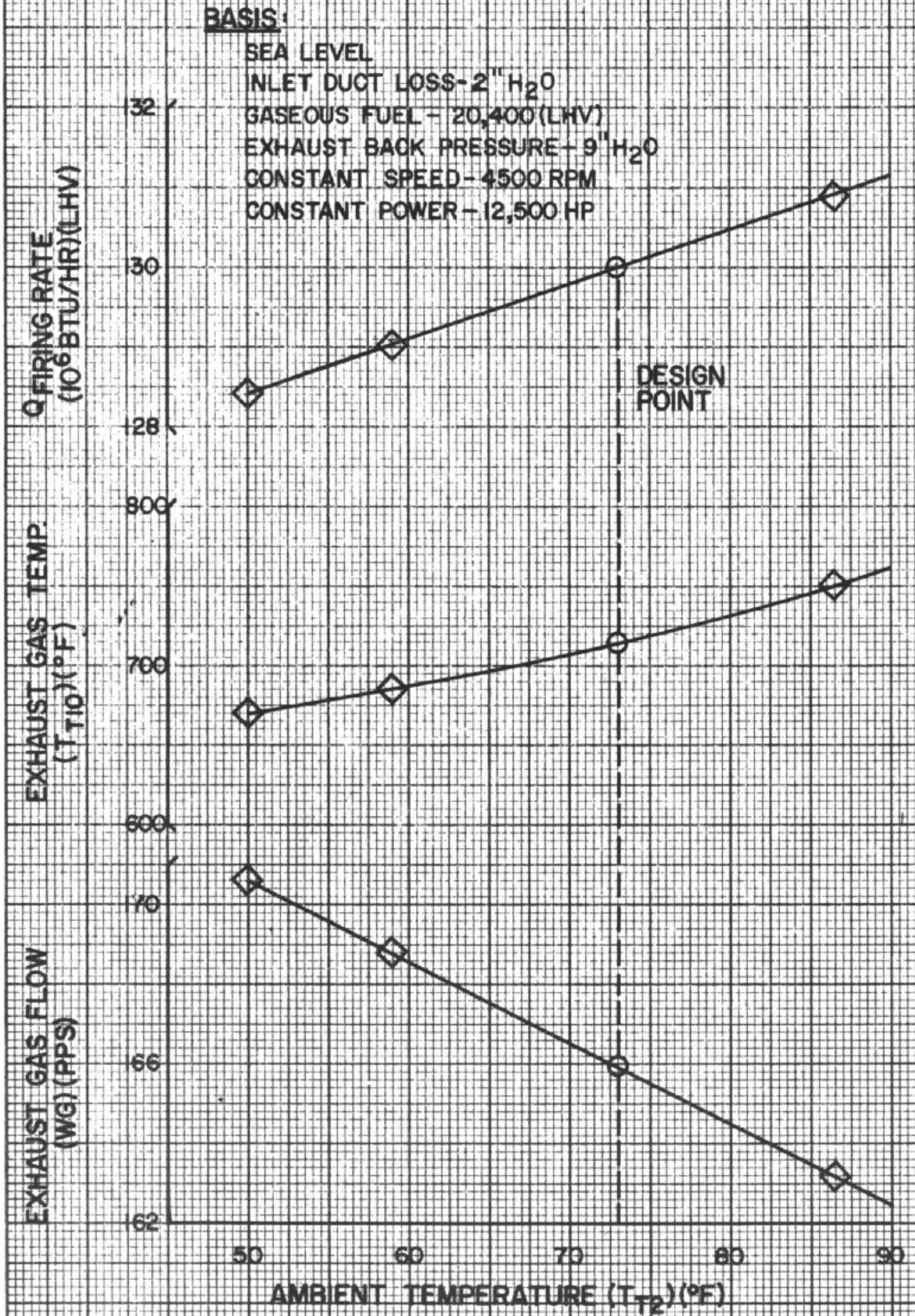
SCHEMATIC SECTION OF GAS TURBINE ENGINE

FIGURE IV-9

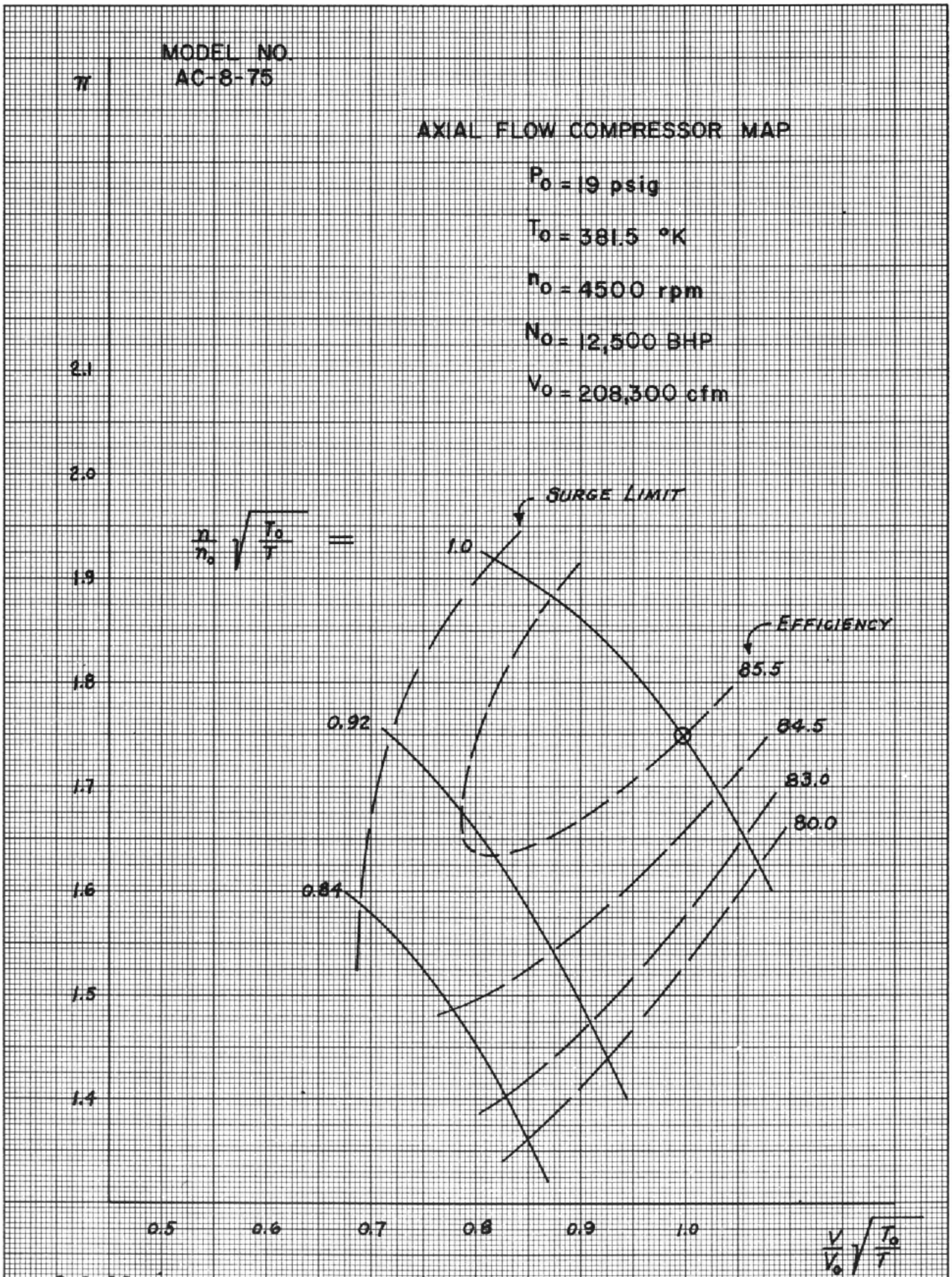
EGR/jh
5-23-68

ESTIMATED FLAT RATE TURBINE PERFORMANCE for DESALINATION PLANT VAPOR COMPRESSOR DRIVE

GAS GENERATOR - PWA GG3C-4 POWER TURBINE - CBRT-48



4-10-68 FIGURE IV-10



2-4-68

FIGURE IV - 11

2.7 Pumps and Motors

The design consideration used in pump selection has been covered in Section 1 of this report. Pump descriptions and materials of construction are covered in the following paragraphs.

Generally speaking, all pumps that handle brine or seawater are fabricated with Ni-Resist casings or bowls, type 316 stainless steel impellers, type 17-4 pH stainless steel shafts and carbon bearings. The distillate pumps are fabricated with cast iron casings and a bronze fitted pump.

For all motors larger than 1 hp, 480V, 3 phase, 60 cycle power is required. Fractional horsepower motors operate on 120V, 1 phase, 60 cycle power.

The performance characteristics of pumps and motors are summarized in the following tabulations:

PUMP DATA SHEET

Service	Raw Seawater Feed
Number Operating	2
Number in stand-by	1
Fluid	Seawater
Specific Gravity	1.03
Temperature	85° F
Capacity - GPM (each)	5400
NPSH available at inlet flange, Ft.	30
Total dynamic head, Ft.	117
Speed, RPM	1760
Efficiency, %	84
Horsepower Required	210
Motor Horsepower	250
Voltage	460

Pump Materials	
Casing	Ni-Resist
Impeller	Type 316, Stainless Steel
Shaft	17-4 PH Stainless Steel
Bearings	Carbon

PUMP DATA SHEET

Service	Screen Wash Water
Number operating	1
Number in stand-by	1
Fluid	Seawater
Specific Gravity	1.03
Temperature	85°F
Capacity - GPM (each)	122
NPSH available at inlet flange, Ft.	30
Total dynamic head, Ft.	230
Speed, RPM	3520
Efficiency, %	74
Horsepower required	12.4
Motor Horsepower	15
Voltage	460
Pump Materials	
Casing	Ni-Resist
Impeller	Stainless Steel, Type 316
Shaft	Stainless Steel, Type 316
Bearings	Oil Lubricated

PUMP DATA SHEET

Service	Deaerated Seawater
Number in Operation	3
Number in stand-by	1
Fluid	Seawater
Specific Gravity	1.03
Temperature	108°F
Capacity - GPM (each)	3560
NPSH available at inlet flange, Ft.	1
Total dynamic head, Ft.	261
Speed, RPM	1760
Efficiency, %	84.5
Horsepower Required	285
Motor Horsepower	300
Voltage	460

Pump Materials	
Casing	Ni-Resist
Impeller	Type 316, Stainless Steel
Shaft	17-4 PH Stainless Steel
Bearings	Carbon

PUMP DATA SHEET

Service	Brine Blowdown
Number in Operation	2
Number in stand-by	1
Fluid	Concentrated Seawater
Specific Gravity	1.07
Temperature	104°F
Capacity - GPM (each)	3210
NPSH available at inlet flange, Ft.	4
Total Dynamic Head, Ft.	58
Speed, RPM	1760
Efficiency, %	85.
Horsepower Required	58.5
Motor Horsepower	60
Voltage	460

Pump Materials	
Casing	Ni-Resist
Impeller	Type 316, Stainless Steel
Shaft	17-4 PH Stainless Steel
Bearings	Carbon

PUMP DATA SHEET

Service	Distillate
Number Operating	2
Number in stand-by	1
Fluid	Distilled Water
Specific Gravity	.994
Temperature	93.°F
Capacity - GPM (each)	3000
NPSH available at inlet flange, Ft.	4
Total dynamic head, Ft.	112
Speed, RPM	1760
Efficiency	85
Horsepower required	100
Motor Horsepower	100
Voltage	460

Pump Materials	
Casing	Cast Iron
Impellers	Bronze
Shaft	Type 316, Stainless Steel
Bearings	Rubber (Water Lubricated)

PUMP DATA SHEET

Service	HP Boiler Feed
Number operating	1
Number in stand-by	1
Fluid	Boiler Feedwater
Specific Gravity	.942
Temperature	257°F
Capacity - GPM (each)	64
NPSH available at inlet flange, Ft.	21
Total dynamic head, Ft.	1080
Motor Horsepower	20
Voltage	460

Pump Materials

Barrel	Carbon Steel
Impeller	Bronze
Shaft	416 Stainless Steel
Bearing	Carbon

PUMP DATA SHEET

Service	Emergency LP Boiler Feed
Number Operating	0
Number in stand-by	1
Fluid	Condensate
Specific Gravity	1.0
Temperature	75°F
Capacity, GPM	64
NPSH available at suction, Ft.	30
Total dynamic head, Ft.	82
Speed, RPM	1760
Motor Horsepower	5
Voltage	460
Pump Materials	
Casing	Cast Iron
Impeller	Bronze

PUMP DATA SHEET

Service	Acid Treatment
Number Operating	1
Number in stand-by	1
Fluid	98% H_2SO_4 Acid
Specific Gravity	1.83
Temperature	75°F
Capacity	Adjustable to 1/2 GPM
Motor Horsepower	1/2
Voltage	120

Service	Anti-Foam Injection
Number Operating	1
Number in stand-by	1
Fluid	3% Anti-Foam solution
Capacity	1 gallon per hour
Motor horsepower	1/20
Voltage	120

Service	Chlorine Scavaging
Number in operation	1
Number in Stand-by	1
Fluid	Sodium Metasilicate Solution
Capacity	2 gallons per hour
Motor horsepower	1/10
Voltage	120

2.8 Forced Draft Fan and Driver

The forced draft fan consists of a fan of Class II construction with backward inclined blade design driven by a natural gas engine through a clutch and a 3 to 1 reduction gear. The fan is designed to supply 298,860 #/hr air at 3.5" water static at the fan discharge. The fan is complete with an access door, split housing, inlet screen, split pillow block bearings, and a Dodge Paraflex coupling. The natural gas engine is a self-contained unit and includes the following major accessories:

(a) radiator and fan
(b) muffler
(c) electric starting motor
(d) battery and alternator
(e) manual throttle
(f) controls and instrumentation
(g) engine housing

2.9 Ductwork

Various sections of ductwork are required in this plant. The forced draft fan discharge duct is connected to the gas turbine exhaust gas plenum and is made of 3/16 in. thick welded carbon steel plate. Also located in this piece of ductwork is a manually operated, normally closed louver type damper. No insulation is required for this section of ductwork as it is not in the hot exhaust gas stream.

The duct that connects the gas turbine exhaust to the heat recovery boiler is also made of 3/16 in. thick welded carbon steel plate. Stiffeners are welded to the outside of the ductwork to reduce plate buckling and vibrations. Block type insulation is mounted internally and is covered with a 16 gage carbon steel liner. A bellows type expansion joint is located in the ductwork near the gas turbine exhaust. A second bellows type expansion joint is located at the entrance to the heat recovery boiler plenum.

The ductwork for the vapor compressor is made of 5/8 inch thick rolled carbon steel plate welded into sections. The elbows and return bends are fabricated from plate also. The vapor compressor is mounted approximately 25 feet above plant grade and has both suction and discharge nozzle facing downward. The compressor suction duct has one 90° bend between the compressor and the fourth effect of the VTE. The discharge duct has two 90° bends located near the compressor discharge and one 90° bend at the entrance to the first effect of the VTE. The weight of the large discharge duct is borne by a support located at the bottom of the return bend. When the vapor compressor is shut down, the steam that condenses in the discharge duct will be trapped in the return bend and can be drained by a steam trap.

Both suction and discharge vapor ducts are designed to withstand a full vacuum and a pressure of 20 psig. The discharge duct is designed for a temperature of 350°F and the suction duct for a temperature of 250°F. Both ducts are externally insulated with 2 inches of block type insulation covered with an aluminum jacket. An extra thickness of insulation will be provided on the discharge duct near the compressor to help dampen the expected compressor noise.

2.10 Steam Turbo Generator

The steam turbo generator is a noncondensing, non reheat, back pressure machine rated to produce 1500 kw while operating with steam conditions of 400 psig, 650°FTT inlet and 19 psig exhaust. The generator is rated for 1875 kva, 480 volt, 3 phase, 60 cycle, .8 pf.

The steam rate will be 22.5 #/kwh when operating at unity power factor and 1875 kw. When operating at 1500 kw and .8 power factor, the steam rate will be 23 #/kwh. The steam flow corresponding to the 1500 kw power generation is 34,500 #/hr.

The multistage steam turbine is connected to the generator through a reduction gear. The turbine, reduction gear and generator are mounted on a common fabricated steel base. The turbine is furnished with the following accessories:

(a) A shaft mounted main oil pump with oil supply reservoir and oil level indicator.

(b) Two full capacity lubricating oil coolers

(c) Two full capacity lubricating oil filters

(d) A steam turbine driven auxiliary oil pump with automatic starting device

(e) Oil relayed governor

(f) Instrumentation and alarms

The generator is provided with a brushless exciter and static voltage regulator with field forcing. The generator is designed for neutral grounding. The drip-proof generator is provided with a shaft mounted fan and is air cooled. A sheet metal enclosure is provided to protect it from the elements.

2.11 Seawater Intake Structure

The intake structure is composed of two sections. The first section, made of concrete, is located on the floor of the bay approximately 1000 feet off shore and serves as the raw seawater intake. The second section is located at the plant site and is a concrete structure that supports the raw seawater feed pumps and motors, the screen wash pumps, the traveling screen, and the trash bar screen. The two sections are connected together by 1000 feet of 30 inch O.D. schedule 80 steel pipe that has been externally coated and wrapped.

The brine blowdown piping is considered a part of the intake structure. This 18" O.D., Schedule 80 steel pipe is externally coated and wrapped and extends 1000 feet beyond the concrete intake structure that is located in the bay. A 1/4 inch corrosion allowance is allowed for both the inlet and brine blowdown pipes.

The traveling screen mentioned above is driven by a 10 hp TEFC electric motor. The screen is 2'-8" wide with sprocket centers 16' apart. The screen is stainless steel construction with a mesh count of from 70 to 100. Fiberglass splash guards are used. Hot dipped galvanized structural steel is used with monel bolts as fasteners.

The trash bar screen is 2'-8" wide by 17 feet deep. The bars are made of stainless steel and are approximately 1/2" thick. The openings are approximately 3 inches clear. The automatic trash rake is driven by a 3 hp TEFC motor.

2.12 Plant Piping and Valves

The materials of construction of the piping are as follows.

Epoxy Lined Carbon Steel Pipe

Deaerated seawater feed from atmospheric degasifier to inlet of the penultimate MSF train. (160°F is the temperature limit)

Fiberglass Reinforced Epoxy Pipe

Deaerated seawater feed from the outlet of the penultimate MSF train to the inlet of the VTE. (Temperatures above 160°F)

Carbon Steel Pipe

Undeaerated seawater feed from the intake structure in the bay to the atmospheric degasifier.
All brine pipe
All product water pipe
All steam and vapor pipe

Stainless Steel Pipe-Type 316

All vent piping

In determining the plant piping materials to be used, consideration was given to limiting the amount of iron in solution in the feed to the first effect of the VTE. Iron in solution at this point would tend to foul the tube bundle appreciably. The other concern was to minimize the entry of pieces of corrosion products and other particulate into the VTE. Such material would tend to plug the distribution nozzles. To minimize iron pickup in the VTE feed, epoxy lined steel pipe and fiberglass reinforced epoxy pipe are used for the heated seawater.

The fiberglass reinforced epoxy pipe used at the OSW installation at Freeport, Texas, has developed cracks which have been attributed to water hammer. Since there are no valves in the fiberglass reinforced epoxy pipe in this particular design, there should be few pressure surges. Any cracks that do develop in this pipe can be repaired by wrapping the damaged pipe with fiberglass cloth and applying resin over the cloth. Repairs should be able to be made in 2 to 3 hours.

The valves used in this plant fall into three categories, namely, hand valves, both gate and globe; check valves; and control valves, both butterfly and block.

The hand valves are standard valves rated as required. Powell gate and globe valves, Fig. 3003 or 3031, have been used in the price estimate. Materials are chosen suitable for the service.

The larger check valves used are all in areas where cast iron is suitable for service. Swing check type valves are used with bronze seats and discs. Powell #559 or equal was one style used in the estimate.

The shut-off valves used on the discharge of the raw seawater pumps are 150# flanged butterfly valves suitable for seawater service. For estimating purposes, the valves chosen for this service were Keystone Fig. 100.

2.13 Electrical

The electrical system is designed to provide 1500 kw, 480 volt, 3 phase, 60 cycle power for the normal operation of the plant utilizing the steam turbo generator. In addition, a 150 kw, 480 volt, 3 phase, 60 cycle gas engine driven generator is to supply power into the system during standby or maintenance periods when the steam turbo generator is not in operation.

The steam turbo generator is provided with indoor drawout switchgear rated for 3000 amperes and complete with protective and metering relaying. The switchgear includes the generator voltage regulator and field forcing panels.

The generator switchgear is tied to two 1600 ampere indoor feeder circuit breakers, integrally mounted with the generator switchgear, to provide power to motors, lighting, and accessory loads, as shown on the Electrical Line and Relay Diagram drawing (Dwg. 4.12 in Appendix). During standby or shutdown periods, the engine driven generator is manually tied into an isolated distribution system to power lighting, control room, air conditioning, welding receptacles and plant air system. The above loads are isolated during the operation of the standby generator.

The multi-unit control center is NEMA 1 suitable for indoor installation consisting of compact, dead front, floor mounted assemblies, housing, full voltage combination motor starters with circuit breakers, necessary power circuits, 480 volt/120-208 volt transformer, and 100 amperers lighting and small motor distribution panel. The starters include a fused secondary control transformer, pushbuttons, lights, and ammeters as shown on the electrical line diagram. All motors are remotely started at the motor location. The control center is completely wired with terminals in accordance with NEMA type C instruction.

Motor starters for the large process pumps are electrically interlocked to prevent the startup of the spare pump when the full load complement of pumps are running. A pump in standby may not be started until one of the pumps comprising the full load complement is shutdown. This is not true when only two full capacity pumps are provided.

The interconnecting power cables are single conductor General Electric "Vulkene" or equal and are wired between components in multiples where required to limit maximum amperage per cable. The maximum cable size between the steam turbo generator and generator switchgear is 1250 MCM and maximum cable size for the remaining cables is 750 MCM. The cables are wired through conduit encased in concrete.

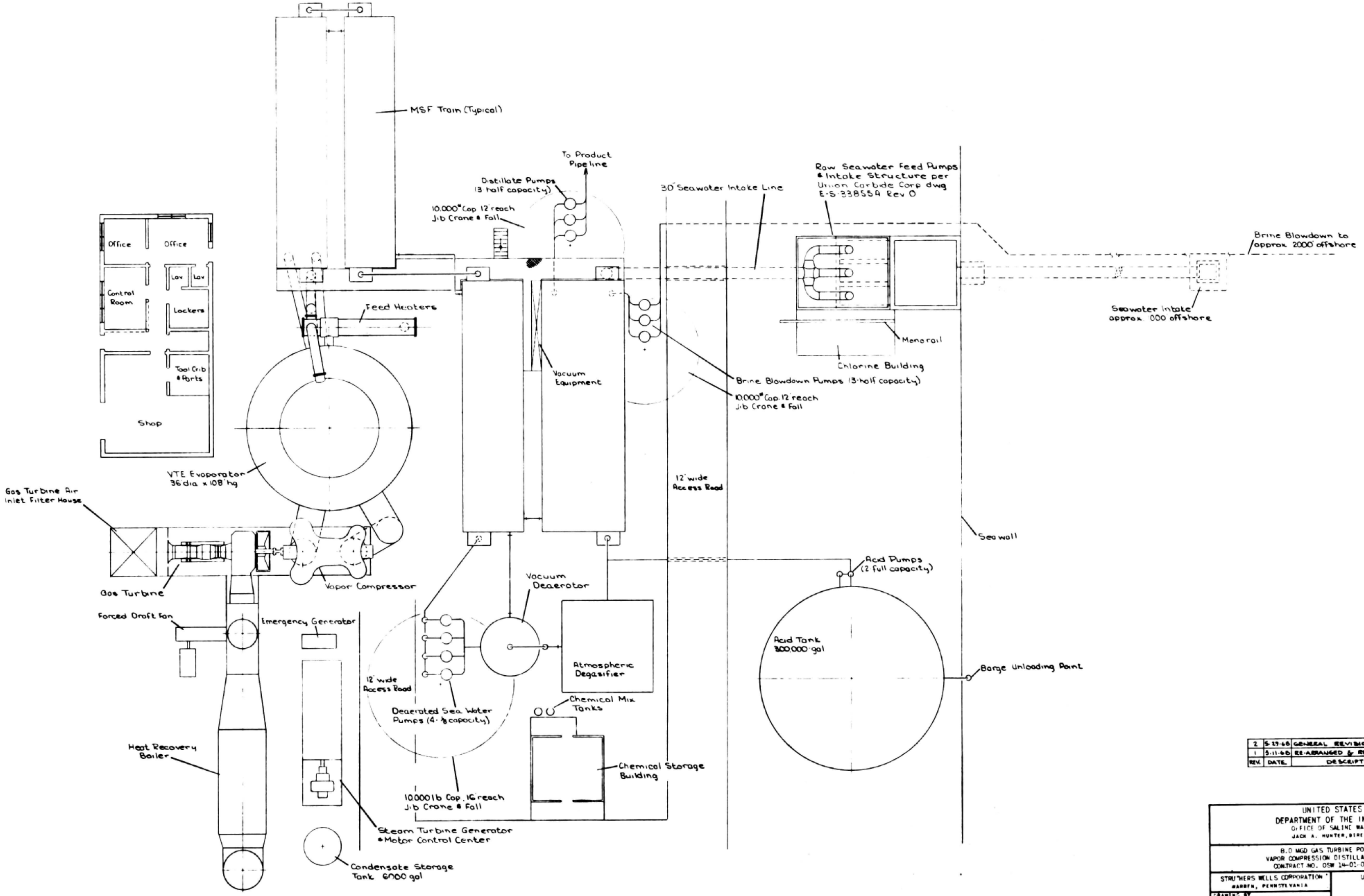
3.0 Construction Description

3.1 General

Bids for the various packages should be solicited for furnishing and erecting the equipment on foundations provided by the prime contractor.

Plant layout may be changed to suit the terrain, the site access, the local topography, and any existing surrounding construction. One possible arrangement is shown on the accompanying plot plan drawing, Figure IV-12.

Construction would commence with preparation of access, filling, and grading. Foundations would then be prepared to suit the site soil conditions and might range from simple slabs to piling. Items likely to require longest



REV.	DATE	DESCRIPTION
2	5-29-68	GENERAL REVISION
1	5-11-68	RE-ARRANGED & REDRAWN

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

8.0 MGD GAS TURBINE POWERED
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442

STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA

DRAWING BY
DESIGNED ____ DATE ____
DRAWN J. WESTER DATE 5-11-68
CHECKED MW DATE ____
APPROVED ____ DATE ____

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

DRAWING TITLE
PLOT PLAN

DATE
DRAWING NO. 67-09-7840-D6 REV. 2

FIGURE IV-12

construction are the seawater intake and brine discharge lines, the Vertical Tube Evaporator (VTE) unit, and the Multistage Flash (MSF) unit. Other items will require shorter time for construction-erection. The VTE, MSF, turbo compressor train and heat recovery boiler units are to be designed for shop fabrication of the largest subassemblies which can reasonably be shipped to the site within rail, road, or barge clearances, whichever is the most economical. Erection at the site will then consist of assembly of the subassemblies.

In order to maintain flexibility of procurement and verification of component guaranteed performance and to obtain unified system responsibility, bids should be solicited in separate bid packages.

The recommended packages would be as follows:

- Vertical Tube Evaporator Package
  - Vertical tube evaporator
  - Brine preheaters
  - Vapor ducts complete to compressor

- Turbo Compressor Package
  - Gas turbine and power turbine
  - Vapor compressor
  - Heat recovery boiler
  - Forced draft fan and driver
  - Boiler feed pumps

- Multistage Flash Package
  - MSF units
  - Deaerator
  - Decarbonator
  - Deaerator feed pumps
  - Brine blowdown pumps
  - Distillate pumps

The following items could be bid separately:

- Steam turbo generator
- General Electrical
- Auxiliary generator
- Piping
- Fuel gas system
- Control room
- Chemical laboratory
- Acid tank
- Fire prevention
- Site preparation

3.2 Site

A description of construction requirements for site development at this juncture can only be hypothetical. In the cost study, it was assumed that a sea wall would exist at the chosen site. Temporary office space, power, water, tool sheds and workman facilities are to be provided by the contractor.

Temporary roads would be constructed, preferably on road beds that would be completed after the heavier loads were in place. As stated in the ground rules, the plant location was considered for the purpose of this study to be the lower Gulf Coast of Texas. No extensive earth work was anticipated.

The plant plot plan is compact. Consideration was given to access during construction and maintenance, but a contractor may wish the general layout to be opened up.

3.3 Foundations

Based on the anticipated plant location, a soil loading of 2000 psf was assumed. Also, the amount of time and labor for foundation excavation was based on the assumption that rock-free, sandy soil is encountered at the site. The prime contractor should build all the foundations on site. A brief description of the foundations designed for the major components is as follows:

(a) VTE - A reinforced concrete raft is constructed 40' wide x 54' long x 2'-6" thick. A hexagon shaped reinforced concrete pedestal 38' from face to face and 3' thick is constructed on top of the raft. Structural steel for support of the four feed heaters rests on one end of the raft.

(b) MSF - Reinforced concrete piers resting on reinforced concrete footings support each MSF train at three points, viz., each end and at midpoint. The top of the footings are located approximately 2 feet below grade.

(c) Gas Turbine and Vapor Compressor - A reinforced concrete slab 45' long by 18' wide x 1'-6" thick is located at elevation 25 feet above grade. A 14' long, 8" thick cantilever slab is located on one end of the main slab for support of the lighter weight intake silencer. The main concrete slab supports the gas turbine and vapor compressor. Ten inch thick, reinforced concrete walls support the main slab. These supporting walls are resting on a 1-6" thick reinforced concrete raft 51 feet long by 24 feet wide.

(d) A reinforced concrete slab foundation measuring 64' long, 14' wide, and 1'-3" thick is required by tne heat recovery boiler and stacks.

A total of approximately 1000 cu. yds. of reinforced concrete foundations were estimated. This figure does not include that required for the intake structure. Approximately 250 cu. yds. of concrete conduit runs were estimated.

3.4 VTE and Feed Heater Erection

From a vendor's standpoint, it is desirable to minimize the amount of field assembly required for the VTE. The unit, as designed, is too large to be completely shop assembled.

Consideration must be given to where the shop assemblies are fabricated, the rail clearances available between the shop and the site, off-loading facilities at the site, etc. Barging of the subassemblies to the site should also be considered.

Drawing 4.6, located in the Appendix, shows the tube bundle for the first effect fabricated in halves. Drawing 4.9 is for the tube bundle for the second, third, and fourth effects as fabricated in quarters.

Because the structural steel tube sheet supports are located around the periphery of the 2nd, 3rd, and 4th effect tube sheets, these tube sheets are the largest in diameter. If rail shipment limiting dimensions are 12'-6" wide by 17'-0" high by 60'-0" long, these larger tube bundles must be fabricated in quadrants if shop assembly is contemplated.

The present design indicates the quadrant sized tube bundle to be shippable if the 30" O.D. center pipe arc is removed from the tube sheet in the shop. The bundle would be shipped with the upper tube sheet on the base of the flat car and the tubes installed in the tube sheets.

The vessel shell is to be shop rolled with the plate edges prepared for field welding at each long and girth seam. Each course will be made of six segmental plates. The elliptical heads will be prepared for field welding in segments. The center pipe will be shop fabricated and prepared for field assembly in five components.

The installation of the porcelain distribution nozzles on top of the vertical tubes will be accomplished in the final stages of erection.

The brine side of the tube sheets that are not protected from the brine solution by the distribution nozzle matrix, shall be given a coat of epoxy paint to inhibit corrosion. The tube bundle support column between the top tube sheet of one stage and the lower tube sheet of the preceding stage should also be epoxy coated as each column will be normally standing in a brine bath.

The four feed heaters will be completely shop fabricated. The size of these heaters will pose no unusual shipping problems. The only difference in the four heaters is in their nozzle orientations. The structural steel to support these heaters should be erected after the VTE second effect tube bundle is in place as additional heater braces protrude from the VTE shell. For ease of handling, the lowest feed heater should be installed first. Care should be used so as not to damage the Cu-Ni cladding on the face of the feed inlet and outlet nozzles during handling.

3.5 MSF Erection

The erection costs for the MSF plant were provided under subcontract by Aqua-Chem, Inc. Their quotation was based on erecting the four trains on foundations provided by the contractor. The four trains would be shop fabricated and shipped to the plant site essentially complete. Included in the multistage flash plant erection is the installation of pumps, motors, switchgear, interconnecting piping, valves, and instrumentation. The electrical cables are run in conduit encased in concrete. The deaerator is a shop assembled vessel. Platforms, ladders and handrails are provided for access to the MSF trains.

3.6 Intake Structure

The construction estimate was performed for this study by ORNL for OSW. The installation of the 30" and 18" O.D. coated and wrapped steel pipe for the seawater intake and brine blowdown, respectively would be done with the aid of a barge. The schedule 80 pipe would be fabricated on shore, coated and wrapped, and floated into place as fabricated. The pipes are then sunk in place and water jets are used to jet the pipe up to 4 feet into the sandy bottom. A maximum depth of water was assumed to be 40 feet. It was assumed that the two pipes would be laid simultaneously for the first 1000 feet. The blowdown pipe is extended an additional 1000 feet to sea.

The use of concrete pipe was investigated. The overall installed cost was approximately 45% greater than the steel pipe installation. The majority of the additional expense was due to the use of divers to guide the pipe in place and the use of steel piling to help form the trench.

The total quantity of reinforced concrete estimated for the bar screen pit, the traveling screen pit and the raw seawater pump pit is approximately 100 cubic yards.

3.7 Gas Turbine and Vapor Compressor

The gas generator, power turbine and enclosure with required piping and controls are shop assembled. The inlet silencer is also shop assembled. The gas turbine exhaust hood is installed in the enclosure prior to shipping the package to the field. The vapor compressor is shipped to the field in three major subassemblies, viz., the upper and lower casings, and the rotor. The flexible coupling is installed and aligned in the field.

The entire power train is mounted on a concrete platform approximately 25 feet above grade. This was done to take advantage of a less expensive vapor compressor offer that used down oriented suction and discharge nozzles. The location of the vapor compressor and power train above grade, as done in this design, should be investigated for each specific vapor compressor considered.

3.8 Heat Recovery Boiler

The heat recovery boiler will be shop fabricated in subassemblies. These subassemblies will be shop erected on two longitudinal W-F beams. After alignment is checked and fit-up is assured, the footings of each support beam will be drilled through the longitudinal beams and marked. In the field, the subassemblies will again be mounted on these longitudinal beams.

Each stack is fabricated in two sections and shipped to the field for erection. The main stack is self-supporting on a concrete slab. The by-pass stack is supported on structural steel mounted over the inlet plenum. The interconnecting piping would be shop fabricated but field installed after boiler erection.

It is contemplated that the high pressure boiler drum, tubes, lower drum and economizer tubes and its associated structural steel and casing would comprise one major subassembly. The low pressure drum, tubes, lower drum and associated structural steel and casing would comprise another major subassembly.

The insulation and metal liner would be installed in the casing in the shop, thereby minimizing the amount of field insulation required.

3.9 Plant Piping

The majority of the plant piping is run above grade on either concrete piers or on structural steel tee frames. The acid feed line from the acid pumps,as well as the raw seawater piping between the raw seawater pumps and the inlet waterbox of the lowest pressure MSF train, are buried to pass beneath the access road. An overhead pipe rack will be installed between the heat recovery boiler and the steam turbo generator and will extend toward the vapor compressor. Boiler feedwater lines and steam lines will be supported from the side of the VTE unit in the vicinity of the vapor compressor discharge duct.

The plant piping was split between the MSF supplier and the contractor for the purposes of this cost study. It was assumed that the contractor would subcontract out all the pipe fabrication.

3.10 Electrical

(a) Conduit to be "Korduct", or equal, non-metallic conduit not less than 24" below grade encased in a minimum of 2 inches of red colored concrete to be used below grade to buildings, and power utilization equipment. Reinforcing steel to be employed under roads.

(b) All interior concealed conduit runs and all exposed conduit runs less than 10 feet above floor level, and all conduit 1 1/4" "Trade Size" and larger should be rigid steel.

(c) Minimum size of conduit to be 3/4" except 1/2" may be used above grade for fixture stems, runs to single receptacles and switches.

(d) Minimum size conduit below grade to be 1" except in slab of buildings where 3/4" conduit may be run to receptacles, light switches, etc.

(e) The underground system to consist of manholes at pull points and junction points, connected by duct banks.

(f) Manholes to be reinforced concrete, rectangular in shape with round covers, and sized to permit pulling, splicing, and routing without damage.

(g) Manholes to include copper-weld ground rod set in the floor of the manway.

(h) Luminaires to be bracket mounted on steel standards.

(i) All structural, vessels, control equipment, and electrical equipment to be grounded.

V. Design Studies

1.0 Introduction

The first phase of this contract was the examination of the thermodynamics, cost and economics of a single purpose gas turbine powered vapor compression desalination plant on a parametric basis. The three primary participants in this phase were Struthers Energy Systems, Inc.(SES); Pratt & Whitney Aircraft (PWA): and subcontractor consultant W. L. Badger Associates, Inc. (Badger). The scope of work performed in the first phase of this contract was defined in the contract document, OSW Contract No. 14-01-0001-1442, as follows:

> "The Contractor shall: (1) Perform an economic study of the utilization of gas turbines in a single purpose water plant to determine preliminary capital and annual cost estimates of two representative sizes of plants;.....
> The study will cover plants utilizing two ranges of gas turbine horsepower.

A. 8,000 - 10,000 hp (Pratt & Whitney Aircraft Model FT-3) with a water plant of approximately 10 MGPD capacity.

B. 14,000 - 20,000 hp (Pratt & Whitney Aircraft Model FT-4) with a water plant of approximately 20 MGPD capacity."

A report entitled "Interim Report - Phase I" was prepared and submitted to the Office of Saline Water with a description of the study made and the conclusions drawn.

After the specific size and cycle arrangement for the final design was decided, a separate study was undertaken to compare the economics of a four-effect Vertical Tube Evaporator with each effect side by side against a VTE with the effects stacked vertically one over the other. A copy of this study report is found in this section, Item 2.2.

In a plant of this nature, various parameters must be considered when designing the components and their interconnections. Design guidelines are furnished in this section, Item 2.3, explaining the various parameters taken into consideration in establishing the final design of the vertical tube evaporator.

2.0 Design Study Summaries

2.1 Phase I Report Summary

Calculations were made, first of all, to determine the quantity and cost of shaft power and steam energy to be used in optimization of the vapor compression desalination plant. Costs were developed for two sizes of gas turbine with exhaust heat recovery at several levels of steam pressure from 35 psia (saturated) to 1265 psia, 950° F, and with supplementary firing of the gas turbine exhaust to temperatures up to 1600° F. The overall operating costs for the prime mover section of the evaporator plant are summarized on Figure V-1.

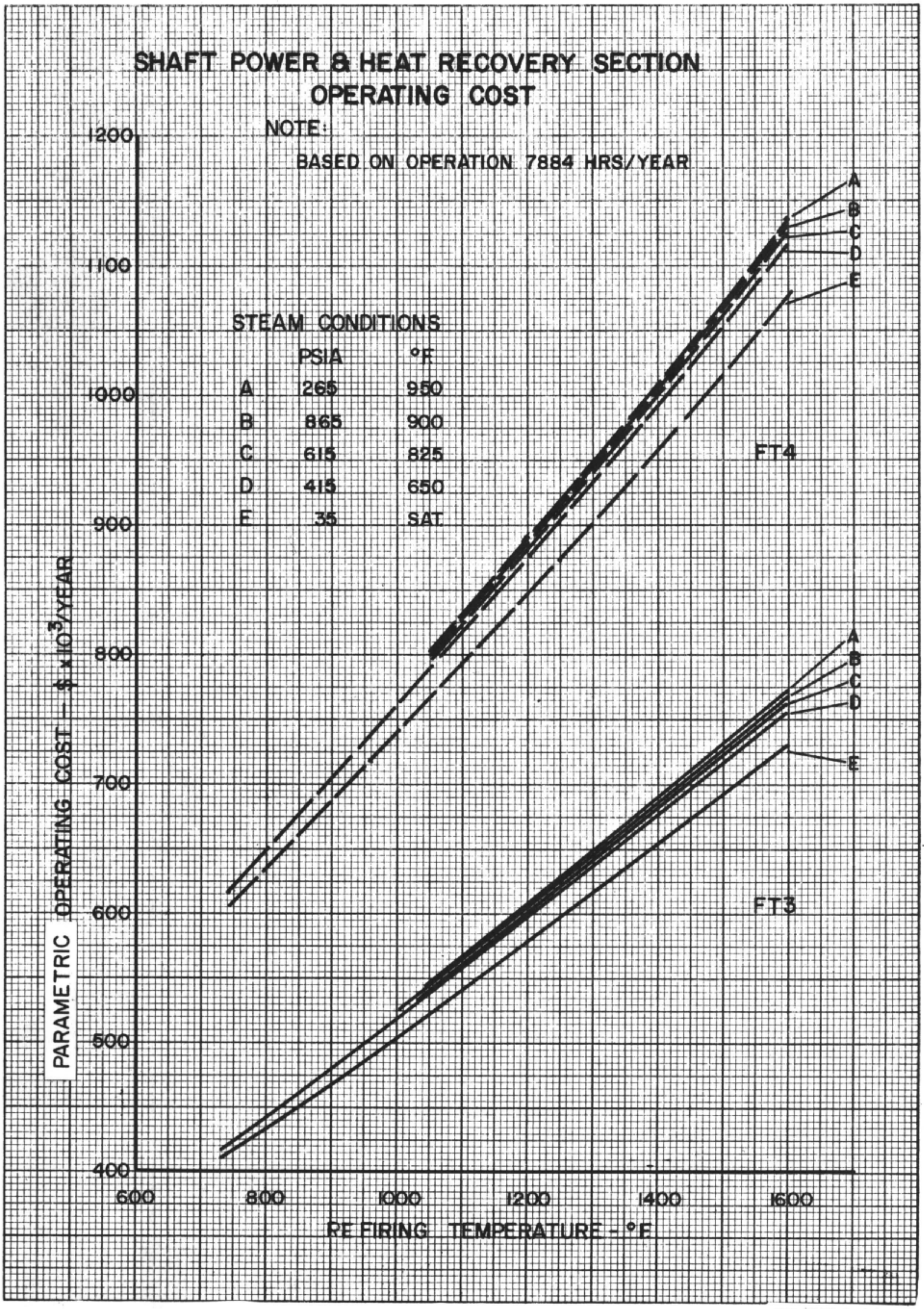
The water plant costs were next developed for combined cycles consisting of vapor compressors operating on a four-effect vertical tube evaporator with seawater feed heating in a multistage flash evaporator. The parametric total water costs are shown on Figures V-2 and V-3 for the two sizes of gas turbines studied. The overall cost range was from 37.5 cents/1000 gallons at 8 MGD capacity to approximately 31.5 cents/1000 gallons at 24 MGD. It should be emphasized that the costs determined in the Phase I study are parametric costs--not actual detailed costs for the various sizes shown.

The considered opinion of all the participants was that the 415 psia, 650° F steam system offered significant operating advantages over the higher steam pressure levels, particularly for the smaller plants. Figure V-4 shows the range of water costs for both sizes of gas turbines at 415 psia. At the unfired boiler operating point, a dual shaft arrangement became possible. The gas turbine would drive the vapor compressor with a steam turbine driven electric generator to provide plant power. Sufficient steam would also be available for air ejector needs. The dual shaft arrangement offered a simpler starting procedure.

If the drivers and driven equipment were all on one shaft, as would be necessary to utilize the steam energy at the higher pressure levels. Startup would require special equipment such as clutches and a vapor by-pass arrangement. Furthermore, the 415 psia pressure level offered the advantages of lower equipment first cost, lower operating labor and maintenance cost. These considerations, and noting that operating at the higher steam pressures offers no improvement in water costs at the capacity levels defined in the project scope, led to a recommendation that the choice of operating conditions for the Phase II activity be limited to the 415 psia level. Normal boiler operation would be at the unfired point, however, supplementary firing equipment would be included for startup requirements and to provide flexibility of operation. The effect of varying fuel cost and capital charges is shown on Figure V-5 and V-6.

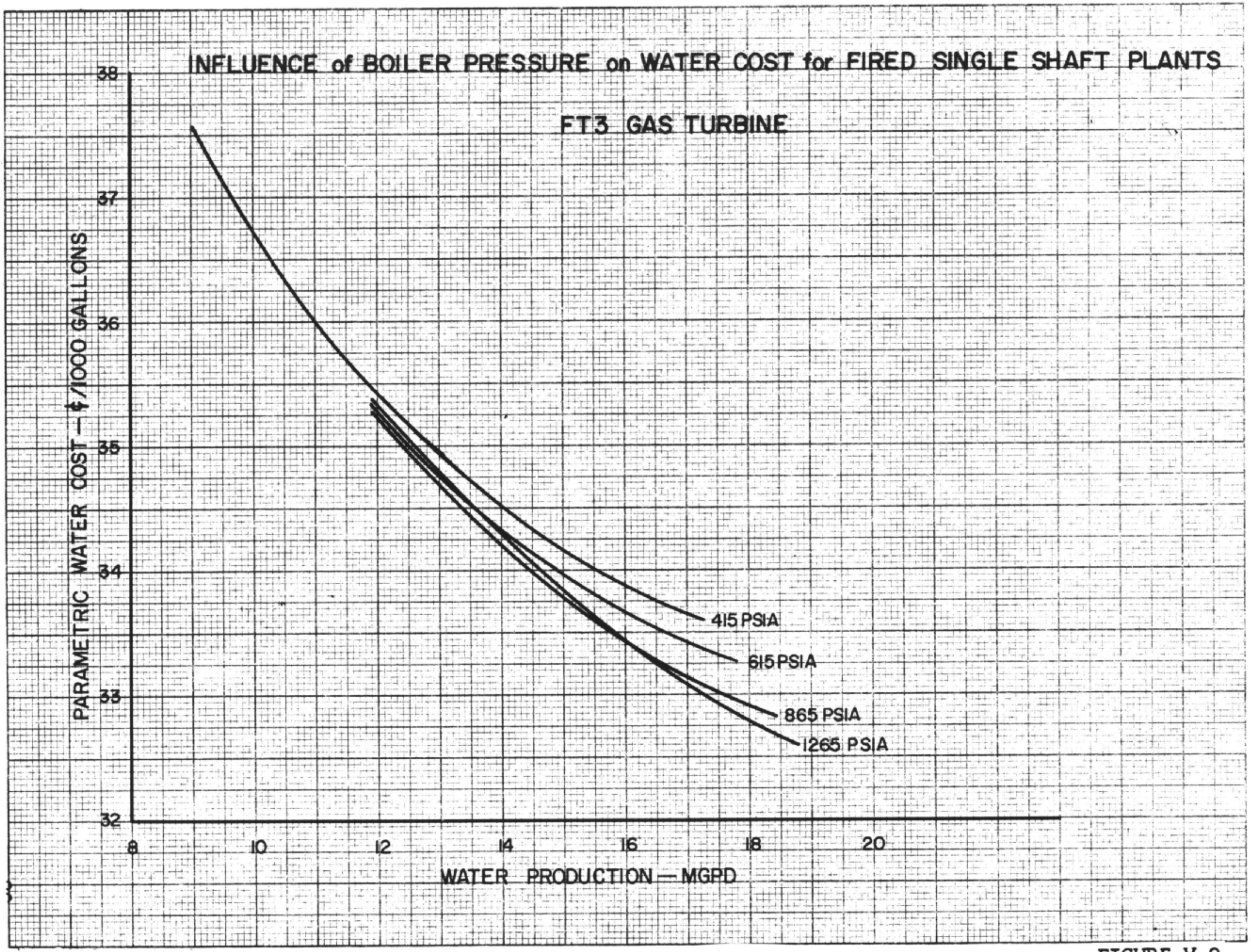
The influence of working temperature difference in the VTE on water costs for the unfired 415 psia boiler plant is shown in Figure V-7. For the FT-3 gas turbine and the unfired boiler, the parametric water cost curve appears to minimize at a water plant size of approximately 11 MGD and a Δt of 4°F. Due to the lack of operating experience and data available for a plant of this design, the use of a 4°F Δt driving temperature in the VTE was not considered judicious. With a low driving temperature, small changes in the fouling on a tube will have a greater affect on the performance of the tube than if a larger Δt were being used.

Also, a plant size of approximately 8.0 MGD was an attractive size of plant to the Office of Saline Water. The Office of Saline Water thus, decided to have the second phase of this study conducted around a 8.0 MGD plant utilizing a 6.+°F Δt in the VTE effects.



	PSIA	°F
A	265	950
B	865	900
C	615	825
D	415	650
E	35	SAT

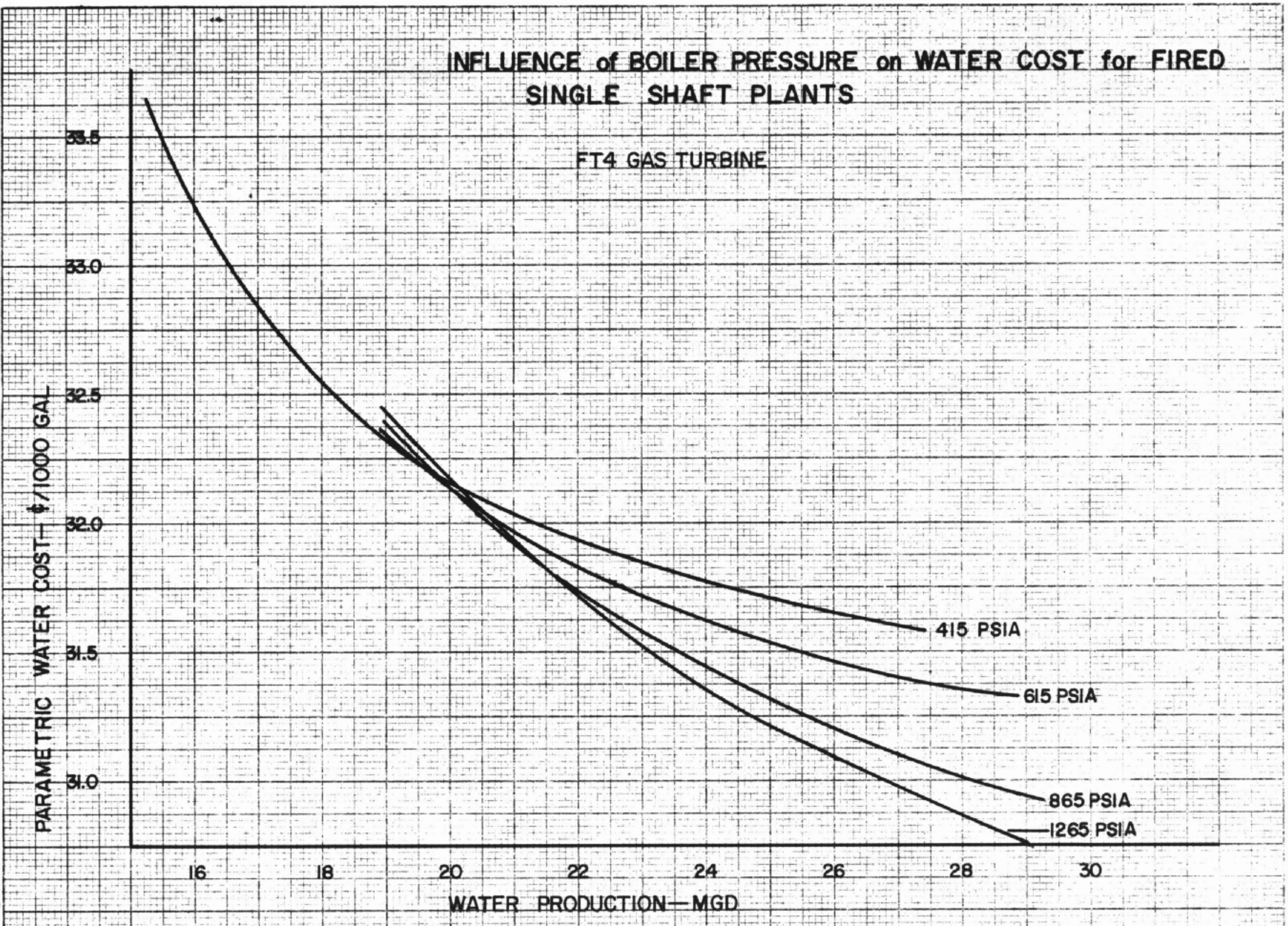
FIGURE V-1



INFLUENCE of BOILER PRESSURE on WATER COST for FIRED SINGLE SHAFT PLANTS

FT3 GAS TURBINE

FIGURE V-2



INFLUENCE of BOILER PRESSURE on WATER COST for FIRED SINGLE SHAFT PLANTS

FT4 GAS TURBINE

FIGURE V-3

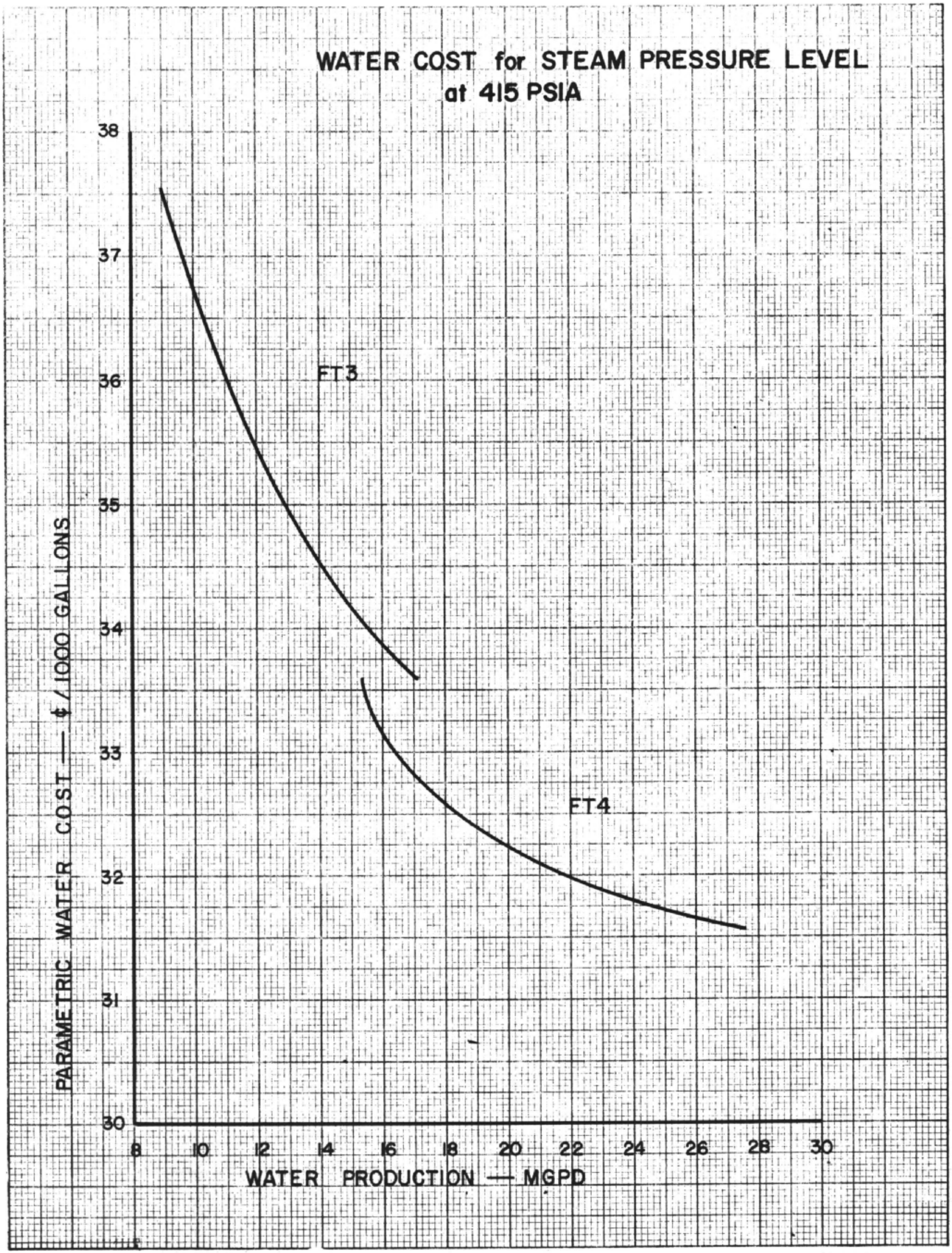

WATER COST for STEAM PRESSURE LEVEL
at 415 PSIA
PARAMETRIC WATER COST — ¢/1000 GALLONS
38
37
36
35
34
33
32
31
30
FT3
FT4
8
10
12
14
16
18
20
22
24
26
28
30
WATER PRODUCTION — MGPD

FIGURE V-4

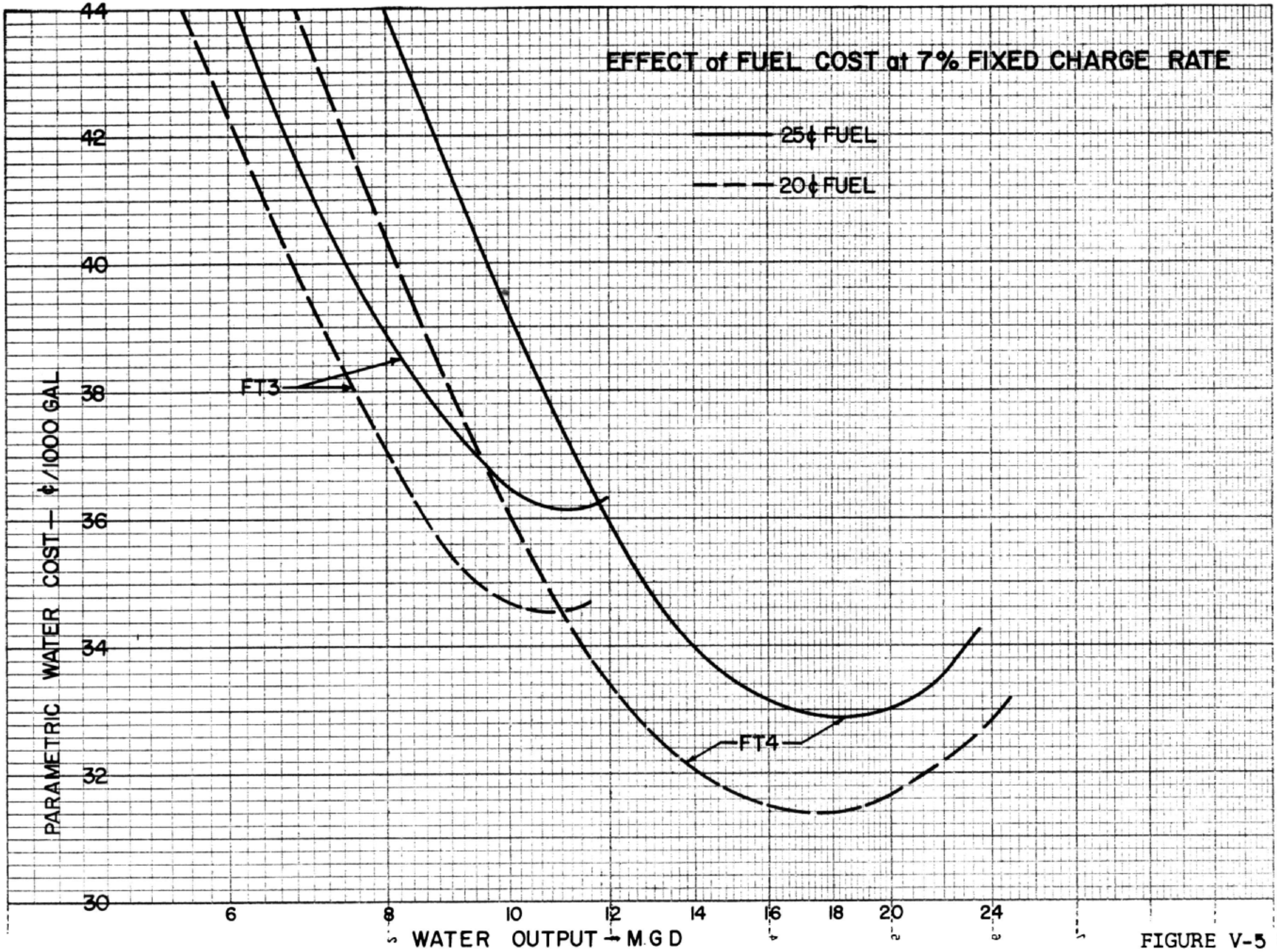
 EFFECT of FUEL COST at 7% FIXED CHARGE RATE
25¢ FUEL
20¢ FUEL
FT3
FT4
PARAMETRIC WATER COST — ¢/1000 GAL
44
42
40
38
36
34
32
30
6
8
10
12
14
16
18
20
24
WATER OUTPUT → M.G.D

FIGURE V-5

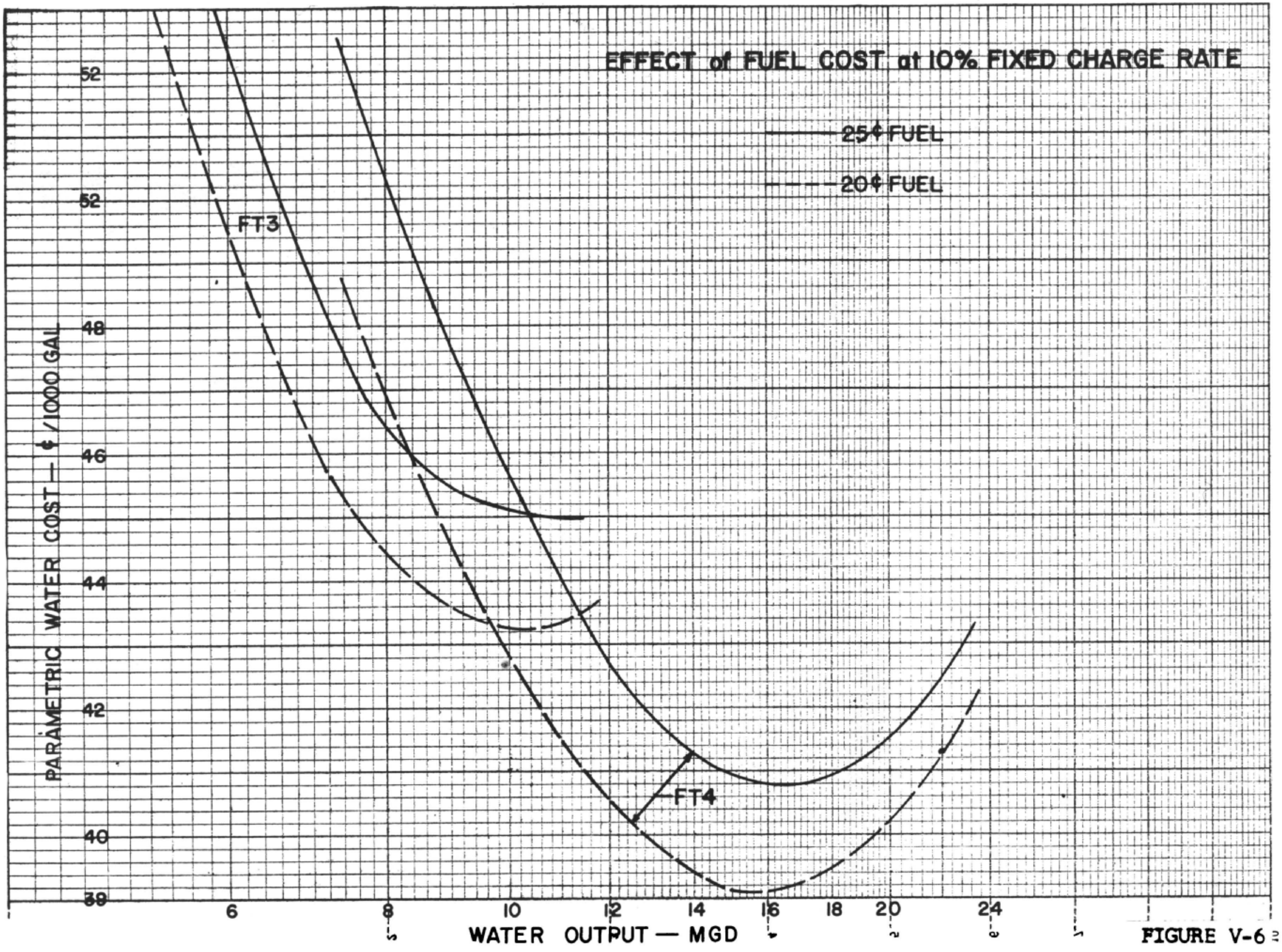
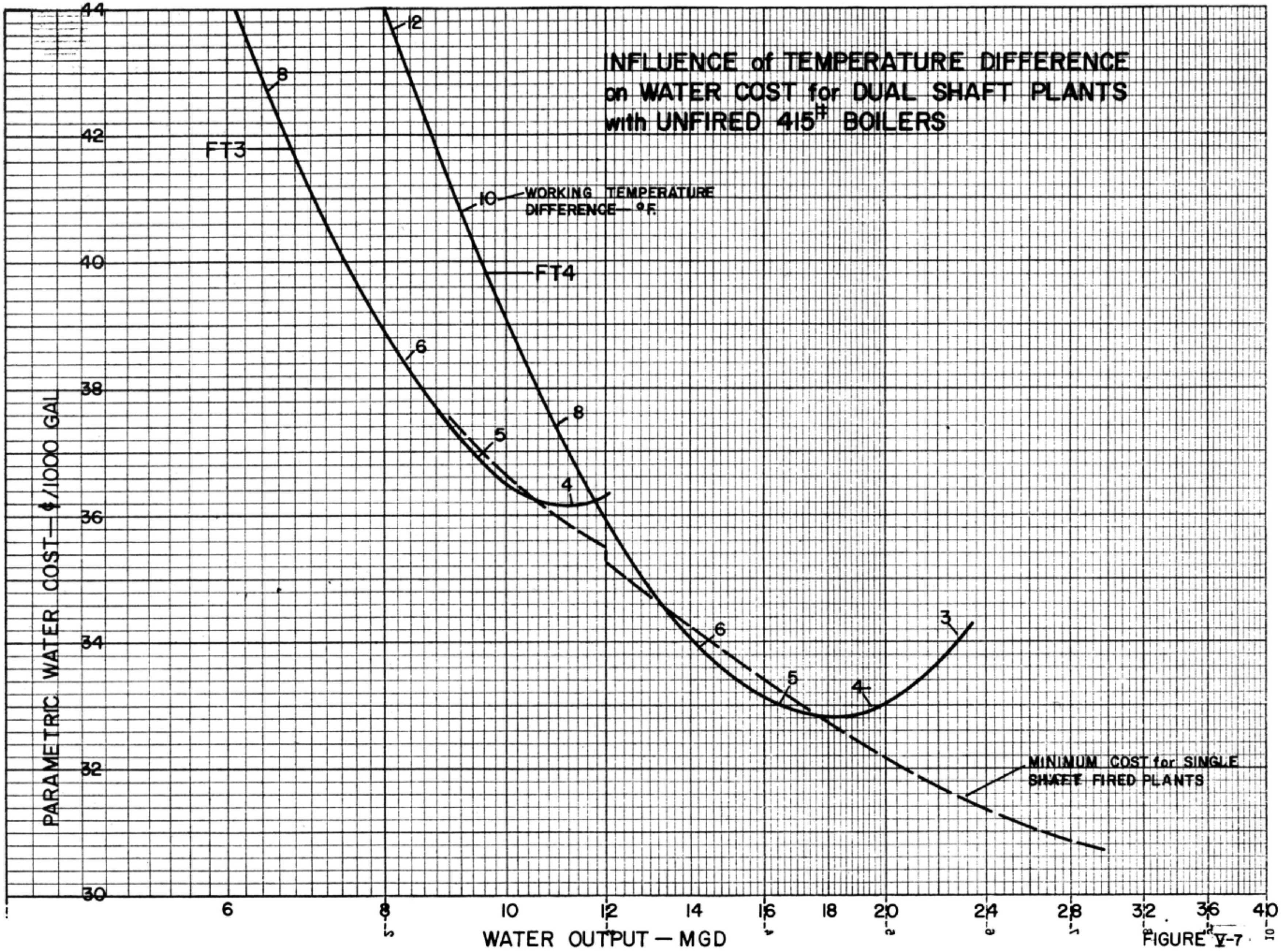

EFFECT of FUEL COST at 10% FIXED CHARGE RATE
25¢ FUEL
20¢ FUEL
FT3
FT4
PARAMETRIC WATER COST — ¢/1000 GAL
52
52
48
46
44
42
40
38
6
8
10
12
14
16
18
20
24
WATER OUTPUT — MGD

FIGURE V-6



INFLUENCE of TEMPERATURE DIFFERENCE
on WATER COST for DUAL SHAFT PLANTS
with UNFIRED 415# BOILERS

FIGURE V-7

2.2 Evaluation of Stacked and Flat Configurations of a Vertical Tube Evaporating Unit

A. Purpose of Evaluation

An evaluation was performed to determine whether a side-by-side or "flat" arrangement of effects of a vertically tubed evaporating unit or a one-over-the-other or "stacked" arrangement of the effects, would give the lowest overall costs. Considerations such as design costs, capital expenditures, construction costs, and operation and maintenance costs were used as the basis of this evaluation. Items that were judged to be equal in both designs did not enter into the comparison.

B. Conclusions

It was determined that the more economical design was the stacked arrangement. This arrangement offers simpler design, less equipment, and a lower operating and maintenance cost. Refer to Table V-4 for the tabulation of the overall cost differences between the stacked plant and the single level plant.

C. Evaporator Vessel Costs

Table V-1 is a tabulation of the various costs associated with the fabrication and erection of the two evaporator concepts. Table V-2 is a tabulation for the basis of the costs used in this evaluation.

The stacked design is predominantly constructed of a single size and thickness of plate whereas the flat design uses a greater variety of size and thickness. The reason for the greater variety of plate size is due to the more complex shape and the requirement for waterbox removal for maintenance of the flat design. It was judged that a 2 cent per pound premium would result in the material for this flat design due to the greater variety required and the wastage that would result from the more complex design.

Comparative unit costs in cents per pound of material delivered to the field for field erection were made. This material could be in the raw form, such as structural beams from the mill or in shop fabricated subassemblies such as the channel heads for the horizontal unit. It is obvious that the cost per pound of such a range of material can have a wide divergence. After consulting with the Chief Estimator and Sales Manager of Dorcon, Inc., a company experienced in field erection of similar steel structures, unit costs of material delivered to the job site were estimated to be $.23/lb for the stacked unit and $.60/lb for the horizontal unit. After adjusting these figures for shipping and basic material charges, the unit costs for shop fabrication are $.06/lb and $.41/lb respectively as shown in Table V-2. The first figure indicates a relatively minor amount of the overall material will be shop fabricated and that fabrication will be minimal. An example of this is that the shell plate would be trimmed and rolled only and shipped to the field for fit up and welding.

The second figure represents relatively complex and extensive shop fabrication; for example, the forming, welding, and machining required on the channel heads.

Referring again to Table V-2, the difference in estimated unit cost of foundations is reflected in the forming cost which is a major portion of the cost of any concrete foundation. With the horizontal unit, there are approximately 36 pedestal type foundations required, each of which would require forming on four sides. The amount of concrete required for the stacked unit is approximately 3 times that for the horizontal unit, resulting in an overall higher foundation cost for the stacked unit by a factor of approximately 1.5.

The field erection figures are based entirely on estimates from Dorcon, Inc. As noted above, this company's primary business is field erection of steel structures. They reported recent experience with towers similar to the vertical unit, and the figure of 50 MH/ton is believed to be a close estimate. Although Dorcon reported no experience with structures similar to the horizontal unit, it was estimated to require 90 MH/ton for erection. This figure is based on their estimate of the lack of accessibility and the general configuration of the horizontal plant when compared with the stacked plant. The field fabrication of the stacked unit would be by well established methods, whereas field erection of the horizontal unit would present uncertainties in positioning of material and components, fit up of components and subassemblies, and matching of supports to foundations.

The design of the flat arrangement was judged to be more complex and to have greater uncertainties, thus requiring a contingency allowance of 10% by the manufacturer compared to a 5% contingency for the stacked design. One item, in particular, of greater complexity is the design of four waterboxes in the flat configuration versus one in the stacked arrangement. In addition to the additional contingency assigned by the manufacturer, a 2% additional contingency was applied to the consulting engineers' fee as a penalty to the flat design.

The painting estimated cost, as shown in Table V-1, is a function of the outside surface. The horizontal unit has an estimated outside surface in excess of 1.5 of the stacked unit.

Total engineering including shop drawings is estimated at $5,000 for the stacked unit and $9,000 for the horizontal unit. The ratio of the horizontal to the stacked reflects the greater complexity of design and greater number of layouts required.

D. Pump Costs

The number of pumps and motors required varies with the plant design. Since brine is delivered to the first VTE effect in either design and the first effect of the stacked arrangement is considerably elevated, the cost of the pump and motor to achieve this higher head is greater in the stacked design. This higher cost is offset by the requirement of nine additional pumps to transfer brine between effects in the flat design. This brine transfer is achieved by gravity in the stacked arrangement.

An additional bonus in the capital costs of the stacked design is that no low pressure boiler feed pump is required. Due to the height of the first effect, feed water for the low pressure boiler will flow by gravity. A breakdown of capital costs associated with pumps is shown in Table V-3 hereafter.

E. Operation and Maintenance Costs

No cost figures were developed for operation and maintenance but due to the fewer pumps required by the stacked design, these costs would be lower than thos experienced with a flat design. Other advantages to the stacked design include simpler operation and greater reliability.

Tube removal and replacement in the flat arrangement would require removal of the covers over the tube bundles, requiring cutting, rewelding and reapplication of anti-corrosion coating and insulation. In the stacked configuration, the tubes can be removed and replaced from within.

F. Other Considerations

In other respects, the stacked design appeared favorable. The difficulty in assigning costs to these considerations prevented their assessment in the tabular evaluation. It is felt that the efficiency, both thermally and aerodynamically, of the stacked unit would be greater. This would be due to its annular flow passages and round tube bundles with central vapor and noncondensibles removal. Also, less on site electrical generation would be required due to the fewer pumps.

During the above investigation, consideration was given to elimination of the requirement for VTE unit vessel to be able to withstand full vacuum. This would have saved about 27% of the weight and cost of the vessel. It was concluded that the ability to operate with the vessel under vacuum was essential for calcium sulfate descaling of the VTE unit. Further consideration of a design without the ability to operate under vacuum was abandoned.

TABLE V-1 VTE UNITS

VERTICAL TUBE EVAPORATOR COMPARATIVE COST ESTIMATE

	(THOUSANDS OF DOLLARS)	
	STACKED	SINGLE LEVEL
a. Vessel Material Delivered to Site	292	538
b. Vessel Field Erection	409	547
c. Tube Bundles, Material & Erection	1048	1023
d. Vessel Foundations	20	13
e. Insulation	36	46
f. Paint	10	15
g. Engineering	5	9
Subtotal	1820	2191
h. Contingency	91	219
Total	1911	2410
Or	Base	499
Basis:		
1. Vessel Weight, M lb.	1168	868
2. Foundations, Cu.Yd.	308	108

TABLE V-2 COST BASIS

VERTICAL TUBE EVAPORATOR COMPARATIVE COST ESTIMATE

	STACKED	SINGLE LEVEL
Material ¢/lb	17	19
Shop Fabrication ¢/lb	6	41
Shipping ¢/lb	2	2
Material Delivered to Site (total above) ¢/lb.	25	62
Foundations $/Yd^3	65	120
Field Erection MH/Ton	50	90
Contingency %	5	10
Prime Contractor-Engineer Consultant		
Procurement		
Installation Engineering		
Supervision of Erection		
Supervision of Startup		
Testing		
Fee		
Subtotal	10%	10%
Contingency	0%	+ 2%
Total	10%	12%

TABLE V-3 PUMPS
COMPARATIVE COST ESTIMATE VTE SYSTEMS

	(THOUSANDS OF DOLLARS) STACKED	SINGLE LEVEL
Deaerated Seawater Feed	3 x 400 hp	3 x 300 hp
Pumps	23,950	10,260
Motors	14,850	11,600
Switchgear	13,620	13,600
Subtotal	52,420	35,460
Brine Pump System	(Not Req)	(9 x 40 hp)
Pumps		30,800
Motors		10,260
Switchgear		10,580
Valves		22,100
Piping		15,700
Foundations		2,160
Installation		13,750
Subtotal		105,350
Return to Boiler	(Not Req)	(2 x 7-1/2)
Pumps		1,120
Motors		350
Switchgear		1,610
Valves		3,950
Piping		2,630
Foundations		280
Installation		1,490
Subtotal		11,430
Total	52,420	152,240
	Base	99,820

TABLE V-4 COMPLETE SYSTEM

VERTICAL TUBE EVAPORATOR COMPARATIVE INSTALLED COST ESTIMATE

(THOUSANDS OF DOLLARS)

		STACKED	SINGLE LEVEL
a.	VTE Unit Design & Erection	1911	2410
b.	Pumps Design & Erection	52	152
	Subtotal	1963	2562
c.	Prime Contractor	196	307
	Total	2159	2869
		BASE	710

2.3 VTE Evaporator Design Guidelines

The design guidelines used in arriving at the design of the VTE as used in this plant were developed by W. L. Badger Associates. A copy of the above mentioned guidelines follows including calculations for the Heat and Material Balance at the design conditions. (Refer to Fig. IV-1):

8.0 MGD VAPOR COMPRESSION EVAPORATOR

DESIGN GUIDELINES FOR VTE SECTION

Introduction

The vertical tube evaporator part of this plant requires most of the heating surface, cost, and bulk of the system. There are a number of different arrangements for the VTE section--the most economical will depend on the materials of construction utilized and the designer's ingenuity. The design guidelines that follow are intended to provide the basis on which various alternative physical arrangements can be compared. These guidelines are based on a considerable amount of preliminary optimization work, which has fixed the number of effects and tube dimensions in the VTE section, the performance required of the feed heaters and the external flows and temperature levels.

Flowsheet

Figure 1 shows the basic flows and flow sequence through the plant. The VTE section comprises the four effects shown stacked one above the other on the left plus the four associated feed heaters. The MSF feed heater train and the vapor compressor have been specified separately. These specifications have already set the external flows and temperature levels. The internal flows and temperature levels have been based on the assumption of having the same heating surface in each effect and the same surface and heat transfer coefficient in each feed heater.

The general feed sequence is that of a forward feed four effect falling film evaporator. The partially preheated seawater feed from the MSF train is heated in series by vapor extracted from each effect of the evaporator. Tubes in the preheaters are 0.042" wall, 90-10 Cu-Ni. The length and diameter shall be best suited to the physical arrangement chosen. The heated seawater then goes through the evaporator tubes in series, being transferred from one effect to the next either by gravity in the arrangement shown in Fig. 1 or by pumps if all effects are on the same level. Evaporator tubes are also 90-10 Cu-Ni, but are fluted longitudinally to a profile developed by General Electric to enhance heat transfer.

Condensate produced in the evaporators and preheaters (except that equivalent to the prime steam introduced as makeup heat and the amount withdrawn as boiler makeup) is flashed from effect-to-effect in the conventional manner and is finally discharged to the MSF train for additional heat recovery. It would be possible to save on preheater surface needs by providing an intermediate flash stage between effects for both condensate and inter-effect brine. However, this would save less than 3000 sq.ft. of surface, which would be almost or probably more than offset by the extra cost of the additional baffles required.

Heat and Material Balances

The design heat and material balance is based on an ambient air temperature of 73°F and the other external conditions shown in Fig. 1. A number of additional balances have been made for off-design point conditions but these have been based on assumed performance of an existing installation. They therefore need not be considered in the design except insofar as they affect allowable liquid and vapor velocities.

The design heat and material balance is included in Figure IV-1. No allowance is shown for heat losses, both because they are expected to be very small relative to the size of the plant and because the energy input from pumps (About 3,000,000 btu/hr. total, 1,000,000 btu/hr. to the VTE section alone) is converted to heat. There is an additional allowance in that the makeup heat quantity shown is about 3% less than that actually available from the waste heat boiler, without supplementary firing.

Evaporator Heating Surfaces

The heat and material balance shows the heat quantities involved and the temperature differences available. These temperature differences include an allowance for boiling point rise losses and for vapor pressure drop in the tubes (which is negligible). However, no allowances are included for vapor pressure drop in vapor piping, separators, and through the condensing side of the tube bundles since these losses will depend on the arrangement chosen. All of these losses, back to 72" compressor suction and discharge flanges, must be compensated for by installation of additional heating surface.

The tubes to be used for the evaporator surfaces are 3" O.D. by .035" wall, of 90-10 Cu-Ni. The tubes will have a total length of approximately 12"-10", with an active fluted length of 12'-6" and with plain ends to permit installation by conventional means. The fluted surfaces have a heat transfer area of 1.0 sq.ft./ft., or 12.5 sq.ft./tube. Design heat transfer coefficients for the present service are:

I - 1482 btu/hr.-sq.ft.-°F.
II - 1473 btu/hr.-sq.ft.-°F.
III - 1463 btu/hr.-sq.ft.-°F.
IV - 1454 btu/hr.-sq.ft.-°F.

These coefficients are based on the boiling point rise at the average seawater concentration in the tube. They include the normal fouling that was encountered during the extended series of tests with seawater from which these coefficients were derived (OSW R & D Report 181) plus an additional fouling allowance of 0.00010. On the basis of a few spot tests (with smooth falling film tubes), it may be assumed that the residual feed heating at the top of the first effect tube is at the log mean ΔT in that zone.

These heat transfer coefficients indicate a requirement of approximately 63,400 sq.ft., or 5075 tubes, per effect, before allowance for vapor side pressure losses.

The tube sheets should be 12'-9" face-to-face, with the tubes flush with the top sheet. An ORNL study indicates that tube sheet thickness is governed only by tube rolling limitations and they have used 1 1/2" thickness. Wind tunnel tests indicate that shell side pressure drop is no different than for smooth tubes and agrees with Grimison's correlation (Perry, Chem. Eng. Handbook, IV Ed., pps. 5-49). Tests included the 1.15 pitch to diameter ratio that they adopted for high temperature effects. This pitch is utilized in the present plant. (See Figure 2)

The feed to each tube is distributed on the tube walls by a distribution nozzle having a pressure drop of approximately 5 psi. Minimum feed per tube is about 1.2 gpm, which for the present plant corresponds to essentially the full flow through the system. ORNL has developed an inexpensive ceramic distribution nozzle with a hex head that can be utilized to protect the top tube sheet from corrosion by use of a suitable pourable silicone rubber used between the nozzles. In this case, the top tube sheet may be of steel. The bottom tube sheet may also be of steel since it is out of the brine flow path.

Plant designs developed by ORNL for large VTE plants involve use of shop assembled modular tube bundles. Each bundle has nominal 10 x 20 ft. rectangular tube sheets (essentially outer tube limits). At a 1.15 pitch/diameter ratio, the present plant would require two such modules per effect. The attached copy of Figure 3 shows the general means employed by ORNL for supporting and sealing such bundles.

Feed Heaters and Venting

Seawater feed will be available from the MSF train at 208.8°F and at a pressure measured at grade of either 40 psig (for a single level plant) or 72 psig (for a stacked plant) when the feed rate is 10% over the design value. The feed heaters should employ 0.042" wall 90-10 Cu-Ni tubes, the tube velocity should be at least 5.0 fps at the design feed rate and the pressure drop should be low enough to permit handling 10% over the design flow at the above feed pressures.

The four feed heaters may be individual bundles but the least expensive arrangement will probably be a long-tube single pass design with shell side dividers to isolate the steam spaces. Vapor supply may be directly from the evaporator vapor space but would better be as vents from the evaporator heating elements if the physical arrangement permits. This will provide about 6% exit vapor flow from the evaporator bundles and should avoid need for steam side baffles in the evaporator bundles. Noncondensibles are not expected to be a real problem (except during startup), both because the feed will have been decarbonated and deaerated and because the unit will operate above atmospheric pressure. The only detectible noncondensibles will probably appear in the second effect vents (as a result of traces of air and CO_2 in the feed) and it would be best to vent this effect, through its feed heater, to the atmosphere. All other vents can then be cascaded to ultimately discharge at this point.

The presence of the spray nozzle distributors in the evaporator tubes, with their small orifices, dictates that no steel be in contact with brine in the feed heater circuit. The preferred contact material is 90/10 clad steel although fiberglass reinforced epoxy may be utilized where practical.

The heat transfer coefficients for the feed heaters should include a fouling factor of about 0.00020, which is approximately that used for the evaporator surfaces (including the fouling probably present in the experimental program). At a coefficient of 570 (based on the vapor head steam temperature), each heater should have 6000 sq.ft. of surface.

Vapor-Liquid Separator Sizing

Entrainment from a falling film evaporator is less than from other evaporator types. This is to be expected since much of the separation takes place within the tubes and the effluent from the tubes is projected downward, away from the vapor outlet. One would therefore expect that falling film evaporators could be operated at higher disengaging velocities than other types. Unfortunately there are no data available for such evaporators that extend beyond the maximum velocities reached in other types (Perry, IV Ed., pg. 11-35). Consequently, unless there are additional in-house data available, it would be prudent to design on the basis of maximum velocities used for these other types, corresponding to a decontamination factor of 100 in Fig. 11-31 of Perry. On this basis, and using the worst off-design point conditions expected, the horizontal free area required for disengagement would be as follows:

I	531 sq.ft.	III	595 sq.ft.
II	569 sq.ft.	IV	625 sq.ft.

This area does not include condensate flashing space, which can be accommodated in otherwise unused vessel volume and need not add to vessel size.

Freeport startup data indicate that the falling film evaporator has a decontamination factor about 60 times higher than other types at the same vapor velocity. This corresponds to about 10 ppm total solids in the distillate, which is substantially lower than needed. As a result, the only entrainment separator needed will be on the last effect, to protect the vapor compressor. Here, as solids content below 5 ppm is desired and the lower it is the longer the compressor can be operated without cleaning (6-12 month intervals are usual at 5 ppm). The separator here should be of Monel mesh, sized primarily on the basis of the effect of its pressure drop on heating surface requirements.

One final consideration in separator sizing is the skirt velocity at the exit of the tube bundle. Here, the velocity of vapor leaving from below the tubes should not be so high as to blow the shower of brine from the tubes at the vapor exit side of the bundle up into the disengaging area. A preliminary analysis indicates that this should not be a problem at skirt velocities up to twice the basic disengaging velocity.

Mechanical Limitations

Materials of construction selected should be based on an assumed 30 year plant life with little downtime allowed for maintenance. Tubes are expected to last the full 30 years but access should be available for retubing if it becomes necessary. A second consideration is that the evaporator tube orifices must not plug rapidly with solids such as might result from using unprotected steel in the major brine passages. Steel, where used, should include a corrosion allowance of approximately 3/8" where in contact with brine and approximately 3/16" where out of contact with brine. Concrete construction, with a steel liner, appears most economical if the plant is built as a single level rectangular design. ORNL suggests protection of the steel, where necessary to avoid orifice plugging, by 1/8" polypropylene sheet.

It would be desirable to design the entire vessel for both 20 psig internal pressure and full vacuum. It is recognized that this may be inordinately expensive for a rectangular single level plant. If such is the case, the vessel must be capable of withstanding at least a moderate vacuum (of about 20" Hg absolute) and must include suitable relief devices to protect against excessive vacua, such as might develop during a forced shutdown.

The pumps that will be needed for inter-effect brine transfer in a single level plant should be sized to provide a feed rate of about 1.2 gpm per tube. The pump flow need not be controlled but level controls will be required to bypass the excess brine to the following effect. Since these pumps must operate on high temperature brines, they should have Ni Resist casings, Monel 505 impellers, and Monel K505 shafts or shaft sleeves.

The plant is to be designed for wind loading, earthquake, etc. conditions appropriate to the Texas Gulf Coast area and is to be based on a maximum soil bearing strength of 2000 psf.

Alternative Arrangements

At least two general physical arrangements should be considered and carried through to final pricing. One is a single level plant, probably of rectangular design and of concrete construction, that would be similar to the arrangement considered most economical by ORNL for very large capacity multiple effect VTE plants. The other is a stacked arrangement, probably of cylindrical design and of steel construction, that could more easily be built to withstand full vacuum.

Advantages for a single level plant are as follows:

1. Less site sensitive relative to soil and wind loadings.
2. Less contained volume.
3. Probably less containment cost, if built of concrete.
4. Feed rate to evaporator tubes can be selected independent of total seawater throughput.
5. Feed heater tubes can easily be horizontal, with resulting improved steam side coefficients.

An alternative single level arrangement would involve placing the effects in concentric circles, with the first effect in the center. This would be similar to the Dow and C.F. Braun conceptual designs for 50 MGD multiple effect plants.

The advantages for a stacked plant are as follows:

1. No pumps are required in this high temperature end of the system, resulting in greater plant reliability.
2. The cylindrical shell can more economically be designed for full vacuum operation.
3. The shell is out of the brine path, resulting in less corrosion of stressed components.
4. The only portions requiring protection against solids pickup by the brine are the first effect heating element head and the frustro-conical sections containing brine feed to the succeeding heating elements.
5. The circumference of each bundle provides more area for steam entrance, resulting in a lower steam side pressure drop. It also provides a tapered steam flow path that reduces steam distribution problems.
6. The vertical height required between tube bundles to permit tube replacement is not wasted in that it also permits developing the hydrostatic head needed to feed orifices of the following effect while still providing more than adequate skirt area for vapor escape.
7. Boiler makeup can be returned by gravity.
8. Fewer problems relative to vessel thermal expansion and fewer large flanged openings.

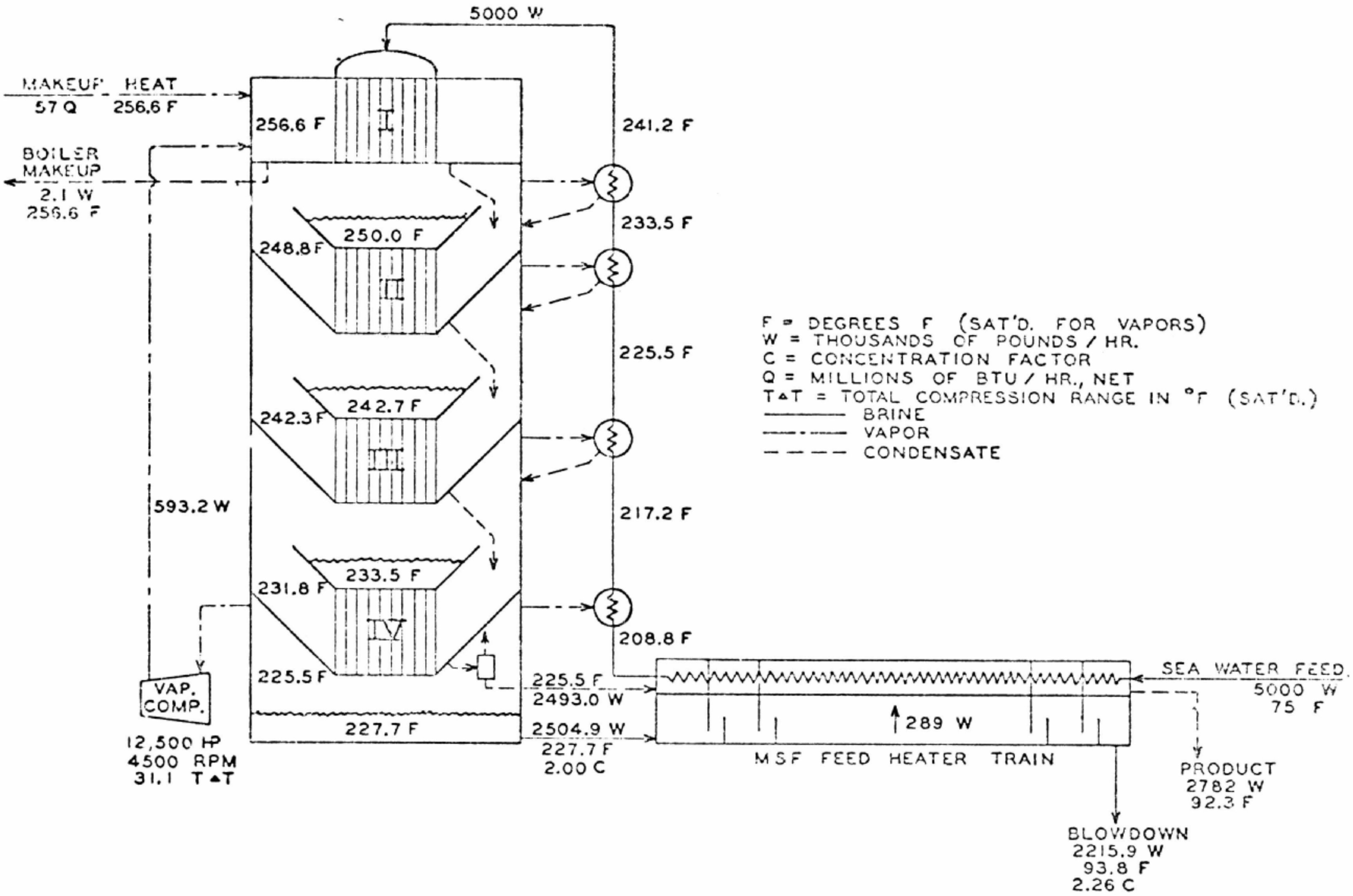
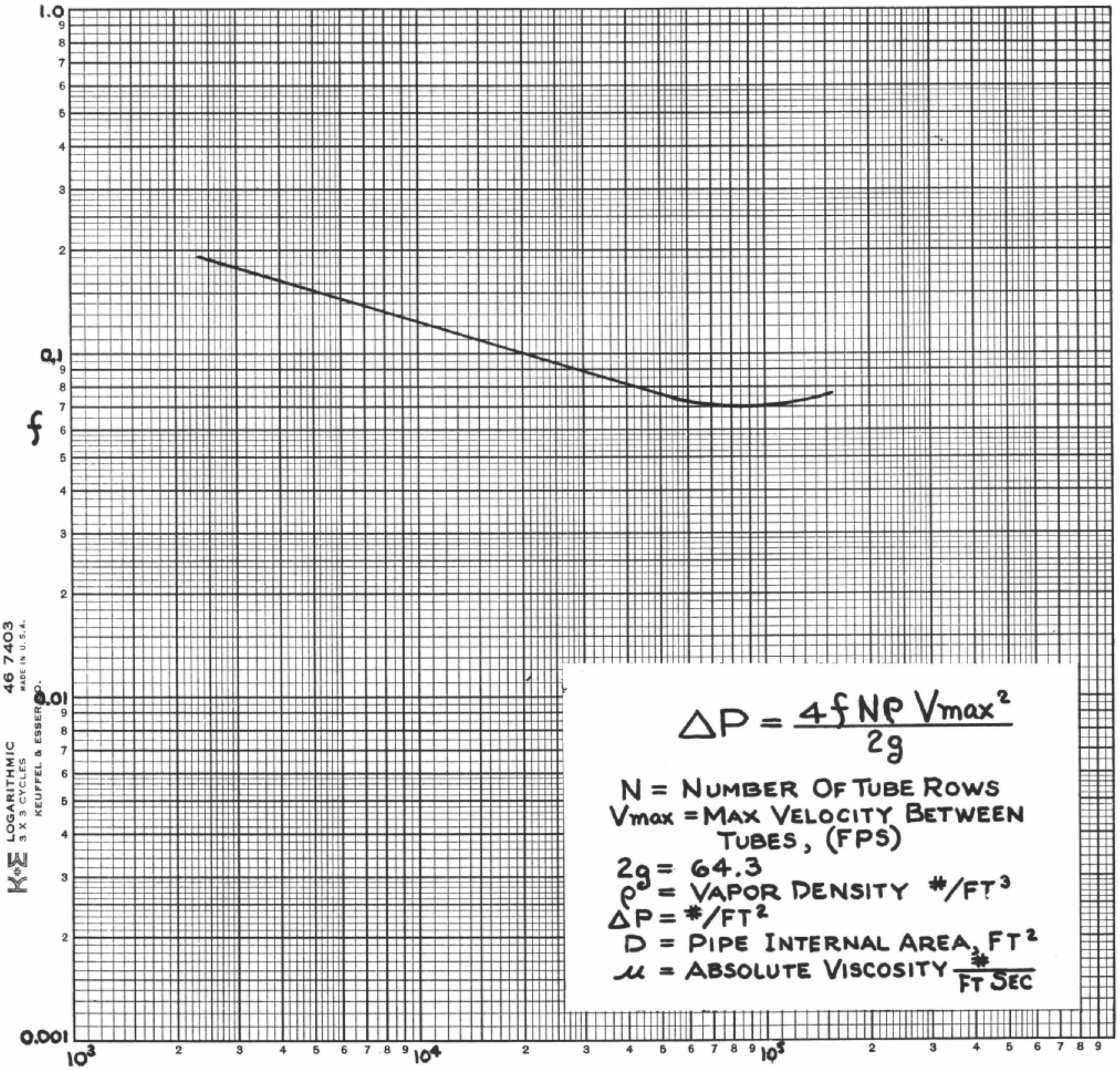


FIGURE I

NORMAL DESIGN CONDITION

PRODUCTION - 8.00 MGD

FIGURE 2



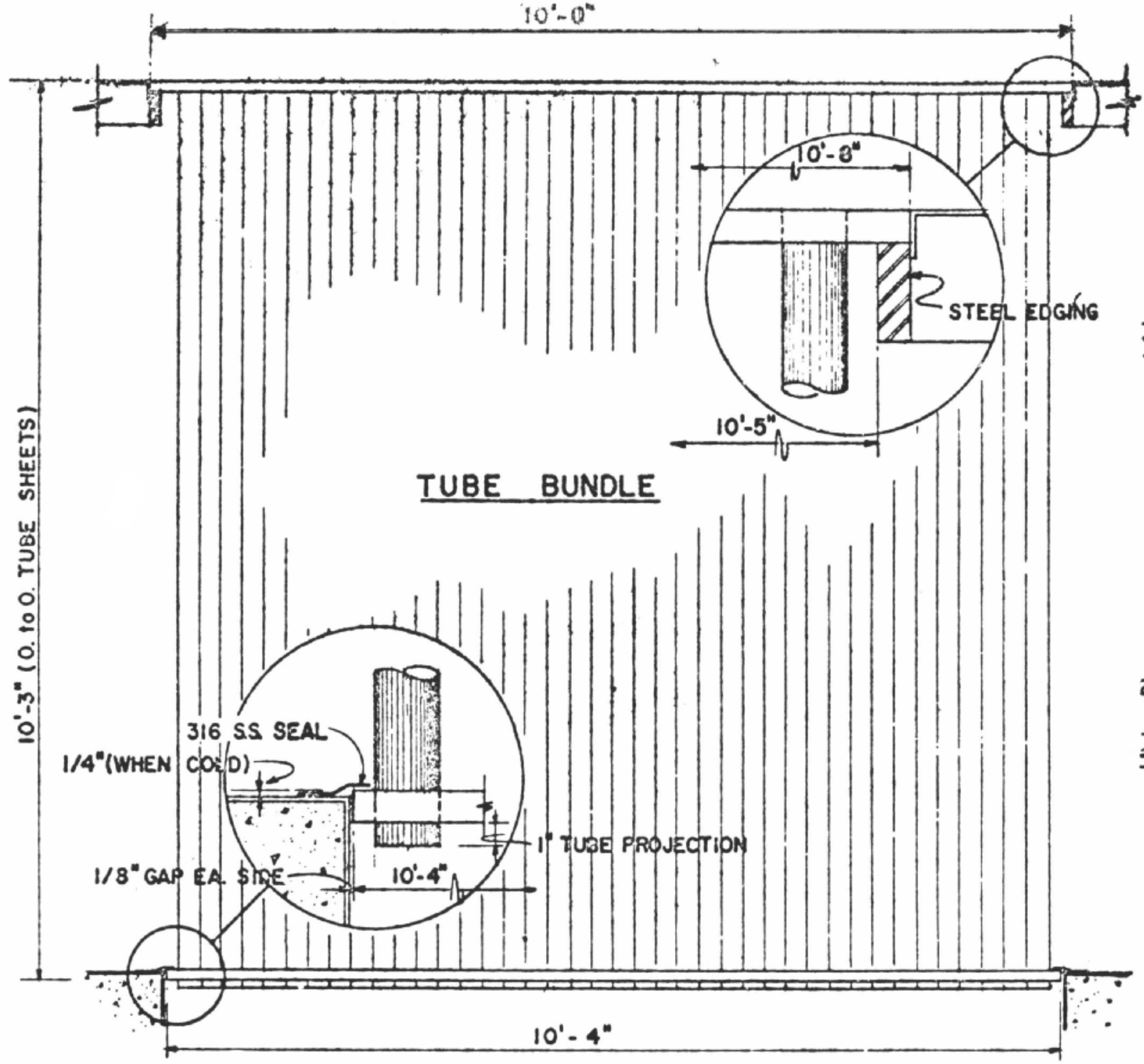
$$\Delta P = \frac{4 f N \rho V_{max}^2}{2g}$$

N = NUMBER OF TUBE ROWS
V_{max} = MAX VELOCITY BETWEEN TUBES, (FPS)
$2g = 64.3$
ρ = VAPOR DENSITY #/FT^3
ΔP = #/FT^2
D = PIPE INTERNAL AREA, FT^2
μ = ABSOLUTE VISCOSITY $\frac{\#}{\text{FT SEC}}$

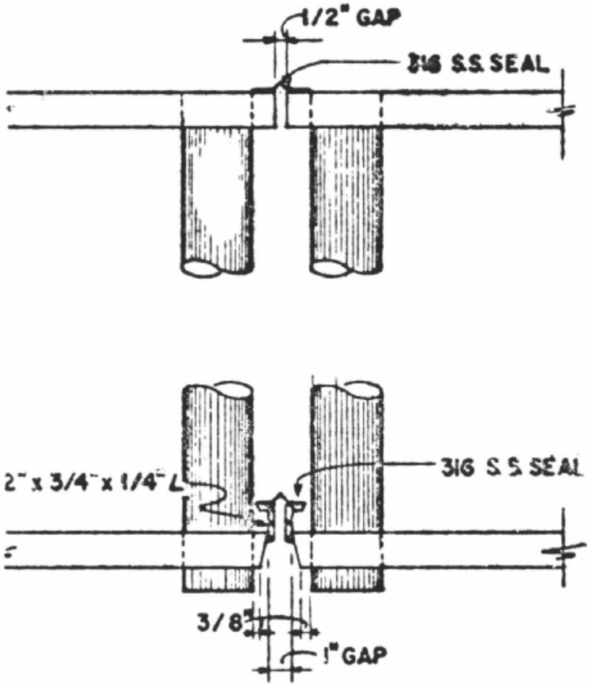
REYNOLDS NUMBER, $N_{Re} = \frac{D V_{max} \rho}{\mu}$

FRICTION FACTORS FOR FLUTED TUBES ON 1.15 PITCH/DIA.RATIO

SOURCE ORNL TH1901



TYPICAL CROSS SECTION
SCALE: 1" = 1'-0"



CONNECTING DETAILS AT ENDS OF 20' LONG BUNDLES

FIGURE 3

250 MGD VTE

HEAT TRANSFER COEFFICIENTS FOR FLUTED TUBES

The tubes proposed for the vapor compression section of this plant are those developed by the General Electric Company in their tests at Wrightsville Beach for the Office of Saline Water (G.E. Diedrich, U.S. Pat. 3,244,601, April 5, 1966 to General Electric Company). The tubes are fluted longitudinally, inside and out, by rolling, and have about 28% more heat transfer surface than a smooth tube of the same outside diameter. The heat transfer coefficients, however, are many times higher than would be indicated by the modest increase in area. The General Electric test program (OSW R. and D. Report 181) generated a substantial amount of heat transfer data and this has been examined to insure the validity of the heat transfer coefficients assumed for the proposed plant.

Overall Heat Transfer Coefficients

The General Electric data were presented as plots of apparent overall coefficients as functions of tube length (5 and 10 ft.), temperature level, and nominal overall temperature difference (5, 10, 15, and 30°F). These coefficients were based on saturated steam and vapor head pressures and hence included no allowance for boiling point rise losses, or for losses due to frictional pressure drop or acceleration of the vapor generated in the tubes. It can easily be shown that frictional and acceleration losses were negligible at the higher temperature levels (175° or more) of interest for the current study. Boiler point rise losses can be estimated from the heat fluxes, feed rates, and feed concentrations, and the assumption that the feed was always at the boiling point. There is some uncertainty here because,

a. heat fluxes could only be calculated as the product of the coefficient and the nominal, or target, temperature difference.
b. feed rate frequently was not given.
c. while the feed was unconcentrated, Wrightsville Beach seawater in the tests of interest, the actual exact concentration was not given.

Recognizing these uncertainties, the correction of the apparent to true coefficients is as shown in the first 11 columns of Table I. Boiling point rises are calculated from the data of Stoughton and Lietzke, J. Chem. Eng. Data 12, 101 (1967) at the average concentration in the tube. All coefficients are based on the extended outside area of the tubes, which was given as 1.0 sq.ft. per foot. Tube outside diameter was given as 3.0 inches and scaling a photograph of the tube gives an inside minimum diameter of about 2.77 inches and a wall thickness of about 0.072 inches.

TABLE I

OVERALL AND PARTIAL COEFFICIENTS FROM G.E. RUNS

From Report 181:

Fig.	L	Evap. T	ΔT	GPM Tube (1)	Feed C.F.	U Appar.	Evap'n #/hr. tube (2)	Av'g. C.F.	BPR	U Corr.	$\frac{10^6}{U}$	$\frac{10^6}{h_s}$	Wall $\frac{10^6 L}{K}$	$\frac{10^6}{h_B}$
14	10	175	5		1	1250	63	1.025	.87	1513	660	55	30	575
15		215	15		1	1600	240	1.1	1.09	1725	580	158		392
16		215	10		1	1650	170	1.07	1.05	1845	542	115		397
18	↓	175	15		1	1500	226	1.10	.95	1602	624	160		434
20		180	10	2.5	1	1600	162	1.07	.94	1768	565	119		416
36	10	250	10	2.5	1	1500	159	1.07	1.16	1698	588	101		457
9	5	180	15		1	1500	114	1.11	.97	1604	623	127		466
9		180	10		1	1640	83	1.08	.94	1812	552	97		425
9		180	5		1	1900	48	1.05	.91	2320	431	62		339
13		185	10		1	1750	89	1.09	.97	1940	515	103		382
14		180	5		1	1650	42	1.04	.91	2020	495	55		410
18		190	15		1	1800	137	1.14	1.03	1933	517	145		342
20		190	10	1.13	1	2000	102	1.10	.99	2220	450	112		308
31		250	10	1.15	1	1900	101	1.10	1.20	2160	462	98		334
32		270	10	1.25	1	1650	89	1.08	1.27	1890	529	86		413
33		275	10	1.25	1	1400	75	1.06	1.27	1603	624	74		520
34,22		280	10	1.25	1	1400	76	1.06	1.28	1605	623	74		519
35	↓	280	5	1.25	1	1800	49	1.04	1.26	2405	415	51		334
39	5	200	30	1.15	1	1400	214	1.23	1.14	1454	687	199		458

1) When not given, assumed 2.5 GPM for 10' and 1.13 GPM for 5' tubes.
2) Evaporation based on assumption that feed was at boiling temperature.
3) Wall resistance (a) As reported in G.E.-50 MGD Design = .0000459
(b) As scaled from Rep. 181 - Min. Thk. = .072/2400 = .000030
4) All coefficients based on extended area of Tube - 1.0 sq.ft./ft.

Steam Film Coefficients

It is generally recognized that the effect of flutes on the steam side of vertical tubes is to draw the condensate into the grooves by surface tension forces. The condensate drains rapidly through the grooves and the film on the lands is much thinner than normal, presenting less resistance to heat transfer. Similar results can be achieved by stretching wires along the length of a vertical tube, as described by Thomas (Ind. Eng. Chem. Fundamentals VI, 97, 1967). Thomas presents a theoretical analysis showing that the ratio of coefficients of enhanced to smooth tube is essentially inversely proportional to the square root of the heat flux. His experimental results confirmed this relationship. Although his empirical expression for the results includes the first power of the heat flux, the results can better be expressed (at the wire distribution where enhancement was greatest) by the relation $h/h_o = 680\ (Q/A)^{-1/2}$, which is in agreement with the theoretical derivation.

Thomas' results can be combined with the "practical" (1.28 times the theoretical) Nusselt relationship for smooth tubes to give the following relationship for tubes enhanced by wires along the surface:

$$h = 810(k^3\rho^2 g/\mu^2)^{1/3}(\mu\ \Delta H/L)^{1/3}(Q/A)^{-0.833}$$

where the dimensions are btu, pounds, hours, and feet.

Carnavos (Proc. First. Symp. on Water Desal. II, 205, 1965) presents some data for steam film coefficients on G.E. fluted tubes and smooth tubes. The results are presented as film coefficients versus heat flux for tubes one foot high. The results for smooth tubes are in excellent agreement with the practical Nusselt relationship. The curve drawn through the fluted tube results has a slope of -0.78, but a curve with the theoretical slope derived above of -0.833 fits the data practically as well. The resulting expression is then the same as that derived above, but with a constant of 1180 instead of 810, representing film coefficients 46% higher than indicated by Thomas. This does not seem an unreasonable improvement because less of the surface should be blanketed by the meniscus of a film drawn into grooves than that of a film drawn to wires.

Accordingly, the following expression was used to estimate the steam film coefficients for the General Electric tests:

$$h = 1180\ (k^3\rho^2 g/\mu^2)^{1/3}(\mu\Delta H/L)^{1/3}(Q/A)^{-0.833}$$

The resulting steam film coefficients for each of the runs of interest are shown in Table II.

TABLE II

STEAM FILM COEFFICIENTS FOR G. E. RUNS

$$h_s = 1180\phi(\mu\Delta H/L)^{1/3}(Q/A)^{-0.833}$$

Fig.	Stm. T	Q/A	L	μf	h_{fg} ΔH	$(\mu\Delta H/L)^{1/3}$	$(Q/A)^{.833}$	ϕ	h_s	$10^6/h_s$
14	180	6,250	10	.84	990	4.42	1440	5020	18,200	54.8
15	230	24,000	10	.62	959	3.90	4480	6175	6,350	158
16	225	16,500	10	.64	962	3.94	3250	6070	8,680	115
18	190	22,500	10	.79	984	4.27	4250	5270	6,250	160
20	190	16,000	10	.79	984	4.27	3170	5270	8,380	119.2
36	260	15,000	10	.53	939	3.68	3000	6830	9,870	101.3
9	195	22,500	5	.755	981	5.29	4270	5380	7,850	127.3
9	190	16,400	5	.79	984	5.38	3250	5280	10,320	96.9
9	185	9,500	5	.81	987	5.43	2060	5150	16,050	62.3
13	195	17,500	5	.755	981	5.29	3450	5380	9,730	102.7
14	185	8,250	5	.81	987	5.43	1820	5150	18,130	55.1
18	205	27,000	5	.71	975	5.17	4970	5620	6,910	144.7
20	200	20,000	5	.735	978	5.25	3830	5500	8,900	112.3
31	260	19,000	5	.53	939	4.63	3650	6830	10,220	97.8
32	280	16,500	5	.48	925	4.46	3250	7220	11,700	85.5
33	285	14,000	5	.47	921	4.44	2850	7330	13,500	74.1
34,22	290	14,000	5	.46	918	4.39	2850	7420	13,500	74.1
35	285	9,000	5	.47	921	4.44	1970	7330	19,500	51.3
39	230	42,000	5	.62	959	4.92	7130	6175	5,030	198.7

Wall and Brine Film Resistances

Carnavos (loc. cit.) seems to feel that the enhancement of the film coefficient on the brine side of fluted tubes is the result of evaporation from the very thin film on the lands of the tube. Our feeling is that it is a result of the increased brine velocity through the flutes. The only practical effect of this difference in interpretation is on the resistance of the metal wall, and hence on the correction for wall resistance when using other than copper tubes. Our interpretation results in the shortest path for the majority of the heat (from land outside to flute inside) and hence the lowest wall resistance. For the copper tubes used in the G.E. tests, the resulting wall resistance should be about 0.000030, versus the value of 0.0000459 assumed in the G.E. 50 MGD plant design.

Subtracting the steam and wall resistances from the total resistance (calculated from the true temperature difference) should give the brine film resistance (plus fouling resistance if present) for the G.E. tests. The results are shown in Table I and plotted in Fig. 4. There is appreciable scatter in the data, but this is to be expected since all the errors in the data and the effects of deviations from the assumptions listed on pg. 106 are thrown into this partial coefficient.

In Fig. 3, there is no discernable trend with tube length or temperature difference, indicating that the equation used for the steam film coefficient is probably reasonably accurate. Also, there is no discernable trend with temperature level, but this would be expected on the basis of a convective falling film heat transfer concept. The theoretical trend with temperature level, based on Dukler, is shown in Fig. 4 by the solid line. Also shown in Fig. 4 are three points calculated from smoothed ORNL data (for a 3-4% NaCl solution), which are in general agreement with the G.E. data from Wrightsville Beach.

The above results indicate that the brine film coefficient at 220°F is on the order of 2500 (a resistance of 400×10^{-6}) based on the outside area, or about 2700 based on the actual inside area. To achieve a coefficient of this magnitude by conduction through a very thin film on the lands of the tube would require that the film thickness be only about 0.0017 inches. This is of the same magnitude as the average depth of water evaporated from the surface each second (0.0011 inches per second at a heat flux of 20,000 btu./hr.sq.ft.). It is unlikely that this is the mode of operation because the short time available for replenishment of the film by flow from the grooves would result in little back diffusion of concentrated brine from the lands and hence gross overconcentration of brine on the lands.

An alternative explanation for the enhanced brine film coefficients is that heat is transferred by convection to the bulk of the brine flowing at high velocity down through the grooves. If the tubes were smooth, the Dukler film concept would predict film coefficients of 1300 and 1480, respectively, for the 1.13 gpm feed rate used for the 5' tubes and the 2.5 gpm feed rate used for the 10' tubes. These correspond, respectively, to film thicknesses of 0.0140 and 0.0215 inches and mean film velocities of 2.43 and 3.50 ft/sec. These are only about half the actual fluted tube coefficient estimated above. The same Dukler concept would predict that a film Reynolds Number of about 100,000 would be needed to achieve a film coefficient of 2700 on a smooth tube. This would require a brine feed rate of about 35 gpm per tube, corresponding to a film thickness of 0.095 inches and a film velocity of 10.9 ft/sec.

While no theoretical analysis has been made, it appears that the feed rates used by G.E. would establish velocities of this magnitude while essentially flooding the grooves. This would help to explain why the coefficient is apparently insensitive to feed rate as long as the feed rate is above the minimum used by G.E. Any excess feed would primarily flood the bore of the tube and do little to accelerate heat transfer over the most effective part of the surface.

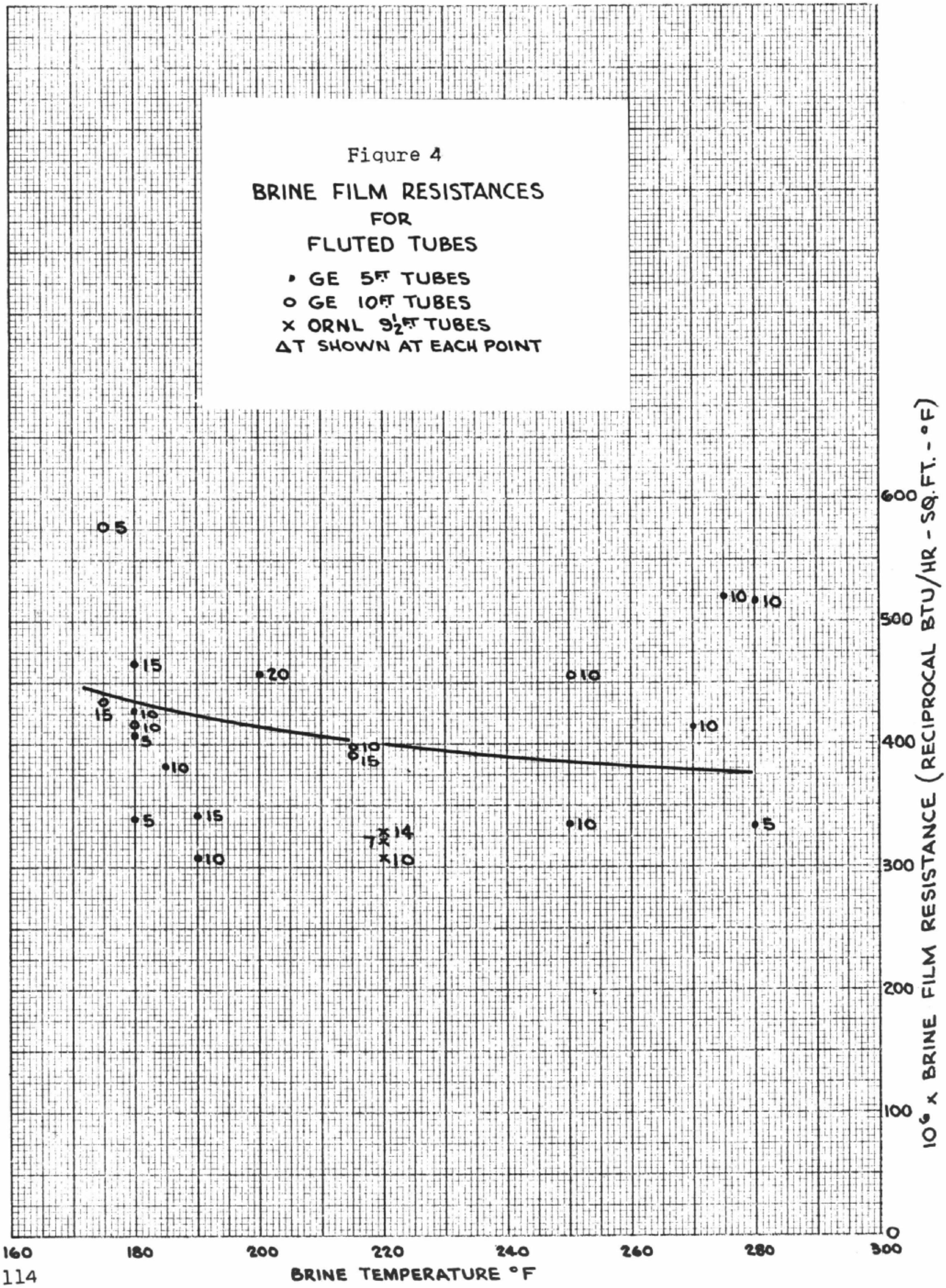


Figure 4

BRINE FILM RESISTANCES FOR FLUTED TUBES

• GE 5FT TUBES
○ GE 10FT TUBES
× ORNL 9½FT TUBES
ΔT SHOWN AT EACH POINT

Selection of Tube Length and Material

The use of longer tubes reduces the cost of tube sheets, tube installation, and feed distributors but requires additional surface and requires more power to elevate the feed to the tops of the tubes. The use of 90-10 Cu-Ni in place of copper can be justified on the basis of longer life expectancy.

A life expectancy for 90-10 tubes equal to the 30 year design plant life can reasonably be expected for this service. No extended data are available for CDA-194 copper tubes, but it appears reasonable to expect that such tubes would probably have to be replaced at least once during the thirty year plant life. If this replacement is at 15 years, it represents a 3.2% average annual charge (at 4-1/4% interest rate) on the replacement cost. It would be hoped that scrap value of the tubes removed would counteract inflation in tube prices.

For 90-10 tubes, purchase cost of tubing is estimated at \$3.19 per square foot and cost of tube sheets, tube installation, distributors at \$6.60 per tube. Allowing 54% for overhead and contingencies, the annual cost of surface at a 5.96% fixed charge rate is 0.293 + .606/L in dollars per square foot. For the copper tubes, the annual cost is about 0.264 + .606/L for the initial set of tubes. For the replacement set, allowing \$3.00 per tube for removal and reinstallation labor, the annual levelized cost over the 30 year plant life is 0.092 + 0.064/L, bringing total annual cost of surface in a plant with copper tubes to \$0.356 + 0.670/L per square foot.

The allowance for power cost depends on plant configuration. With a stacked four effect evaporator, allowing a height between effects sufficient to permit tube replacement, the incremental annual power cost for the 8.0 MGD plant at 4 mills/kwh + 80% pump and motor efficiency is \$518 per foot of tube length.

Using these parameters, the annual cost of power and surface for the 8 MGD plant, based on the heat transfer coefficients calculated above for 250°F, is as follows:

		Surface		Total	
Length	Power	Cu.	90-10	Cu.	90-10
Note: Costs are in Thousands of Dollars					
5'	$ 2.6	$108.7	$103.8	$111.3	$106.4
10	5.2	96.3	90.5	101.5	95.7
12.5	6.5	94.1	88.0	100.6	94.5
15	7.0	93.0	86.6	100.8	94.4
20	10.4	91.7	84.9	102.1	95.3
30	15.5	90.8	83.7	106.3	99.2

This comparison indicates that a tube length of 12.5 ft. is reasonably close to the optimum for either tube material and that 90-10 tubes are justifiable over copper until such time that the copper tubes can be shown to have a life expectancy of greater than 15 years.

Effect of Tube Proportions and Material

The foregoing analysis indicates no effect of tube length on the brine side coefficient. The effect of tube length should therefore be felt only on the steam side and the magnitude of this effect is fairly well understood from the theoretical derivation and experimental data. The net result is that at high temperature differences and hence at high heat fluxes (such as used in most of the G.E. tests), the steam film resistance is higher and the effect of length more important than it is at low heat fluxes (as in the present design) where the brine film resistance is by far the most important.

In the design proposed for the thermocompression evaporator, the heat flux would be about 9200 btu/hr.-sq.ft. if 90/10 tubes were used or 10,500 if copper tubes were used. With tubes of the same profile as used by G.E., the brine film resistance would be about 390 x 10^{-6} at the 250°F first effect temperature and 400 at the 230°F last effect temperature. This brine film resistance, due to the nature of its determination, probably also includes the extent of fouling that would normally be encountered. Judging from the difference between G.E. and ORNL data in Fig. 4, this fouling allowance is probably on the order of 0.00008. If an additional 0.00010 fouling resistance is included for design purposes, the resistances would be as follows:

Brine Temperature	250°F		230°F	
Tube Material	Cu	90-10	Cu	90-10
Tube Wall Thickness, in.	.072	.035	.072	.035
Brine film resistance (x 10^6)	390	390	400	400
Tube Wall	30	112	30	112
Additonal fouling	100	100	100	100
Steam film at 5'long	60	54	62	56
10'	76	68	78	70
12.5'	82	73	84	75
15'	87	78	89	80
20'	96	86	98	88
30'	109	98	113	101

The resulting overall design heat transfer coefficients as a function of length are then as follows:

Brine temperature	250°		230°	
Tube material	Cu	90/10	Cu	90/10
Length - 5'	1723	1525	1690	1497
10'	1678	1492	1646	1467
12.5'	1662	1482	1628	1457
15'	1647	1470	1617	1445
20'	1623	1453	1592	1428
30'	1590	1428	1557	1403

Assuming the minimum inside diameter of the tube is smooth and free for vapor flow, the acceleration and friction losses for the 2.77" I.D. tube can be expressed as:

$$\Delta P_a = 4.75 \times 10^{-9} W^2 v$$

$$\Delta P_f = 5.03 \times 10^{-10} W^{1.8} vL$$

where the pressure drops are in psi, W is vapor rate in pounds per hour per tube, L is tube length in feet, and v is vapor specific volume in cubic feet per pound. The resultant losses, converted to losses in temperature difference, would be as follows, for the 90/10 tubes:

Length	250°	230°
5'	.00036°F	.00068°F
10'	.0017	.0031
15'	.0042	.0078
20'	.0082	.015
30'	.021	.040

From this analysis, while the losses increase rapidly with tube length, they are negligible even at the greatest lengths. This would indicate that a tube diameter substantially less than 3" could be used. However, since no data are available on effect of tube diameter on cost of fluted tubes, other diameters cannot now be considered.

Seawater Concentration Limits

Vapor compression plants differ from conventional multiple effect or multistage plants in that most of the evaporation is accomplished at fairly high temperature. As a result, the seawater concentrations that must be endured at high temperature are almost as high as the ultimate blowdown concentrations. To keep decarbonating acid consumption to a minimum, the vapor compression effects must therefore be designed to operate at the highest concentration at which it is believed that scaling can be avoided.

The concentration limits for these plants are determined by the precipitation limits of anhydrous calcium sulfate (the insoluble anhydrite). This form of scale has a marked tendency to supersaturate and even when it does precipitate, it accumulates at only a very slow rate. The kinetics of anhydrite precipitation in seeded seawater solutions were investigated by Moriyama and Utsunomiya (J. Chem. Soc. Japan, Ind. Chem. Sect. <u>60</u>, 238 (1937)). Their results show a rapid increase in crystallization velocity with increasing temperature - much more rapid than is normally encountered. Our own experimental results at still higher temperature (OSW Report 487, February 15, 1964, to OSW) confirm this trend, as shown in Figure 18. This drawing shows the crystallization velocity constant in the equation:

$$-dC_{Ca}/dt = K_s a \ (C_{Ca}) \ (C_{SO_4}) - K_s$$

where C = concentration - moles/liter, of calcium and sulfate
t = time - minutes
a = crystal surface area - cm^2/liter of solution
K_s = solubility product constant of anhydrite - $(moles/liter)^2$

If it is assumed that an evaporator tube is already completely coated with anhydrite scale, this equation can be used to determine the rate at which anhydrite will continue to accumulate on the tube. The results are shown on Figure 19 as a function of temperature and seawater concentration factor (the concentration factor is based on a value of unity at a chlorosity of 19.862, or 3.518% total solids). The equilibrium solubility curve for anhydrite is derived from the data of Tanaka, Nakamura, and Hara (J. Chem. Soc. Japan, Ind. Chem. Sect. 34, 779 (1931)) and is based on the assumption that sulfuric acid has been used for decarbonation.

These rate data indicate that the maximum potential scaling should be independent of flow regime. At identical film temperatures and concentrations, potential scaling should be no more severe in a falling film tube than in a tube flowing full under forced convection.

The data, however, does indicate the point at which scale should actually start to form. In the absence of a solid phase of the same material, any compound must be super-saturated to a considerable extent before it will nucleate spontaneously or precipitate on the tube walls (OSW R. and D. Report No. 25). The extent of super-saturation depends on the material, the time of contact, and the crystallographic nature of the solid surface present. No definitive data is available on this aspect for the seawater-anhydrite system. It appears reasonable to assume that the extent of super-saturation that can be endured is directly related to the maximum potential scaling rate that would result if the tubes were already coated with scale. In other words, if an operating condition that resulted in a value of X = 1.0 in Figure 19 were known to result in scale-free operation, any other set of conditions that resulted in the same or lesser value of X should also be scale-free. This assumption appears reasonably well justified by the data of Baldwin-Lima Hamilton (Proc. First Int. Symp. on Water Desalination, Vol. 2, pg. 317 (1965)). The limiting scale-free concentrations and the corresponding values of X are as follows:

Temperature, °F	Conc. Factor	X
250	2.0	4 (hemihydrate limit controls)
263	1.65	6.5
282	1.0	10

These data are for the brine heater of a multiple stage flash evaporator in which the contact time of the seawater with the heating surface is usually on the order of 6 seconds.

Data for the practical scale-free limits for falling film evaporators are less well defined. However, the residence time, which is the only variable other than concentration and temperature that should affect scaling, is of the same magnitude (6 seconds) in the LTV as in the MSF brine heater, so scaling conditions should be comparable. The original LTV pilot plant operated at Wrightsville Beach scale-free for 1000 hrs. at a brine temperature of 252°F and a concentration factor of 1.7. This was done when the evaporator was tubed with steel tubes and corresponds to a value of X = 3 in Figure 19. With aluminum brass tubes, the pilot plant evaporator could be kept scale-free at higher values of X. The Freeport Demonstration Plant, after the original steel tubes were replaced, has also operated scale-free at conditions corresponding to high values of X. Pertinent first effect conditions were as follows:

Run	Av'g I	Conc. Factor			
No.	BD Temp.	SWF	I BD*	X	Scaling
5	238	1.02	1.10	0.1	No
6	261	0.91	.98	1.0	No
7a	270	0.94	1.01	3.5	No
7b	280	0.94	1.01	10	Last 6 ft. of 1/2 of tubes
7c	275	0.97	1.05	7	Lower end of 1/2 of tubes
8	265	0.83	1.08	2	No
9	270	0.81	1.08	4.5	?
10	265	.95?	1.08	2	No, but fouled

Note: *Calculated assuming 8% evaporation in first effect. From Run 8 on, assuming also that recirculation was used, as planned, to increase first effect feed concentration factor to 1.0.

The General Electric Company tests of fluted tubes at Wrightsville Beach (OSW R. and D. Report No. 181) are the most nearly pertinent to the present plant design by the runs were of only short duration. Their high temperature results were as follows:

Run	Temp.	Conc. Factor	ΔT	X	Scaling
9	270	≈ 1.1	10	4.5	No
10	275	1.125	10	8	No
11	280	1.092	10	13	Yes
12	280	1.077	5	13	Yes

From the foregoing, it can be concluded that scaling is likely to be encountered at a value of X somewhere between 5 and 10 and that operating at conditions involving a value of X on the order of 1.0 should be reasonably safe.

For the present study, a value of X = 0.6 was taken as representing the maximum design temperatures and concentrations. This resulted in a maximum brine temperature of 250°F in the first effect and a temperature-concentration profile that could be arranged to involve an equal scaling risk in each effect. For a given compression ratio, this value of X determined the blowdown concentration facts from the last effect of the vapor compression section, and consequently the concentration from the plant as a whole. Thus, for a given production rate, lower compression ratios reduce the power requirement but increase the amount of seawater needed and hence the cost of sulfuric acid.

HEAT AND MATERIAL BALANCE FOR VTE

Basis

a) 5,000,000 lb/hr. seawater feed at 208.8°F from MSF train.

b) 593,200 lb/hr. vapor compressed from 225.5° sat'd. temp. (227.7° actual) to 256.6°F sat'd. equivalent to 12,500 H.P. at 84% efficiency.

c) 61,660 lb/hr. steam from LP boiler & steam turbine at 257°F, sat'd.
Heat content of steam = (61,660) (1166.35 Btu/lb vapor)...........= 71,917,000 Btu/hr.
Less return cond. (61,660) (225.6 Btu/lb. cond. @ 256.6°F)........= 13,910,000 Btu/hr.
d) Heat loss allowance in VTE.......................................= 1,007,000 Btu/hr.
Net Makeup Heat = 57,000,000 Btu/hr.

e) Note - There is an additional heat loss allowance in that heat generated by fall of water through VTE is ignored, equivalent to approx.
(5,000,000 lb/hr) (100 ft. fall) (1.286 x 10^{-3}Btu/ft.lb. = 643,000 Btu/hr.

f) 2,100 lb./hr. of first effect condensate assumed returned to boiler as makeup for ejector steam and miscellaneous losses.

g) Equivalent of 6,000 sq. ft. feed heaters at U = 570 Btu/hr.-sq. ft.-°F

h) Vapor and condensate enthalpies from Kennan & Keyes "Thermodynamic Properties of Steam", 1936.

i) Specific heats from Badger Dwg. B-4319, Figure 5, attached.

j) Latent heats taken at saturated vapor temp. to allow for heat of solution.

HEAT AND MATERIAL BALANCE FOR VTE (CONTINUED)

Assumed Temperature Distribution (°F)

Effect	I	II	III	IV
Steam Temperature	256.6	248.8	241.3	233.6
ΔT for Heat Transfer & Vapor Friction	6.6	6.1	6.1	6.2
Brine Temp. (Average/exit)	250.0	242.7	235.2/235.3	227.4/227.7
Boiling Point Rise (Average/exit)	1.2	1.4	1.6/1.7	1.9/2.2
Vapor Temperature (Actual)	250.0	242.7	235.3	227.7
Vapor Saturation Temperature	248.8	241.3	233.6	225.5

Compressed Vapor Enthalpy

Enthalpy at Compressor Inlet (225.5° Sat'd., 227.7° Actual) = 1156.4 Btu/lb.
Compressor Work - (12,500 H.P.) (2547 Btu/H.P.-Hr.)/(593,200 lb./hr.) = 53.7 "
Enthalpy at Compressor Discharge 1210.1 "

Desuperheating Requirement

Enthalpy of compressed vapor at saturation = 1166.2 Btu/lb.

Am't 256.6° condensate to recycle (941.0 Btu/lb. latent heat)
= (593,200) (1210.1 - 1166.2)/(941.0) = 26,300 lb./hr.

Feed Heater Temperatures

ΔT_i = Inlet ΔT = Steam T - Brine T = $T_s - T_i$
ΔT_o = Outlet ΔT = Steam - " = $T_s - T_o$

Q = Heat load, Btu/hr = $WC_p(T_o - T_i)$ = (5,000,000 lb./hr)(.9754 av'g)($\Delta T_i - \Delta T_o$)

Log mean Temp. Diff = $(\Delta T_i - \Delta T_o)/2.3 \text{ Log } (\Delta T_i/\Delta T_o)$ = Q/UA = Q/(570) (6000)

Combining: $\text{Log}(\Delta T_i/\Delta T_o) = UA/2.3WC_p$ = (570) (6000)/(2.3)(5,000,000)(.9754) = Log 2.02

Heater (4) - $\Delta T_i = T_s - T_i$ = 225.5 - 208.8 = 16.7°F; ΔT_o = 16.7/2.02 = 8.3°F
T_o = 225.5 - 8.3 = 217.2°F

Heater (3) - ΔT_i = 233.6 - 217.2 = 16.4°; ΔT_o = 16.4/2.02 = 8.1°; T_o = 225.5°F

HEAT AND MATERIAL BALANCE FOR VTE (CONTINUED)

Heater (2) - ΔT_i = 241.3 - 225.5 = 15.8°; ΔT_o = 15.8/2.02 = 7.8° T_o = 233.5°F
" (1) - ΔT_i = 248.8 - 233.5 = 15.3°; ΔT_o = 15.3/2.02 = 7.6° T_o = 241.2°F

Heat Balance around Effects (in 1000's of Btu/hr.)

I EFFECT

	Q
Makeup Heat in - from above	57,000
+Compr. Vapor - (593,200 lb./hr)(1210.1 - 225.2 Btu/lb.)	584,243
Heat load on I Effect Tubes = Q_I =	641,243
Used for Feed htg - (5,000,000W)(.9795C_p)(250.0 -241.2°F)	43,098
Heat available for evap'n	598,145

I Evap'n = 598,145/(946.3 Btu/lb. Latent Heat) = 632,088 lb/hr
I Blowdown to II = 5,000,000 - 632,088 = 4,367,912 lb/hr at 250.0°F

" Conc'n Factor = 5,000,000/4,367,912 = 1.14
I Condensate to II = 593,200 - 2100 lb/hr to boilers = 591,100 lb/hr at 256.6°F

II EFFECT

	Q
Q in from I Vapor if saturated	598,145
+ Superheat in " = (632,088) (1.2°BPR)(0.48C)	364
+ I Cond. Flash = (591,100W)(1.0168C_p)(256.6 - 248.8°F)	4,688
- to (1) Feed Heater = (5,000,000W)(.9778C_p)(241.2 - 233.5°F)	-37,645
Heat Load on II Effect Tubes	565,552
+ I Blowdown Flash = (4,367,912W)(.9748C_p)(250.0 - 242.7°F)	31,082
Heat Available for Evaporation	596,634

II Evap'n at 241.3° Sat'd = 596,634/951.3 = 627,177 lb./hr.
II Blowdown = 4,367,912 - 627,177 = 3,740,735 lb/hr at 242.7°F
" Conc'n Factor = 5,000,000/3,740,735 = 1.34
Condensate out = 591,100 + 632,088 = 1,223,188 lb/hr at 248.8°F

III EFFECT

	Q
Q from II Vapor if Sat'd	596,634
+ Superheat = (627,177W)(.48C_p)(1.4°BPR)	422
+ Cond.Flash = (1,223,188W)(1.0149C_p)(248.8 - 241.3°F)	9,311
- to (2) Heater = (5,000,000W)(.9762C_p)(233.5 - 225.5°F)	-39,048
Heat Load on III Tubes	567,328

HEAT AND MATERIAL BALANCE FOR VTE (CONTINUED)

III EFFECT

	Q
+II Blowdown Flash = (3,740,735W)(.9662C_p)(242.7 - 235.3°F) =	26,746
Heat Available for Evap'n in III	594,074
III Evap'n at 233.6° Sat'd = 594,074/956.4 = 621,156 lb/hr	
III Blowdown = 3,740,735 - 621,156 = 3,119,579 lb/hr at 235.3°F	
Conc'n Factor = 5,000,000/3,119,579 = 1.56	
Condensate out = 1,223,188+627,177 = 1,850,365 lb/hr at 241.3°F	

IV EFFECT

	Q
Q from III Vapor if Sat'd	594,074
+ Superheat = (621,156W)(.48C_p)(1.7° BRP)	507
+ Cond. Flash = (1,850,365W)(1.0130C_p)(241.3 - 233.6°F)	14,433
- to (3) Heater = (5,000,000W)(.9747C_p)(225.5 - 217.2°F)	-40,450
Heat Load on IV Tubes	568,564
+ III Blowdown Flash = (3,119,579W)(.9560C_p)(235.3 - 227.7°F)	22,666
Heat Available for Evap'n in IV	591,230
IV Evap'n at 225.5° Sat'd = 591,230/961.6 = 614,840 lb/hr.	
IV Blowdown = 3,119,579 - 614,840 = 2,504,739 lb/hr at 227.7°F	
" Conc'n Factor = 5,000,000/2504,739 = 1.99	
Condensate out = 1,850,365+ 621,156 = 2,471,521 at 233.6°F	

FINAL FEED HEATER - (4)

Total Vapor From IV -	614,840 lb/hr
Return to Compressor	593,200
Surplus to (4) Feed Heater	21,640 lb/hr

	Q
Heat Available = (21,640)((961. + (0.48) (2 2°BPR)) =	20,833
+Cond. Flash = (2,471,521W)(1.0112C_p)(233.6 - 225.5°F) =	20,244
Total Heat Available to (4)	41,077
Heat Req'd = (5,000,000W)(.9732C_p)(217.2 - 208.8°F) =	40,874
Heat Surplus - Treated as Heat Loss Allowance =	203,000 Btu/hr.

HEAT AND MATERIAL BALANCE FOR VTE (CONTINUED)

OVERALL MATERIAL BALANCE

Blowdown from IV	2,504,739	Lb/Hr	at 227.7°F
Comul. Condensate from IV	2,471,521		at 225.5°F
+ Surplus IV Vap. condensed in (4) Heater	21,640		"
I Condensate returned to boiler	2,100		at 256.6°F
TOTAL = FEED =	5,000,000	lb/hr	

OVERALL HEAT BALANCE

Q In - Makeup Heat	57,000	M Btu/Hr.
+Compressor Work - (12,500 H.P.)(2547 Btu/HP-Hr.)	31,837	
TOTAL IN	88,837	"
Q Out (Above 208.8°F Feed Temp.)		
Distillate - (2,493,161 W)(1.0090 C_p)(225.5 - 208.8°F)	42,011	"
Blowdown - (2,504,739 W)(0.9404 C_p)(227.7 - 208.8F)	44,518	
Makeup - (2,100 W)(1.0120 C_p) (256.6 - 208.8°F)	99	
"Surplus" at (4) Feed Heater	203	
TOTAL OUT	86,831	"
EXCESS OF HEAT IN OVER HEAT OUT	2,006	"

Excess per pound Total Distillate = 2006/(2,493,161 + 2100) = 0.805 Btu/Lb.

This excess is approx. equal to Theoretical Work of separating fresh water from seawater. It is also approx. equal to the boiling point rise times the difference in specific heat of water liquid and vapor.

i.e. --(1.62°F BPR)(1.01 - 0.48C_p) = 0.85 Btu/Lb.

HEATING SURFACE REQUIREMENTS (Before allowance for vapor side friction)

ΔT in I Preheating Zone;256.6° Steam, 241.2 to 250.0° Brine; $\Delta T_m = 10.4°F$

I	Surface Preheating - (43,098,000 Q)/(10.4°F)(1482 U) = 2,800 Sq. ft.		
I	" Evaporating (598,145,000 Q)/(6.6°F)(1482 U)	=61,150	63,950 Sq. Ft.
II	" = (565,552,000 Q)/(6.1°F)(1473 U)		62,940
III	" (567,328,000 Q)/(6.1°F)(1463 U)		63,570
IV	" (568,564,000 Q)/(6.2°F)(1454 U)		63,070
	AVERAGE SURFACE		63,400 Sq. Ft.

Equivalent to 5072 Tubes, 3" O.D. by 12'-6" Long per Effect

HEAT AND MATERIAL BALANCE FOR VTE(CONTINUED)

VAPOR SIDE ΔT LOSSES

		TOTAL LOSS*	MEAN LOSS**
I	Bundle	.03°F	.02°F
II	Bundle	.04°F	.02°F
III	Bundle	.05°F	.02°F
IV	Bundle	.06°F	.03°F
IV	Mesh		.05°F
Vapor Pipe and Deflectors			.19°F
		TOTAL	.33°F

Effect on Tube Count:

$$5072\ \left(\frac{25.0°F}{25.0 - 0.33}\right) = 5140 \text{ tubes}$$

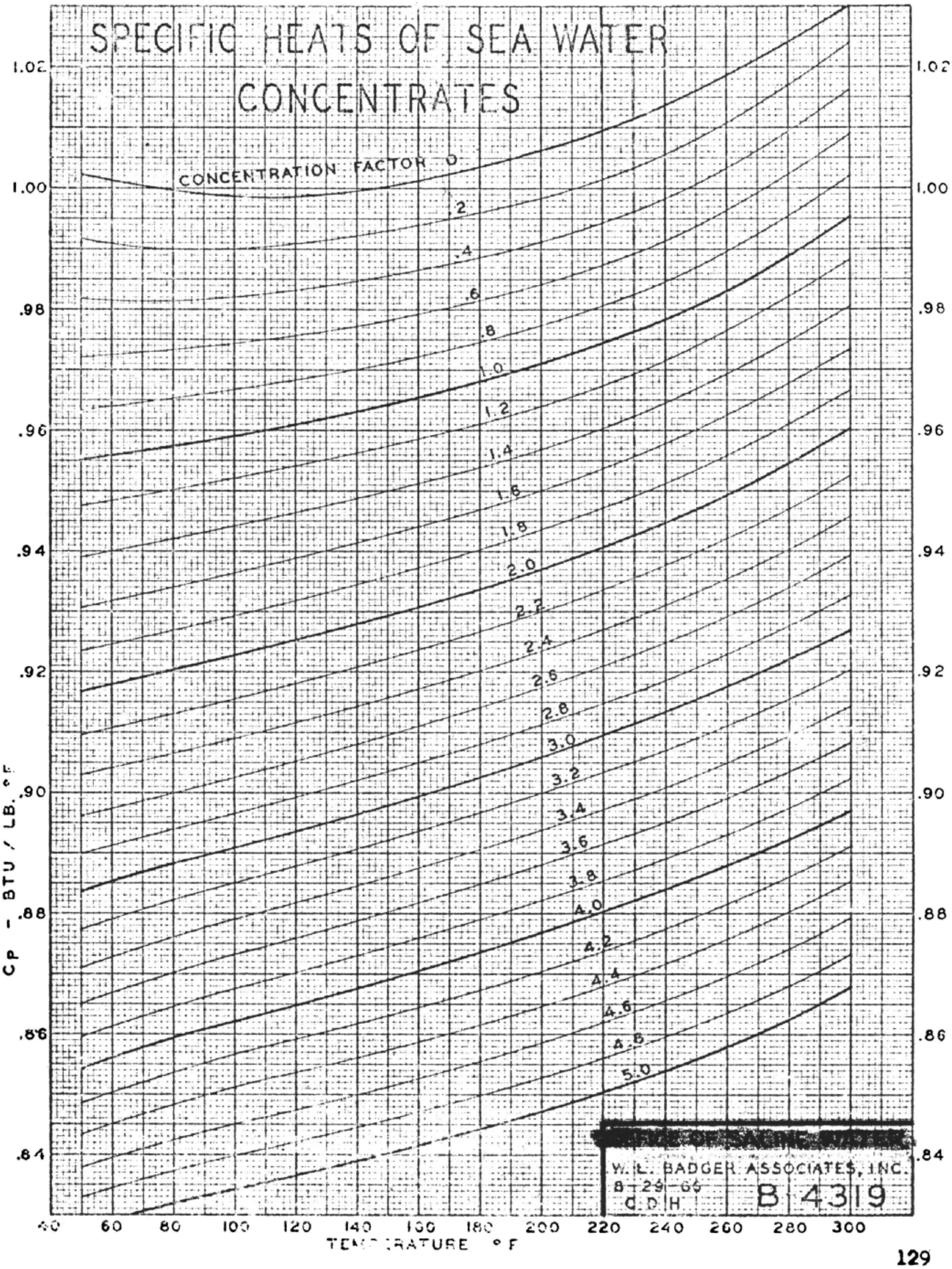
Average Surface per Effect = 5140 tubes x 12.5 Ft^2/tube = 64,250 Ft^2

*Represents total temperature loss of vapor in flowing through tube bundle
**Represents average temperature loss of vapor in flowing through tube bundle.

Total tubes provided = 20,560

Total area provided = 257,000 Ft^2

FIGURE 5



SPECIFIC HEATS OF SEA WATER CONCENTRATES

OFFICE OF SALINE WATER
W.L. BADGER ASSOCIATES, INC.
8-29-66
C.D.H
B 4319

VI. Economics

1.0 General

The plant, as designed, will produce water at a cost of 39.33 cents per 1000 gallons, based on operation at 100% plant capacity 90% of the time and fuel at 20¢/MM btu.

The total capital cost of the plant, shown in Table VI-1 is $7,511,655 which is equivalent to 93.4 cents/gallon/day product capacity. Equipment costs were derived from bids received from qualified vendors. The erection costs were estimated under the supervision of Pratt & Whitney Aircraft and Struthers Energy Systems. Prices and wages are representative of first quarter, 1968 costs. A detailed breakdown of the capital costs appears in Table VI-2. The annual production costs are shown in Table VI-3.

TABLE VI-1

CAPITAL COSTS*
for
8,04 x 10^6 MGD Gas Turbine Powdered Vapor Compressor
VTE - MSF Distillation Plant

Special Equipment	Capital Cost $
Vertical Tube Evaporator including tubes and spray nozzle	$ 1,732,490
Multistage Flash Evaporator Complete: including pumps, piping, deaerator, degasifier, and tube bundles	1,977,710
Gas Turbine - Vapor Compressor Power Train Complete	1,193,000
Subtotal	4,903,200
Standard Engineering Equipment	
Heat Recovery Boiler Complete	199,075
Steam Turbo-generator Complete with Switchgear	259,380
Auxiliary Generator and Engine Driver	14,720
Pumps and Motors (excluding MSF plant)	48,940
Feed Heaters	130,010
Subtotal	652,125
Process Facilities (excluding MSF plant)	
Seawater Intake Structure (excluding pumps)	401,110
Site Development, Buildings and Foundations	198,185
Insulation (excluding heat recovery boiler)	60,340
Piping, Electrical, and Instrumentation	358,815
Monorails	4,600
Subtotal	1,023,050
TOTAL DIRECT CAPITAL COST	6,578,375

*Capital Costs include materials, vendor profit, vendor contingency, shop and field labor, overhead, erection and freight.

TABLE VI-1 (CONTINUED)

Other Plant Costs	
Engineering Expense of A/E(8% Direct Capital Costs)	$ 526,270
Interest During Construction (2% Direct Capital Costs)	131,565
Start-Up Expense	25,370
Site Cost (4 arcres @ $5,000/acre)	20,000
Construction Equipment Rental	125,610
Subtotal	828,815
A/E's Contingency (15% of A/E's Field Work)	104,465
TOTAL CAPITAL COSTS	$ 7,511,655
Capital Cost per Gallon of Daily Capacity (@8.04 MGD)	0.934

TABLE VI-2

DETAILED CAPITAL COSTS

I. VTE Evaporator including the following equipment:

Steel Heads Bottom Cover Pipe nozzles Reinforcing plates Tube bundle supports Center pipe Cones Deck plates Piping Deminsters	$ 201,270
Vertical Double Fluted Tubes	771,000
Spray Nozzles	8,410
Design Engineering	5,000
Shop Labor	153,700
Field Labor (includes 20% for high time and cutout)	138,950
Subtotal	1,278,330
20% Gross Profit margin (includes G. & A. and Profit)	255,665
Subtotal	1,533,995
10% Contingency	153,400
Freight	45,095
Total Erected Price	$1,732,490

II. MSF Unit Including:

Deaerator
Decarbonator
Vacuum Equipment
Instruments and control valves
Valves
Insulation
Acid pumps (2)
Antifoam pumps (2)
Autofoam mix tank
Distillate pumps and drivers (3)

TABLE VI-2 (CONTINUED)

Brine pumps and drivers (3)	
Feed pumps and Drivers (See Note 1 Below) (3)	
Decarbonator fans (2)	
Piping	
F.O.B. Milwaukee, Wisconsin by Vendor	1,350,000
Note 1.	
Modify above price for furnishing 4-1/3 capacity feed pumps and drivers instead of 3-1/2 capacity pumps	(4,790)
Add larger acid tank	32,500
Subtotal	1,377,710
Freight and Erection	600,000
Total Vendor Selling Price Erected	1,977,710
III. Gas Turbine and Vapor Compressor including:	
Inlet housing and inlet silencing	
Lube system	
Emergency D.C. lube pump	
Fire protection system	
Controls and instrumentation	
Gas generator	
Power turbine	
Vapor compressor	
Freight	
Erection	
Start-up	
Base and Mounts	
Total Vendor Selling Price	1,193,000
IV. Heat Recovery Boiler & Accessories including:	
Dump stack with valve	
Superheaters	
H.P. Boiler	
Economizer	
L.P. Boiler	
Exhaust stack	
Boiler instrumentation & controls	
Process piping and insulation	
Valves	
Refiring system	
Isolating damper	
Subtotal	141,805
Erection	25,785
Subtotal	167,590

TABLE VI-2 (CONTINUED)

	Vendor bid price, F.O.B. factory	167,590
	Freight	6,175
	Subtotal	173,765
	H.P. Boiler feed pumps and drivers (2)	8,325
	L.P. Boiler feed pump (1)	750
	Auxiliary condensate storage tank	2,140
	Inlet duct and expansion joint	2,500
	F.D. Fan and engine driver complete	11,595
	Total price including erection	199,075
V.	Steam Turbo-Generator including:	
	Lubricating oil system	
	Instruments and controls	
	Emergency oil pumps	
	Freight	
	Technical supervision	
	Vendor bid	230,000
	Erection on furnished foundations	5,780
	Switchgear including:	
	48 V DC Battery System	
	Electrically operated main breaker	
	2 manually operated breakers	
	Lightning arrestors	
	Surge Capacitors	
	Freight	
	Erection	
	Technical Supervision	23,600
	Total	259,380
VI.	Auxiliary Generator and Gas Engine Driver including:	
	Instruments and Controls	
	Housing	
	Fuel strainer	
	12 V starting batteries	
	Freight	
	Vendor Bid	14,180
	Field labor for unloading	540
	Total	14,720

TABLE VI-2 (CONTINUED)

VII. Pumps and Motors (excluding the following)

Deaerated seawater pumps
Distillate pumps
Brine blowdown pumps
Antifoam pumps
Acid pumps
Lube oil pumps
H. P. Boiler feed pumps
L. P. Boiler feed pumps

Including delivered and erected:

Raw seawater feed pumps and motors (3)	39,765
Screen wash pumps and motors (2)	8,545
Sodium Metasilicate pumps and motors (2)	630
Total	48,940

VIII. Feed Heaters includes:

Tubes
Shells
Nozzles

Vendor Bid	128,000
Freight	1,180
Mounting on furnished foundations	830
Total	130,010

IX. Seawater Intake Structure includes:

Concrete structures
Intake pipe
Blowdown pipe
Traveling screen
Traveling rake
Erection

Subtotal	320,880
Overhead and Profit	80,230
Total	401,110

TABLE VI-2 (CONTINUED)

X. Site, Buildings and Foundations including:	
Excavation and Backfill (excluding MSF and Intake) (includes 10% design margin)	5,920
Roadways (includes 10% design margin)	14,080
Concrete Foundations (includes 5% design margin)	56,400
Steel and Steel Buildings (includes 10% design margin)	26,000
Fencing	5,210
Operations building and shop including: Foundation Building and air conditioning Air compressors Lab, furniture and supplies	90,575
Total	198,185
XI. Insulation Subcontract (excluding MSF, Gas Turbine, and Heat Recovery Boiler)	
VTE	29,700
Feed heaters	2,535
Vapor Compressor	1,905
Piping	20,240
Subtotal	54,380
10% for design margin	5,440
Freight	520
Total	60,340
XII. Piping, Electrical and Instrumentation	
A. Piping and Valves including duplex 24" Strainer (Excluding MSF and between intake and bay)	181,330
Freight	11,470
Field labor (includes 10% design margin)	65,655
Subtotal	258,455

TABLE VI-2 (CONTINUED)

B. Electrical (excluding MSF unit and motors)	
Includes:	
Motor control center	
Lighting panel	
Lighting transformer	
Conduit and cable	
Code call and P/A system	
Freight	
Field labor	
Subtotal	83,130
C. Instrumentation (excluding MSF, Gas Turbine, Vapor Compressor, Heat Recovery Boiler)	
VTE	12,105
Supplementary Steam Turbo-Generator	2,310
Intake Structure & Pumps	815
Process pipe	2,000
Subtotal	17,230
Total	358,815
XIII. Monorail Cranes (excluding gas turbine and all supporting steel)	
Includes:	
Brine blowdown pump	
Seawater pump & chlorine building	
Distillate pump	
Deaerated seawater pump	
Power turbine and vapor compressor	
Subtotal	4,465
Freight	135
Total	4,600
GRAND TOTAL	6,578,375

TABLE VI-3

ANNUAL PRODUCTION COSTS
for
8.04 x 10^6 MGD Gas Turbine Powered Vapor Compression
VTE-MSF Distillation Plant

Fuel Cost Base	$.20/$10^6$ BTU		$.25/$10^6$ BTU	
	$/year	$/1000 gal	$/year	$/1000 gal
Direct Production Costs				
Fuel @ 90% Load Factor				
Gas Turbine (144.3 x 10^6 BTU/hr HHV)	227,530	.0861	284,415	.1077
Boiler Trimming (1.5 x 10^6 BTU/hr HHV)	2,365	.0009	2,955	.0011
Chemicals	91,125	.0345	91,125	.0345
Direct Operating Costs				
Payroll (13 people)	101,705	.0385	101,705	.0385
Maintenance Contract for G.T.-V.C.	50,475	.0191	50,475	.0191
Lube Oil for G.T.-V.C.	7,200	.0027	7,200	.0027
Other Maintenance @ .5% of Cap. Cost minus G.T.-V.C. Costs	26,925	.0102	26,925	.0102
Total Direct Costs	507,325	.1920	564,800	.2138
Indirect Costs				
Payroll extras @$.94/hr	24,440	.0093	24,440	.0093
General and Administrative @ 30%	37,845	.0143	37,845	.0143
Depreciation(30 Year) and int. (4.25%)(Cap.Rec.Fact.=5.9557%)	447,370	.1693	447,370	.1693
Insurance(.25% of Cap. Cost)	16,445	.0062	16,445	.0062
Interest on Working Capital (60 days @ 6%/yr.)	5,695	.0022	5,695	.0022
Total Indirect Costs	531,795	.2013	531,795	.2013
TOTAL ANNUAL PRODUCTION COST Based on 2642 x 10^6 Gal/Year	$1,039,120	.3933	$1,096,595	.4151

2.0 Capital Cost Qualifications

2.1 Vertical Tube Evaporator

The capital cost of the VTE was estimated from material take offs made from general arrangement drawings of the unit and from tube sheet detail drawings. Because of the tube sheet size, tube bundle shipment and erection methods had to be considered. The VTE estimate is based on building the tube bundles in quarters in the shop and welding them in place in the field. Any expansion joints between tube bundle quarters would be fabricated in place after erection.

Specifications were written for the furnishing of the 20,560 3" O.D. double fluted tubes required in the four effects of the VTE. Of the four companies approached, none were able to offer quotations. An estimate was therefore made of the purchase price of the VTE tubes. The price used in the economic evaluation was $3.00/square foot of enhanced area of tube which includes the freight from the manufacturer to the fabricating shop. Each tube is 12'-10 3/4" long and has an active fluted length of 12'-6" making the price per tube to be $37.50. It is felt that this would be a representative price for the tubes when the copper market has stabilized. (The copper strike of early 1968 had an upsetting effect on the price stability of tubes)

The price of the porcelain distribution nozzles was furnished by ORNL and is based on a 1967 quotation from Knox Porcelain Corporation. The quoted price has been increased 4% up to $414.10/1000 units to account for escalation.

The tube sheet costs are based on not using a clad steel. A pourable silicone rubber is used in securing the porcelain nozzles to the tube tops, thus isolating the majority of the top tube sheet from the brine solution. The tube sheets have sufficient thickness to allow up to 3/8" corrosion to take place in any unprotected area without damaging the structural integrity.

2.2 Multistage Flash Evaporator

The cost estimate of the MSF unit was provided, under subcontract, by Aqua-Chem, Inc. of Waukesha, Wisconsin. The total price, FOB Milwaukee, Wisconsin, for the equipment as described in the specification for the MSF unit located in the Appendix of this report was $1,350,000. Erection was estimated at $600,000.

Two modifications were made to the estimated price. The three deaerated seawater pumps quoted by Aqua-Chem were 450 hp, one-half capacity each. Four, one-third capacity pumps, rated at 300 hp each were substituted at a total price decrease of $4790. This was based on a cost differential between the two sizes of pumps and motors of $7280 each.

The acid tank size was changed from 10,000 to 280,000 gallons at a total price addition of $32,500 in order to take advantage of substantial savings to be realized in acid costs by barging in the chemical from Corpus Christi, Texas.

2.3 Gas Turbine and Vapor Compressor Power Train

Pratt & Whitney independently obtained quotations from Sulzer Brothers for the furnishing of a vapor compressor suitable for the service intended. The estimated selling price of the complete power train, consisting of the gas generator, power turbine, and vapor compressor installed on purchaser's foundations is $1,193,000. Approximately 30% of this selling price is associated with the vapor compressor. The cost estimate includes the following: bases, "industrial" sound treated enclosure, inlet silencing for gas generator and power turbine only, lubrication systems emergency d.c. pumps, fire protection system, sequencing controls and instrumentation in cabinets, vapor compressor with water wash nozzles and special materials, and gear type coupling between compressor and power turbine. Also included are shipping costs, 9% import duty on the vapor compressor, field erection, startup and checkout of the power train. Not included in the power train costs are the costs of the vapor ducts to and from the vapor compressor as well as the required thermal insulation on the vapor compressor. These costs are shown elsewhere.

2.4 Heat Recovery Boiler

The cost estimate for this piece of equipment was developed by Struthers Energy Systems and is based on current pricing policies. Quotations were obtained for the boiler feed pumps and for the F.D. fan and natural gas engine driver as shown in the detailed cost estimate, Table VI-2.

2.5 Operations Building

A more complete breakdown of the estimated costs of the operations building is provided in Table VI-4.

2.6 Site Costs

Because the actual site is unknown, certain assumptions had to be made concerning site improvements. No costs are included for building a sea wall, pier, or barge unloading dock. Costs of $14,080 are included to build 1/2 mile of hard-surfaced roadway to serve as access to the property and access among the pieces of equipment. A fence around the periphery of the 400 foot square plant site was provided at a cost of $5210. Property costs of $5000/acre were assumed.

2.7 Other Plant Costs

The architect-engineer's engineering expense is assumed to be 8% of the total direct capital costs. This 8% may be broken down as follows:

Fee - 2%
Engineering - 3%
Procurement - 2%
Other - 1%

Total 8%

The start-up expense to be expected is shown in Table VI-5.

The costs for the construction equipment to be rented by the architect-engineer in the field is shown on Table VI-6.

To allow for areas where the definition of scope between the A/E and the vendors is not as complete as it should be, a 15% contingency has been allowed on the field work expected to be performed by the A/E. The estimated value of the A/E's field work and the corresponding contingency is shown in Table VI-7.

TABLE VI-4

OPERATIONS BUILDING

Item	Total Cost-$	Remarks
1. Foundations & Floor Slab	3,900	Concrete - Price based on OSW Report #72-Escalated to 1968
2. Building	32,500	Concrete - Price based on OSW Report #72-Escalated to 1968 block Includes all utilities, heat and air conditioning, vinyl tile floor in lab, office & hallways, painting, built-in benches & cupboards, toilet facilities, sinks, and shower. Current Prices.
3. Equipment		
a. Laboratory	3,465	Includes all necessary equipment, apparatus and chemicals to adequately service the complete plant. Current Prices.
b. Office	2,150	Includes all desks, chairs, filing cabinets, waste baskets, typewriter, calculator, desk lamps, office supplies and forms needed for small production office. Current Prices.
c. Maintenance	3,200	Minimal equipment to service plant. Major maintenance will be contracted. Current Prices.
(1) Spare Parts	10,000	Spare parts are minimal.
d. Janitors equip. & supplies	360	Includes all equipment and supplies needed to service plant and office. Current Prices.
e. Air compressor system	35,000	Includes: 2 compressors, 1 instrument air dryer, 1 air receiver, 1 filter and silencer, 2 motors and starters, 1 lot of piping. Current Prices.
TOTAL	90,575	

TABLE VI-5

JOB NO. & TITLE 67-09-7840 OSW Start-Up Costs
CLIENT Office of Saline Water
JOB LOCATION Texas Gulf Coast

TAKEOFF
PRICED RCG
CHECKED HW

APPROVED
DATE 4-17-68
SHEET of

ITEM AND DESCRIPTION	QUANTITY	UNIT	Time MAT'L.	Time S/C	MANHOURS UNIT	MANHOURS TOTAL	MANHOURS $/MH	TOTAL COST	TOTAL COST SUB-CONT.	TOTAL COST TOTAL
1. VTE	2 engs.		one wk.			80	10.00			800
2. MSF	2 engs.		two wks.			160	10.00/hr			1600
	1 fact.		two wks.			10 days $90/day + 15% living				1035
3. G.T. & V.C. Compressor										INCL.
4. Steam Turbo-gen. & Switchgear	2 engs.		one wk.			80	10.00			800
	1 fact.					10 days $100.00/day + 15%				1150
5. Emergency Generator	1 eng.					8	10.00			80
	1 fact.					8 hr $100.00 + expenses				120
6. Boiler and F.D. Fan	1 eng.		one wk.			40	10.00			400
	1 fact.		one day			8 hr $100.00 + expenses				120
7. Pumps	1 eng.		one wk.			40	10.00			400
8. Feed Heaters	2 engs.		2 wks.			80	10.00			800
9. Intake Structure, screens	1 eng.		3 days			24	10.00			240
Eng. hr. by A/E						512				
VTE Hydro										3000
Boiler Hydro										1000
Assume 3.0 men/ eng manhour @ $9.00/hr					(512 x 3.0 x 9.00)					13825
TOTAL										25370

TABLE VI-6

EQUIPMENT RENTAL COSTS

Item	Quan	Description	Est.Cost
1	1	Scaffolding	
1A		Rent @ 680.00/month @ 3 mo.	2,040
2A		Erection & Removal @ 12.70/100sq. ft.	1,587
2	1	Concrete testing	5,000
3	2	Air compressor @ 125 CFM @ 200.00/mo x 6	1,200
4	1	Air compressor @ 250 CFM @ 420/mo x 6	2,520
5	1	Back hoe @ 1250/month x 5	5,250
6	1	½ cy Cement bucket @ 45.00/ mo x 6	275
7	1	1 cy Cement bucket @ 65/mo x 6	390
8	1	Compactor, gas @ 150.00/month x 2	300
9	1	130 Ton crane @ 18' @ 7500.00/mo x 6	45,500
10	2	20T hydraulic's (wheel) @ 1400 ea x 6	16,800
11	1	Loader 3yd. cap. @ 1875.00/mo x 6	11,150
12	2	Trucks @ 900/mo x 6	10,800
13	5	Welders (gas) 300 amp @ 140/mo x 6	3,720
14	5	Welders (gas) 200 amp @ 100/mo x 6	3,500
15	2	Generators (gas) 5 KW @ 125/mo x 6	1,500
16	3	Pumps (gas) @ 90/mo x 3	810
17	1	Dozer 65HP @ 1140/mo/6mo	6,840
18	1	Clean-up	3,000
19	1 Lot	Welding rod @ 13,712 Lin ft. @ 0.25	3,429
			125,611

TABLE VI-7

JOB. NO. & TITLE 67-09-7840 A/E's Contingency

CLIENT Office of Saline Water

JOB LOCATION Texas Gulf Coast

TAKEOFF

PRICED RCG

CHECKED HW

APPROVED

DATE 4-26-68

SHEET OF

ITEM AND DESCRIPTION	QUANTITY	UNIT	UNIT COST		MANHOURS			TOTAL COST			
			MAT'L.	S/C	UNIT	TOTAL	$/MH	MATERIAL	LABOR	SUB-CONT.	TOTAL
1. Steam Turbogenerator Installation & Switchgear									5 964		
2. Emergency Generator Installation									540		
3. Pumps Installation									1 890		
4. Feed Heater Erection									830		
5. Site, Buildings, & Foundations									198 185		
6. Piping, Electrical, Instrumentation									358 815		
7. Monorails									4 600		
8. Equipment Rentals									125 610		
Subtotal									696 434		
15% Contingency									104 465		

3.0 Annual Cost Qualifications

Table VI-3 shows the annual operating costs for this facility. The operating costs are shown for two different fuel costs. Each fuel cost is expressed on two different bases, viz., one in dollars per year and the other in dollars per 1000 gallons of product water. It should be noted that the cost tables are based on producing full load daily production (8.04 MGD) for 7884 hours per year.

3.1 Fuel Costs

The estimated fuel consumption for the gas turbine when operated at 12,500 shp with 2" inlet loss, 9" exhaust back pressure, 73°F ambient temperature, and sea level will be 144.3 x 10^6 btu's (HHV) per hour when burning the natural gas fuel specified. The analysis of the fuel used for the study is as follows - % by volume:

CH_4 - 90.92
C_2H_6 - 3.77
C_3H_8 - 1.61
C_4H_{10} - 0.74
C_3H_{12} - 0.24
C_6H_{14} - 0.11
N_2 - 2.20
O_2 - 0.38
CO_2 - 0.03

Heat of Combustion:

HHV - 22,595 btu/lb LHV - 20,402 btu/lb

If the machine is operated 7,884 hours per year and the fuel costs $0.20 per million btu (HHV), the fuel cost for the gas turbine will cost approximately $227,530 per year.

At plant full load conditions, it is expected the heat recovery boiler may require a small amount of fuel for trimming. This amounts to an annual cost of $2,365 for 7,884 hours based on 20¢/MM btu fuel.

3.2 Chemical Costs

Prices for chemicals to be used in the plant are shown in Table VI-8.

3.3 Payroll Costs

The direct operating costs associated with manpower are shown in Table VI-9.

TABLE VI-8

ANNUAL CHEMICAL COSTS

SUMMARY

Chemical	Delivered Price-¢/lb.	Stream Concentration ppm	Usage lbs/1000 Gals. Prod.Water	Cost/M Gals. Prod.Water,¢
1. Sulfuric Acid	1.582	111.	1.656	2.6198
2. Antifoam	45.5	.5	0.0075	0.3412
3. Chlorine	6.94	2.5	0.0435	0.3019
4. Sodium metasilicate	11.15	2.0	0.0167	0.1862
				3.4491

Basis for Prices

1. Obtain 98% from Corpus Christi in 2000 ton barges. Price based on quotation of 2/7/68 - $30.75/Ton plus 0.875/Ton freight (100% acid) - 1.582 ¢/lb
   Need 40' dia. x 30' storage tank (280,000 Gals.)

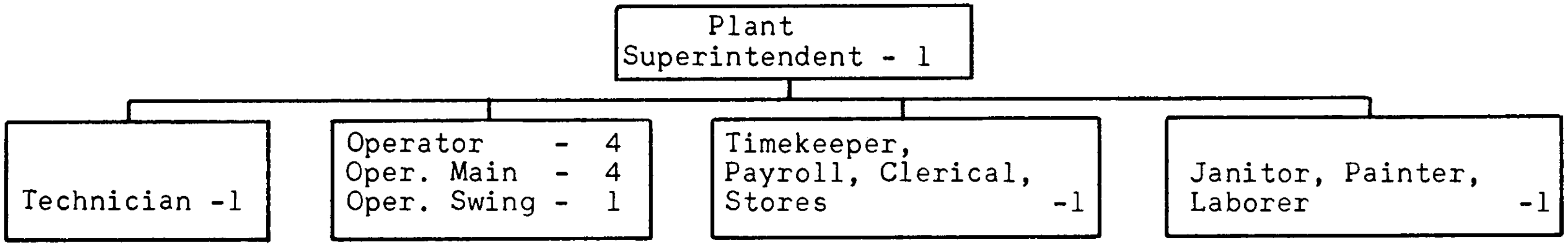
2. Hagan C-1 price quotation of 2/22/68 is $198 for 450 # net/ drum in 5 drum lots FOB Houston, Texas, plus freight of $1.50/cwt to Texas Gulf Coast - Delivered price 44.0 + 1.50 = 45.5¢/lb.

3. Chlorine will be received in one ton cylinders (approx. 5/month req'd). Price has been confirmed as of 3/22/68. Dixie Chemical Co., Houston, Texas.

4. Sodium metasilicate (in 100 lb. bags), price quotation of 2/22/68 is $9.65/cwt in 26-50 bag lots FOB Houston, Texas, plus freight of $1.50/cwt to Texas Gulf Coast. Delivered price 9.65 + 1.50 P 11.15¢/lb.

TABLE VI-9
GAS TURBINE-VAPOR COMPRESSION CYCLE
8 MGD SEAWATER EVAPORATOR

DIRECT OPERATING COSTS - MANPOWER



Using Rates Applicable for Texas Gulf Coast Area

1	- Plant Superintendent	$ 12,240
1	- Technician	8,000
9	- Operators @ $7,900	71,100
1	- Clerical	5,675
1	- Janitor and Laborer	4,690
13		$101,705
	Plus 94¢/hr. fringe benefits - 2000 hr. av/yr.	24,440
		$126,145
	Plus G and A @ 30%	37,845
		$163,990

3.4 Maintenance Costs

The estimated cost of a service contract required to maintain the power train is $50,475 per year when operated at no greater than 12,500 hp on natural gas fuel, 7,884 hours per year. This amounts to $6.40 per operating hour. The 12,500 hp is the base load rating at 73°F which is the mean ambient temperature for the Texas Gulf Coast area. It is assumed that the number of hours of operation above and below 73°F will be equal over the period between overhauls. The service contract includes:

1. A spare gas generator that will be supplied for use during scheduled overhaul periods.
2. The gas generator will receive a hot section inspection after every 4,000 hours and be overhauled after every 16,000 hours of operation at design rating.
3. The free turbine will be inspected once per year and be overhauled after every 100,000 hours of base load operation.
4. The vapor compressor will be inspected once per year. Supervision and parts will be available to overhaul the vapor compressor once in the 30 year life. Spare vapor compressor parts will be stored at the site but not owned by the purchaser.
5. Supervision and parts will be available for any unexpected repairs due to wear and tear on the machinery required on the gas generator, free turbine and vapor compressor.
6. This service contract does not cover repairs brought on by the forces of nature, fire, or operator error. The contract does not cover the cost of labor which would be required at the site.
7. If the purchaser should take out rotating machinery insurance on the power train, the cost of the service contract would have to be re-evaluated and probably reduced.

It is estimated that the annual cost for lubricating oil will be approximately $7,200. This estimate includes the oil consumed in operation, oil changes and oil flush. The oil cost is based on two complete lubrication systems, one for the gas generator and one to be shared by the power turbine and vapor compressor. Both systems will use a synthetic type oil.

Since the labor required to perform maintenance on the gas turbine vapor compressor power train is not provided in the above mentioned maintenance contract, additional money has to be set aside to hire outside labor during plant shutdowns. Other maintenance costs expected to be encountered will be for outside assistance in the overhaul of various process pumps. One half (1/2) percent of the original capital costs--not including the gas turbine vapor compressor power train--have been assumed to be able to cover these other maintenance expenses.

3.5 Other Indirect Annual Costs

Depreciation (30 years) and interest of 4.25% were specified by the Office of Saline Water. This corresponds to a capital recovery factor of 5.9557%.

The water plant is assumed to be a municipal water plant and be exempt from paying taxes.

3.6 Electrical Power Generating Costs

Although the fuel costs as shown in Table VI-3 include the cost associated with generating the power required on site, the overall costs of producing electricity on site as compared to purchasing the required power can be compared as shown in Table VI-10.

TABLE VI-10

COMPARISON OF ON-SITE POWER GENERATION VS. PURCHASED POWER

Direct Capital Cost Related to <u>On-Site Generation</u>

1.	Steam Turbo-generator	$230,000
2.	Erection of Turbo generator	5,780
3.	H.P. Boiler Cost including erection	94,465
4.	H.P. Steam Piping	28,750
5.	H.P. Boiler Feed Pumps	8,325
	Total	$367,320

Direct Production Costs

a) Steam Turbo-generator
Assumed generator efficiency of 96% plus 1% loss in red. gear and 1% loss from turbine radiation. Each kw of electricity out of generator requires

$$\frac{.3413}{.94} \text{ btu/kw hr} = 3630 \text{ btu/kw hr}$$

Assumed 99% efficiency in burning fuel in Heat Recovery Boiler and $.20/$10^6$ btu fuel (HHV) cost of making power is:

$$\frac{\$.20 \times 3630 \text{ btu/kwh} \times \frac{1000 \text{ mils}}{\$}}{.9 \times .99 \times 10^6 \text{ btu}} = .814 \frac{\text{mils}}{\text{kw hr}}$$

Direct Capital Cost Related to <u>Purchased Power</u>

1.	Transformer	$11,000
2.	Erection & Freight	3,000
3.	Switchgear	4,000
4.	Erection & Freight	2,000
5.	Vacuum Pumps & Motors	25,000
6.	Erection & Freight	2,000
	Total	$47,000

Purchased Power Costs Assumed to be $\frac{10 \text{ mils}}{\text{kw hr}}$

TABLE VI-10 (CONTINUED)

On-Site Generation

b) Auxiliary Generator

$$\frac{\left(\frac{78.8\#\text{fuel}}{\text{hr}}\right)\left(\frac{20300\text{ btu}}{.9\ \#}\right)\text{LHV}\left(\frac{\$.20}{10^6\text{btu}}\right)\left(\frac{1000\text{mils}}{\$}\right)}{150\text{ kw}}$$

$$= 2.370\ \frac{\text{mils}}{\text{kw hr}}$$

Average Annual Direct Production Costs:
Based on 1500 kw at 90% of time and
150 kw at 10% of time

$$\frac{\left(\frac{.814\text{ mils}}{\text{kw hr}}\right)\left(\frac{7884\text{hr}}{\text{yr}}\right)(1500\text{kw})+\left(\frac{2.370\text{mils}}{\text{kw hr}}\right)\left(\frac{876\text{hr}}{\text{yr}}\right)(150\text{kw})}{\left(7884\ \frac{\text{hr}}{\text{yr}}\right)(1500\text{kw})+\left(876\ \frac{\text{hr}}{\text{yr}}\right)(150\text{kw})} = .831\frac{\text{mils}}{\text{kw hr}}$$

Direct Operating Costs

a) Maintenance (1% of Cap.Cost)=$3,675

$$\text{or } \frac{\$3,675 \times 1000\text{ mils}/\$}{1500\text{ kw} \times 7884\text{ hr/yr}} = .311\ \frac{\text{mils}}{\text{kw hr}}$$

Total Direct Costs $1.142\ \frac{\text{mils}}{\text{kw hr}}$

Indirect Costs

a) Depreciation

$$\frac{(5.9557\%)\left(\frac{\$367,320}{\text{yr}}\right)(1000\text{mils}/\$)}{1500\text{ kw} \times 7884\text{ hr/yr}} = 1.850\ \frac{\text{mils}}{\text{kw hr}}$$

Purchased Power

Direct Operating Costs

a) Maintenance Nil

Total Direct Costs $10.000\ \frac{\text{mils}}{\text{kw hr}}$

Indirect Costs

a) Depreciation

$$\frac{(5.9557\%)\left(\frac{\$47,000}{\text{yr}}\right)(1000\text{mils}/\$)}{(1500\text{ kw} \times 7884\text{ hr/yr} + 150\text{ kw} \times 876\text{ hr/yr})/(11,957,400\text{kw hr/yr})} = .023\frac{\text{mils}}{\text{kw hr}}$$

TABLE VI-10 (CONTINUED)

On-Site Generation

b) Insurance (.25% of Cap.Cost)

$$\frac{\frac{(.25\%)(\underline{\$367,320})(1000\text{mils}/\$)}{\text{yr}}}{1500\text{ kw} \times 7884\text{ hr/yr}} = .078\ \frac{\text{mils}}{\text{kw hr}}$$

$$\text{Total Production Cost} = 3.070\ \frac{\text{mils}}{\text{kw hr}}$$

Purchased Power

b) Insurance (.25% of Cap.Cost)

$$\frac{\frac{(.25)(\underline{\$47,000})(1000\text{mils}/\$)}{\text{yr}}}{11,957,400\text{ kw hr/yr}} = .010\ \frac{\text{mils}}{\text{kw hr}}$$

$$\text{Total Production Cost} = 10.033\ \frac{\text{mils}}{\text{kw hr}}$$

Assumptions used in this table include the following:

a) The plant load remained unchanged at 1500 kw for 90% of the time.
b) The 150 kw of auxiliary power required when the plant is not operating was furnished by the auxiliary generator in the case of on-site generation and was purchased in the case of purchased power. This occurs 10% of the time.
c) The plant water production remained unchanged in both cases.
d) Purchased power was supplied at 13,800 volts and the step down transformer and switchgear on the secondary voltage was 480 volts, 3, in both cases.
e) Purchased power rates were assumed to be 1¢/kw hr.
f) Fuel rates were assumed to be $\$.20/10^6$ btu.

VII. Inventions

To the best of our knowledge, there were no inventions made during this study. A cursory patent and literature search disclosed the following that deal in one way or another with the process or equipment described. Patents relative to the MSF feed preheater and the power train are not included.

USP 643,794 Feb. 20, 1900, to Robert Harvey

Multiple effect evaporator with effect superimposed one above the next.

USP 1,252,962 Jan. 8, 1918, to Soderlund and Boberg (Techno-Chemical Labs.)

A falling film vapor compression evaporator with feed preheated by distillate and blowdown.

USP 3,021,265 Feb. 13, 1962, to P. B. Sadtler (Chicago Bridge & Iron Co.)

The combination of a multiple effect vapor compression evaporator with a MSF feed preheater for seawater distillation.

USP 3,244,601 Apr. 5, 1966, to G. E. Diedrich (General Electric Co.)

Doubly fluted tubes for evaporators.

Badger, W. L., Chem. & Met. Eng. 28 Nos. 1 & 2 (1923) - "Vapor Recompression Systems for Evaporators" - A review of patents literature, and practice to that time.

Badger, W. L. and Standiford, F. C., Nat. Acad. Sci. - Nat. Res. Council, Publ. 568, p. 103-14 (1956). Report of a 1955 study for OSW of the economics of desalting water with a combination LTV thermocompression and LTV multiple effect feed preheating evaporator.

VIII. Recommendations

The components used in the design of this plant are all commercially available. It is recommended, however, that before a plant of this general nature be constructed that a tube bundle similar to the one utilized in this plant be built and tested. The tube bundle should be tested using 90-10 Cu-Ni 3" O.D. double fluted tubes. Data obtained from such a test module would be used to verify the overall heat transfers coefficients developed in this design.

It is also recommended that consideration be given to protecting the bottom side of the lower tube sheet in each VTE effect from corrosion. The design as presented in this report does not include any such protection. A Cu-Ni clad or a sprayable silicone rubber should be investigated. The reason for concern in this particular area is that plugging of the distribution nozzles could occur if corrosion products were allowed to form.

One other area of investigation in this particular design should be in the necessity of using a Cu-Ni clad steel for the lower vessel course of plates in the VTE fourth effect. Any corrosion products forming at this point will not plug any distribution nozzles. Any large corrosion pits that form could be spot welded during one of the overhaul periods.

IX. Abstract of Report

Wightman H + Rorstrom EG + Standiford FC + Bassilakis CA
+ Foster-Pegg RW
DESIGN AND ECONOMIC STUDY OF A GAS TURBINE POWERED VAPOR COMPRESSION PLANT FOR EVAPORATION OF SEAWATER

Struthers Energy Systems, Inc., Warren, Pennsylvania
Pratt & Whitney Aircraft, East Hartford, Connecticut

OSW Contract No. 14-01-0001-7840, July, 1968, 292p,46fig,12ref.

The study of two sizes of gas turbine drivers was conducted and a 12,500 shp, dual shaft, gas turbine driver was chosen as the main power train. The plant is designed to produce 8.0 MGD. The cycle uses a VTE and a MSF unit in series. The gas turbine driven axial flow vapor compressor operates across 4 effects of the VTE. Gas turbine exhaust heat is recovered in a heat recovery boiler. Only on-site power is generated in the back pressure turbine rated for 1500 kw. The water cost developed for the plant is $0.39/1000 gal. The total capital cost of the plant is approximately $7,500,000. Drawings showing VTE tube sheet configurations and general outlines are provided. A heat and material balance is provided. Vendors' bids received for plant equipment are provided.

*Compressors + *design + conceptual design + *economic evaluation + direct costs + single-purpose plant economics + *falling film evaporation + *vertical tube evaporators + *gas turbines + *extended heat transfer surfaces + *heat recovery boiler

Notes: Heat recovery boiler is a new word that should be added to the Thesaurus.

X. Appendix

1.0 General Specifications

1.1 Vertical Tube Evaporator
1.2 Multistage Flash Evaporator
1.3 Gas Turbine Vapor Compressor Power Train
1.4 Feed Heaters
1.5 Heat Recovery Boilers
1.6 Steam Turbo generator
1.7 Vertical Pumps
1.8 Boiler Feed Pumps
1.9 Forced Draft Fan and Driver
1.10 Auxiliary Generator and Driver
1.11 VTE Tubes

2.0 Bids Received

2.1	Pumps	FMC Corporation Worthington Corporation Ramsay Pump & Supply
2.2	Forced Draft Fan	Motive Parts Company Busch Company Westinghouse Electric Co.
2.3	MSF Plant	Aqua-Chem, Inc.
2.4	Emergency Generator	Motive Parts Company Onan
2.5	Steam Turbine Generator & Switchgear	General Electric
2.6	Sulfuric Acid Tank	W. L. Badger Associates, Inc.

3.0 Calculations

3.1 Vertical Tube Evaporator, Tube Sheet Thickness
3.2 Economic Calculations

4.0 Drawings

4.1 Dwg. 67-09-7840-D5 Rev. 1 Heat Recovery Boiler
4.2 Dwg. 67-09-7840-F1 VTE General Arrangement
4.3 Dwg. 67-09-7840-F2 VTE Plan & Bottom Views
4.4 Dwg. 67-09-7840-F3 VTE General Arrangement with Bottom Ellipsoidal Head
4.5 Dwg. 67-09-7840-F4 VTE Plan & Bottom Views with Bottom Ellipsoidal Head
4.6 Dwg. 67-09-7840-F5 VTE Tube Bundle, First Effect, in quadrants
4.7 Dwg. 67-09-7840-F6 VTE Tube Bundle, First Effect, in halves
4.8 Dwg. 67-09-7840-D1 VTE Tube Bundle, Lower Effects, in halves

4.9	Dwg.	67-09-7840-D2	VTE Tube Bundle, Lower Effects, in quadrants
4.10	Dwg.	67-09-7840-D3	Feed Heater Arrangement
4.11	Dwg.	67-09-7840-D4	Feed Heater Tube Layout
4.12	Dwg.	67-09-7840-E3	Electrical Line Diagram
4.13	Dwg.	B4372	Piping & Instrument Diagram

1.1 SPECIFICATION FOR VERTICAL TUBE EVAPORATOR

A. General

The specification outlined in the following paragraphs covers the requirements for a vertical tube evaporator to operate in conjunction with a multistage flash evaporator. Preheated seawater produces fresh water distillate in the VTE unit.

B. Operation

The VTE unit comprises the four effects shown on the Heat and Material Balance, Dwg. No. B-4366. These are stacked one above the other. Seawater enters the VTE unit at 241.2° F from the four feed heaters which are in series. The seawater is introduced into the first effect above the tubes. Steam and compressed vapor are brought into the first effect on the outside of the tubes. The seawater flows through porcelain nozzles above each tube; the pressure is thereby reduced which, along with the exchanged heat, promotes flashing. The resulting vapor flows to the outside of the tubes in the next stage where heat is exchanged, resulting in flashing inside the tubes and condensing outside. This process continues through two more effects. Concentrated brine is drawn off the bottom of the unit. Fresh water also collects at the bottom in a separate compartment.

C. Performance

At an ambient temperature of 73° F, standard seawater (3.50% T.S.) feed of 5,000,000 lbs/hr at a saturation temperature of 241.2° F, a makeup heat input of 58,032,000 btu/hr, and 593,200 lbs/hr. of recompressed vapor from the last effect to the first effect, the output from the VTE unit shall be as follows:

(1) 2,493,161 lbs/hr of fresh water distillate at 225.5° F.
(2) 2,504,739 lbs/hr of brine at a concentration of 6.97% T.S. and 227.7° F.
(3) 2,100 lbs/hr of boiler makeup water at 256.6° F.

D. Design

1. Conditions

    (a) Code: ASME Boiler and Pressure Vessel Code, 1965; Section VIII, Unfired Pressure Vessels. Code stamp is required.
    (b) Pressure: Full Vacuum
    (c) Temperature: 300° F

(d) Maximum allowable internal pressure: 35 psig
(e) Corrosion Allowances:
Steel in contact with vapor - 3/16"
Steel in contact with brine - 3/8"
90-10 Cu-Ni surfaces - 0

2. Wind Velocity: 100 miles/hr. This figure should be reviewed when actual plant location has been determined.
3. The general arrangement shall be similar to that shown on Dwg. No. 67-09-7840-F1.

E. VTE Construction

1. Materials of construction are to be based on an assumed 30 year plant life with minimum downtime for maintenance. Tubes are expected to last the full 30 years, but access must be provided for retubing if it becomes necessary. A second consideration is that the tube distributor spray nozzles must not plug with solids such as might result from using unprotected steel in the brine passages upstream of the nozzles.

2. The top head, the conical collection basins above effects II, III, IV, the bottom cover plate, and the bottom shell course shall be carbon steel with 1/16" thick 90-10 Cu-Ni cladding.

3. The shell, structural supports, and vent piping shall be carbon steel. All bare unprotected carbon steel surfaces in contact with brine shall be spray coated at assembly with suitable material.

4. The tubes to be used for the evaporator surfaces, are 3" O.D. by .049" wall of 90-10 Cu-Ni according to ASME SB-111. Each tube is to have a total length of 12'-10 1/2" with an active fluted length of 12'-6" and with plain ends to permit installation by conventional means. The tubes are to be fluted longitudinally to a profile developed by General Electric Company. The minimum wall after fluting shall be .035". The fluted surfaces have a heat transfer area of 1.0 sq.ft./ft.

5. The feed to each tube is to be distributed to the walls by a distribution spray nozzle having a pressure drop of approximately 5 psi. The minimum feed per tube is about 1.2 gpm, which corresponds to essentially the full flow through the system. The distribution nozzles have been developed by Oak Ridge National Laboratories. They are to be ceramic, as manufactured by Knox Porcelain Company, Fig. No. 4, or equal. The nozzles shall mount above each tube of each effect with a hexagonal flange which will cover and protect the tube sheet surface from corrosion. The

nozzles shall be sealed and secured to the top tube sheet of each effect with a pourable silicone rubber, similar to General Electric Company type RTV-112. The method of nozzle installation shall be as follows:

The tubes shall be installed such that 1/4 inch of each tube projects above the top tube sheet in each bundle. Silicone rubber shall be poured on top of the tube sheet between the protruding tubes to a depth of 1/4 inch. The rubber shall be allowed to cure 24 hours. Silicone rubber shall then be applied to the bottom of each distribution nozzle flange and the nozzle inserted into the tube. After another 24 hour period, the gaps between the nozzles shall be filled with silicone rubber and allowed to cure.

6. All tube sheets are to be carbon steel. The thickness of the tube sheets at the tubes, based upon tube rolling limitation, is 1 1/2" minimum. Any area of tube sheets in contact with brine shall be spray coated at assembly with suitable material.

7. An entrainment separator is required below the last effect to protect the vapor compressor from fouling due to moisture carry over. The separator is to be 4" thick, of Monel, Yorkmesh style 931 or equal.

8. The minimum horizontal free area required for vapor disengagement for each effect is as follows:

   Effect 1 - 531 sq. ft.
   Effect 2 - 560 sq. ft.
   Effect 3 - 595 sq. ft.
   Effect 4 - 625 sq. ft.

   The horizontal free area for vapor disengagement is that area between the diameter of the outer row of tubes and the maximum inside diameter of the conical catch basins.

F. Painting and Insulation

All exposed steel surfaces shall be cleaned and given one coat of primer, red lead or zinc chromate. The outside of the vessel shall be insulated for a maximum heat loss of 1,000,000 btu/hr based upon a vessel shell temperature of 260°F and an ambient temperature of 20°F.

G. Field Erection

It is the intent of this specification that the Bidder include complete field erection, less foundation, with his proposal.

H. Design Responsibility

The Bidder shall be responsible for the overall design of the VTE unit and he shall guarantee performance in accordance with Section C.

1.2 SPECIFICATION FOR MULTISTAGE FLASH EVAPORATOR

A. General

The specification outlined in the following paragraphs covers a requirement for a multistage flash evaporator to operate in conjunction with a thermocompression evaporator. The MSF unit will function as a seawater feed heater for the TC evaporator and will produce additional distillate by flashing the brine blowdown from the TC section.

B. Operation

The MSF evaporator shall function as a once through unit with the basic flow cycle generally as shown on Figure 1. The manufacturer shall provide the optimum arrangement of stages to achieve the performance requirements stated elsewhere in this specification. Provision shall be made for extracting the seawater feed from the evaporator for deaeration and decarbonation (with sulphuric acid injection) at a temperature to be determined by the manufacturer. As compared to a conventional MSF evaporator, this unit is to be designed to handle a large distillate flow entering from the TC evaporator. The unit must operate at a last stage vacuum that will vary with seawater temperature in the range of 60°F to 90°F with the normal condition at 75°F.

C. Performance

1. Normal Condition

At ambient air temperature of 73° seawater temperature of 75°F, the MSF evaporator is to be capable of long term continuous operation at the following duty (see Figure 1):

(a) heat 5,000,000 lbs/hr of standard seawater (3.50% T.S.) from 75°F to 208.8°F.

(b) Utilizing heat from 2,493,000 lbs/hr of distillate from the TC evaporator entering at 225.5°F and flashing to about 92.3°F.

(c) utilizing heat from 2,504,700 lbs/hr of brine blowdown (7.0% T.S.) from the TC evaporator entering at 227.7°F and flashing down to about 93.9°F.

For normal operation, the plant shall be capable of handling the following range of flows without major adjustment:

seawater feed--------------5.0 to 5.5 million lbs/hr
condensate in (at 225.5°F)-2.0 to 2.9 million lbs/hr
Brine in (at 227.7°F)------2.3 to 3.2 million lbs/hr

2. Off-Design Operating Conditions

(a) cold seawater at 60°F (see Figure 2), the manufacturer shall specify the maximum temperature to which the seawater will be heated at this condition with distillate and brine flows as shown.

(b) high ambient with seawater at 85°F (see Figure 3).

(c) startup at normal seawater temperature (see Figure 4). The plant shall be designed to maintain the interstage seals with the reduced flows as shown. Consideration should be given to diverting brine flow into the distillate section during startup, if other methods of maintaining seals are not feasible.

(d) reduced brine temperature (see Figure 5), the brine channels shall be capable of handling a flow of 3,670,000 lbs/hr when operating at a reduced brine temperature of 197.4°F.

(e) maximum capacity at normal seawater temperature (see Figure 6).

D. Design

The MSF evaporator may be designed as a single vessel for field erection or as several vessels of a size suitable for shop assembly for rail or water shipment. The internal design, arrangement of stages, tube length, tube sheet seals, brine and distillate orifices, and other details shall be to the manufacturers proven design now in satisfactory service. Novel features not proven in service shall not be used.

The plant shall be complete with pumps, structurals, mounting arrangements, piping between vessels and pumps, instruments and controls, and all other components necessary for a complete operating plant. For deaerator and decarbonation requirements, see Section F.

E. Evaporator Construction

The evaporator shall be designed in accordance with standard practice for seawater service with choice of materials such that the presence of solid corrosion products in the brine will be kept to a minimum level.

1. Shell - steel, designed for full vacuum with 3/16" corrosion allowance. Manways and sight glasses shall be provided for each stage.

2. Tubing - iron modified 90-10 Cu.Ni.
    - size - for undeaerated seawater-20 gage (0.035" wall)
        - for deaerated seawater---18 gage (0.049" wall)
    - velocity - minimum 5 fps at 5 million lbs/hr feed rate
        - maximum 7 fps at 5 million lbs/hr feed rate
    - tubes shall be straight but need not be individually removeable.

3. Tube sheets - carbon steel with 1/4" min. 90-10 cladding on the brine side.

4. Waterboxes - steel with 1/8 inch 90-10 cladding, or fiberglass reinforced epoxy. All waterboxes shall have 18" manholes to permit access for plugging leaking tubes.

5. Interstage dividers - steel with 3/16 inch corrosion allowance on each side. Suitable elastomer bushings shall be provided for that portion of divider through which tubes pass, if that portion of divider is made of steel.

6. Demisters - shall be provided if required, to maintain a maximum impurity level of 500 ppm for that portion of the distillate produced in the MSF train. Demisters shall be of Monel mesh.

7. Arrangement - common-wall construction may be used provided there is access from one side or the other from the outside, to each stage. There is no limitation on tube length but provisions shall be included to take partially heated raw seawater from the stage at which its temperature is about 4°F below the final blowdown brine temperature and to return the treated seawater to the next stage.

An estimate is desired of the extra cost of keeping the entering condensate separate from that produced in the flash train. This feature is desired to permit continued operation in the event of a leaky tube in the flash system.

F. Deaeration and Decarbonation

For the deaeration, decarbonation and ejector system, the manufacture shall:

(a) provide performance and operating data on these systems for supply by others.

(b) quote as an extra for the supply of these systems as part of the MSF evaporator package.

The basic design of the evaporator is predicated on removing raw seawater from the heating stages when it has reached a temperature about 4°F below the blowdown temperature. This stream will be acidified, stripped of carbon dioxide in an atmospheric packed tower, and then passed into a vacuum deaerator. It is suggested that steam for the deaerator be obtained by flashing blowdown (about 4°F) in a vessel placed at barometric height with an appropriate allowance in the blowdown pump head.

Evaporator and deaerator vents shall be piped to a direct contact, seawater cooled, barometric pre-condenser before entry into the injector system. Direct contact intercondensers shall be used in the ejector system. Alternate systems to the manufacturer's preference for this service will be considered.

Steam for air ejector operation is available at 400 psig, 650°F. The manufacturer is to specify the steam consumption, decarbonator fan horsepower, and raw seawater pressure required at the inlet waterbox of the flash plant measured at grade. The desired maximum residuals of the deaerator effluent are 20 ppb oxygen and 4 ppm carbon dioxide.

The deaerator, decarbonator and interconnecting piping shall be of lined steel or 90-10 Cu.Ni. construction. A pump between decarbonator and deaerator is not required.

G. Pumps

The following pumps shall be included for the major flow streams based on two pumps operating in parallel, each at half the capacity for the stream. A spare half capacity pump shall be included for standby and to allow outage for repairs. Capacities stated below are totals for two pumps.

1. Deaerated seawater feed - Maximum capacity 5,500,000 lb/hr seawater, at about 90°F, pumping from essentially full vacuum measured at a point 24 foot above grade, to a pressure of 72 psig measured at grade, at the discharge of the high temperature waterbox. Maximum allowable pump load is 800 bhp. Alternately manufacturers shall quote pumps of the same capacity at 40 psig

discharge head. The limit on horsepower would not apply for this condition.

2. Brine blowdown - Maximum capacity of 3,400,000 lb/hr, from equivalent of essentially full vacuum in last stage to a pressure of 7.5 psig measured at grade at the discharge of a wide open blowdown level control valve.

3. Distillate - Maximum capacity of 3,000,000 lb/hr. at a discharge pressure of 25 psig measured at grade downstream of metering, control, and impure product dump system.

4. Raw seawater - this pump will be furnished by customer. Manufacturer shall advise the discharge head required to deliver the seawater to the decarbonator-deaerator system.

5. Materials:

   Seawater and brine - Type II Ni-resist. casings; 316 stainless steel shafts, impellers, and barrels.
   Distillate - Cast iron, bronze fitted.

6. Pump drives - all pumps shall be motor driven and manufacturers shall include motors but not starters in the quotation. Motors shall be T.E.F.C. type, NEMA B classification, suitable for outdoor installation. AC power supply will be 440/220 volts.

H. Piping

The manufacturer shall furnish piping between vessels and pumps as follows:

1. Deaerated seawater feed - epoxy lined steel up to 160°F, fiberglass reinforced expoxy pipe above 160°F.
2. Blowdown brine - carbon steel with 1/4 inch corrosion allowance.
3. Vents - stainless steel type 316
4. Distillate - carbon steel with 1/4 inch corrosion allowance.

I. Instruments and Controls

The manufacturer shall provide all the necessary controls, gages, thermometers, etc. needed for proper operation of the MSF evaporator and associated pumps. The following is a minimum list:

1. Sight glasses (2) and pressure gage taps at each stage.
2. Thermometer wells in each flash stream at each stage (if practical).
3. Thermometer wells and pressure gage taps in each inlet waterbox and in final discharge waterbox.
4. Level controls and alarms for distillate and blowdown streams.
5. Pump failure alarms.
6. Recording and integrating distillate flowmeter.
7. Conductivity meter, alarm, and diversion valve on distillate stream.

J. Insulation and Painting

The manufacturer shall provide insulation on vessels and piping as required to maintain performance and temperatures throughout the plant. Vessels shall be painted with one primer and one finish coat of a grade suitable for coastal weather conditions.

K. Installation

The manufacturer shall provide structurals and mounting arrangements for installation on the customers foundations. Installed dry and operating weights of all components shall be stated.

L. Quotation

Prices shall be quoted according to the following schedule:

1. Shop assembled evaporator vessels, with prefabricated piping complete with accessories, FOB factory, with shipping weights.
2. Price differential for decarbonator, deaerator and ejector systems.
3. Price differential for deaerated seawater feed pump at 40 psig discharge head.
4. Evaporator materials, components and accessories for field erected design, FOB factory.
5. Price for erection of evaporators on customer's foundation, including freight to job site at a Texas Gulf Coast location, to provide a turnkey installation.

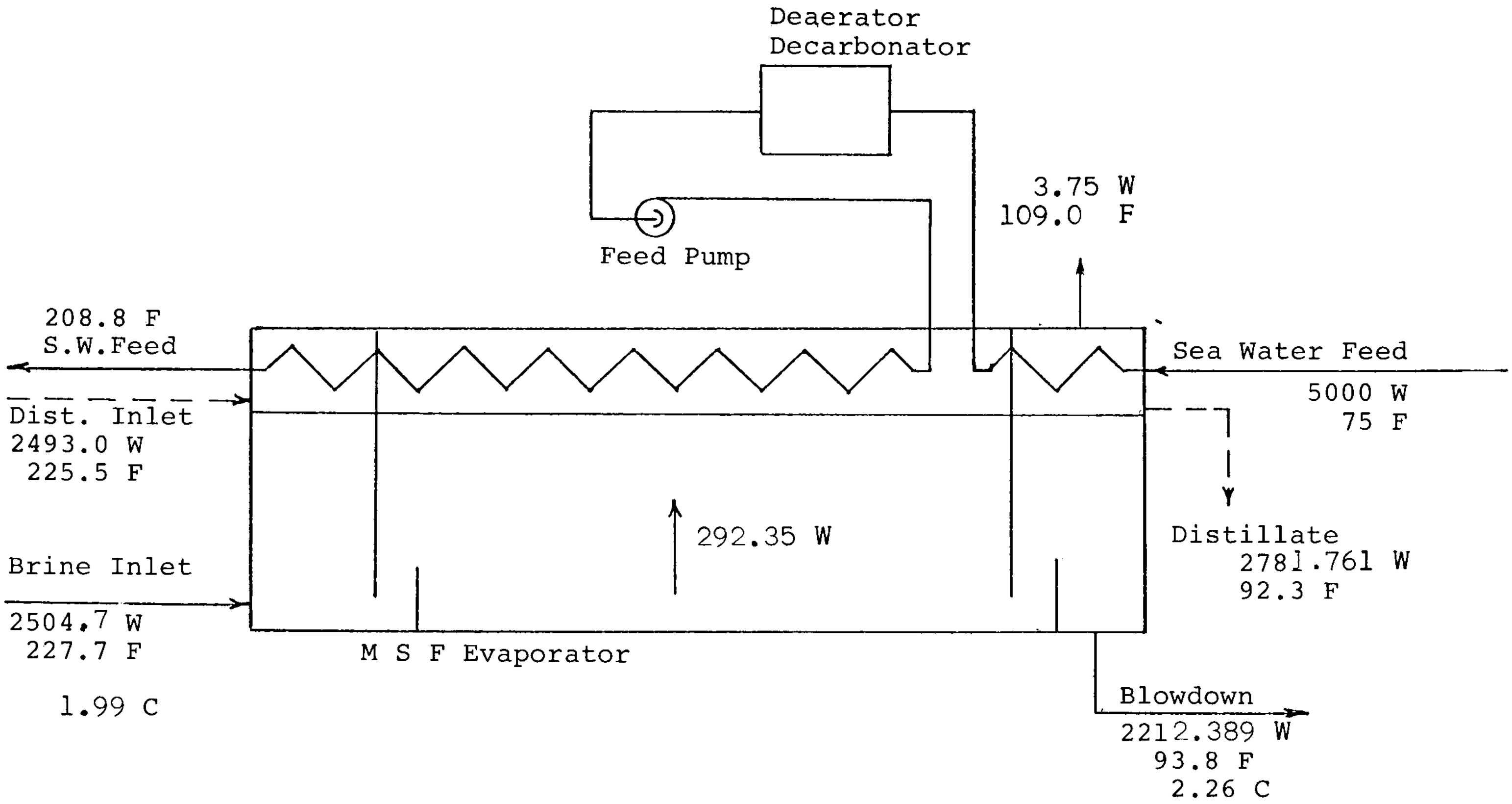
6. Price for supplying drawings in advance of an order for the evaporator to include,

   Heat balance
   Diagrammatic flow diagram
   General arrangement and setting plan
   Sectional view of evaporator stage showing general details of tube bundle, flow channels and orifice arrangements
7. Price basis for tubing costs, including weights and price per pound from which a factor can be calculated to adjust for changes in copper price.

8. Schedule of pricing for start-up services.

M. Delivery

Manufacturer shall advise best estimate of manufacturing lead time for mid 1969 delivery and startup of the plant.

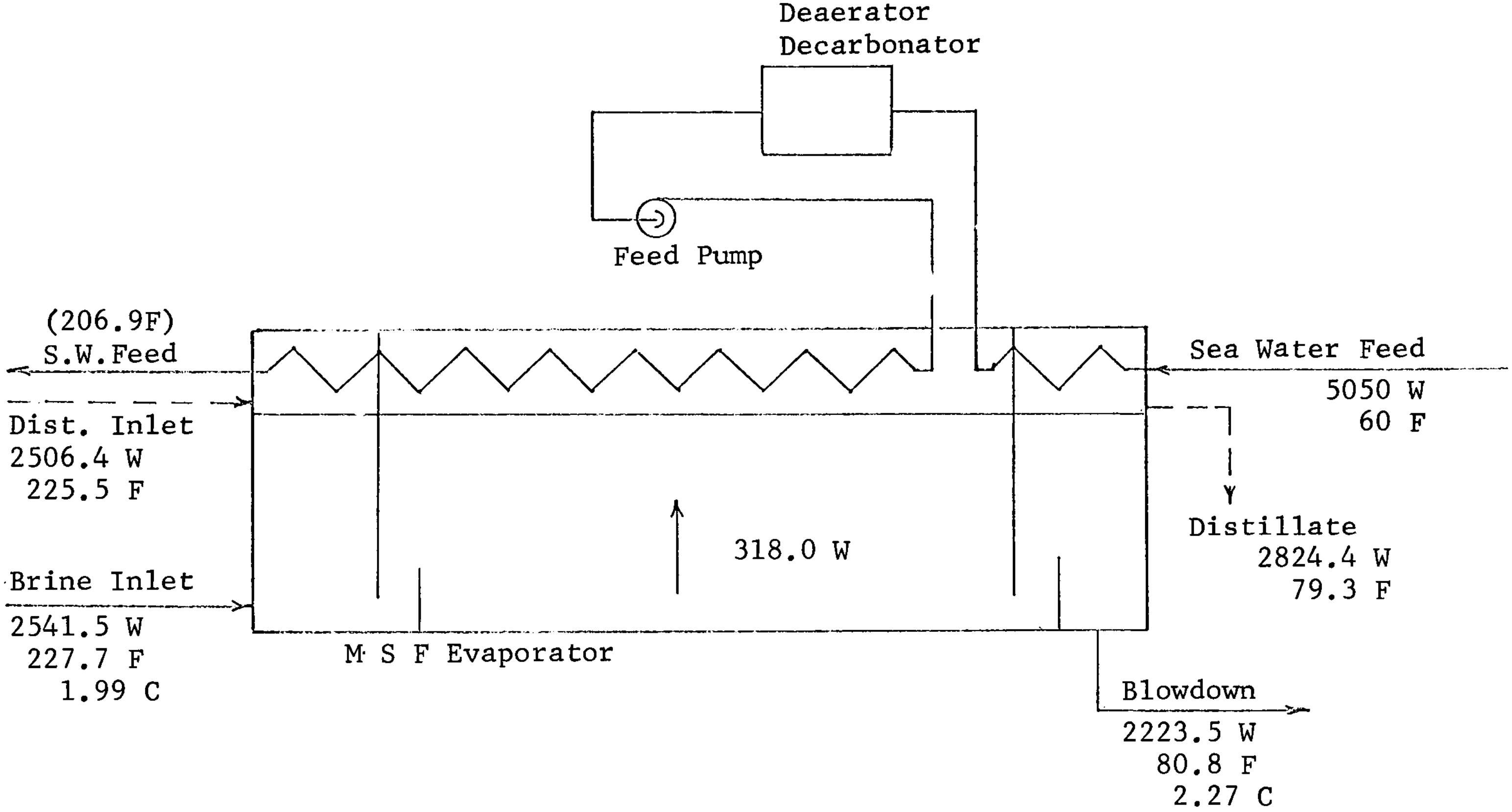


W = 1000 lbs/hr
F = Deg. F.
C = Conc. Factor

Operating Mode No. 1

Normal Condition

Figure No. 1

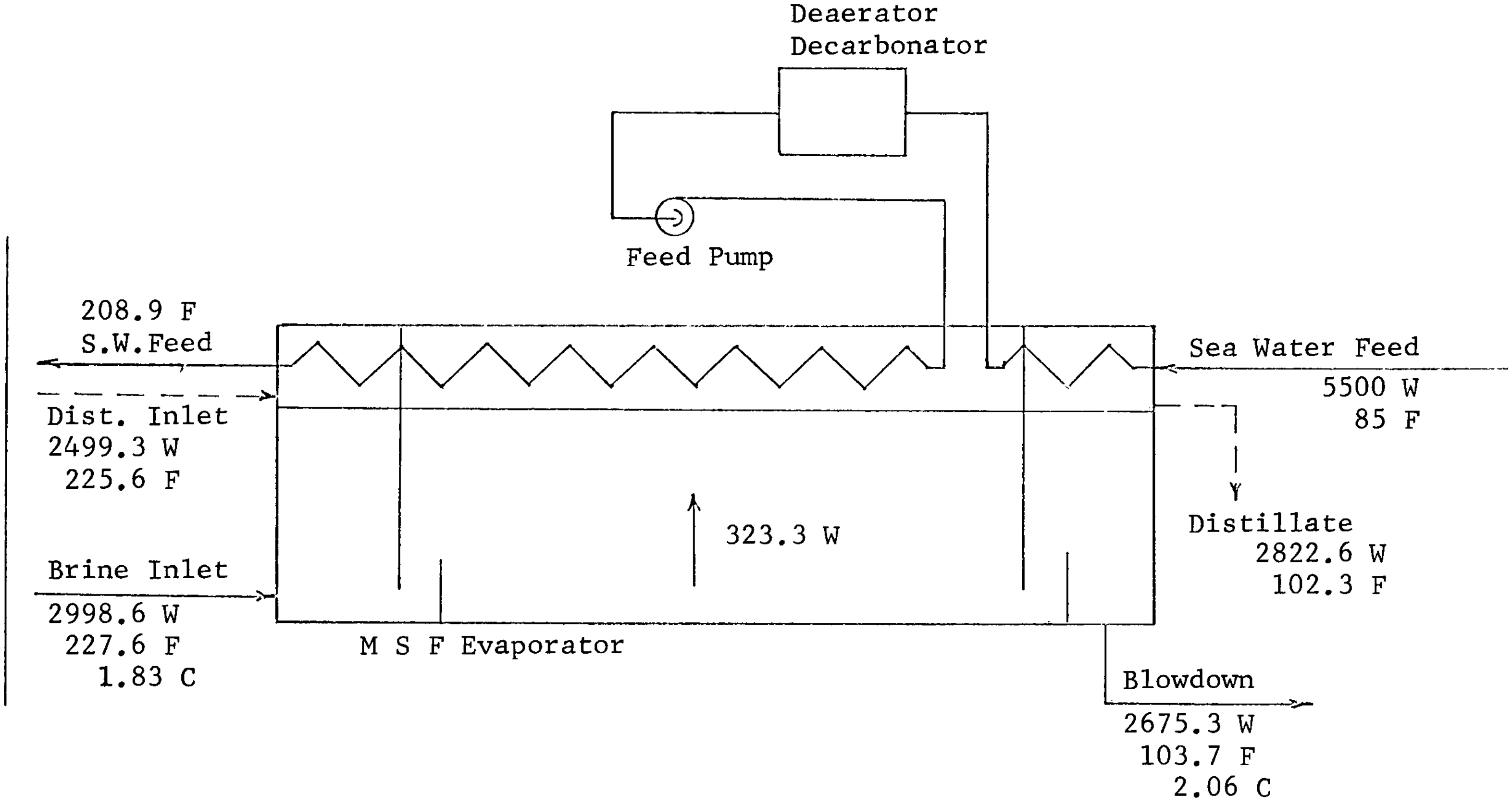


W = 1000 lbs/hr
F = Deg. F.
C = Conc. Factor

Operating Mode No. 2
Low Ambient Condition

Figure No. 2

THERMO COMPRESSION EVAPORATOR

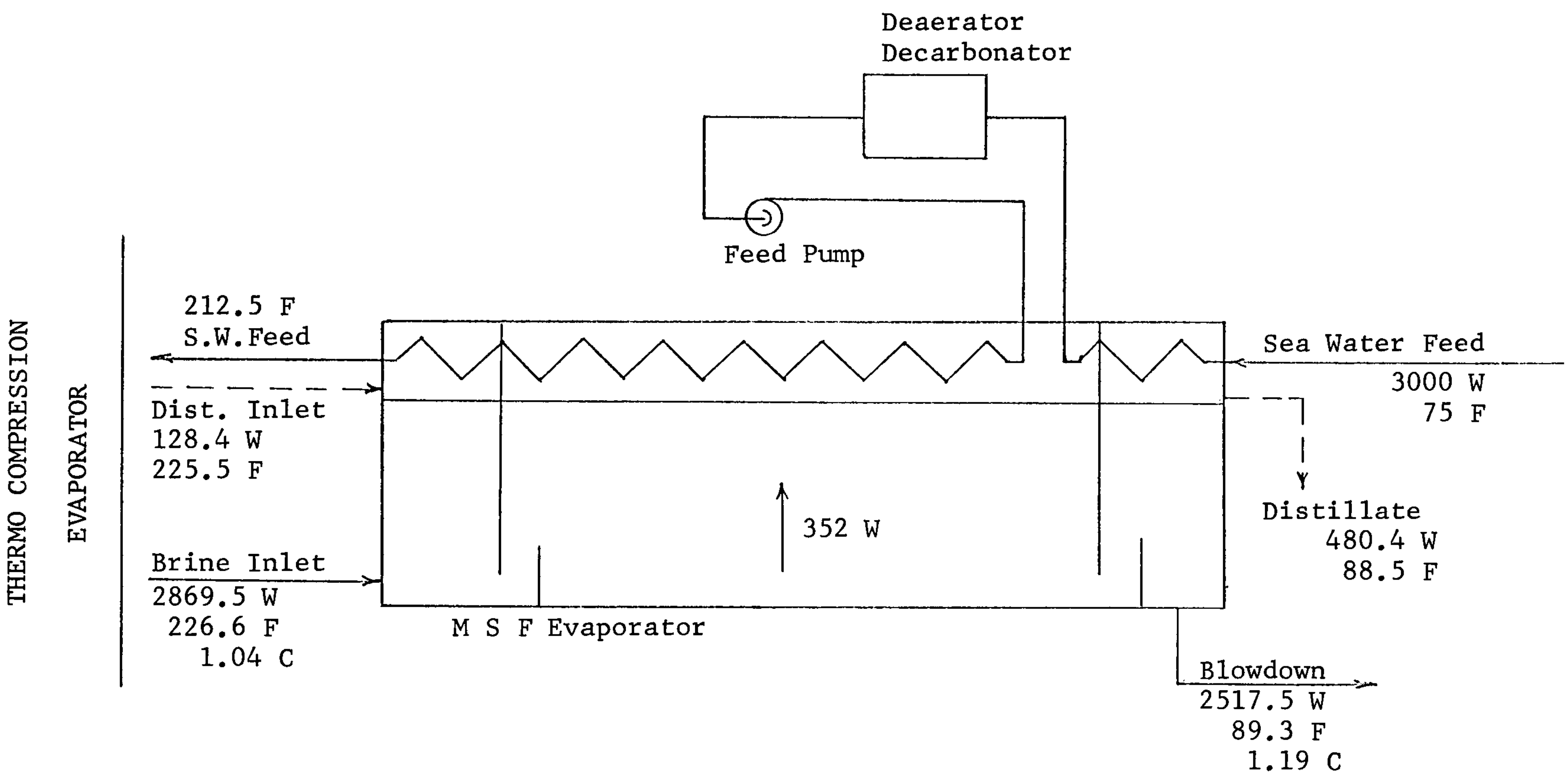


W = 1000 lbs/hr
F = Deg. F.
C = Conc. Factor

Operating Mode No. 3

High Ambient Temp.

Figure No. 3

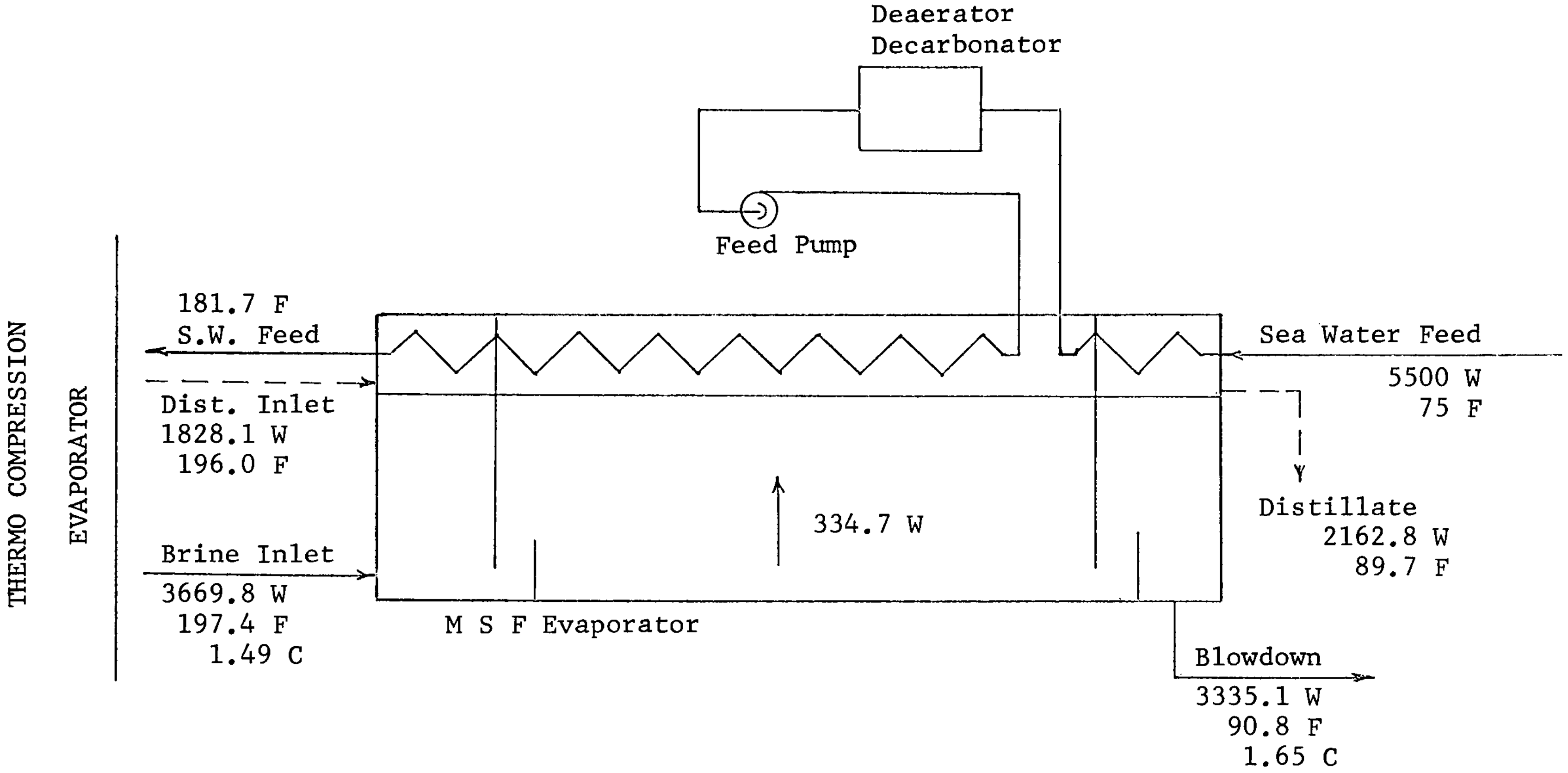


W = 1000 lbs/hr
F = Deg. F.
C = Conc. Factor

Operating Mode No. 4

Start-Up

Figure No. 4



W = 1000 lbs/hr
F = Deg. F.
C = Conc. Factor

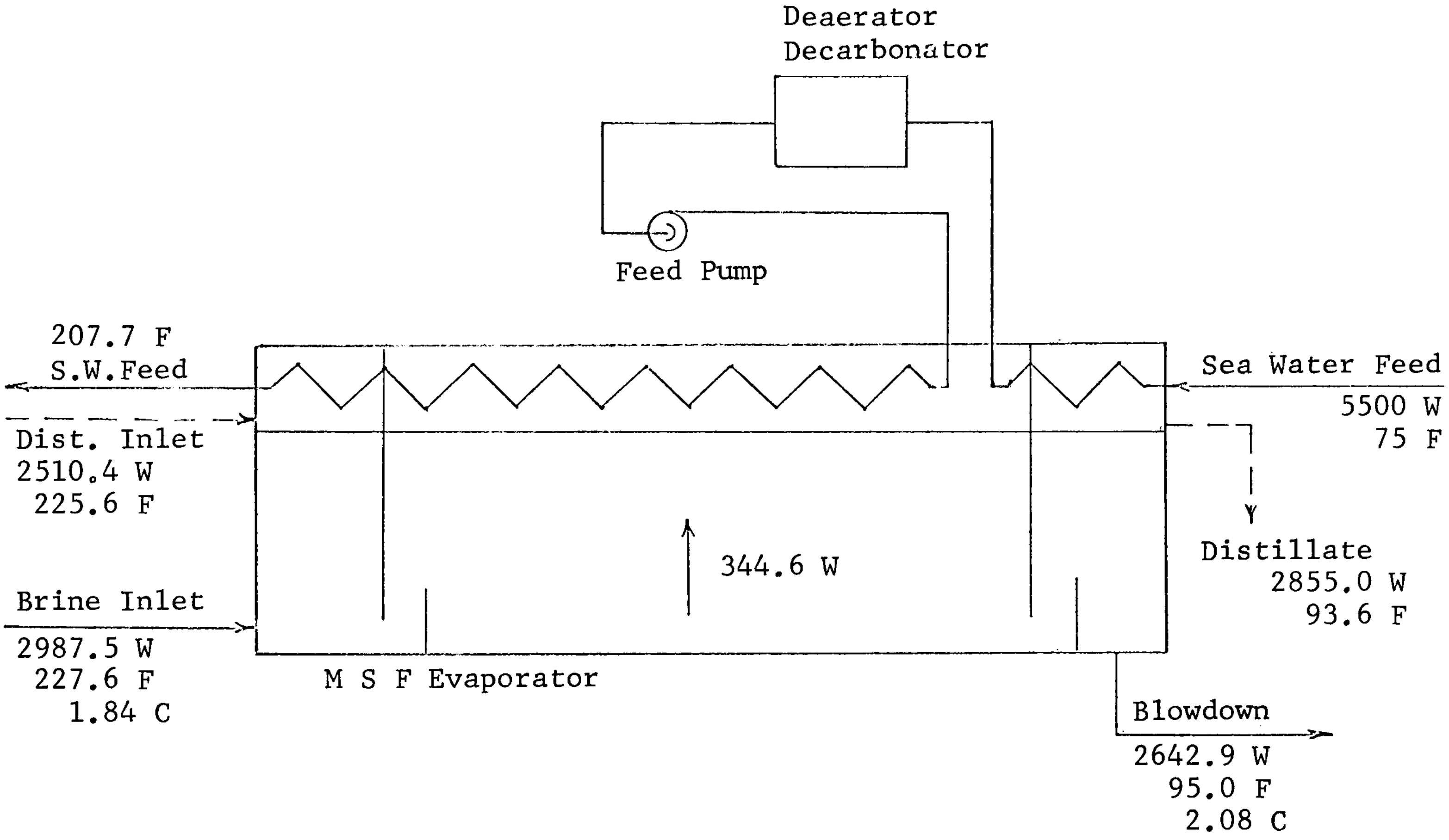
Operating Mode No. 5

Low Brine Inlet Temp.

Figure No. 5

THERMO COMPRESSION

EVAPORATOR



W = 1000 lbs/hr
F = Deg. F.
C = Conc. Factor

Operating Mode No. 6

Maximum Condition

Figure No. 6

1.3 SPECIFICATIONS FOR COMBINED GAS TURBINE-VAPOR COMPRESSOR POWER TRAIN

A. General

This specification covers the requirements for equipment and installation on purchaser's foundations of a gas turbine powered vapor compressor which will compress water vapor across several effects of a seawater evaporator. This gas turbine vapor compressor package (hereinafter referred to as the turbo compressor) will consist of the following:

1. Gas Turbine

A gas turbine prime mover mounted on a base, prepiped and prewired terminating with an exhaust elbow capable of 360° rotation and including:

a. A weatherproof acoustically insulated enclosure.
b. An inlet stack with industrial area sound treatment.
c. An exhaust elbow to purchaser's waste heat boiler duct.
d. A flexible gear type coupling.
e. A natural gas expansion turbine for starting the gas turbine.

2. Vapor Compressor

A directly driven vapor compressor with vertical inlet and discharge elbows and with thermal, acoustical insulation, and water washing nozzles and drains.

3. Accessories

a. Controls and instrumentation
b. Lubrication system.

B. General Operation

The desalination plant in which this turbo compressor will be used is a combination multi-flash and thermo compression evaporator. The turbo compressor will be operated at essentially constant output over a range of ambient conditions from 50° to 90°F. Regulation of the vapor compressor output will be accomplished primarily by regulating gas turbine firing rate. In normal operation, a speed variation of ±5% is expected. Control signals will come from the plant central control house located (50) feet from the turbo compressor.

C. Performance and Operation

1. Vapor Compressor Design Conditions

The vapor compressor has to compress 593,000 lbs/hr of water vapor entering at a pressure corresponding to 225.5°F saturation temperature (but with 227.7°F actual temperature) to a pressure corresponding to 256.6°F saturation temperature (a compression ratio of approximately 1.75). The actual inlet volume is 208,300 cfm. The plant design is based on the assumption of an axial flow vapor compressor with an 84% adiabatic efficiency. If the efficiency is other than 84%, we wish to maintain the above weight flow and discharge pressure and will design to accommodate a different suction pressure and compression ratio. The water vapor to the compressor will contain less than 20 ppm entrained brine. The brine will contain less than 70,000 ppm total dissolved salts. This corresponds to a gas turbine net shaft power of 12,500 horsepower.

2. Gas Turbine Design Conditions

The gas turbine shall be designed to produce the required net shaft horsepower to drive the vapor compressor at its design point at 73°F and 14.67 psia, while exhausting into a waste heat boiler with 9 inches W.G. back pressure.

3. Flat Rating

The gas turbine shall be capable of delivering the design shaft power over an ambient temperature range of 50° to 90°F. The gas turbine shall produce this power while burning natural gas fuel specified herein and with inlet silencing suitable for NEMA rank "h" at 400 feet.

4. Fuel

The sole fuel for the gas turbine shall be natural gas. The gas will be supplied to the unit enclosure at 350 psig pressure. A typical analysis to use for design and performance calculations shall be:

% by volume: CH_4 - 90.92; C_2H_6 - 3.77; C_3H_8 - 1.61; C_4H_{10} - 0.74; C_3H_{12} - 0.24; C_6H_{14} - 0.11; N_2 - 2.20; O_2 - 0.38; CO_2 - 0.03. HHV - 22,595 btu/lb; LHV - 20402 btu/lb.

5. Continuous Operation

The water plant will be operated at its design output for at least 7,884 hours per year (90% load factor).

Planned shutdowns for inspection or overhaul shall be restricted to maximum of two (2) per year.

6. Maximum Speed

During periods of light loading (startup and shutdown), an over-riding speed control shall hold the turbo compressor to the maximum allowable operating speed of the machinery, without tripping out.

7. Torsional Characteristics

The gas turbine and vapor compressor shall be matched so that no excessive or damaging vibration or whipping shall be encountered in the operating range.

8. Startup and Shutdown

The turbo compressor shall be cranked to starting speed by means of a natural gas powered starter turbine. A sequencing system shall be provided to automatically sequence the gas turbine from initiation of start signal to idle speed. A similar sequencing system shall be provided to automatically sequence the gas turbine from initiation of shutdown signal to complete shutdown.

D. Vapor Compressor Requirements

1. Surging Limits

It is desired that the normal duty be accomplished at the point of highest vapor compressor efficiency. Surging limits are not critical, but it is hoped that the following conditions can be met or approximated without the addition of adjustable inlet vanes or stators.

a. At design speed - the compressor should be able to operate without surging a 15% reduction in flow and a corresponding head increase.

b. Reduced speed - it is desired that the compressor should also be able to operate without surging at a speed such that 50% of design intake volume flow is compressed to a 1.55 compression ratio.

2. Compressor Efficiency

The expected and guaranteed adiabatic efficiency will be based on the average static conditions at the inlet and outlet flanges. The average static pressure will be calculated from pitot traverses of the ducts. The inlet and outlet ducts will be 72 inch I.D. pipe.

3. Construction

a. The water plant will be designed for a 30 year life and a high availability factor. The suggested construction materials are:

   1. Casing - cast iron
   2. Rotor, shaft and blading - 14% Cr, 1% Ni steel. However, the manufacturer may use his standard, if it will meet the duty specified.

b. It is preferred that the vapor inlet and discharge connections be vertically downward. These inlet and outlet pipes should be 72 inch I.D. pipe. The compressor shaft must be horizontal.

E. Accessories

1. Instrumentation and Controls

The turbo compressor package shall include all instrumentation and controls particular to the gas turbine and vapor compressor that are required for safe operation from the central control house.

2. Lubrication

The contractor will supply a complete lubrication system for the turbo compressor, including pumps, coolers, filters, tanks, and d.c. powered emergency oil pumps if required for run down, should air power be lost.

F. Materials

All parts that will be exposed to the atmosphere shall either be protected by suitable coating or be composed of suitable materials for coastal conditions.

G. Spare Parts

The contractor shall include all spare parts to be kept on hand by the customer that will be needed for a two (2) year period.

H. Information Supplied by Contractor in Quotation

1. Performance

a. Performance curves showing the variables listed below over the range of ambient temperature from 40° to 90°F while producing the design output:

1. Fuel consumption
2. Exhaust gas temperature
3. Exhaust gas flow

b. Compressor map for vapor compressor

c. The vapor flow, vapor pressure ratio, vapor compressor adiabatic efficiency, fuel consumption, exhaust gas flow and exhaust gas temperature shall be guaranteed at the design point (73°F ambient).

d. The exhaust temperature quoted should be consistent with a heat balance around the gas turbine with all losses taken into account. A detailed heat balance at the design point shall be included in the quotation.

e. Net shaft power and output shaft speed at the design point.

2. Physical

a. Weight, dimensions and foundation loading diagram.
b. Weight of heaviest component to be lifted after erection.
c. Critical speeds.

3. Cost

a. Price installed at site on customer's foundations including black start capability, controls and spare parts.
b. Maintenance contract charges, including inspections and overhauls. The contractor shall list what is covered under the maintenance contract.

4. Maintenance Schedule for "Flat Rating" Operation

a. Time between inspections that require shutdown
    Time required for inspections.
b. Time between overhauls
    Time required for overhauls.
c. If there are different classes for inspections and overhauls, list them separately.
d. The types of lubricating oil required, quantity used per year and cost.

1.4 SPECIFICATION FOR FEED HEATERS

A. General

The specification outlined in the following paragraphs covers the requirements for four feed heaters to operate in series flow of seawater between the multistage flash evaporator and the vertical tube evaporator.

B. Operation

The feed heaters are to be shell and tube type heat exchangers with seawater on the tube side and water vapor extracted from each effect of the VTE unit on the shell side.

5,000,000 lbs/hr of standard seawater (3.50% T.S.) from the MSF train at a saturation temperature of 208.8°F. enter heater No. 4. The saturation temperature of the seawater leaving heater No. 1 shall be 241.2°F. Vapor from the first effect of the VTE unit enters the shell side of heater No. 1 at 29.2 psia and 1.2 °F of superheat. Heater No. 2 takes vapor from the second effect at the saturation temperature of 241.3°F. Heater No. 3 takes vapor from the third effect at the saturation temperature of 233.6°F. Heater No. 4 takes vapor from the fourth effect at the saturation temperature of 225.5°F. Vapor condenses in all heaters.

C. Performance and Design

The performance and design conditions of each heater are given on the attached exchanger specification sheets which form a part of this overall specification.

D. Painting

All exposed steel surfaces shall be cleaned and given one shop coat of red lead or zinc chromate primer. Interior surfaces shall be thoroughly cleaned and coated with a suitable rust preventative.

E. Intent

The bidder shall be responsible for the design of the feed heaters and shall guarantee performance in accordance with this specification. Heater supports, field erection, and insulation are not part of this specification and are to be provided by others.

EXCHANGER SPECIFICATION SHEET

CUSTOMER Office of Saline Water		JOB NO. REFERENCE NO.
ADDRESS		PROPOSAL NO.
PLANT LOCATION		DATE
SERVICE OF UNIT Seawater Feed Heater		ITEM No. 1
SIZE	TYPE	CONNECTED IN Series
SURFACE PER UNIT	SHELLS PER UNIT	SURFACE PER SHELL

PERFORMANCE OF ONE UNIT

	SHELL SIDE		TUBE SIDE	
FLUID CIRCULATED	Steam		Seawater (3.50% T.S.)	
TOTAL FLUID ENTERING lbs/hr	39,760		5,000,000	
VAPOR				
LIQUID lbs/hr			5,000,000	
STEAM lbs/hr	39,760			
NON-CONDENSABLES lbs/hr	20			
FLUID VAPORIZED OR CONDENSED				
STEAM CONDENSED	39,760			
GRAVITY—LIQUID	1.0		1.028	
VISCOSITY—LIQUID				
MOLECULAR WEIGHT—VAPORS	18.0			
SPECIFIC HEAT—LIQUIDS		B.T.U./#	0.978	B.T.U./#
LATENT HEAT—VAPORS	946.3	B.T.U./#		B.T.U./#
TEMPERATURE IN	250.0	°F	233.5	°F
TEMPERATURE OUT	248.8	°F	241.2	°F
OPERATING PRESSURE GAGE	14.5	#/SQ. IN.	52	#/SQ. IN.
NUMBER OF PASSES	1		1	
VELOCITY		FT./SEC.	Approx. 6	FT./SEC.
PRESSURE DROP		#/SQ. IN.	Approx. 2	#/SQ. IN.

HEAT EXCHANGED—B.T.U./HR. 37,653,000 M.T.D. (CORRECTED)

TRANSFER RATE—SERVICE (0.0005) Fouling Factor) CLEAN

CONSTRUCTION OF ONE SHELL

DESIGN PRESSURE	35 & Full Vac.	#/SQ. IN.	75 & Full Vac.	#/SQ. IN.
TEST PRESSURE	53	#/SQ. IN.	112	#/SQ. IN.
DESIGN TEMPERATURE	300	°F	300	°F

TUBES 90-10 Cu-Ni NO. O.D. 7/8 BWG. 19 LENGTH PITCH

SHELL Carbon Steel I.D. O.D. THICKNESS

SHELL COVER FLOATING HEAD COVER

CHANNEL 90-10 Cu-Ni Clad CHANNEL COVER 90-10 Cu-Ni Clad

TUBE SHEETS—STATIONARY 2-1/8" incl. 3/8" Cu-Ni Clad

BAFFLES—CROSS Carbon Steel TYPE THICKNESS

BAFFLE—LONG TYPE THICKNESS

TUBE SUPPORTS THICKNESS

GASKETS

CONNECTIONS—SHELL—IN 28" OUT 8" SERIES 150

CHANNEL—IN 24" OUT 24" SERIES 150

CORROSION ALLOWANCE—SHELL SIZE 3/16 TUBE SIDE 0

CODE REQUIREMENTS ASME Sect. VIII

WEIGHTS—EACH SHELL BUNDLE FULL OF WATER

NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)

REMARKS: Se [illegible]

EXCHANGER SPECIFICATION SHEET

CUSTOMER Office of Saline Water
JOB NO.
REFERENCE NO.
ADDRESS
PROPOSAL NO.
PLANT-LOCATION
DATE
SERVICE OF UNIT Seawater Feed Heater
ITEM NO. 2
SIZE
TYPE
CONNECTED IN Series
SURFACE PER UNIT
SHELLS PER UNIT
SURFACE PER SHELL

PERFORMANCE OF ONE UNIT

		SHELL SIDE		TUBE SIDE	
FLUID CIRCULATED		Steam		Seawater (3.50% T.S.)	
TOTAL FLUID ENTERING	lbs/hr	41,020		5,000,000	
VAPOR					
LIQUID	lbs/hr			5,000,000	
STEAM	lbs/hr	41,020			
NON-CONDENSABLES	lbs/hr	5			
FLUID VAPORIZED OR CONDENSED					
STEAM CONDENSED		41,020			
GRAVITY—LIQUID		1.0		1.028	
VISCOSITY—LIQUID					
MOLECULAR WEIGHT—VAPORS		18.0			
SPECIFIC HEAT—LIQUIDS			B.T.U./#	0.976	B.T.U./#
LATENT HEAT—VAPORS		951.3	B.T.U./#		B.T.U./#
TEMPERATURE IN		241.3	°F	225.5	°F
TEMPERATURE OUT		241.3	°F	233.5	°F
OPERATING PRESSURE	GAGE	10.9	#/SQ. IN.	60	#/SQ. IN.
NUMBER OF PASSES		1		1	
VELOCITY			FT./SEC.	Approx. 6	FT./SEC.
PRESSURE DROP			#/SQ. IN.	Approx. 2	#/SQ. IN.

HEAT EXCHANGED—B.T.U./HR. 39,022,000
M.T.D. (CORRECTED)
TRANSFER RATE—SERVICE (0.0005 Fouling Factor)
CLEAN

CONSTRUCTION OF ONE SHELL

DESIGN PRESSURE	35 & Full Vac.	#/SQ. IN.	75 & Full Vac.	#/SQ. IN.
TEST PRESSURE	53	#/SQ. IN.	112	#/SQ. IN.
DESIGN TEMPERATURE	300	°F	300	°F

TUBES 90-10 Cu-Ni **NO.** **O.D.** 7/8 **BWG.** 19 **LENGTH** **PITCH**
SHELL Carbon Steel **I.D. O.D.** **THICKNESS**
SHELL COVER **FLOATING HEAD COVER**
CHANNEL 90-10 Cu-Ni Clad **CHANNEL COVER** 90-10 Cu-Ni Clad
TUBE SHEETS—STATIONARY 2-1/8" incl. 3/8" Cu-Ni Clad
BAFFLES—CROSS Carbon Steel **TYPE** **THICKNESS**
BAFFLE—LONG **TYPE** **THICKNESS**
TUBE SUPPORTS **THICKNESS**
GASKETS
CONNECTIONS—SHELL—IN 28" **OUT** 3" **SERIES** 150
CHANNEL—IN 24" **OUT** 24" **SERIES** 150
CORROSION ALLOWANCE—SHELL SIZE 3/16 **TUBE SIDE** 0
CODE REQUIREMENTS ASME Sect. VIII
WEIGHTS—EACH SHELL **BUNDLE** **FULL OF WATER**
NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)
REMARKS: [illegible]

EXCHANGER SPECIFICATION SHEET

CUSTOMER Office of Saline Water
JOB NO.
REFERENCE NO.
ADDRESS
PROPOSAL NO.
PLANT LOCATION
DATE
SERVICE OF UNIT Seawater Feed Heater
ITEM No. 3
SIZE
TYPE
CONNECTED IN Series
SURFACE PER UNIT
SHELLS PER UNIT
SURFACE PER SHELL

PERFORMANCE OF ONE UNIT

	SHELL SIDE	TUBE SIDE
FLUID CIRCULATED	Steam	Seawater (3.50% T.S.)
TOTAL FLUID ENTERING lbs/hr	42,260	5,000,000
VAPOR		
LIQUID lbs/hr		5,000,000
STEAM lbs/hr	42,260	
NON-CONDENSABLES lbs/hr	10	
FLUID VAPORIZED OR CONDENSED		
STEAM CONDENSED	42,260	
GRAVITY—LIQUID	1.0	1.028
VISCOSITY—LIQUID		
MOLECULAR WEIGHT—VAPORS	18	
SPECIFIC HEAT—LIQUIDS	B.T.U./#	.974 B.T.U./#
LATENT HEAT—VAPORS	956.4 B.T.U./#	B.T.U./#
TEMPERATURE IN	233.6 °F	217.2 °F
TEMPERATURE OUT	233.6 °F	225.5 °F
OPERATING PRESSURE GAGE	7.5 #/SQ. IN.	66 #/SQ. IN.
NUMBER OF PASSES	1	1
VELOCITY	FT./SEC.	Approx. 6 FT./SEC.
PRESSURE DROP	#/SQ. IN.	Approx. 2 #/SQ. IN.

HEAT EXCHANGED—B.T.U./HR. 40,417,000
M.T.D. (CORRECTED)
TRANSFER RATE—SERVICE (0.0005 Fouling Factor)
CLEAN

CONSTRUCTION OF ONE SHELL

	SHELL SIDE	TUBE SIDE
DESIGN PRESSURE	35 & Full Vac. #/SQ. IN.	75 & Full Vac. #/SQ. IN.
TEST PRESSURE	53 #/SQ. IN.	112 #/SQ. IN.
DESIGN TEMPERATURE	300 °F	3000 °F

TUBES 90-10 Cu-Ni NO. O.D. 7/8 BWG. 19 LENGTH PITCH
SHELL Carbon Steel I.D. O.D. THICKNESS
SHELL COVER FLOATING HEAD COVER
CHANNEL 90-10 Cu-Ni Clad CHANNEL COVER 90-10-Cu-Ni Clad
TUBE SHEETS—STATIONARY 2-1/8" incl. 3/8" Cu-Ni Clad
BAFFLES—CROSS Carbon Steel TYPE THICKNESS
BAFFLE—LONG TYPE THICKNESS
TUBE SUPPORTS THICKNESS
GASKETS
CONNECTIONS—SHELL—IN 28 OUT 3 SERIES 150
CHANNEL—IN 24 OUT 24 SERIES 150
CORROSION ALLOWANCE—SHELL SIZE 3/16 TUBE SIDE 0
CODE REQUIREMENTS ASME Sect. VIII
WEIGHTS—EACH SHELL BUNDLE FULL OF WATER
NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)
REMARKS: [illegible]

EXCHANGER SPECIFICATION SHEET

CUSTOMER Office of Saline Water		JOB NO. REFERENCE NO.
ADDRESS		PROPOSAL NO.
PLANT LOCATION		DATE
SERVICE OF UNIT Seawater Feed Heater		ITEM No. 4
SIZE	TYPE	CONNECTED IN Series
SURFACE PER UNIT	SHELLS PER UNIT	SURFACE PER SHELL

PERFORMANCE OF ONE UNIT

	SHELL SIDE	TUBE SIDE
FLUID CIRCULATED	Steam	Seawater (3.50% T.S.)
TOTAL FLUID ENTERING lbs/hr	42,690	5,000,000
VAPOR		
LIQUID lbs/hr		5,000,000
STEAM lbs/hr	42,690	
NON-CONDENSABLES lbs/hr	15	
FLUID VAPORIZED OR CONDENSED		
STEAM CONDENSED	42,690	
GRAVITY—LIQUID	1.0	1.028
VISCOSITY—LIQUID		
MOLECULAR WEIGHT—VAPORS	18	
SPECIFIC HEAT—LIQUIDS	B.T.U./#	.977 B.T.U./#
LATENT HEAT—VAPORS	961.6 B.T.U./#	B.T.U./#
TEMPERATURE IN	225.5 °F	208.8 °F
TEMPERATURE OUT	225.5 °F	217.2 °F
OPERATING PRESSURE GAGE	4.4 #/SQ. IN.	72 #/SQ. IN.
NUMBER OF PASSES	1	1
VELOCITY	FT./SEC.	Approx. 6 FT./SEC.
PRESSURE DROP	#/SQ. IN.	Approx. 2 #/SQ. IN.

HEAT EXCHANGED—B.T.U./HR 41,051,000 M.T.D. (CORRECTED)

TRANSFER RATE—SERVICE (0.0005 Fouling Factor) CLEAN

CONSTRUCTION OF ONE SHELL

	SHELL SIDE	TUBE SIDE
DESIGN PRESSURE	35 & Full Vac. #/SQ. IN.	75 & Full Vac. #/SQ. IN.
TEST PRESSURE	53 #/SQ. IN.	112 #/SQ. IN.
DESIGN TEMPERATURE	300 °F	300 °F

TUBES 90-10 Cu-Ni NO. O.D. 7/8 BWG. 19 LENGTH PITCH

SHELL Carbon Steel I.D. O.D. THICKNESS

SHELL COVER FLOATING HEAD COVER

CHANNEL 90-10 Cu-Ni Clad CHANNEL COVER 90-10 Cu-Ni Clad

TUBE SHEETS—STATIONARY 2-1/8" incl. 3/8" Cu-Ni Clad

BAFFLES—CROSS Carbon Steel TYPE THICKNESS

BAFFLE—LONG TYPE THICKNESS

TUBE SUPPORTS THICKNESS

GASKETS

CONNECTIONS—SHELL—IN 28" OUT 3" SERIES 150

CHANNEL—IN 24" OUT 24" SERIES 150

CORROSION ALLOWANCE—SHELL SIZE 3/16 TUBE SIDE 0

CODE REQUIREMENTS ASME Sect. VIII

WEIGHTS—EACH SHELL BUNDLE FULL OF WATER

NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)

REMARKS: [illegible]

1.5 SPECIFICATION FOR HEAT RECOVERY BOILER

1. General

This specification covers the requirements for one heat recovery boiler which will be part of a vapor compression desalination plant.

The heat recovery boiler is to be suitable for utilizing gas turbine exhaust gases supplemented with pressurized firing with natural gas as fuel. For startup power requirements prior to starting the gas turbine, air supplied by a forced draft fan will be utilized as combustion air for pressurized natural gas fuel.

2. Operation

The heat recovery boiler will be a drum type for two pressure levels of steam and its application would be as shown on the Flow Diagram, Figure 1, attached to this specification.

The guaranteed continuous output of the boiler and superheater will be 35,400 lb/hr of steam at 415 psia and 650°F with 257°F saturated liquid feed water entering the boiler. The boiler outlet pressure will be controlled.

A low pressure drum type boiler is to be included to utilize the low grade heat in the gases leaving the high pressure boiler to provide dry saturated steam. The guaranteed continuous output of the L.P. boiler will be 27,160 lbs/hr of steam at 33.7 psia with 257°F saturated liquid feedwater entering the boiler. The boiler pressure will be controlled. The heat recovery boiler is to be designed to produce 25% additional steam based on the continuous output shown above.

The heat recovery boiler design is to be based on the following gas turbine optimum conditions:

(a)	Maximum exhaust gas flow	614,160#/hr
(b)	Minimum exhaust gas flow	597,600#/hr
(c)	Maximum gas exhaust temp.	750°F
(d)	Minimum gas exhaust temp.	666°F

The heat recovery boiler to generate 19,000 #/hr steam at 415 psia and 650°F at startup utilizing a forced draft fan.

The maximum back pressure on the gas turbine to be 9" WC. The maximum allowable combustion chamber temperature during startup at one-half air flow through the recovery boiler to be 1200°F.

The feed water will be deaerated distilled product water diverted from the plant.

3. Arrangement

The heat recovery boiler will include the following components arranged to utilize gas turbine exhaust gases or fresh air from a forced draft fan:

(a) Flue gas duct to gas turbine with reverse flow check damper, manual damper drive, and expansion joints.

(b) Flue gas duct to forced draft fan with manually operated damper and expansion joint.

(c) Turbine exhaust dump stack with damper and damper drive.

(d) Supplementary cold air firing system

(e) Superheater

(f) High pressure boiler

(g) Economizer

(h) Low pressure boiler

(i) Exhaust stack.

4. Design and Construction

The following design detail requirements are intended to identify particular features of design as follows:

General

(a) The heat recovery boiler and all of the equipment furnished must be suitable for continuous outdoor service.

(b) The heat recovery boiler shall be of the pressurized type.

(c) The heat recovery package to feature all external finned heat transfer surface.

(d) Thermocouple and pressure taps to be included between each coil section.

(e) The heat recovery boiler to include all duct work required to interconnect the single gas turbine and auxiliary forced draft fan with the boiler. Also included shall be the ductwork to the main stack and the auxiliary stack, complete with dampers, linkages, pneumatic type drives, and drive supports. The boiler inlet ductwork shall be supported and designed to accommodate reasonable loads from the gas turbine and forced draft fan exhaust duct.

Design pressure of the boiler inlet ductwork, including the windbox, shall be 14 inches W.G. for continuous operation at the maximum operating temperatures stated in the performance tables.

(f) The dump and boiler stacks shall be 40 feet high above grade, and shall include a painter's trolley and track with suitable cageless ladder to top of stack.

The stack shall be free standing and shall be unsupported laterally and be designed for winds up to 100 mph.

Boiler Casing

(a) The casing temperature shall not exceed 150°F, by making use of internal castable refractory or block insulation. Block insulation to be contained in a sandwich construction with the steel casing on the outside and no less than 22 ga. stainless or 16 ga. carbon steel liner on the inside surface, as required by local temperatures. Alternate layers of block insulation shall have staggered joints. If castable refractory is required, it shall be "gunned" on in the field to prevent damage in transit.

(b) Access doors to be provided between each coil section to permit inspection when the unit is shutdown.

Supplementary Firing

(a) Supplementary firing to be accomplished by pressurized gas firing duct type burners to provide flame coverage over the total duct area. Natural gas pressure at a minimum of 25 psig will be available to the burner assembly.

(b) Pressure tight sight glasses to be located in the burner section to permit visual inspection of the burners, the flame pattern, and the initial rows of tubes.

Superheater

(a) The superheater to consist of two sections separated by the supplementary firing section. On boiler start-up, the upstream superheater section to be by-passed by the steam. During normal operation, both superheater sections would be operational.

(b) Each superheater section to consist of vertical tubes with steam flow inside the tubes in a pass arrangement consistent with the most economical use of space, material, and available pressure drop.

(c) Tube and fin materials are to be consistent with temperature environment.

(d) The superheater is to be drainable and headers are to include removable inspection ports.

(e) Suitable casing seals are to be provided for superheater connections.

(f) The superheater is to include all header supports, guides, and restraining devices necessary to absorb both safety valve reactions and reasonable loads imposed by piping external to the package.

High Pressure Boiler

(a) The boiler is to consist of a steam drum and a mud drum interconnected with finned vertical risers and jacketed downcomers.

A scrubbing type separator is to be provided to produce steam with solids content no greater than 1 ppm.

(b) The boiler assembly is to be top supported so as to allow thermal expansion resulting from changes in operating temperatures.

Economizer

(a) The coils are to be of all welded construction with the tubes interconnected with return bends.

(b) All controls are to be upstream of the economizer.

Low Pressure Boiler

(a) The boiler will be similar to the high pressure boiler except that it will operate at the reduced pressure. A minimum of internals will be required since steam purity will not be a problem.

(b) Feed water will be returned to the boiler at 25 psi static head.

Structural Steel

(a) All boiler framing as well as a complete system of platforms, stairs, hand rails, ets., and miscellaneous steel shall be furnished and designed in accordance with the requirements of the current Uniform Building Code.

(b) The boiler structure is to be designed for all live and dead loads to which it will be subjected, including piping furnished by others.

(c) All steel shall be shop cleaned in accordance with Standard SP-3 of Steel Structures Painting Council and shall then receive one shop coat of approved metal primer.

5. Boiler Accessories

All safety valves, hand valves, continuous blowdown valves as well as water gages and level switches shall be included with the heat recovery boiler.

6. Tools

The heat recovery package to include any special tools required for the operation and/or maintenance of the equipment furnished. Such tools shall be new and of first class quality and shipped to the job site separately from other materials and clearly marked as to their intended use.

7. Cleaning and Preservation

(a) Drums shall be clean and free of rust, grease and mill scale prior to shipment.

(b) Precautions shall be taken to prevent corrosion of the equipment furnished while it is in transit to the job site and in storage awaiting erection.

8. Data

The performance and technical data of the heat recovery boiler to be as shown on the attached sheets.

9. Controls

The operation of the heat recovery boiler to be controlled from a central control room. All process steam and combustion controls will be part of the centralized control center.

A. Boiler Controls

a. Controls to be pneumatic devices with 3-15 psig. output.

b. The feed water control system for the high pressure boiler to be of the 3-element type, and for the low pressure boiler feedwater control to be the 2-element type.

c. The control system to include all parameters, such as pressure, temperature, flow level to properly maintain steam process control.

B. Combustion Control

a. The combustion control system shall be designed to include all accessories required to safely maintain steam pressure and proper combustion conditions in the boiler.

b. The system to be operational during startup and during periods that supplementary heating is required.

c. The boiler combustion safeguard to be designed in accordance with Factory Insurance Association and Factory Mutual requirements.

PERFORMANCE DATA

1. Feedwater Temp., °F 257

2. Feedwater Flow lb/hr 63,260

3. Superheated Steam Flow lb/hr 35,400

4. Superheater Outlet Steam Pressure, psia 415

5. Superheater Outlet Temperature, °F 650

6. Saturated Steam Flow lb/hr 27,160

7. Low Pressure Boiler Steam Pressure, psia 33.7

8. Low Pressure Boiler Steam Temperature °F 257

9. High Pressure Boiler Blowdown Flow #/hr 700

10. Fuel Fired in Boiler $\frac{\text{HHV Btu}}{\text{Hr.}}$

11. Economizer Feedwater Inlet Pressure to High Pressure Boiler, psia

12. Economizer Feedwater Inlet Temperature to High Pressure Boiler, °F

13. Flue Gas Temperatures:
    a) Entering Boiler °F 713 @ guarantee point
    b) Leaving 1st Superheater Section, °F

c) Entering Superheater after Supplementary Heating, °F ______________________

d) Leaving Superheater after Supplementary Firing, °F ______________________

e) Leaving High Pressure Boiler, °F ______________________

f) Leaving Economizer, °F ______________________

g) Final Stack Temp. °F ______________________

14. Pressure Drops:

a) Drum to S.H. Outlet,psi ______________________

b) Economizer Inlet to Drum,(excl.head),psi ______________________

c) Air (gas) inlet,"H_2O ______________________

d) Superheater, "H_2O ______________________

e) H.P. Boiler, "H_2O ______________________

f) Economizer, "H_2O ______________________

g) L.P. Boiler, "H_2O ______________________

h) Stack (net) "H_2O ______________________

i) Total, Owner's Inlet to Stack Outlet, "H_2O 9" Max.

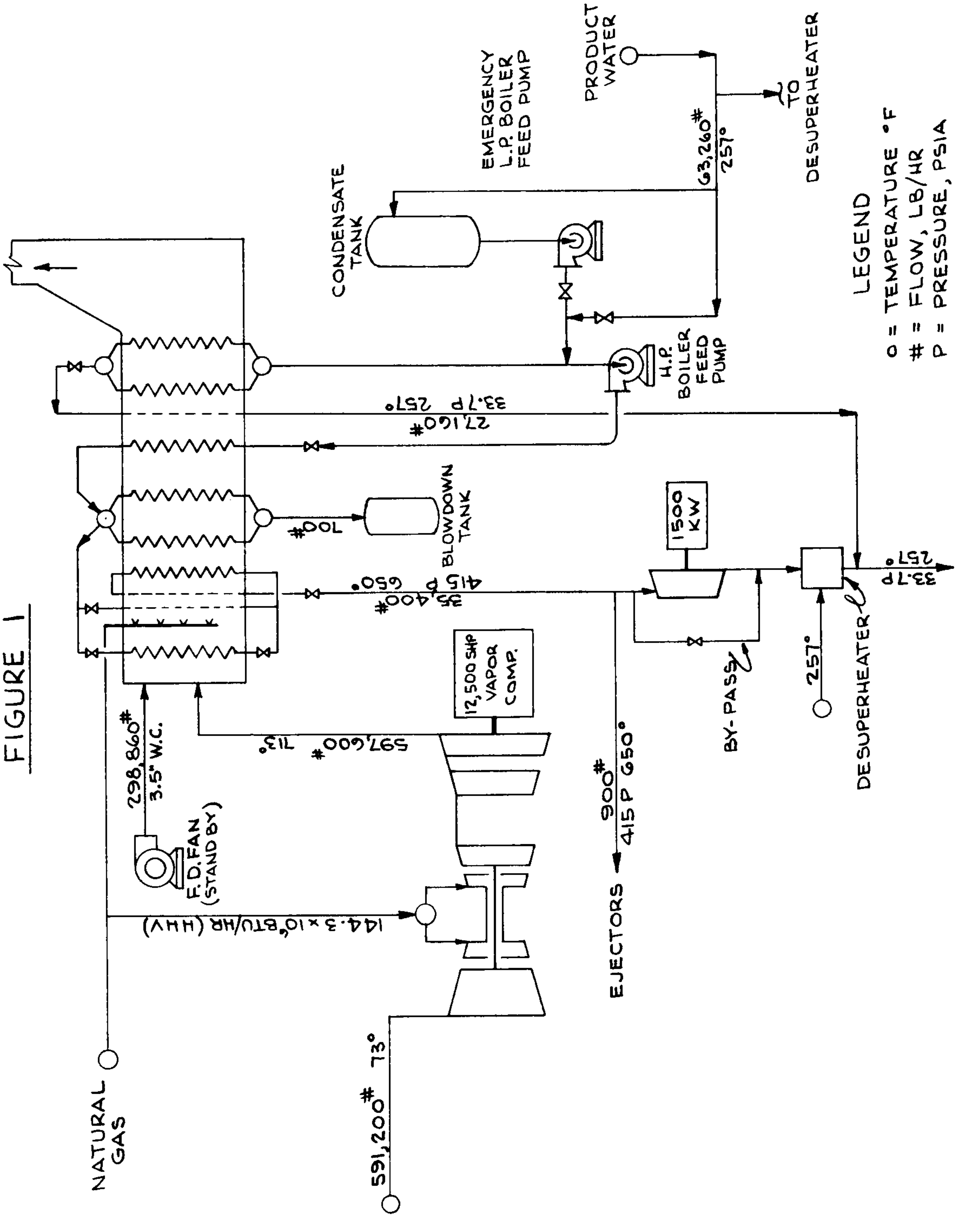
15. Percent Steam in Economizer ______________________

TECHNICAL DATA

STEAM GENERATOR DATA:

1. Heating Surface: Sq.ft.)
    - a. HP Boiler ____________
    - b. LP Boiler ____________
    - c. Superheater ____________
    - d. Economizer ____________
2. Design Pressure
    - a. Boiler Casing, "H_2O ____________
    - b. HP Boiler, psi ____________
    - c. Superheater, psi ____________
    - d. Economizer, psi ____________
    - e. LP Boiler, psi ____________
3. Net Weights, lb.(not shipping weight)
    - a. Structural steel supports ____________
    - b. One (1) steam generating unit complete (except structural steel supports, refractories & insulation) ____________
    - c. Refractories and Insulation ____________
    - d. Ducting and stacks ____________
    - e. Total Net Weight ____________
4. Burners
    - a. Number of burners required ____________
    - b. Type of burners ____________
    - c. Manufacturer of burners ____________
    - d. Size (MFR.'s rating) Btu/hr ____________
    - e. Igniter rating, Btu/hr. ____________

FIGURE 1



POWER AND PROCESS STEAM FACILITY FLOW DIAGRAM DESIGN POINT	DRAWN BY	GEORGE WIEDMAIER 5-29 68	DWG NO	REV.
	CHECKED BY	HW		
	SCALE			

1.6 SPECIFICATIONS FOR STEAM TURBO GENERATOR

A. General

The specification covers the requirement for one steam turbo generator unit which will furnish auxiliary power. The unit is part of a gas turbine driven vapor compression desalination plant.

B. Operation

The steam turbine generator shall be a back pressure machine with a guaranteed output at the generator terminals of 1500 kw. The throttle flow for this generation shall be 34,500 #/hr with a throttle pressure and temperature of 400 psig and 650°F respectively and an exhaust pressure of 19 psig saturated.

One air cooled generator matched to the turbine shall be furnished with a minimum reactive capability of 1875 kva, 3 phase,60 cycle, 480 volts, .80 scr. This generator shall be able to operate continuously at 110% of the guaranteed turbine output. The generator to be provided with a brushless exciter with separately mounted static voltage regulator.

Six leads to be brought out from the generator to allow installation of current transformers for differential protection and for making up the neutral connection for solid neutral grounding.

The generator to have a ventilating and cooling system including shaft mounted ventilating fans.

The generator to be provided with space heaters with remote mounted temperature meter with transfer and test switch.

The turbo generator unit to be a direct connected machine, with suitable speed reduction gear provided and designed in accordance with AGMA Standards.

The turbo generator unit to be suitable for mounting as a unit on a one-piece base and suitable for outdoor installation and operation.

C. Accessories

The turbine shall include the following accessories:

1. A shaft-mounted main oil pump with oil supply reservoir and oil level indicator.

2. Two full capacity lubricating oil coolers designed for water inlet conditions of 95°F and 125 psig.

3. Two full capacity lubricating oil filters.

4. Turbine driven auxiliary oil pump with automatic starting device controlled by the system oil pressure capable of supplying sufficient oil for lubrication and control purposes.

5. Low bearing oil pressure trip device and trip alarm.

6. Constant speed oil-relayed governor and governor oil pump.

7. A low oil level trip alarm.

8. Piping between all components, complete with all necessary valves, strainers, orifices, etc., and necessary pressure gages and switches.

9. Terminal boxes on all motors.

The generator control accessories mounted on an indoor low voltage drawout switchgear equipment to include the following accessories:

1. One low voltage drawout power circuit breaker, 3000 amperes, electrically operated, 48 volt DC control with shunt trip and without series over-current trip devices.

2. Seven current transformers (3 for circuit relaying and metering, 3 for differential relays, 1 for voltage regulator). A terminal box complete with shorting type terminal blocks to be furnished near the bushing current transformers.

3. Three over-current relays with voltage restraint for generator external fault back-up protection.

4. Three differential relays with high speed sensitivity for generator internal fault protection.

5. One manual reset lockout relay to assure reset of a tripped protective relay prior to reclosing main circuit breaker.

6. One manual reset field lockout relay to assure reset of a tripped protective relay prior to reclosing field circuit breaker.

7. Three potential relays (2 for metering, 1 for voltage regulator).

8. One control power transformer for voltage regulator.
9. One static voltage regulator and field forcing panels.
10. One generator over-voltage relay to limit over-voltage occurring on sudden load changes.
11. One over-frequency relay to limit over speed during an abnormal operating condition of the prime mover.
12. One ground relay for ground-fault protection on a grounded-neutral system.
13. One field ammeter.
14. One generator ammeter with switch.
15. One generator voltmeter with switch.
16. One generator wattmeter.
17. One generator varmeter.
18. One generator frequency meter
19. One temperature meter with transfer and test switch.
20. One voltage adjusting rheostat.
21. One set of terminals for incoming line.

The generator accessories remote to the switchgear cubical to be as follows:

1. Four current transformers at generator neutral terminals for differential and ground relaying, a terminal box complete with shorting type terminal blocks to include the above.
2. One 48 volt DC plant type battery and automatic voltage regulated charger.
3. Three lightning arresters.
4. Three capacitors
5. Two clamp type grounding terminals bolted to machine frame.
6. Rotor-lifting devices complete with cables and slings.
7. Auxiliary panels, switchgear and motors shall be shop painted for installation in outdoor enclosure. Finish color to be a standard ASA color, to be specified later.
8. Necessary sole plates complete with shims and wedges.

D. Design and Construction

The unit and accessories shall be designed and constructed in accordance with all applicable sections of the latest editions of the Standards of the ASME, IEEE, NEMA, TEMA, ASA and ASTM, and any laws or regulations having jurisdiction over such apparatus.

E. Performance

1. The quality of workmanship and materials will be first class in every respect, that the equipment will be entirely suitable for the purpose intended, that all equipment and materials will comply with any and all codes applicable, and that the turbine performance will not be less than stated in this specification.

2. Performance graphs and diagrams to include the following:

   (a) Gland leakages
   (b) Generator and mechanical losses
   (c) Basic pressure correction
   (d) Initial pressure correction
   (e) Initial temperature correction
   (f) Generator reactive capability.
   (g) Generator saturation
   (h) Generator "V"
   (i) Water rate lb steam/kwh

3. The steam turbine and generator to conform to the attached specifications.

F. Tools

Special maintenance tools as required to be furnished. Tools shall be new first class quality, and shall be shipped to the job in separate containers clearly marked with the name of the equipment for which they are intended.

G. Shipment Preparation

The equipment shall be subassembled prior to shipment to permit minimum field labor insofar as shipping restrictions permit. A list of subassemblies shall be furnished for approval after award.

All finished surfaces and electrical equipment shall be protected against weather, rust and mechanical damage.

All shell openings and pipe connections shall be protected by plugs or covers. All threaded connections shall be provided with thread protectors.

STEAM TURBINE - GENERATOR DATA SHEETS

TURBINE

Type and Model No.

Rated output, KW

Last stage blade length/tip velocity

Speed

Annulus area of last stage

Steam connections, number/size

H. P. Inlet

H. P. Output

Steam valves, number/size

Main Steam Stop

Governor controlled Inlet

Maximum crane lift required, operating floor to centerline of hook

Total shipping weight, complete unit

Heaviest piece during erection, name/weight

Heaviest piece after erecting, name/weight

GENERATOR

Type and Model No. ____________________

Output ____________________

Speed ____________________

Power Factor ____________________

Voltage ____________________

Voltage Regulation @ 1.0 P.F./0.9 P.F.(%) ____________________

Generator reactance, KVA Base (%) ____________________

Synchronous direct (sat/unsat)X'd ____________________

Transient direct (sat/unsat)X'd ____________________

Subtransient direct (sat/unsat)X'd ____________________

Short circuit ratio ____________________

EXCITER

Type and Model No. ____________________

Rated output, KW ____________________

Voltage at mas. gen. output/ceiling voltage ____________________

Current at max. output/max. excitation ____________________

Speed, rpm ____________________

Nominal speed of response ____________________

1.7 SPECIFICATION FOR VERTICAL PUMPS

A. General

This specification covers the requirements for vertical pumps which will be part of a vapor compression desalination plant. The pumps to be half capacity with two pumps operating in parallel and one pump as standby to allow outage for repairs.

B. Design and Construction

The vertical pumps to be complete with motor drivers integrally mounted on a structural steel base located below nozzles. Pump requirements shall be as follows:

1. The pump discharge to be designed for surface discharge with flanged connection.
2. Pumps for seawater and brine service to be the flooded oil tube type construction since it is desirable to exclude water from the oil tube. Distillate pumps may be water lubricated. Design to follow manufacturer's recommendations.
3. Each pump unit shall be provided with a self-contained lube oil system servicing both the pump and its driver.
4. Pumps and drivers shall be connected with a forged steel gear type flexible coupling or manufacturer's standard. Couplings shall be bored and key sealed to fit pump and drive shafts.
5. Pump seals shall be packing gland type.
6. The pump and driver shall be free from undue vibration and shall withstand all stresses that may be developed throughout the entire operating range as well as stresses due to full load starting.
7. Critical speed shall be a safe margin above operating speed.
8. Pumps and drivers shall be suitable for outdoor installation without protective covering.
9. The head developed by the parallel pumps shall rise continuously from maximum capacity to shutoff, such that two pumps connected in parallel shall perform with stability and without operating difficulty.

10. Materials of construction of pumps for seawater and brine service to be Type II Ni-resist casings or CK-20 Alloy, Type 316 stainless steel shafts and impellers. Materials for distillate service to be cast iron, bronze fitted.

11. Pumps to include motors, less starters, and shall be T.E.F.C., NEMA B Classification. Power at 460 volts is available. On large horsepower motors 2400 and 4160 volt power to be considered.

C. Pump Requirements

The following vertical pumps covered by the above specifications to include a tank enclosing the vertical pump:

Service	Total Number Pumps Required	Capacity Per Pump lb/hr	Total Dynamic Head Ft.	NPSH Avail. At Inlet Flange, Ft.	Suction Fluid Temp. °F
1. Deaerated Seawater Feed	4	1,833,300	261	1'	108
2. Distillate	3	1,428,000	112	4'	102
3. Brine Blowdown	3	1,667,000	58	4'	104

The following vertical pumps not to include an enclosing tank:

Service	Total Number Pumps Required	Capacity Per Pump lb/hr	Total Dynamic Head Ft.	NPSH Avail. At Inlet Flange, Ft.	Suction Fluid Temp. °F
1. Raw Seawater Feed*	3	2,975,000	117	30'	85
2. Screen Wash Pump*	2	67,000	230	30'	85

* Distance from pump baseplate to inlet bell is 12'

CENTRIFUGAL PUMP AND MOTOR DATA SHEET

Pump

Manufacturer ____________________
Type and Size ____________________
Weight ____________________
Flow Normal/Design ____________________
Pressure Suction/Discharge ____________________
NPSH Available/Required ____________________
Suction Connection ____________________
Discharge Connection ____________________
RPM ____________________
Rating ____________________
Efficiency (At Rating) ____________________
No. of Stages ____________________
Lubrication ____________________
Cost ____________________

Driver

Manufacturer ____________________
Type and Size ____________________
HP ____________________
Weight ____________________
RPM/Voltage/Phase ____________________
Cost ____________________

1.8 SPECIFICATION FOR BOILER FEED PUMP

A. General

This specification is for cost estimating of three, half capacity boiler feed pumps required for a single purpose gas turbine powered desalination plant. For bidder's convenience, the uncompleted portions of the specification may be filled out and returned as their quotation.

B. Description

Applicable to one half capacity pump. One centrifugal pump size ________ type ________, horizontal, split case, enclosed impeller, complete with bearings and lube system, including motor and pump mounted on a common base plate with drip lip, steel coupling guard, Falk type flexible coupling for direct connect to ________ hp motor.

C. Process Specifications (Per Pump)

Fluid circulated	Boiler Feed Water
Flow rate, gpm	32
Operating temperature, °F	257
Specific gravity	.942
Total dynamic head, ft.	1080
NPSH available, ft.	21
Suction pressure, psig	28
Efficiency, %	________
Brake horsepower	________
Motor horsepower	________
Section nozzle, in. _____	Type
Discharge nozzle, in.	________
Nozzle flange rating _______	#ASA raised face

Motor

Construction:	TEFC, NEMA B Classification
Volts	460
Phase	3
Cycles	60
hp	________
Speed rpm	________

D. Special Notes

1. Motor to be supplied by ________, mounted by ____________.
2. Motor to be non-overloading over range of impeller selected.
3. Pump to be supplied with the following equipment:

1.9 SPECIFICATION FOR FORCED DRAFT FAN AND DRIVER

A. General

The specification covers the requirement for one forced draft fan and gas engine driver for startup purposes for a gas turbine driven vapor compression desalination plant.

B. Operation

The fan shall be designed for operation at 100° F and 14.7 psia intake air conditions and shall supply 298,800 #/hr air at 3.5" water static pressure at the fan discharge.

C. Ambient Conditions

The fan shall be suitable for outdoor operation at 50 feet elevation. Ambient air temperature ranges from + 32° FDB to + 100° FDB.

D. Design and Construction

The fan to be a single inlet non-overloading centrifugal type directly connected to a gas engine through a combination clutch and speed reducer and coupled with a Dodge Paraflex or equal coupling.

The housing shall be of steel plate not less than 3/16 inch thick and securely braced to insure against warping and vibration under all conditions of operation.

An access door to be provided for access to the discharge space. This door to be designed for convenient opening and closing and shall be air tight when closed. A split housing to be provided so that the entire rotating assembly including shaft and bearing can be removed in the event a wheel replacement is required.

A heavy, structural steel base or equivalent construction shall be provided to support the housing structure and the engine. Sufficient bearing surface for blocks and wedges shall be provided for in setting up and leveling.

Open inlets shall be provided with removable split screens of rigid construction which shall be attached to the housing so as to avoid all vibration. These screens shall be of 1/8 inch hot dipped galvanized wire with 2 inch mesh and shall be placed to give minimum air resistance.

E. Flexible Coupling

Dodge Paraflex or approved equal, flexible coupling shall be furnished, and shall be of ample size to transmit the maximum torque which can be developed under all starting and operating conditions. The bore of the coupling shall not exceed the manufacturer's recommendation.

F. Rotor and Shaft

The rotor shall operate safely at all possible engine speeds without vibration. The rotor shall be both statically and dynamically balanced. The shaft shall be of adequate size and strength to withstand safely all operating conditions including maximum torque experienced from accelerating engine from idle to full speed. The lowest critical speed shall be well above the maximum operating speed. Details of construction of the rotor structure shall be such as to avoid pockets in which foreign matter may accumulate. Non-weldable alloy steel shall not be used in construction of the rotor.

G. Fan Bearings

Bearings shall be a split pillow block type suitable for the service and construction.

H. Engine

The gas engine driver should be a self-contained unit, including the following equipment:

(a) Self-contained cooling water system including water pump, fan, radiator, thermostat, and interconnecting hoses.
(b) Complete lubricating system including a full flow oil filter and cooler if required for continuous operation.
(c) Oil bath air filter.
(d) Exhaust system including muffler and stack adequately protected from weather when engine is shutdown.
(e) Starter motor and switch including 12 volt battery.
(f) Controls and linkages including a manually adjustable throttle, tachometer, oil pressure and water temperature gages.

The fuel will be natural gas and will be supplied to suit at approximately 4 to 6 oz. pressure at the engine carburetor.

The gas engine and components shall be sized to operate continuously at all the ambient condition ranges mentioned in Item C and shall be suitable for the service.

I. Data Sheets

Design of the engine driven forced draft fan to be in accordance with the attached data sheets.

GAS ENGINE DATA SHEET

Type and Model Number ____________________

Operating H.P. ____________________

Operating Speed (RPM) ____________________

Fuel Requirements (#/Hr) @ 20430 $\frac{BTU}{\#}$ LHV ____________________

Engine weight (#) ____________________

Width, Length, Height (Ft.) ____________________

Number of Cylinders ____________________

Cylinder Arrangement ____________________

Cylinder Base/Stroke (In.) ____________________

Displacement (Cu.In.) ____________________

Compression Ratio ____________________

F. D. FAN DATA SHEET

Type and Model Number	
Flow (#/hr)	298,800
Pressure Rise (In. H_2O)	3 1/2"
Speed (RPM)	
Width, Length, Height (Ft.)	
Weight of Fan Housing Complete (#)	
Housing Discharge Size (Ft.)	
Intake Size (Ft.)	
Fan Tip Speed Operating (FPM)	
Fan Tip Speed Maximum (FPM)	
Bearing Type	Heavy Duty Anti-Friction
Lubricating Requirements	
Bearing Cooling Requirements	NONE

1.10 SPECIFICATIONS FOR GAS ENGINE GENERATOR

A. General

This specification covers the requirement for one gas engine generator for standby auxiliary power for a gas turbine driven vapor compression desalination plant.

The generator set to consist of a gas engine directly coupled to an electric generator, together with the necessary switchgear, controls and accessories, to provide continuous electric power into an existing power network.

The standby generator set shall be started and switched on the load manually.

B. Operation

The generator set shall be rated for 100 kw, 480 volts, 3 phase, 60 cycle, 4 wire, .80pf.

The load to be served by the generator set consists of 40 kw non-inductive load plus 80 hp motor load. The maximum motor horsepower to be started at one time is 20 hp.

The gas engine would be a self-contained unit suitable for operation on natural gas and will be supplied at the pressure designated by the bidder. The heating value of the fule is 20,430 btu/lb. LHV.

C. Design and Construction

The gas engine driver shall be a self-contained unit, including the following equipment:

a. Engine cooling shall be an integral radiator type using water coolant.

b. Complete lubricating system as required for continuous operation.

c. An oil bath air cleaner and silencer, as recommended by the bidder.

d. Exhaust system including muffler and stack adequately protected from weather and personnel suitable for moderate silencing. The muffler shall be located at the engine.

e. Starter motor including a 12 volt battery.

f. Controls and linkages including a manually adjustable throttle, tachometer, oil pressure and water temperature gages.

g. The gas engine shall be provided with high water temperature, over-speed alarm lights with audible alarm, and system shutdown.

The generator shall be engine driven, single bearing, synchronous, brushless conforming to applicable NEMA standards. It shall be connected to the engine flywheel by means of a flexible disc-type coupling, and shall include the following panel-mounted equipment:

a. Circuit breaker
b. Voltage regulator
c. AC ammeter
d. AC voltmeter
e. Frequency meter
f. Manual start-stop control

GAS ENGINE GENERATOR DATA SHEET

Gas Engine

Type and Model No. ____________________

Operating HP ____________________

Operating Speed (RPM) ____________________

Fuel Requirements, #/hr, @ 20,430 Btu/lb LHV ____________________

Overall Dimensions ____________________

Number of Cylinders ____________________

Cylinder Base/Stroke (in.) ____________________

Displacement (cu.in.) ____________________

Compression Ratio ____________________

Generator

Type and Model No. ____________________

Output ____________________

Speed ____________________

Power Factor ____________________

Voltage ____________________

Voltage Regulation % ____________________

Frequency Regulation % ____________________

1.11 SPECIFICATION FOR VTE TUBES

The VTE tubes to be in accordance with the following specifications:

Type	Longitudinally fluted, inside and out, by rolling, similar to those developed by the General Electric Co. (U.S. Pat. 3,244,601,April 5, 1966)
Material	90-10 Cu.Ni.
Size - at tube ends	3" O.D. x 0.049" wall
- at fluted section	3" O.D. x 0.035" wall
Total Length	12' - 10 3/4"
Active Fluted Length	12' - 6"
Fluted Heat Transfer Area	1.0 ft^2/ft length
Quantity of Tubes	20,560
Spare Tubes Required	10%

FMC CORPORATION

HYDRODYNAMICS DIVISION · PEERLESS PUMP

76 BEAVER STREET, NEW YORK, NEW YORK 10005 · (212) 344-4350
TELEX: 1-2345

Price Quotation No.
Please refer to this number in any order placed with us for this equipment.

Reply to:

201 Penn Center Boulevard
Room 301
Pittsburgh, Pennsylvania 15235
(412) 824-5472

May 28, 1968

Struthers Energy Systems, Inc.
P. O. Box 8
Warren, Pennsylvania - 16365

ATTENTION: HAL WIGHTMAN, PROJECT ENGINEER

Re: Saline Water Project

Gentlemen:

We are offering the following Peerless Pumps for your consideration:

Item 1 Sea Water Feed Pump (3 required)

Capacity:	5500 GPM
Head:	261 Feet

The pump will consist of the following:

Motor:	500 HP, 1800 RPM, 3 phase, 60 cycle, 460 volt, vertical solid shaft T.E.F.C. motor.
Head:	16" x 20" x 30" HL fabricated steel head.
Barrel:	30" x 19'-4" long of fabricated steel.
Column:	16" x 13' long in 5' sections flanged steel including 304 SS spiders and 1-15/16" shafting (17-4 PH ss steel)
Bowl Assembly:	16 HH, 4 stage, NiResist Bowls, 316 SS impellers, 17-4 PH impeller shaft and carbon bearings.

The water passages in the head, barrel and the column will be coated with Macor coating with a 20 ML thickness.

The pump as described will cost $14,633.00 net each.

The motor as described will cost $13,058.00 net each.

Item 2 Distillate (3 required)

Capacity: 2850 GPM
Head: 112 Feet

The pump will consist of the following:

Motor: 125 HP, 1800 RPM, 3 phase, 60 cycle, 460 volts, vertical solid shaft, T.E.F.C. motor.

Head: 10" x 14" x 20" HL fabricated steel head.

Barrel: 20" x 11'-6" long fabricated steel.

Column: 12" x 8' long in 5' sections flanged steel including 304 spiders and 1-11/16" 316 SS shafting.

Bowl Assembly: 14 HH, 2 stage, cast iron bowls, bronze impellers and 316 SS impeller shaft.

The pump as described will cost $4,636.00 net each.

The motor as described above will cost $2,509.00 net each.

Item 3 Brine Blowdown (3 required)

Capacity: 3340 GPM
Head: 58 Feet

Motor: 75 HP, 1800 RPM, 3 phase, 60 cycle, 460 volts, vertical solid shaft, T.E.F.C. motor.

Head: 12" x 16" x 24" HL fabricated steel head.

Barrel: 24" x 18'-2" long fabricated steel.

Column:	14" x 16' long in 5' sections, flanged steel including 304 SS spiders, 1½" SS shafting.
Bowl Assembly:	16 HXB, 1 stage, NiResist Bowls with 316 SS impellers and 316 SS impeller shaft.

The water passages in the head, barrel and the column will be coated with Macor coating with a 20 ML thickness.

The pump less motor as described will cost $8,682.00 net each.

The motor as described will cost $1,549.00 net each.

Item 4 Raw Sea Water Feed (3 required)

Capacity:	5950 GPM
Head:	117 Feet

Motor:	250 HP, 1800 RPM, 3 phase, 60 cycle, 460 volts, vertical hollow shaft motor.
Head:	14" x 14" x 20" fabricated steel head.
Column:	14" x 3" x 1-15/16" oil lubricated column and shafting. The column will be 14" flanged with 3" extra heavy tubing and 1-15/16" 316 SS shafting suitable for the 12' overall length as shown in the specifications.
Bowl Assembly:	16 HH, 2 stage, NiResist Bowl assembly with 316 SS impellers and 316 SS impeller shaft.

The unit will be factory assembled for shipment to a domestic destination.

The pump as described will cost $6,647.00 net each.

The motor as described will cost $6,193.00 net each.

Item 5 Screen Wash Pump (2 required)

Capacity: 134 GPM
Head: 230 Feet

Motor: 15 HP, 1800 RPM, 3 phase, 60 cycle, 460 volt, vertical hollow shaft motor.

Head: 4" x 4" x 12 fabricated steel head.

Column: 4" x 1½" x 1" oil lubricated column and shafting. The column assembly will be 4" flanged with 1½" extra heavy tubing and 1" 316 SS shafting suitable for the 12' overall length as shown in the specifications.

Bowl Assembly: 7 LB, 10 stage, NiResist bowl assembly with 316 SS impellers and 316 SS impeller shaft.

The Pump as described will cost $3,840.00 net each.

The motor as described will cost $432.00 net each.

Alternate Item 1 - (4 units)

Capacity: 3680 GPM
Head: 261 Feet

Motor: 300 HP, 1800 RPM, 3 phase, 60 cycle, 460 volt, vertical solid shaft, T.E.F.C. motor.

Head: 14" x 16" x 22" fabricated steel head.

Barrel: 22" x 20' long of fabricated steel.

Column: 12" x 13' long in 5' sections flanged steel including 304 SS spiders 1-15/16" shafting (17-4 PH SS steel).

Bowl Assembly: 16 MC, 4 stage, NiResist bowls with 316 SS impellers and 17-4 PH shaft and carbon bearings.

The water passages in the head, barrel and the column will be coated with Macor coating with a 20 ML thickness.

The pump as described will cost $11,730.00 net each.

The motor as described will cost $6,793.00 net each.

The Macor 547 coating is a Fumarie-Epoxy coating applied to 20 MILS thick. After application it is cured at 70^{O}F for 5 days or at 125^{O}F for 1 day. Damaged surfaces can be patched and the surface smoothness is good. Macor 547 can be applied to rough or machined cast iron, bronze, or fabricated steel. Removal of the coating is accomplished by sand blasting. It can be used with liquids to 250^{O}F and is especially good on parts exposed to sea water.

Item 6 Low Pressure Condensate Pump

Capacity: 64 GPM
Head: 82 Feet

Peerless 3 x 1½ x 10½ (A-50) and cast iron case, bronze impeller, SS shaft sleeve, horizontal end suction pump, complete with base (drip rim), coupling Falk T-31, coupling guard, and 5 HP, 1800 RPM, 3 phase, 60 cycle, 460 volt, TEFC horizontal motor.

The unit as described above will include motor and will cost $607.00 net each.

Item 7 Boiler Feed Pump (3 required)

Capacity: 32 GPM
Head: 1080 Feet TDH

Motor: 50 HP, 3600 RPM, 3 phase, 60 cycle, 460 volt, vertical solid shaft, T.E.F.C. motor.

Peerless 1½" x 3" x 10" VDM, 7 stage vertical high pressure pump.

Head: Carbon steel, ASTM-A7-58T.

Barrel:	Carbon steel, ASTM-A7-58T.
Bowl Assembly:	Cast iron bowls with bronze impellers, carbon bearings, 416 SS impeller shaft.

The unit as described will cost $2,769.00 net each.

The motor as described will cost $1250.00 net each.

The performance of this pump will be as shown in Curve #2835751.

Prices quoted are F.O.B. factory Los Angeles, California with freight prepaid and allowed to Texas Gulf Coast.

Terms are net 30 days.

State and local taxes are not included.

Delivery 14-20 weeks from receipt of purchase order and written permission to proceed with fabrication.

This quotation is for acceptance within thirty (30) days from date herein, but in the meantime, prices may be changed upon proper notice.

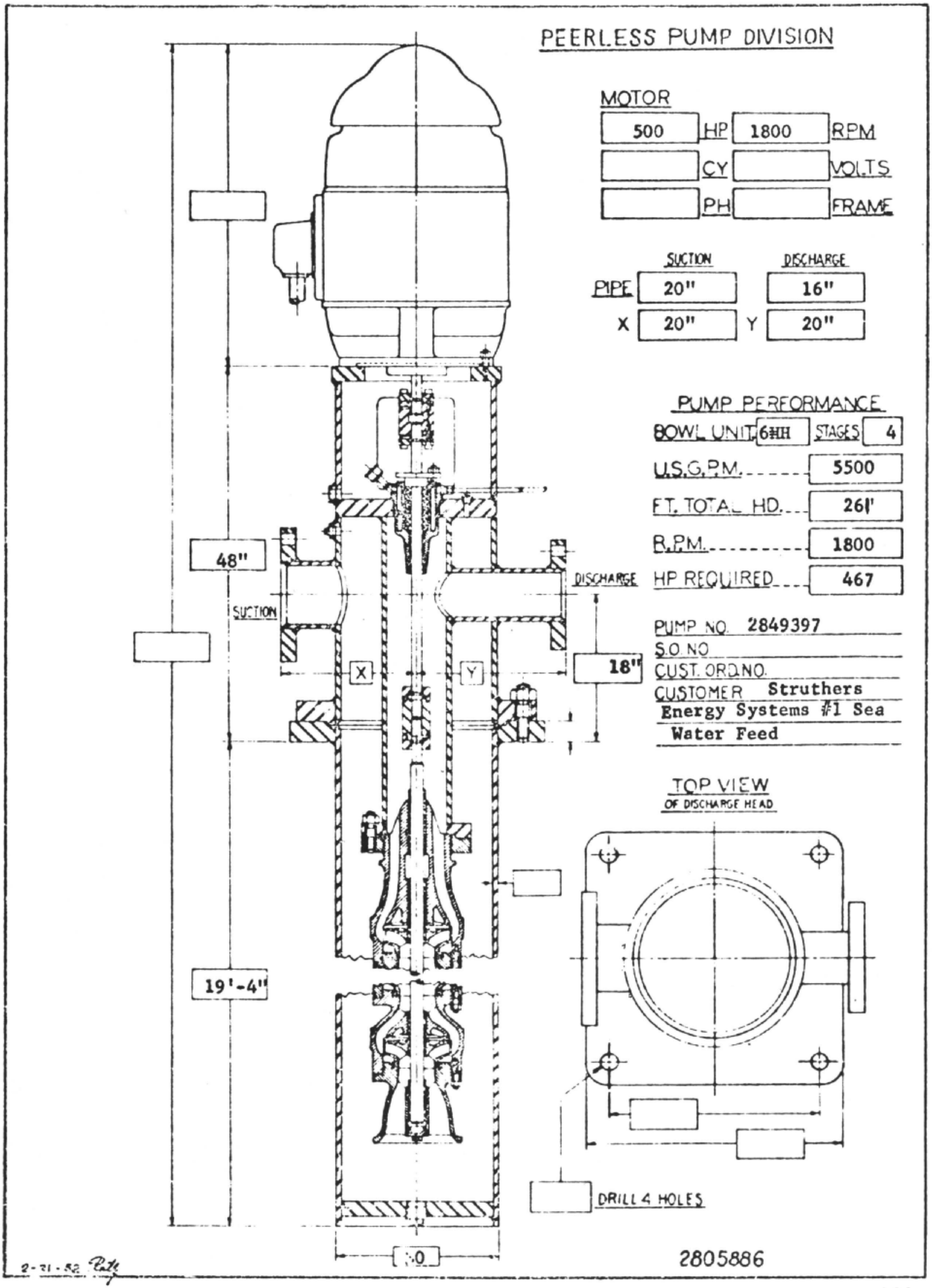
If we may be of further service, please do not hesitate to contact us.

Yours very truly,

Walter D. Nea

Walter D. Nea

WDN/vrc



PEERLESS PUMP DIVISION

MOTOR

500	HP	1800	RPM
	CY		VOLTS
	PH		FRAME

	SUCTION		DISCHARGE
PIPE	20"		16"
X	20"	Y	20"

PUMP PERFORMANCE

BOWL UNIT 6HH STAGES 4

U.S.G.P.M. 5500

FT. TOTAL HD. 261'

R.P.M. 1800

HP REQUIRED 467

PUMP NO. 2849397

S.O. NO

CUST. ORD.NO.

CUSTOMER Struthers Energy Systems #1 Sea Water Feed

TOP VIEW
OF DISCHARGE HEAD

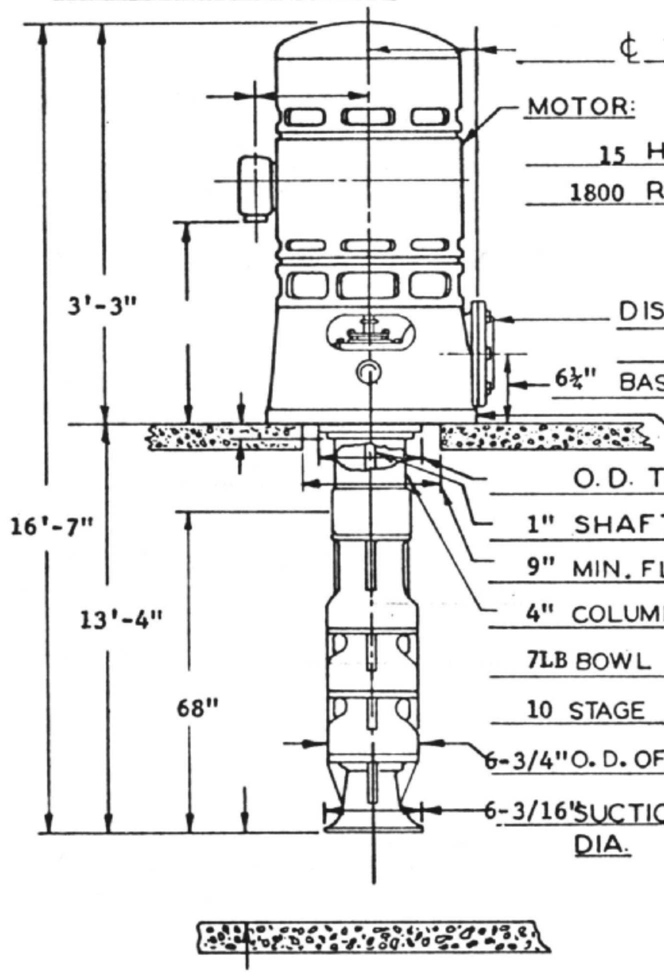
2805886

2-21-52 Pate

FORM NO. 2 82 9005

PEERLESS PUMP

CLOSE COUPLED
SURFACE DISCHARGE
℄ TO FACE OF FLANGE

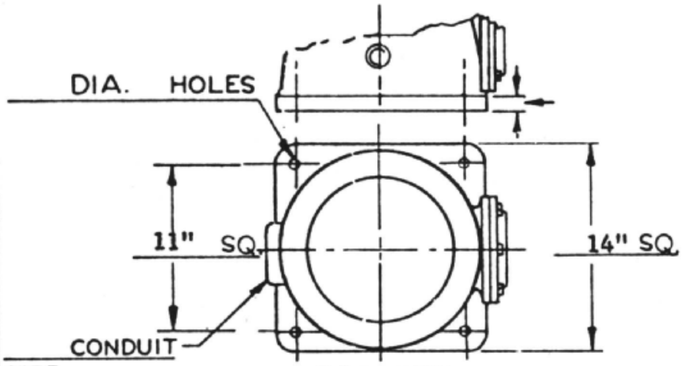


MOTOR: MFR. TYPE
15 H.P. CY. VOLTS
1800 R.P.M. PH. FRAME

DISCHARGE COMPANION FLANGE FOR:

6¼" BASE TO ℄ OF DISCHARGE
4x4x12 DISCHARGE HEAD
O. D. TOP COL. FLANGE
1" SHAFT
9" MIN. FLOOR OPENING
4" COLUMN
7LB BOWL UNIT ASSEMBLY
10 STAGE
6-3/4" O. D. OF BOWLS
6-3/16" SUCTION BELL DIA.

PUMP RATING
G.P.M. 134
FT. FIELD HD. 230



TOP VIEW

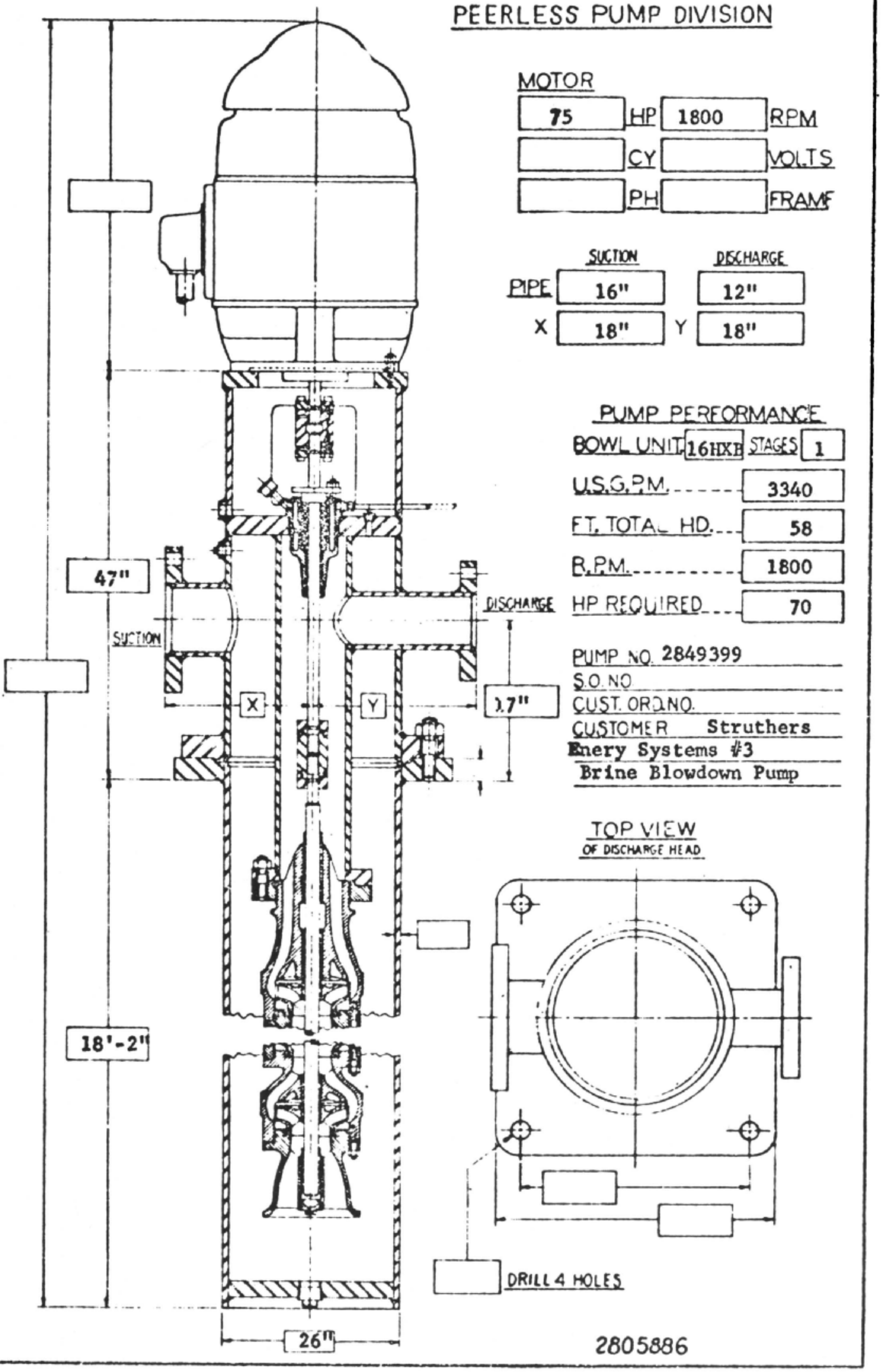
HYDRODYNAMICS DIVISION
PEERLESS PUMP
Los Angeles 31, Calif • Indianapolis 8, Ind

S.O. NO.
SOLD TO: Struthers Energy Systems
ORDER NO.
USER
ITEM NO. 2849401
PUMP IDENTIFICATION:

THIS CERTIFIED PRINT
☐ FOR APPROVAL
BY ________ DATE ________
☐ FOR CONSTRUCTION
BY ________ DATE ________

DRN. BY: J. C. CHK'D BY: DATE: 4-9-68

PUMP NO. 2849401



PEERLESS PUMP DIVISION

MOTOR

75	HP	1800	RPM
	CY		VOLTS
	PH		FRAME

	SUCTION		DISCHARGE
PIPE	16"		12"
X	18"	Y	18"

PUMP PERFORMANCE

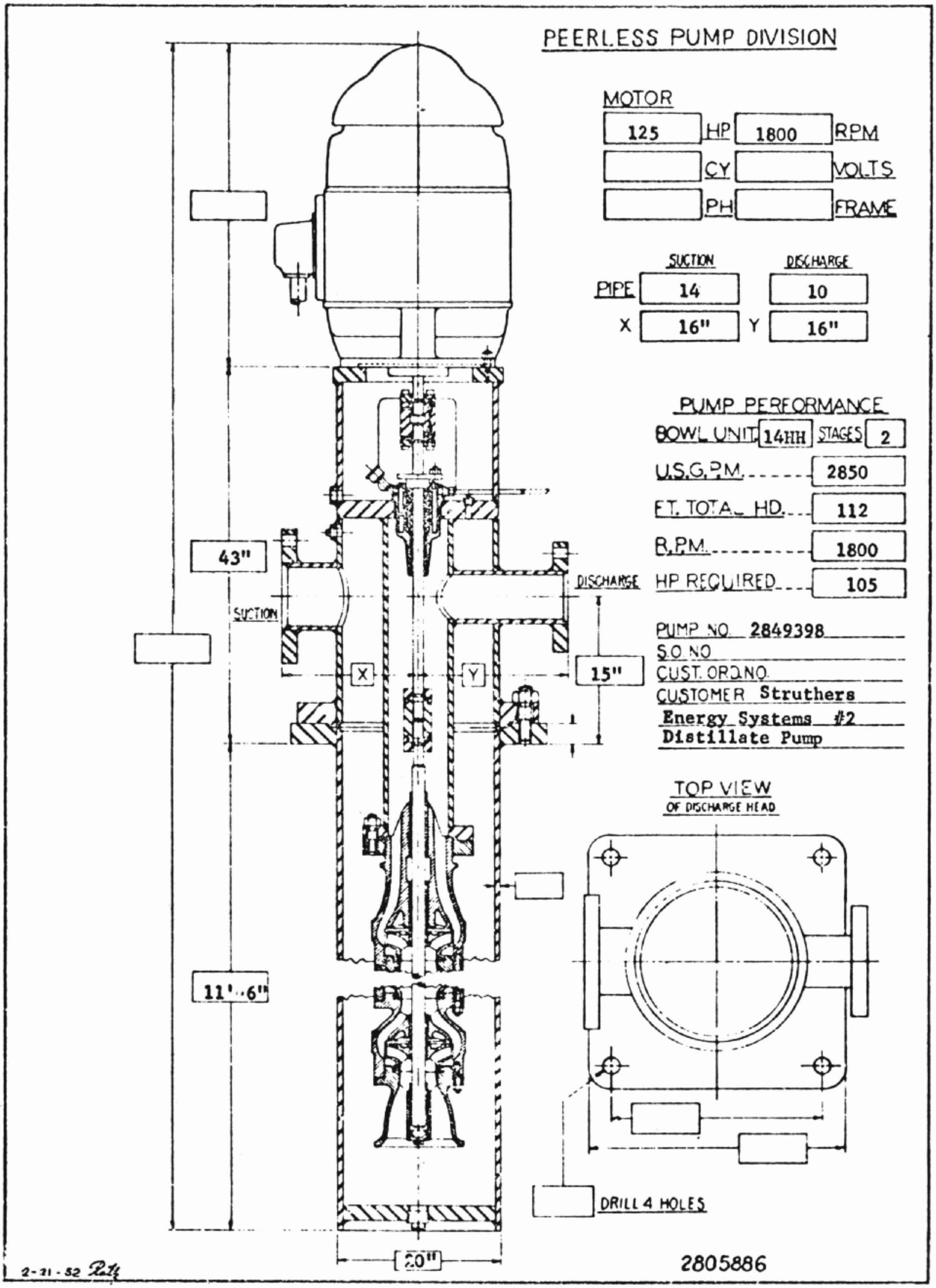
BOWL UNIT	16HXB	STAGES	1
U.S.G.P.M.	3340		
FT. TOTAL HD.	58		
R.P.M.	1800		
HP REQUIRED	70		

PUMP NO. 2849399
S.O. NO.
CUST. ORD. NO.
CUSTOMER Struthers
Enery Systems #3
Brine Blowdown Pump

TOP VIEW
OF DISCHARGE HEAD

2805886

2-21-52 Pati



PEERLESS PUMP DIVISION

MOTOR

125	HP	1800	RPM
	CY		VOLTS
	PH		FRAME

	SUCTION	DISCHARGE
PIPE	14	10
X	16"	
Y		16"

PUMP PERFORMANCE

BOWL UNIT 14HH STAGES 2
U.S.G.P.M. 2850
FT. TOTAL HD. 112
B.P.M. 1800
HP REQUIRED 105

PUMP NO. 2849398
S.O. NO
CUST. ORD. NO.
CUSTOMER **Struthers Energy Systems #2 Distillate Pump**

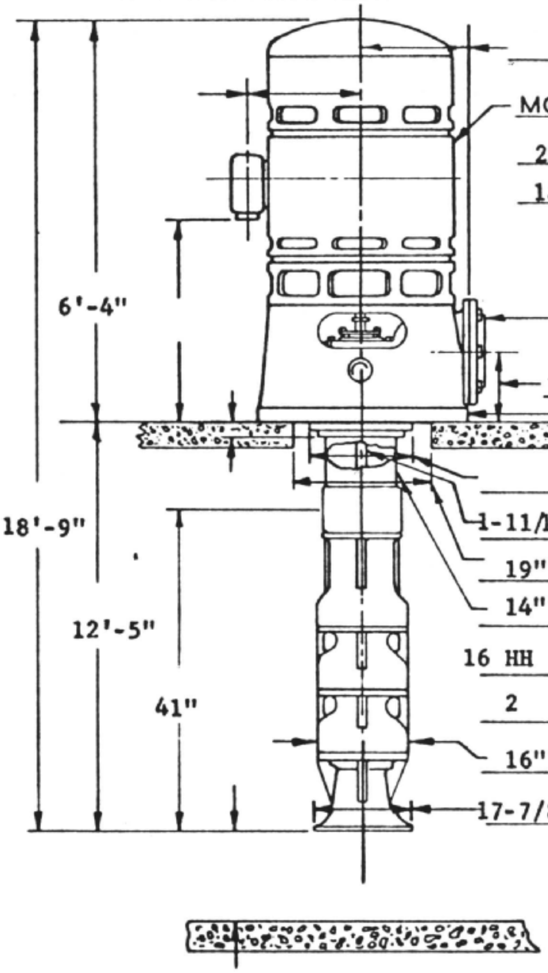
2805886

FORM NO. 2 82 9005

PEERLESS PUMP

CLOSE COUPLED

SURFACE DISCHARGE



℄ TO FACE OF FLANGE

MOTOR: MFR. TYPE

250 H.P. CY. VOLTS

1800 R.P.M. PH. FRAME

DISCHARGE COMPANION FLANGE FOR:

13" BASE TO ℄ OF DISCHARGE

14x14x20 DISCHARGE HEAD

O. D. TOP COL. FLANGE

1-11/16 SHAFT

19" MIN. FLOOR OPENING

14" COLUMN

16 HH BOWL UNIT ASSEMBLY

2 STAGE

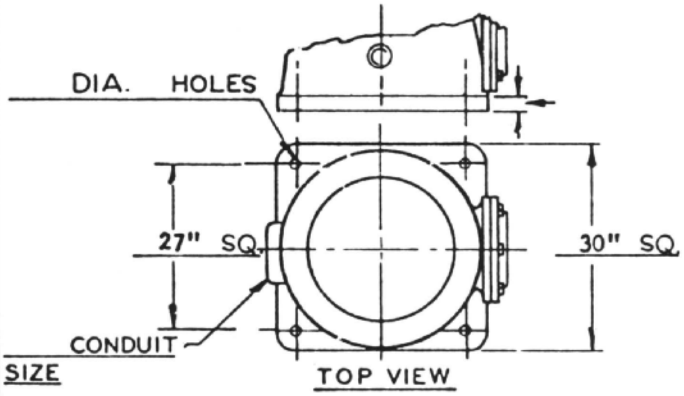
16" O. D. OF BOWLS

17-7/8 SUCTION BELL DIA.

PUMP RATING

G.P.M. 5950

FT. FIELD HD. 117



S.O. NO.

SOLD TO: Struthers
Energy Systems

ORDER NO.

USER [illegible]

ITEM NO. 2849400

PUMP IDENTIFICATION:

THIS CERTIFIED PRINT

☐ FOR APPROVAL

BY ________ DATE ________

☐ FOR CONSTRUCTION

BY ________ DATE ________

HYDRODYNAMICS DIVISION
PEERLESS PUMP
Los Angeles 31, Calif • Indianapolis 8, Ind

DRN. BY J. C. CHK'D BY: DATE: 4-9-68

PUMP NO 2849400

HYDRAULIC PERFORMANCE WARRANTY

Guaranteed at designated point only and is contingent on
1. Proper and adequate flow to pump suction.
2. Proper submergence and NPSH available.
3. Fluid free of gas, air and abrasive matter.
4. Impeller with proper lateral adjustment.

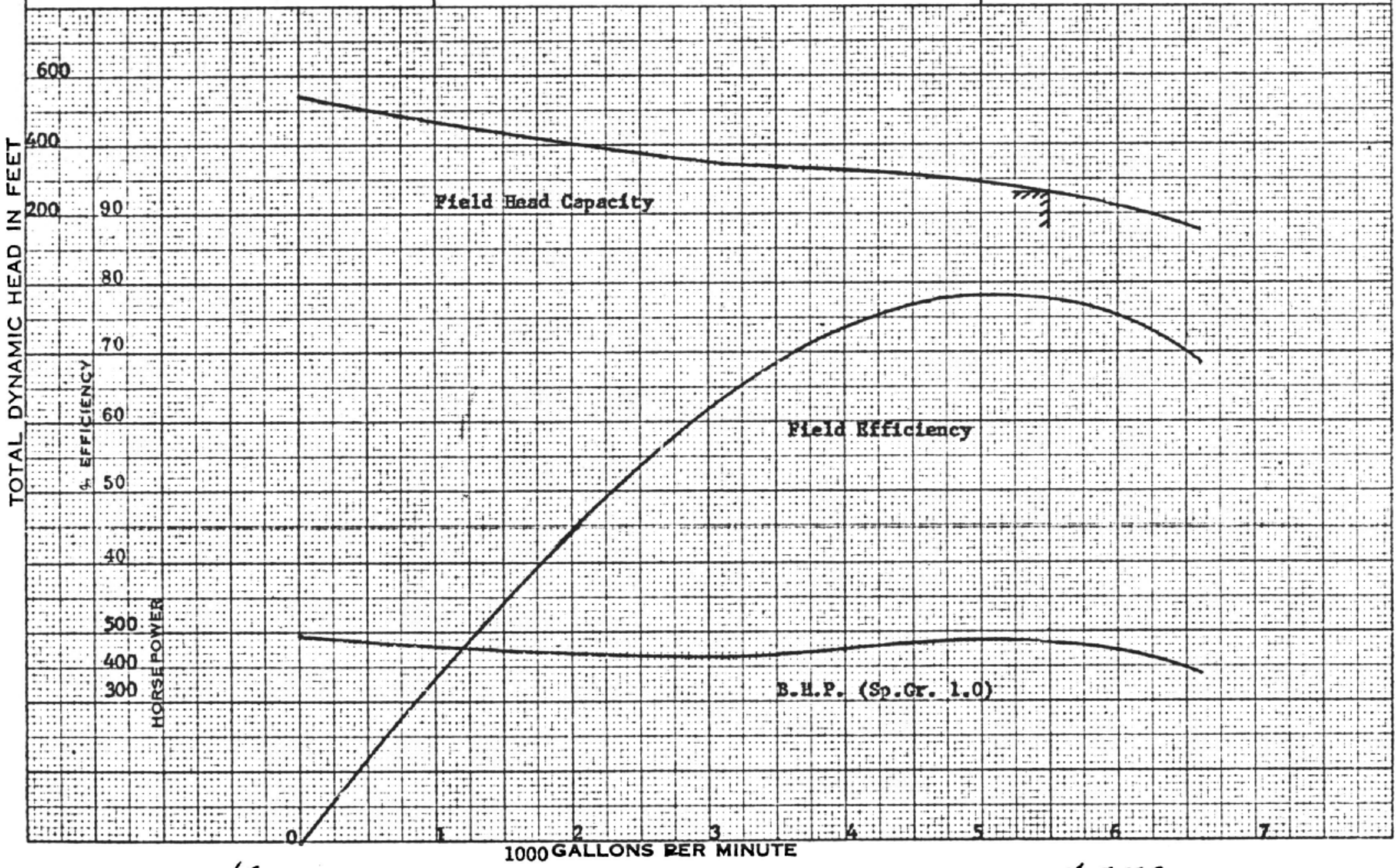
PEERLESS PUMP

HYDRODYNAMICS DIVISION

Los Angeles 31, Calif. • Indianapolis 8, Ind.

FOR STRUTHERS ENERGY SYSTEMS INC.
#1 SEA WATER FEED PUMP

CURVE NO 2849397
PUMP TYPE Hydroline
COLUMN 13' of 16" x1-15/16
BOWL 16 HH STAGES 4
RPM 1775 IMPELLER NO 2620735
PUMP NO S/O NO



PLOTTED BY JCC. FROM TEST NO.

DATE 4-28-68

FORM E-1

HYDRAULIC PERFORMANCE WARRANTY

Guaranteed at designated point only and is contingent on
1. Proper and adequate flow to pump suction.
2. Proper submergence and NPSH available.
3. Fluid free of gas, air and abrasive matter.
4. Impeller with proper lateral adjustment.

fmc CORPORATION

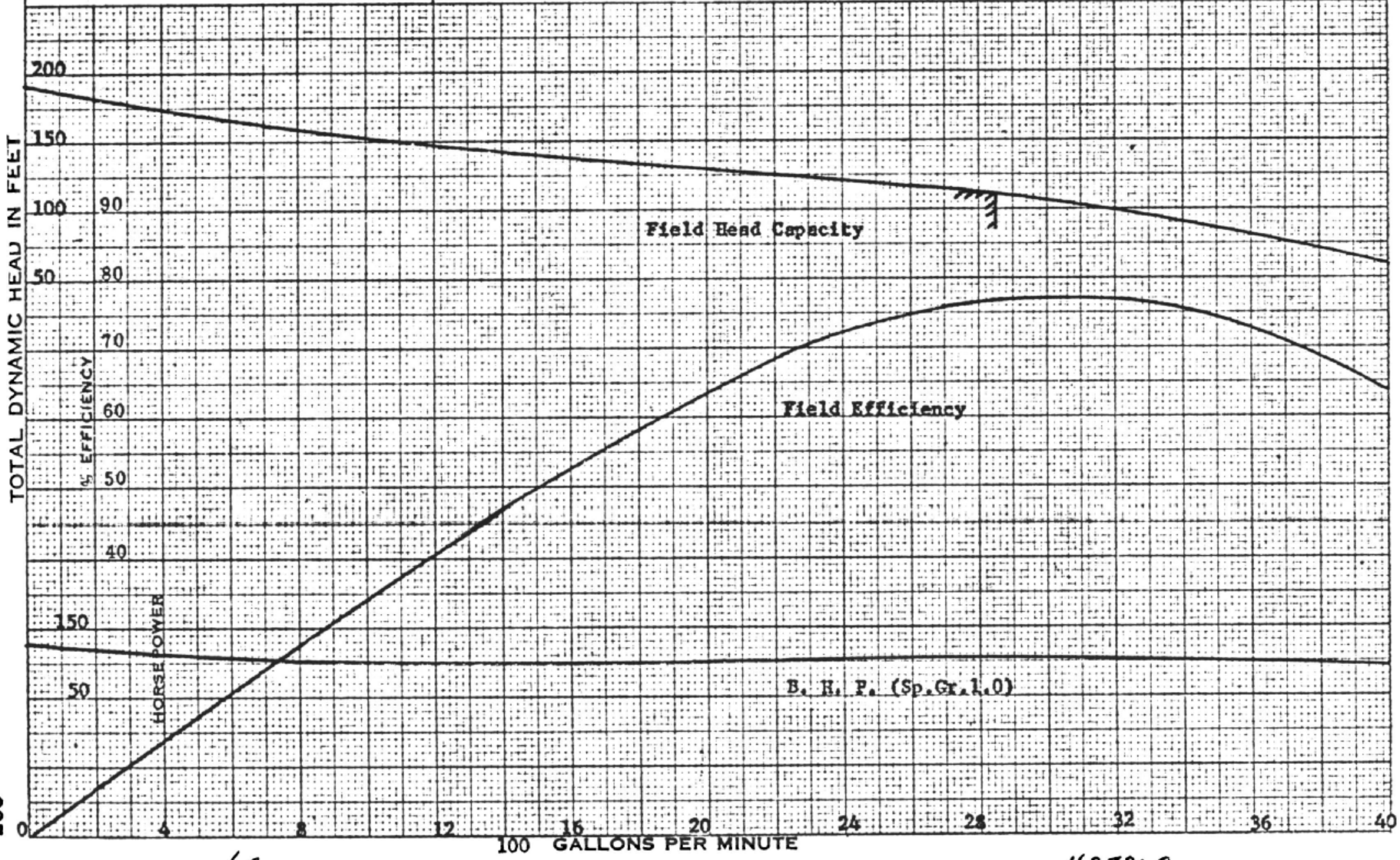
PEERLESS PUMP

HYDRODYNAMICS DIVISION

Los Angeles 31, Calif. • Indianapolis 8, Ind.

FOR STRUTHERS ENERGY SYSTEMS, INC.,
#2 DISTILLATE PUMP

CURVE NO 2849398
PUMP TYPE HYDROLINE
COLUMN 8' of 12" x 1-11/16
BOWL 14 HH STAGES 2
RPM 1770 IMPELLER NO 2621959
PUMP NO ______ S/O NO ______



PLOTTED BY J.E. C. FROM TEST NO. ______ DATE 4-8-68-8 FORM E-1

HYDRAULIC PERFORMANCE WARRANTY

Guaranteed at designated point only and is contingent on
1. Proper and adequate flow to pump suction.
2. Proper submergence and NPSH available.
3. Fluid free of gas, air and abrasive matter.
4. Impeller with proper lateral adjustment.

fmc CORPORATION

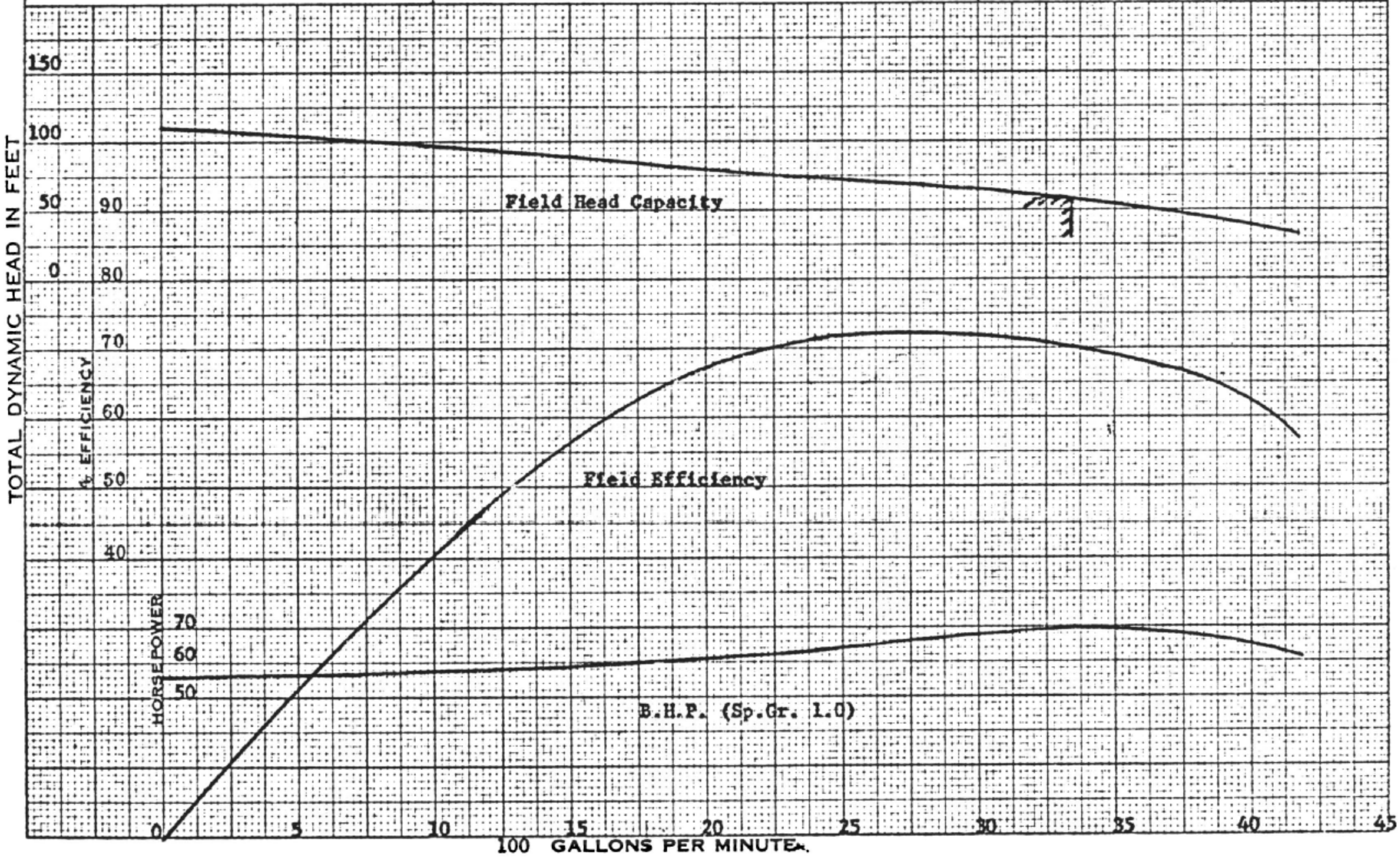
PEERLESS PUMP

HYDRODYNAMICS DIVISION

Los Angeles 31, Calif. • Indianapolis 8, Ind.

FOR STRUTHERS ENERGY SYSTEMS INC.
#3 BRINE BLOWDOWN PUMP

CURVE NO 2849399
PUMP TYPE Hydroline
COLUMN 16' of 14"
BOWL 16 HXB STAGES 1
RPM 1760 IMPELLER NO 2617216
PUMP NO S/O NO



PLOTTED BY J. C. FROM TEST NO.

DATE 4-9-68

FORM E-1

HYDRAULIC PERFORMANCE WARRANTY

Guaranteed at designated point only and is contingent on

1. Proper and adequate flow to pump suction.
2. Proper submergence and NPSH available.
3. Fluid free of gas, air and abrasive matter.
4. Impeller with proper lateral adjustment.

fmc CORPORATION

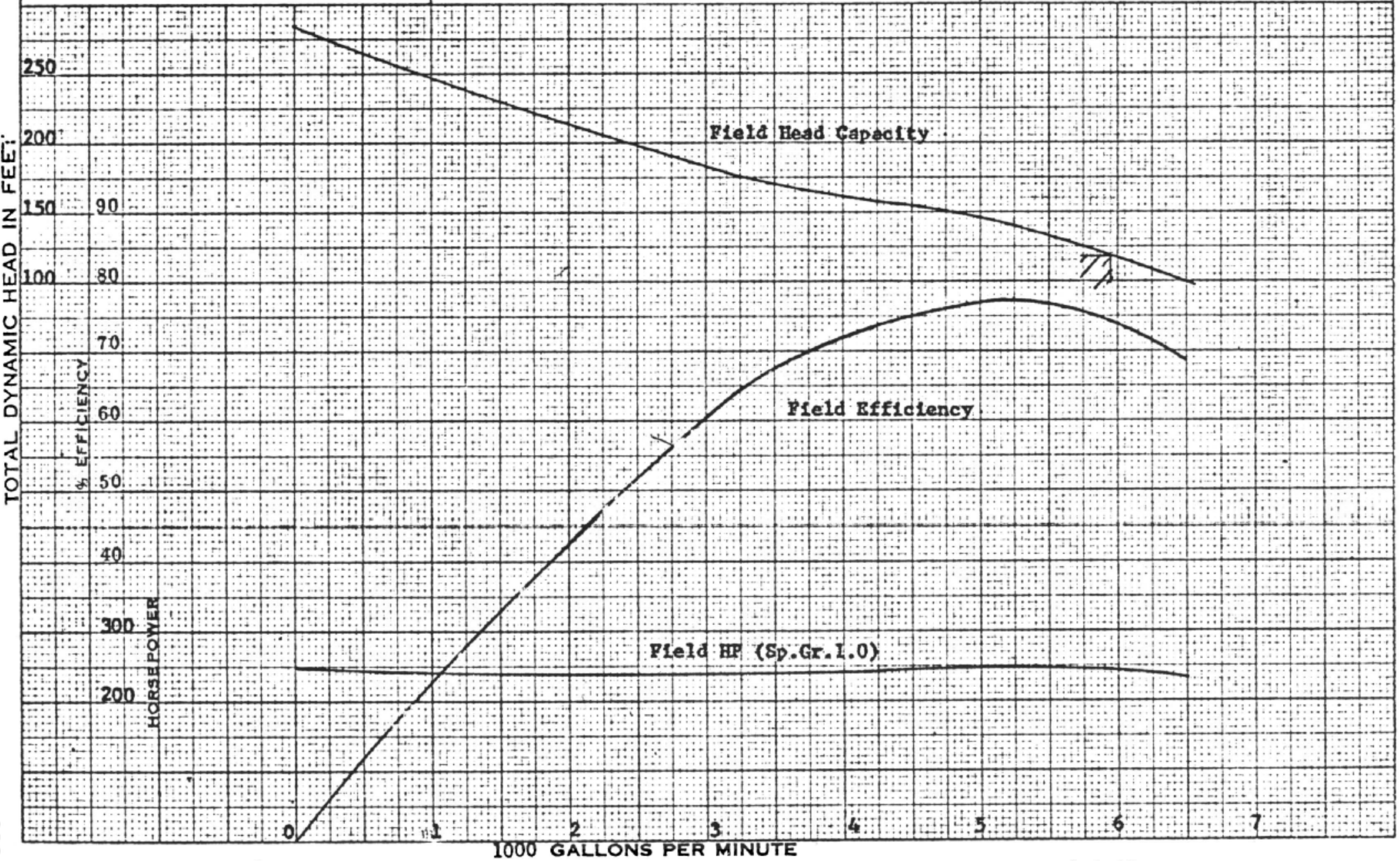
PEERLESS PUMP

HYDRODYNAMICS DIVISION

Los Angeles 31, Calif. • Indianapolis 8, Ind.

FOR STRUTHERS ENERGY SYSTEM INC.
No 4 Raw Sea Water Feed Pump

CURVE NO 2849400
PUMP TYPE VERTICAL TURBINE
COLUMN 9' of14" x 1-11/16
BOWL 16 HH STAGES 2
RPM 1785 IMPELLER NO 26207 35
PUMP NO S/O NO



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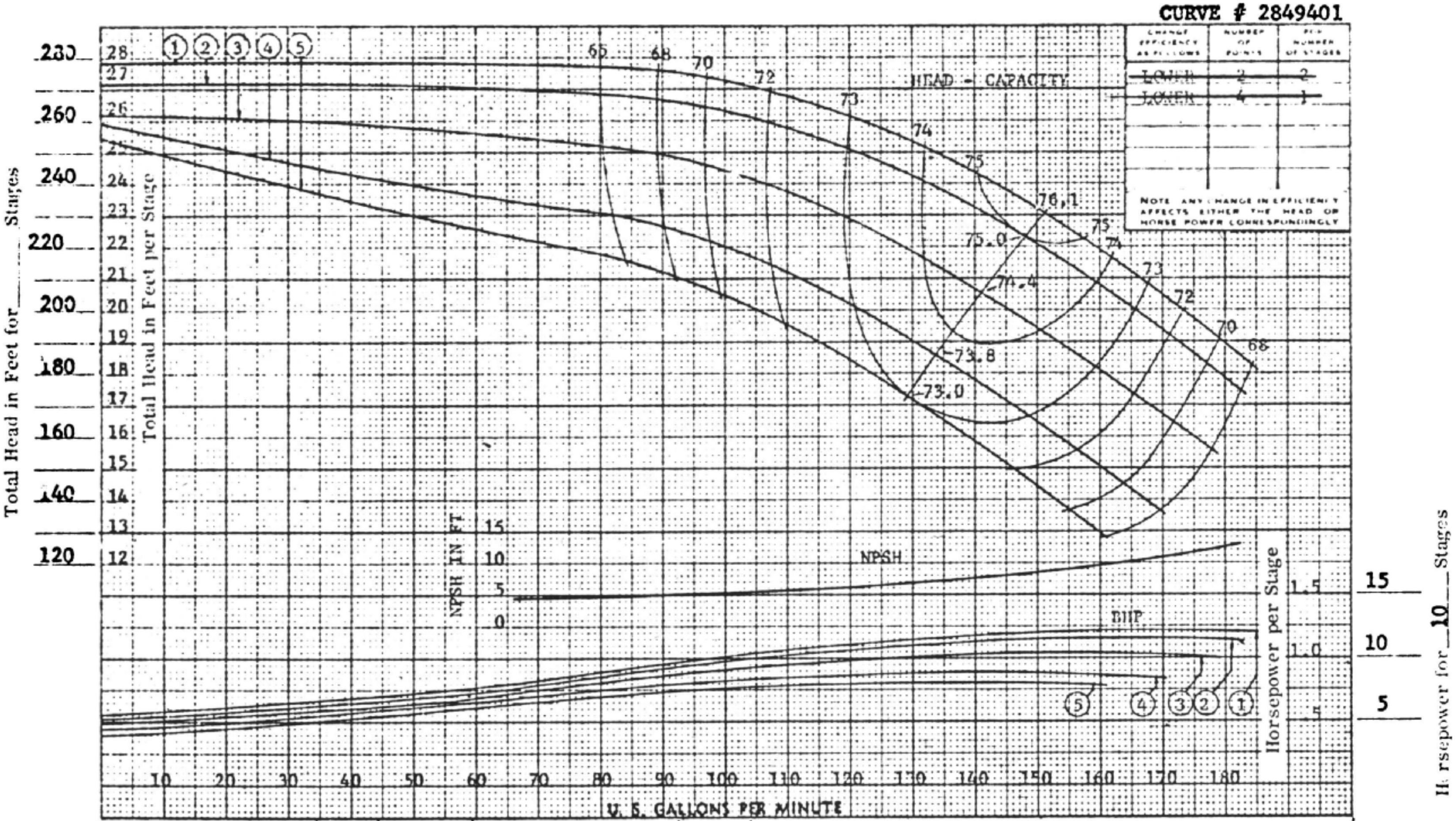
CURVE # 2849401



HYDRAULIC PERFORMANCE WARRANTY	CURVE	IMPELLER	IMPELLER DIA.	FROM
Guaranteed at designated point only, and contingent on:	1	2626207	5 5/16"	44137
	2	2626207	5 3/16" × 5 5/16"	44274
Proper flow to pump suction Proper submergence Fluid free of gas, air & abrasives Proper lateral setting of impeller	3	2626207	5 1/32" × 5 5/16"	
	4	2626207	4 13/16" × 5 5/16"	44321
	5	2626207	4 5/8" × 5 5/16"	44353

Customer **STRUTHERS ENERGY SYSTEM INC.**

Item **#5 SCREEN WASH PUMP**

Peerless Ref. No:

Laboratory Performance		BOWL	2626204 CIE
SIZE 7 LB	RPM 1760	CURVE	2847292

PUMP DESCRIPTION: Driver **15 HP, TEFC Motor**; Head **4x4x12 F**; Column **7'x 7-1/2 of 4" x 1"**

GUARANTEED BOWL ☐ FIELD ☐ PERFORMANCE: Capacity **134** gpm; Head **230** ft; Eff **67.7** %; BHP **11.9**

2.1

WORTHINGTON
CORPORATION

205 Walbridge Building, 43 Court Street, Buffalo, New York 14202 Tele: 853-3675 Area 716

April 18, 1968.

Struthers Energy Systems Inc.,
P.O. Box 8,
Warren, Pa. 16365.

Attention: Mr. Hal Wightman,
Project Engineer.

Subject: Saline Water Project,
Our Proposal BFL-124-68A

Gentlemen:

To confirm our telephone conversations of April 17th 1968 and April 18th 1968, we propose to furnish the equipment as described in our proposal BFL-124-68A 1 thru 3 and attachments.

We are offering our motor driven vertical turbine pumps to facilitate your various applications. A can type tank has been furnished for items 1 and 2 to accommodate the low NPSH available.

Attached specification sheet 2404-S3 gives a sectional view and approximate dimensions of pump model 6M-9-4(item 4) stage unit. All pumps selected have construction similar to that shown on this specification sheet.

Attached specification sheet 2440-S1 gives sectional views and approximate dimensions of the can tanks and T type discharge heads used on items 1 and 2.

Suitable performance curves are attached for all selections.

We trust this proposal will help you in studying these various applications. If you have any questions, please do not hesitate to contact us.

Yours very truly,

WORTHINGTON CORPORATION.

Terry Per

TP/hc

Terry Perko,
Buffalo Sales Office.

EQUIPMENT FOR LIQUID AND GAS HANDLING AND FOR THE CONVERSION OF ENERGY INTO USEFUL WORK
AIR CONDITIONING COMPANY • MACHINERY GROUP • ELECTRIC AND CONTROL GROUP
GENERAL OFFICES: HARRISON, NEW JERSEY

WORTHINGTON

VERTICAL TURBINE PUMP TABULATION SHEET

BFL-124-68A
Proposal Number

1 of 3
Page

ITEM NUMBERS LISTED BELOW

4/18/68
Date

Saline Water
Customer Reference

Struthers Energy Systems Inc.
CUSTOMER NAME

Warren, Pa.
CITY - STATE

		ITEM NO. 1	ITEM NO.	ITEM NO. 2	ITEM NO.
CONDITIONS OF SERVICE	SERVICE	SeaWaterFeed		SeaWaterFeed	
	LIQUID	sea water		sea water	
	LIQUID TEMP. °F.	ambient		ambient	
	SP. GR./VAPOR PRESSURE	1.03/negl.		1.03/negl.	
	VISCOSITY	negl.		negl.	
	CAPACITY GPM	5340		3560	
	WELL ID/DEPTH				
	SUMP DEPTH				
	HEAD AT DISCHARGE				
	TOTAL HEAD	261		261	
	NPSH AVAILABLE /req'd	1'/22'		1'/27'	
PERFORM.	BOWL EFFICIENCY %				
	PUMP EFFICIENCY %	85		84.5	
	PUMP RPM	1760		1760	
	PERFORMANCE CURVE *	2430-1 pg.123		2430 pg.233	
	BHP @ DESIGN/MAX.	425/436		285/300	
PUMP	NO. OF UNITS	(3)		(4)	
	IMPELLER SECTION	20H-500-3		15HH-410-4	
	SUCTION PIPE				
	STRAINER				
	COLUMN SIZE/TYPE	14"enclosed		12" enclosed	
	DISCHARGE HEAD type T	14"x16"x30"		12" x 14" x 25"	
	SIZE ~~DISCHARGE~~ tank	36"dia.x23'lg.		30" dia. x 28'lg.	
	BULLETIN NO.				
DRIVER	Motor HP/RPM	450/1800		300/1800	
	current	3/60/460		3/60/460	
	enclosure	TEFC		TEFC	
	type	induction		induction	
CONTROL	shaft/thrust	VHS/extra high		VHS/High	
ACCESS.	Suction	16"		14"	
	Discharge	14"		12"	
	Stages	3		4	
SHIP'T	SHIPMENT** weeks	15		20	
	APPROX. SHIPPING WT. lbs	12965		12486	
PRICE	NET PRICE	$20,330.		$14,050.	
	F.O.B. freight allowed	Denver, Colo.		Denver, Col.	
	PRICE ADJUSTMENT CLAUSE*	10		10	

*PRICE ADJUSTMENT clause 10 (FORM DO-531) APPLIES TO WORTHINGTON PRODUCTS. THE PRICES FOR THE FOLLOWING PURCHASED EQUIPMENT WILL BE ADJUSTED TO REFLECT THE VENDORS' PRICES IN EFFECT AT TIME OF SHIPMENT: motors

Terms of Payment

**NUMBER OF WEEKS AFTER RECEIPT OF ORDER, COMPLETE MANUFACTURING INFORMATION AND NECESSARY APPROVAL OF DRAWINGS
UNLESS OTHERWISE STATED WORTHINGTON'S "STANDARD CONDITIONS OF SALE" ARE A PART OF THIS PROPOSAL.

WORTHINGTON

VERTICAL TURBINE PUMP TABULATION SHEET

BFL-124-68A
Proposal Number

2 of 3
Page

ITEM NUMBERS LISTED BELOW

4/18/68
Date

Saline Water
Customer Reference

Struthers Energy Systems Inc.
CUSTOMER NAME

Warren, Pa.
CITY - STATE

		ITEM NO. 3	ITEM NO.	ITEM NO. 4	ITEM NO.
CONDITIONS OF SERVICE	SERVICE	RawSeaWater Feed		Screen Wash	
	LIQUID	water		water	
	LIQUID TEMP. °F.	85		85	
	SP. GR./VAPOR PRESSURE	1.10/negl.		1.10/negl.	
	VISCOSITY	negl.		negl.	
	CAPACITY GPM	5400		122	
	WELL ID/DEPTH				
	SUMP DEPTH				
	HEAD AT DISCHARGE				
	TOTAL HEAD feet	117		230	
	NPSH AVAILABLE feet	30		30	
PERFORM.	BOWL EFFICIENCY %				
	PUMP EFFICIENCY %	84		74	
	PUMP RPM	1760		3520	
	PERFORMANCE CURVE *	2430-1 pg.119		2403 pg.37	
	BHP @ DESIGN/MAX.	210/215		12.4/13	
PUMP	NO. OF UNITS	3		2	
	IMPELLER SECTION	20H-500-1		6M-9-4	
	SUCTION PIPE				
	STRAINER	20" basket		6" basket	
	COLUMN SIZE/TYPE 10'	14" open flg'd		3½" open th'd	
	DISCHARGE HEAD	N2412		N-1203	
	SIZE DISCHARGE				
	BULLETIN NO.				
DRIVER	Motor HP/RPM	250/1800		15/3600	
	Current	3/60/460		3/60/230-460	
	enclosure	TEFC		TEFC	
	type	induction		induction	
CONTROL	Shaft/Thrust	VHS/high		VHS/high	
ACCESS.	Suction (w/strainer)	20"		6"	
	Discharge	12"		3"	
	Stages	1		4	
SHIP'T	SHIPMENT** weeks	10-12		6	
	APPROX. SHIPPING WT. lbs	5890		706	
PRICE	NET PRICE	$10,290.		$1034.	
	F.O.B. freight allowed	Denver, Col.		Denver, Col.	
	PRICE ADJUSTMENT CLAUSE*	10		10	

*PRICE ADJUSTMENT clause 10 (FORM DO-531) APPLIES TO WORTHINGTON PRODUCTS. THE PRICES FOR THE FOLLOWING PURCHASED EQUIPMENT WILL BE ADJUSTED TO REFLECT THE VENDORS' PRICES IN EFFECT AT TIME OF SHIPMENT: motors

Terms of Payment

*attached

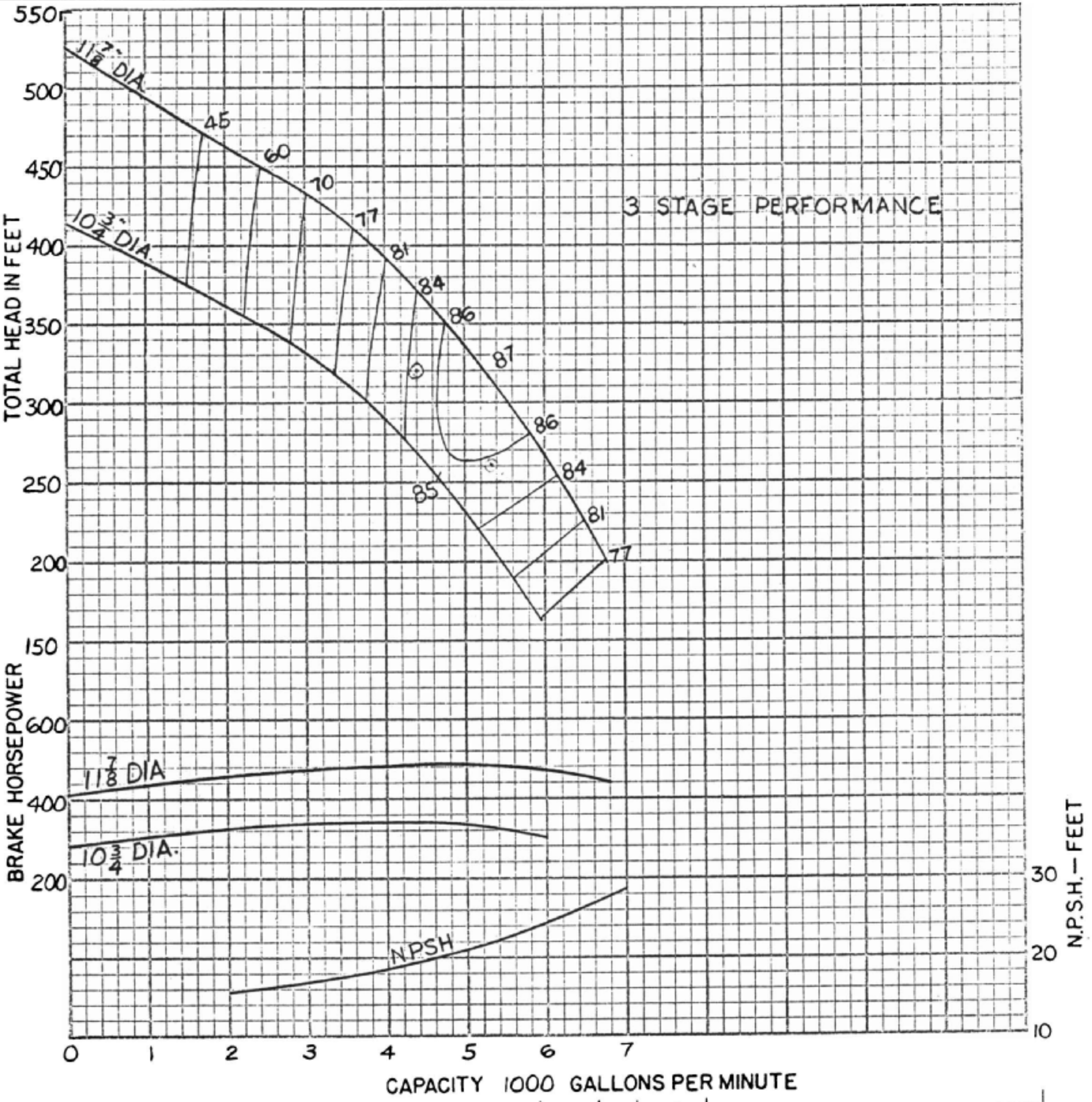
**NUMBER OF WEEKS AFTER RECEIPT OF ORDER, COMPLETE MANUFACTURING INFORMATION AND NECESSARY APPROVAL OF DRAWINGS. UNLESS OTHERWISE STATED WORTHINGTON'S "STANDARD CONDITIONS OF SALE" ARE A PART OF THIS PROPOSAL.

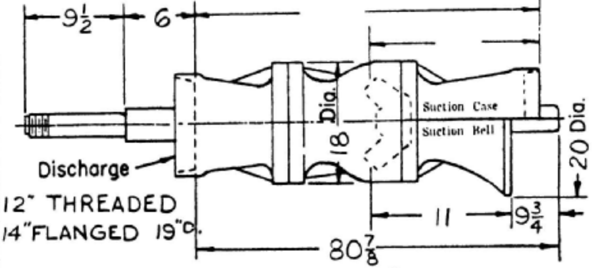
Printed in U.S.A.

DO553 161

RATING CURVES
(60 CYCLES)

20H-500
1760 RPM





For additional stages add $18\frac{5}{16}$ per stage.

Efficiency shown is for stages or more, with standard materials. For fewer stages or other materials change efficiency as shown.

No. of stages	Eff. change	MATERIAL	Eff. change	Standard materials	
				Impeller — bronze	
				Bowl — cast iron / enamelled	
6	—	Impeller-bronze	—	Thrust factor	36.5
5	—	Impeller-c.i.	-1	Rotor wt. per stage (lbs.)	88
4	—	Impeller-c.i. enm.	—	Bowl wt. 1st stage (lbs.)	725
3	—	Bowl-c.i. enm.	—	Bowl wt. add'l. stage (lbs.)	350
2	—	Bowl-cast iron	-2	Max. bowl horsepower	570
1	—	Bowl-bronze	-1	Impeller eye area (sq. in.)	85

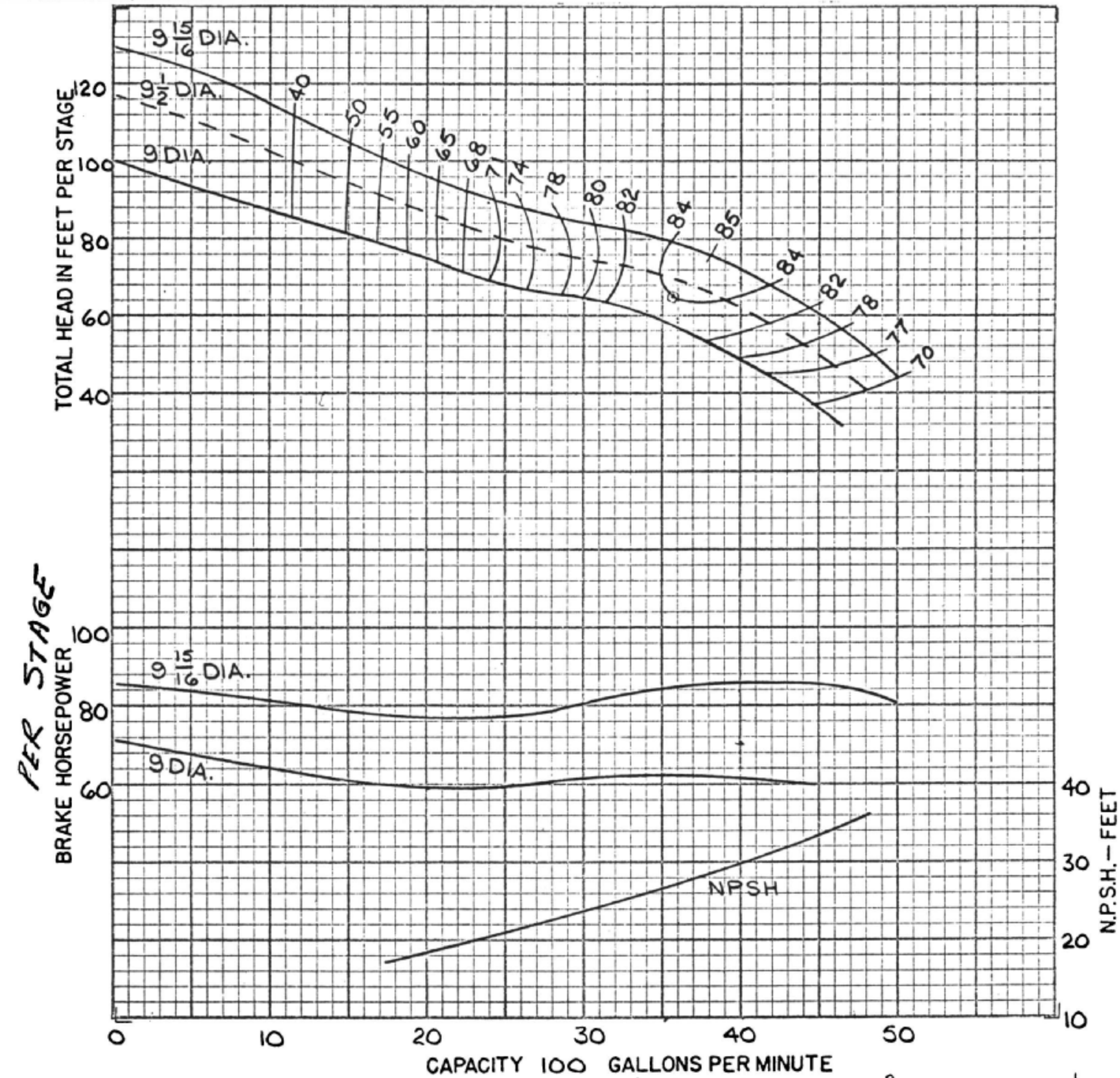
Impeller shaft diameter	2.25	Column pipe	12	14
Minimum impeller shaft end play	.68	Suction pipe	—	

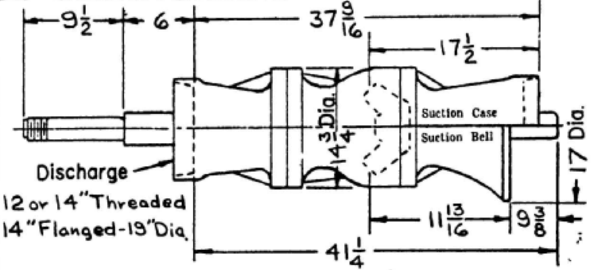
Supersedes
Sect. 2403 Page 231
April 1, 1960 Issue

RATING CURVES
(60 CYCLE)

May 1, 1960

15HH-410
1760 RPM





For additional stages add 15¼ per stage.

Efficiency shown is for 2 stages or more, with standard materials. For fewer stages or other materials change efficiency as shown.

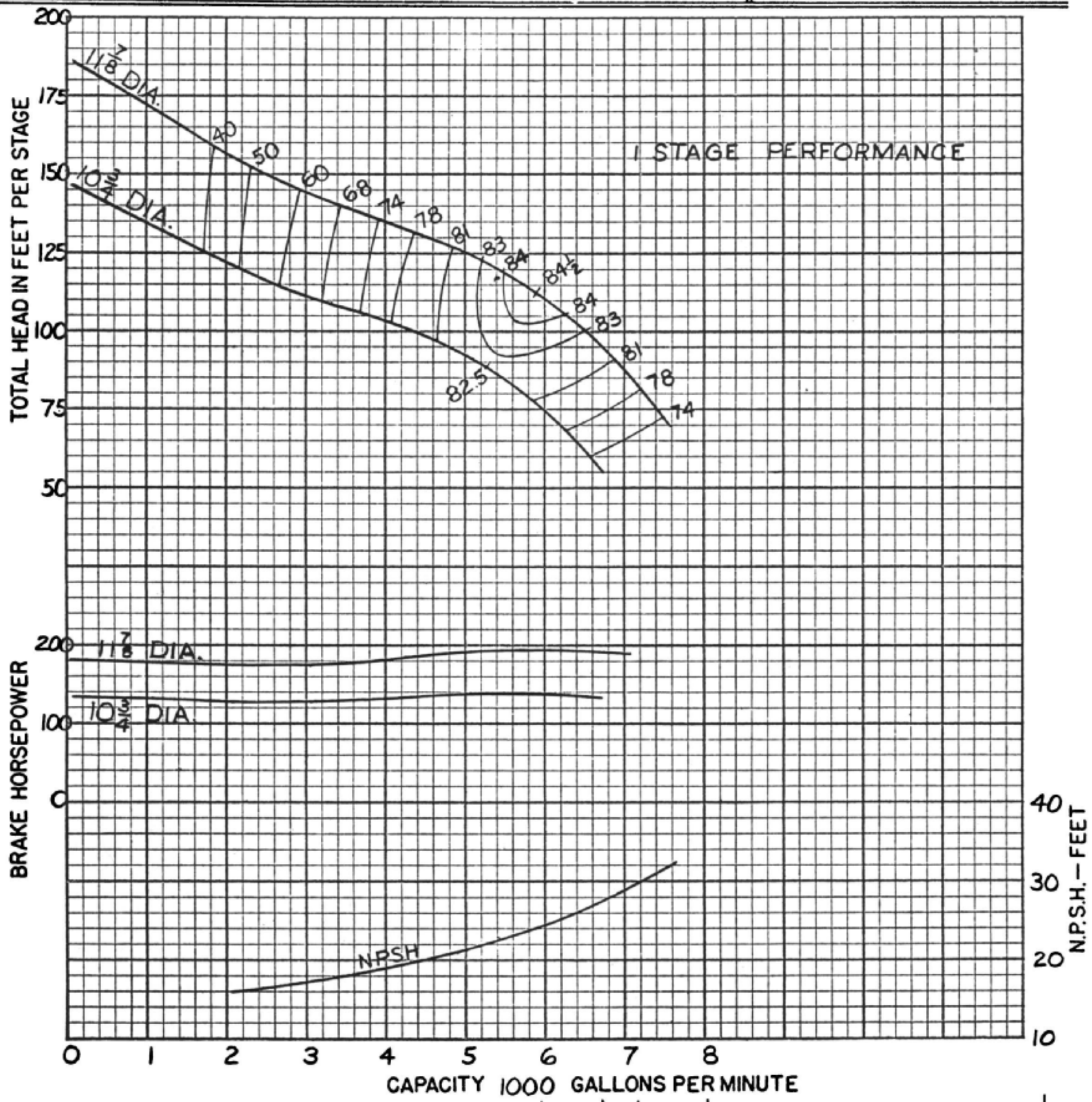
No. of stages	Eff. change	MATERIAL	Eff. change	Standard materials						
				Impeller — bronze						
				Bowl — cast iron / enamelled						
6	—	Impeller-bronze	—	Thrust factor	25.4					
5	—	Impeller-c.i.	-1	Rotor wt. per stage (lbs.)	45					
4	—	Impeller-c.i. enm.	+1	Bowl wt. 1st stage (lbs.)	415					
3	—	Bowl-c.i. enm.	—	Bowl wt. add'l. stage (lbs.)	180					
2	—	Bowl-cast iron	-2	Max. bowl horsepower	570	Impeller shaft diameter	2.25	Column pipe	12	14
1	-2	Bowl—bronze	-1.5	Impeller eye area (sq. in.)	53.5	Minimum impeller shaft end play	.81	Suction pipe	14	

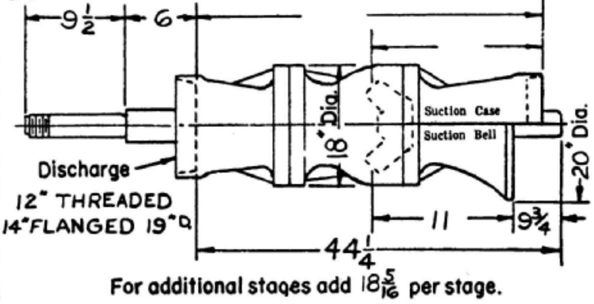
VERTICAL PUMP DIVISION, DENVER, COLORADO
Litho'd in U.S.A.

RATING CURVES

(60 CYCLES)

20H-50u
1760 RPM





For additional stages add 18 5/16 per stage.

Efficiency shown is for 1 stage[redacted], with standard materials. For [redacted] other materials change efficiency as shown.

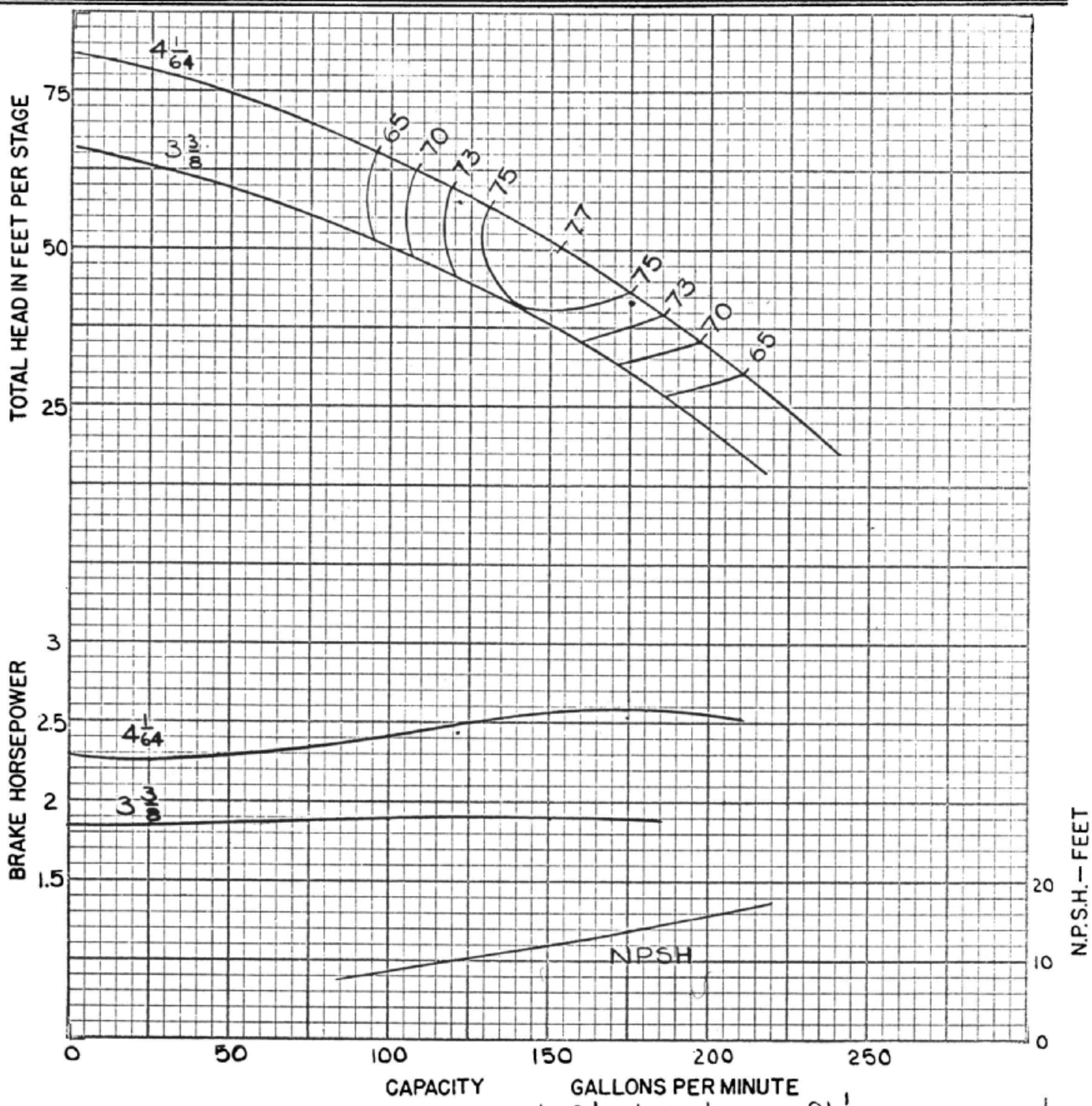
No. of stages	Eff. change	MATERIAL	Eff. change	Standard materials	
				Impeller — bronze	
				Bowl — cast iron / enamelled	
6	—	Impeller-bronze	—	Thrust factor	365
5	—	Impeller-c.i.	-1	Rotor wt. per stage (lbs.)	88
4	—	Impeller-c.i. enm.	—	Bowl wt. 1st stage (lbs.)	725
3	—	Bowl-c.i. enm.	—	Bowl wt. add'l. stage (lbs.)	350
2	—	Bowl-cast iron	-2	Max. bowl horsepower	570
1	—	Bowl-bronze	-1	Impeller eye area (sq. in.)	85

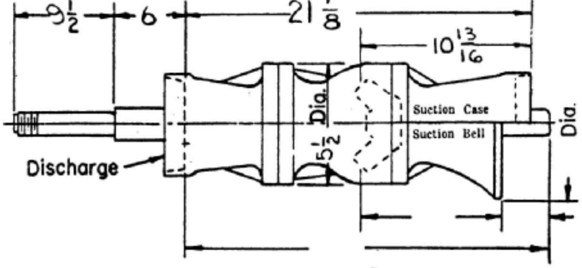
Impeller shaft diameter	2.25	Column pipe	12	14
Minimum impeller shaft end play	.68	Suction pipe	—	

NEW

RATING CURVES
(60 CYCLE)

6M-9
3520 RPM





For additional stages add $4\frac{3}{8}$ per stage.

Efficiency shown is for 4 stages or more, with standard materials. For fewer stages or other materials change efficiency as shown.

No. of stages	Eff. change	MATERIAL	Eff. change	Standard materials Impeller — bronze Bowl — cast iron / enamelled					
6	—	Impeller-bronze	—	Thrust factor	2.5				
5	—	Impeller-c.i.	-1	Rotor wt. per stage (lbs.)	4				
4	—	Impeller-c.i. enm.	+2	Bowl wt. 1st stage (lbs.)	50				
3	-1.5	Bowl-c.i. enm.	—	Bowl wt. add'l. stage (lbs.)	16				
2	-3.5	Bowl-cast iron	-5	Max. bowl horsepower	80	Impeller shaft diameter	1	Column pipe	3.5
1	-6	Bowl-bronze	-4	Impeller eye area (sq. in.)	4.1	Minimum impeller shaft end play	.38	Suction pipe	3.5

VERTICAL TURBINE PUMP DIVISION, DENVER, COLORADO
Litho'd in U.S.A.

RAMSAY PUMP & SUPPLY CO.
Pump Engineers

E. E. ZIMMERMAN, PRES & TREAS.
G. C. MOORE, SR., EXECUTIVE VICE PRESIDENT
G. C. MOORE, JR., VICE PRESIDENT-SALES

KEENAN BUILDING
PITTSBURGH, PA. 15222

261-1155 · 1239
WAREHOUSE AND SHOP
HOFFMAN & KNOTT ST., N. S.
PITTSBURGH, PA. 15233

May 24, 1968

Struthers Energy Systems, Inc.
P. O. Box 8
Warren, Pennsylvania 16365

Attention: Mr. Hal Wightman

Gentlemen:

Subject: Boiler Feed Pumps for the OSW Contract

In accordance with our recent conversation, we wish to quote on our Aurora Type Apco-Chem Pump as follows:

ONE (1) Aurora 1-1/2" x 3" CT-923-XLD, 316 stainless steel Apco-Chem Heavy Duty Process Turbine Pump. Unit will meet designed conditions of 32 GPM at 1080' TDH when handling water at a temperature of 257° F. Unit will be supplied with all wetted parts of 316 stainless steel, water cooled packing box, Quench Type packing gland, and Viton gasket. Unit will further be complete with cast iron baseplate, Woods spacer coupling, and a 40 HP, 3500 RPM, 3/60/230/460 TEFC, Chemical Plant motor.

Net price, f.o.b. Aurora, Illinois $2,785.00

Delivery: Approximately 8 - 10 weeks

Trusting this will be satisfactory, we are,

Yours very truly,
RAMSAY PUMP & SUPPLY CO.

J. W. Brown, Jr.
Sales Engineer

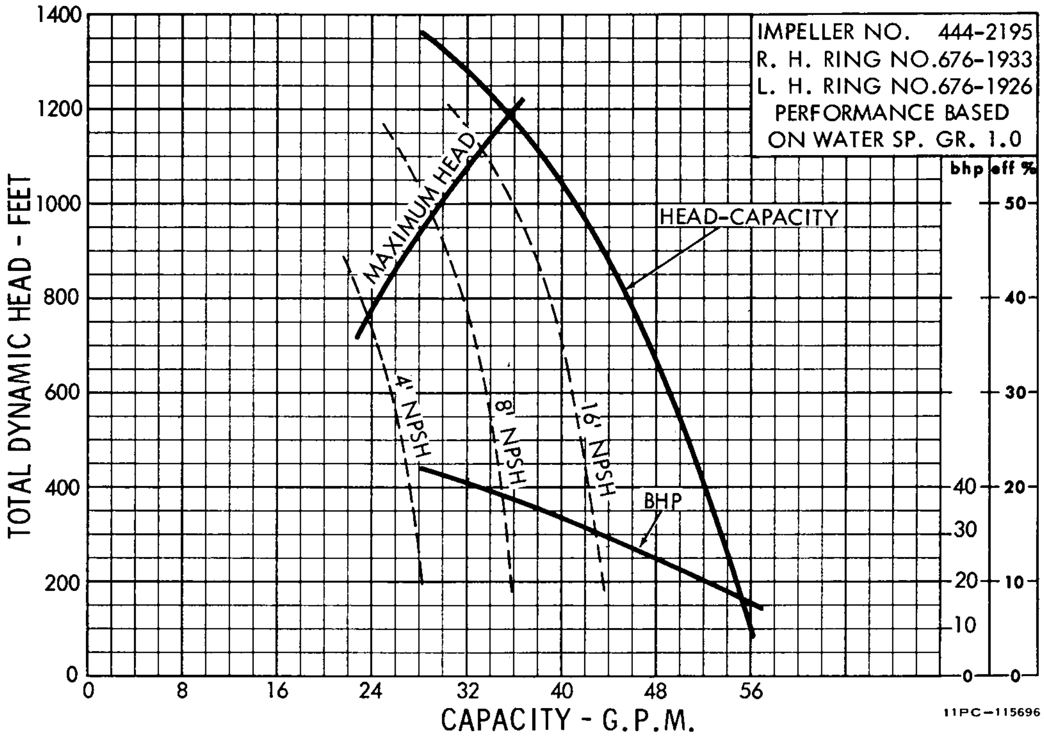
JWBJr/la

Enclosure

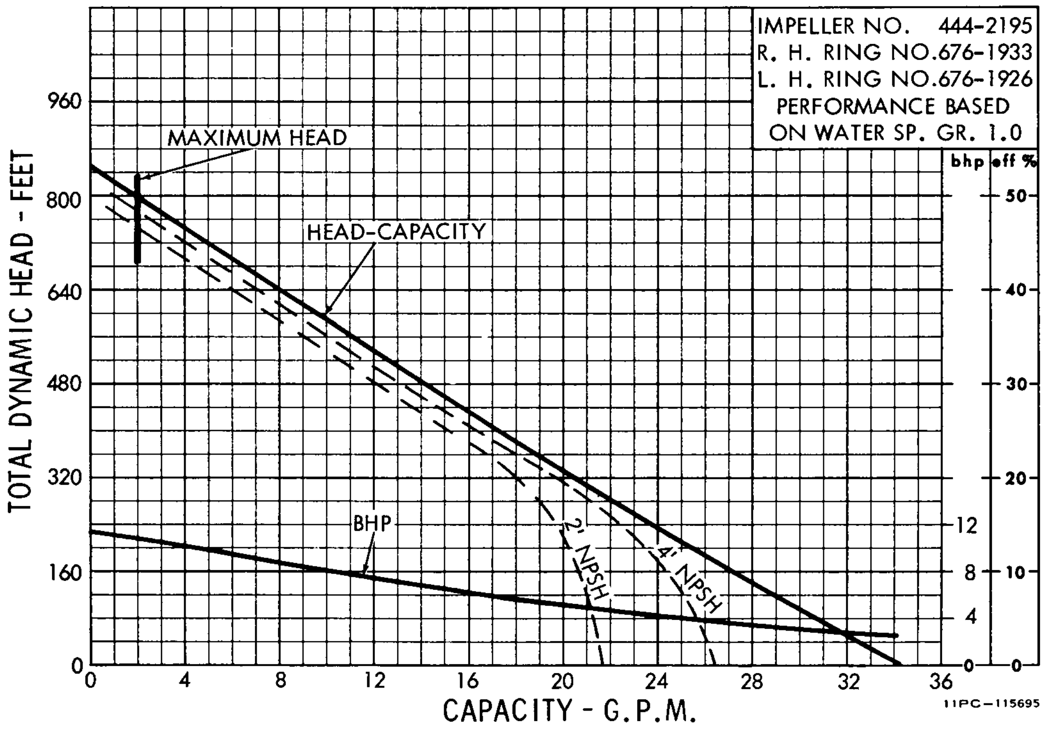
CT-923 APCO-CHEM

OPEN CLEARANCE

3500 R.P.M.



1750 R.P.M.



AURORA PUMP

A UNIT OF GENERAL SIGNAL CORPORATION

AURORA • ILLINOIS

2.2

MPC

MOTIVE PARTS COMPANY OF PENNSYLVANIA
6399 PENN AVENUE . PITTSBURGH, PA. 15206 · 412 – 441-1000

April 10, 1968

STRUTHERS ENERGY SYSTEMS, INC.
P.O.Box 8
Warren, Pennsylvania 16365

Attention: Mr. Hal Wightman

Gentlemen:

In reply to your inquiry which covers the requirement for one forced draft fan and gas engine driver, we are quoting the following:

1 - Combination Forced Air Fan and Natural Gas Engine with reduction gear and clutch, mounted on a sub-base steel frame. The fan is a Class II construction, arrangement 3, SWSI with backward inclined blade design, for non-overloading power characteristics, rated 298,800 pounds per hour, 70,200 CFM at 3.5 inches S.P. at 100 degrees F. Fan complete with access door, split housing, inlet screen, SKF split pillow block bearings, No. 3 Fast or Dodge Paraflex coupling.

Natural gas engine shall contain a unit mounted radiator, fan, thermostat, oil filter, muffler, electric starting motor, alternator, 12 volt battery, manual throttle, tachometer, oil pressure gauge, water temperaturegauge and natural gas Ensign carburetor. Attached to the engine flywheel will be a combination clutch and speed reducer rated 3:1. The fan must operate at 700 RPM and the engine at 2100 RPM.

Total Net Price $ 7,967.00

For the addition of 3/8 inch thick plate housing, but not including cones (only sides and scroll)
Add $ 1,790.00

Your specifications state that a means shall be provided for access to the fan wheel for replacement and repair without the removal of the rotor from its bearings. The fan people don't see how it would be possible to replace a wheel without removing the rotor unless there is no duct work on the inlet. If we can assume that there is no duct work on the inlet, you would actually need a fan in Arrangement #1 and then the customer could remove the inlet cone and pull the wheel without disturbing the shaft and bearings. If this is so, then to supply the fan in Arrangement #1, as quoted above instead of Arrangement #3, an additional price of $690.00 would be included.

WAUKESHA MOTOR CO

WAUKESHA MOTOR COMPANY DISTRIBUTOR · PARTS - SALES - SERVICE

Our quotation mentions a Fast or Dodge Paraflex coupling. We are advised to recommend the Dodge Paraflex because past experience has indicated less vibration with this coupling. We will supply a split pillow block bearing so that the entire rotating assembly could be removed, including the shaft and bearings, if a wheel replacement is desired.

Delivery is 16 to 18 weeks after approval of drawings. Allow six weeks additional for completion of drawings for approval.

The overall arrangement with fan and engine is approximately 124" H x 140" L x 105" D.

Thank you for this opportunity to quote. Please contact this writer for additional information.

Prices are F.O.B., Michigan. Terms: 1% 10 Days, Net 30 Days.

Very truly yours,

MOTIVE PARTS CO. OF PA.,

John Libroth

John Libroth,
Sales Engineer

JL:jg

Enclosure:

F. D. FAN DATA SHEET

Type and Model Number	Clarage type AF-Model 3120
Flow (#/hr)	298,800
Pressure Rise (In. H_2O)	3 1/2"
Speed (RPM)	700
Width, Length, Height (Ft.)	6'-7 1/2"x8'-8 1/4"x9'-9 11/16"
Weight of Fan Housing Complete (#)	3900
Housing Discharge Size (Ft.)	62 11/16" x 48"
Intake Size (Ft.)	65" dia. hole
Fan Tip Speed Operating (FPM)	11,000 FPM
Fan Tip Speed Maximum (FPM) 1061 x 15.71	16,668 FPM
Bearing Type	Heavy Duty Anti-Friction
Lubricating Requirements	Standard
Bearing Cooling Requirements	NONE

GAS ENGINE DATA SHEET

Type and Model Number	Waukesha Model 195
Operating H.P.	63.5
Operating Speed (RPM)	2100
Fuel Requirements (#/hr) @ 20430 $\frac{\text{BTU}}{\#}$ LHV	38 #/hr
Engine weight (#)	1400#
Width, Length, Height (Ft.)	60"Lx 41"Hx 24"W
Number of Cylinders	six
Cylinder Arrangement	straight six
Cylinder Base/Stroke (In.)	4 1/8 x 4
Displacement (Cu.In.)	320
Compression Ratio	9:1

$$11{,}900 \text{ hr } \frac{\#}{20{,}430} = 37.9 \ \#/\text{hr}$$

2.2

BUSCH CO. 4907 PENN AVE. / PITTSBURGH, PA. 15224 / 412 -- 362-6000
manufacturers and representatives

April 4, 1968

Struthers Energy Systems
P. O. Box 8
Warren, Pennsylvania 16365

Attention: Mr. Hal Wightman

Subject: Forced Draft Fan for Desalination Plant

Gentlemen:

Per our conversation on April 2, 1968, and per your letters of inquiry, we offer the following budgetary quotation:

One (1) Joy Series 1000 Axivane Fan, Model No. 48-26½-100SN-1750. Fan is to be driven direct through a floating shaft and flexible coupling. The natural gas drive engine is to be mounted external of the fan, and furnished with drive shaft and flexible coupling.

We have selected a fan shaft based on an engine with 80 HP at 1800 rpm. Should a different motor be selected, it is possible that we may require a different drive shaft. Fan shaft to be furnished with the fan is approximately 24" in length. The maximum length of the floating shaft that we could provide is 57".

Capacity:

- 70,000 cfm (298,800$^{\#}$/hr)
- P_s = 3.5" wg P_t = 4.48" wg
- BHP at conditions is 75
- RPM at conditions is 1750
- Tipspeed = 21,988 fpm
- Maximum rpm = 1900

Note: Maximum rotor rpm is 1900; we therefore suggest that the gas engines selected

(Continued)

be equipped with a governor to limit the speed to 1800 rpm.

Fan Specification:

Fan housing is hot rolled steel SAE1020, $\frac{1}{4}$" thickness, with 3/8" end flanges. Each flange will be continuously welded around the periphery of the housing and will be provided with bolt holes for bolting inlet bell cones or companion flanges. Housing is continuously welded and expanded by mechanical means to insure concentricity. Fan housing is shot blasted to insure good paint adherence inside and outside. Not less than eight (8) stationary guide vanes of 3/16" thickness shall be welded inside the fan housing.

Fan rotor hub and blades shall be of cast aluminum construction. Hub to be cast of aluminum No. 356-T6 heat treated, and blades shall be of cast aluminum alloy No. 356. Fan blades will be airfoil shaped for maximum efficiency and shall vary in twist and width from hub to tip to obtain equal air distribution along the blade length. Blade tip clearance to fan housing shall not exceed 0.10". Fan blades will be adjustable through a pitch range of 25° to 55° to vary volume and pressure characteristics across this range.

Fan rotor will be whirl-tested to 125% of operating speed and shall be statically and dynamically balanced on the shaft to a maximum tolerance guaranteed in writing, of one (1) mil double amplitude at design operating speed.

Fan supports shall be constructed of 3/16" thick carbon steel.

Our budget estimate price for this fan is approximately $2,000.00. This price would include the following accessories:

- Inlet bell
- Inlet screen
- 24" floating shaft with flexible coupling to fan rotor
- External grease leads
- Fan supports
- Rubber-in-shear type vibration isolators
- One (1) outlet cone

Enclosed will be a fan dimension sheet for the standard Series 1000 Axivane Fan, Arrangement #4.

(Continued)

For all practical purposes, all dimensions will remain as shown for this fan.

Should you have any questions, or require any further engineering data, firm pricing, and delivery, please contact me at your earliest convenience.

Very truly yours,

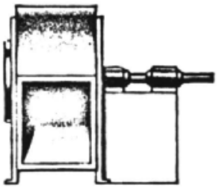
J Howard Conley

J. Howard Conley

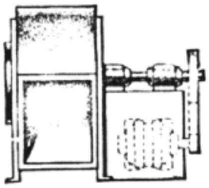
JHC:me

Enclosure

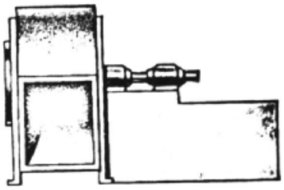
ARRANGEMENT OF DRIVE*



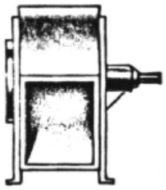
Arrangement No. 1, SW, SI
For belt drive or direct connection. Wheel overhung. Two bearings on base.



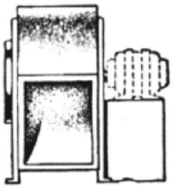
Arrangement No. 9, SW, SI
For belt drive. Wheel overhung. Two bearings with prime mover outside base.



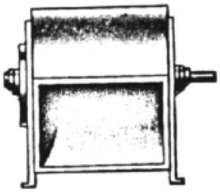
Arrangement No. 8, SW, SI
For belt drive or direct connection. Arrangement No. 1 plus base for prime mover.



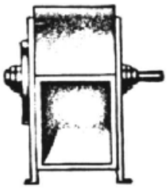
Arrangement No. 2, SW, SI
For belt drive or direct connection. Wheel overhung. Bearings in bracket supported by fan housing.



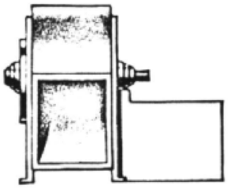
Arrangement No. 4, SW, SI
For direct drive. Wheel overhung on prime mover shaft. No bearings on fan. Base mounted or an integrally direct connected prime mover.



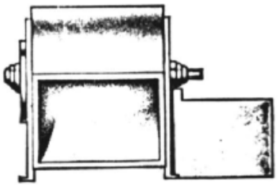
Arrangement No. 3, DW, DI
For belt drive or direct connection. One bearing on each side and supported by fan housing.



Arrangement No. 3, SW, SI
For belt drive or direct connection. One bearing on each side and supported by fan housing. Not recommended in sizes 27″ diameter wheel and smaller.



Arrangement No. 7, SW, SI
For belt drive or direct connection. Arrangement No. 3 plus base for prime mover. Not recommended in sizes 27″ diameter wheel and smaller.

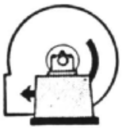


Arrangement No. 7, DW, DI
For belt drive or direct connection. Arrangement No. 3 plus base for prime mover.

DESIGNATION OF DIRECTION OF ROTATION AND DISCHARGE*

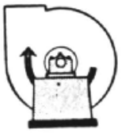
Counter-Clockwise
Top Horizontal
CCW-THD

Clockwise
Top Horizontal
CR-THD

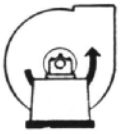


Clockwise
Bottom Horizontal
CR-BHD

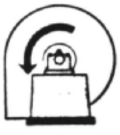
Counter-Clockwise
Bottom Horizontal
CCW-BHD



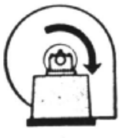
Clockwise
Up Blast
CR-UBD



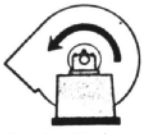
Counter-Clockwise
Up Blast
CCW-UBD



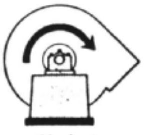
Counter-Clockwise
Down Blast
CCW-DBD



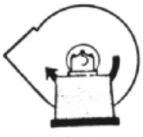
Clockwise
Down Blast
CR-DBD



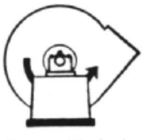
Counter-Clockwise
Top Angular Down
CCW-TADD



Clockwise
Top Angular Down
CR-TADD



Clockwise
Bottom Angular Up
CR-BAUD



Counter-Clockwise
Bottom Angular Up
CCW-BAUD

Counter-Clockwise
Top Angular Up
CCW-TAUD

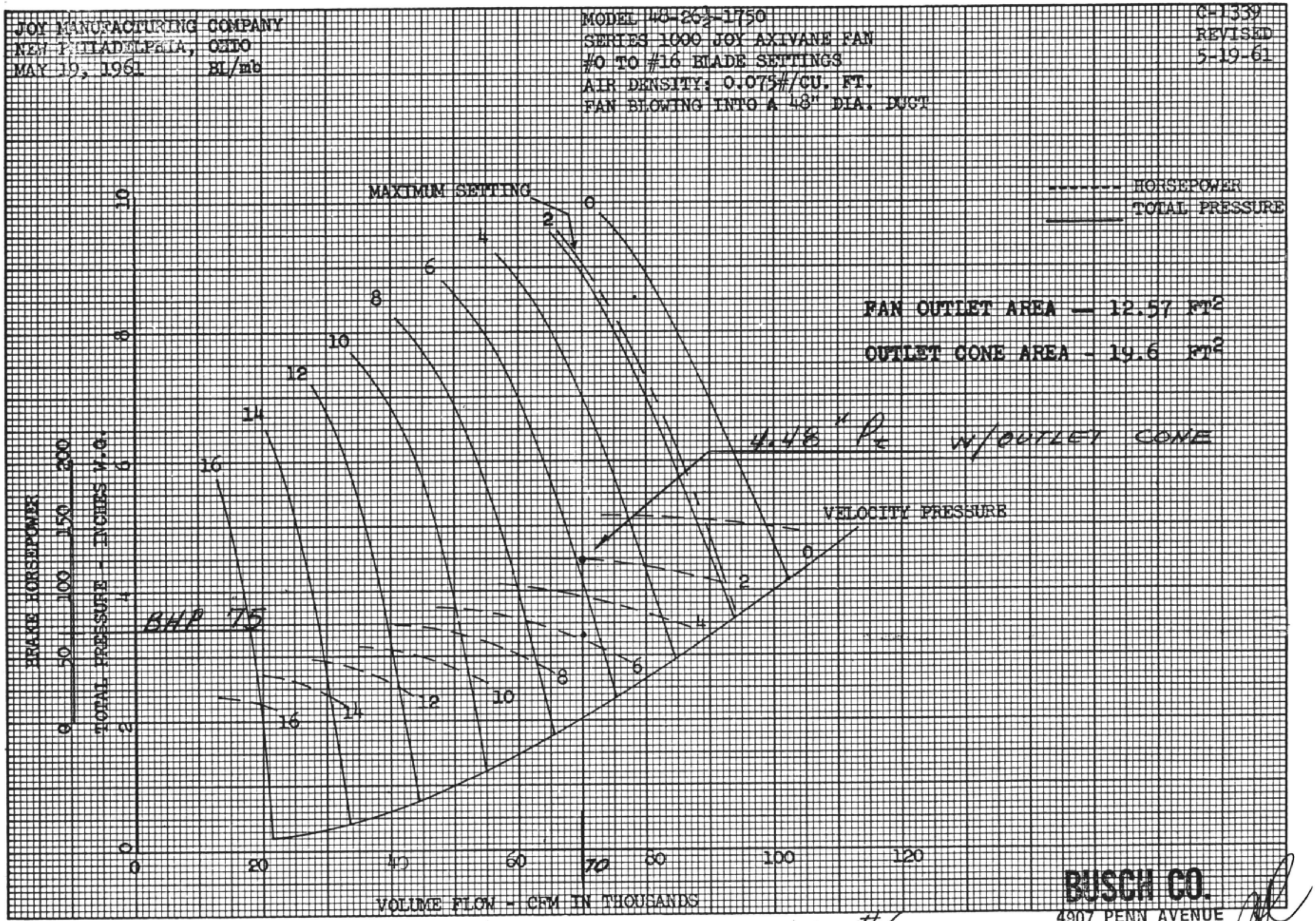
Clockwise
Top Angular Up

Direction of Rotation is determined from drive side for either single or double width, or single or double inlet fans. The driving side of a single inlet fan is considered to be the side opposite the inlet regardless of actual location of the drive. For fan inverted for ceiling suspension, Direction of Rotation and Discharge is determined by its position when fan is standing on the floor.

JOY MANUFACTURING COMPANY
NEW PHILADELPHIA, OHIO
MAY 19, 1961 BL/mb

MODEL 48-26½-1750
SERIES 1000 JOY AXIVANE FAN
#0 TO #16 BLADE SETTINGS
AIR DENSITY: 0.075#/CU. FT.
FAN BLOWING INTO A 48" DIA. DUCT

C-1339
REVISED
5-19-61



FAN OUTLET AREA — 12.57 FT²

OUTLET CONE AREA - 19.6 FT²

BLADE SETTING #6
70 000 CFM AT 3.5"SP

BUSCH CO.
4907 PENN AVENUE
PITTSBURGH, PA. 15224
Telephone 362-6000

JOY MANUFACTURING COMPANY

AIR MOVING EQUIPMENT • NEW PHILADELPHIA, OHIO

Submittal Print **Series 1000** **Direct Driven** **Arrange. #4**

Drawing For: **Reference** ☒ **Approval** ☐ **Revised Print** ☐

If approval is required, fabrication will be held pending return of approved copy of this print. All dimensions are suitable for installation purposes.

Customer

STRUTHERS ENERGY SYSTEMS
P.O. BOX 8
WARREN, PA. 16365

Project DESALINATION PLANT

Architect

Engineer HAL WIGHTMAN

Joy Order No. N/A

Customer Order No. N/A

FAN DATA

LINE	MARKING	SIZE	CFM	OV(FPM)	SP	TP	BHP
A		48-26½-100SK	70,000		3.5	4.48	75
B							
C							
D							
E							
F							
G							
H							
J							

Elevation ______________ **Temp.** ________ ° **F.**

OPTIONAL ACCESSORIES

LINE	HORIZ. SUPPORT LEGS	SUSPENSION CLIPS	INLET BELL	INLET SCREEN	INLET CONE	OUTLET CONE	ISOLATORS - RUBBER	ISOLATORS - SPRING	VORTEX BREAKERS	COMPANION ANGLE
A	X		X	X		X	X			
B										
C										
D										
E										
F										
G										
H										
J										

ADDITIONAL DATA

N/A

MOTOR DATA (60 cy)

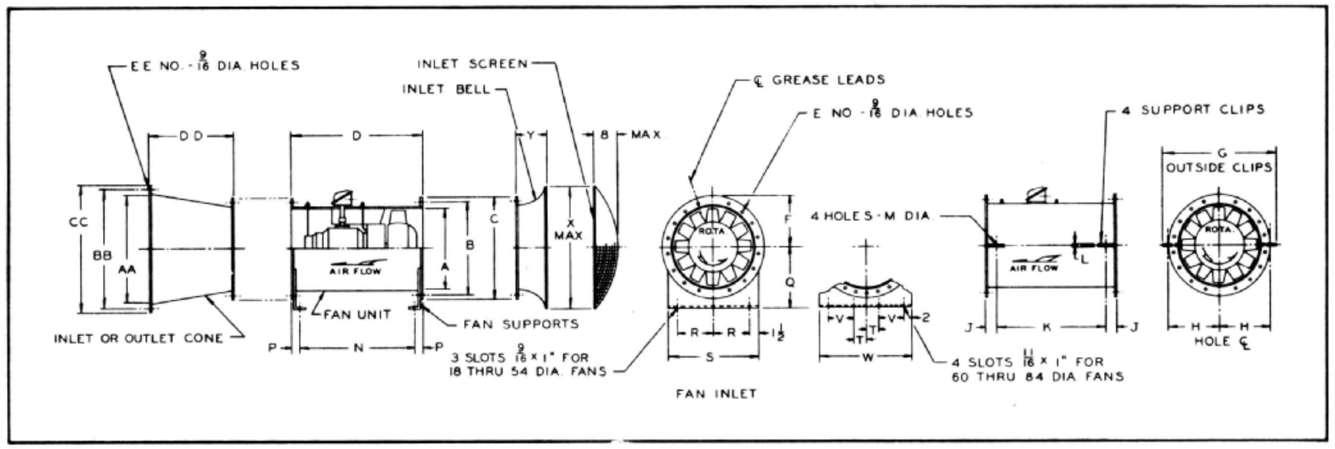
LINE	HP	RPM	Frame	V	Ph	Type
A						
B						
C						
D						
E						
F						
G						
H						
J						

Motors are TEAO Unless Noted
If Explosion Proof Req'd: Class .... **Group** ....

SUBMITTED BY J. Howard Conley **DATE** ....

DIMENSIONS (inches) JOY SERIES 1000 AXIVANE® FANS

Adjustable Pitch **Direct Driven** **Arrange. #4**



FAN UNIT						SUPPORT CLIPS						FAN SUPPORTS								Bell & Screen	Inlet Bell	RECOMMENDED CONE (INLET OR OUTLET) (1.5/1.0 AREA RATIO)				
"A" Casing Dia.	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	V	W	X	Y	AA	BB	CC	DD	EE
18	19⅞	21⅜	28	12	10 11/16	23⅜	10⅝	1¾	24½	⅜	9/16	25½	1¼	13½	7¼	17½				25½	4	22	23⅞	25⅜	12	12
21¼	23⅛	24⅝	31	12	12 5/16	26⅝	12¼	1¾	27½	⅜	9/16	28½	1¼	15½	8½	20				29¾	4½	26	27⅞	29⅜	14	12
23¼	25⅛	26⅝	33	12	13 5/16	28⅝	13¼	1¾	29½	⅜	9/16	30½	1¼	16½	11¾	26½				32¼	5	28	29⅞	31⅜	14	12
25¼	27⅛	28⅝	33	12	14 5/16	30⅝	14¼	1¾	29½	⅜	9/16	30½	1¼	18½	12½	28				35	5½	32	33⅞	35½	20	12
27¼	29⅛	30⅝	33	12	15 5/16	32⅝	15¼	1¾	29½	⅜	9/16	30½	1¼	19½	13¾	30½				37½	6	34	35⅞	37½	20	12
29¼	31⅛	32⅝	33	12	16 5/16	34⅝	16¼	1¾	29½	⅜	9/16	30½	1¼	20½	14½	32				40	6¼	36	37⅞	39⅜	20	12
32	33⅞	35⅜	33	12	17 11/16	37⅜	17⅝	1¾	29½	⅜	9/16	30½	1¼	22½	16	35				43¾	6½	40	41⅞	43⅜	24	16
34	35⅞	37⅜	36	12	18 11/16	39⅜	18⅝	1¾	32½	⅜	9/16	33½	1¼	23½	17	37				46¼	7¼	42	43⅞	45⅜	24	16
36	38	39⅜	36	12	19 11/16	41⅜	19⅝	1¾	32½	⅜	9/16	33½	1¼	24½	18	39				49	7½	44	46	47½	24	16
38	40	41⅜	40	12	20 11/16	43⅜	20⅝	1¾	36½	⅜	9/16	37½	1¼	26½	19	41				51½	8	48	50	51⅜	28	16
42¼	44¼	45¾	42	16	22⅞	47¾	22⅞	2⅛	37¾	½	13/16	39	1½	29	18½	40				57	9	52	54½	56½	28	16
45	47	48½	44	16	24¼	50½	24¼	2⅛	39¾	½	13/16	41	1½	31	19½	42				60½	9½	56	58½	60½	32	24
48	50	51½	48	16	25¾	53½	25¾	2⅛	43¾	½	13/16	45	1½	33	21	45				64½	10	60	62½	64⅜	34	24
54	56½	58½	48	16	29¼	59½	28¾	2⅛	43¾	½	13/16	45	1½	36½	23½	50				72	10½	66	69	71⅜	34	24
60	62½	64½	48	24	32¼	65½	31¾	2⅛	43¾	½	13/16	43¾	2⅛	40½	–	–	9	19	60	80	11½	72	75	77½	34	24
66	69	71½	48	24	35¾	71½	34¾	2⅛	43¾	½	13/16	43¾	2⅛	45	–	–	10	21	66	88	12	80	83½	86½	40	24
72	75	77½	48	24	38¾	77½	37¾	2⅛	43¾	½	13/16	43¾	2⅛	48	–	–	11	23	72	94	12	88	91½	94½	46	24
78	81½	84½	48	24	42¼	83½	40¾	2⅛	43¾	½	13/16	43¾	2⅛	52	–	–	12	25	78	100	12	96	99½	102½	52	24
84	87½	90½	48	24	45¼	89½	43¾	2⅛	43¾	½	13/16	43¾	2⅛	56	–	–	13	27	84	106	12	104	107½	110½	58	24

DIMENSIONS ARE COMMON TO ALL HUB SIZES

MOTOR WEIGHTS

INTERNAL-DIRECT CONNECTED T.E.A.O.

NEMA FRAME SIZE	WEIGHT IN POUNDS U FRAME	WEIGHT IN POUNDS T FRAME
143		44
145		51
182	50	66
184	60	78
213	100	130
215	115	150
254	160	200
256	200	268
284	270	315
286	310	415
324	455	510
326	515	570
364	670	790
365	750	875
404	950	1085
405	1075	1200
444	1215	1585
445	1545	1885

WEIGHTS-FAN AND ACCESSORIES (less motor)

Weight In Pounds

Fan Casing Dia. Inches	14" Dia. Hub	17½" Dia. Hub	21" Dia. Hub	26½" Dia. Hub	Fan Supports	Inlet Bell	Screen	Inlet or Outlet Cone
18	190				14	3	2	44
21¼	230	250			18	4	2	57
23¼	250	275			25	5	3	62
25¼	270	295	360		29	6	3	96
27¼	275	300	370		34	7	3	103
29¼	295	315	390		36	8	4	109
32	340	365	440		42	9	4	143
34	380	405	485	550	45	10	5	151
36	400	425	505	580	50	12	5	160
38		470	555	630	58	15	6	192
42¼		630	725	809	65	17	7	283
45		690	785	880	88	18	7	338
48			875	970	96	20	8	379
54				1100	111	30	10	442
60				1205	241	40	12	486
66				1340	296	60	17	637
72				1450	331	64	19	780
78				1585	381	73	21	950
84				1700	446	78	24	1122

2.2

Westinghouse Electric Corporation

700 Ellicott Square Bldg.
Buffalo, N. Y. 14203

April 4, 1968

*Struthers Energy Systems, Inc.
Post Office Box 8
Warren, Pennsylvania 16365

Attention: Mr. Hal Wightman, Project Engineer

Subject: Gas Turbine Desalination Plant
Forced Draft Fan Driver
Our Negotiation No. 13-EM-1039

Gentlemen:

Replying to your inquiry of March 7, 1968 and your letter of March 14, 1968 we are pleased to offer the following:

Performance:

Lb. Per Hour	Temperature	Density	CFM	Static Pressure	RPM	HP
298,800	100° F.	.071	70200	3.5 inches	1170	55

At 32° F. ambient air temperature fan horsepower will be 62.5.

(1) vane axial Axiflex size L1060-1170 fan complete with 3/8 inch housing; two access doors; inlet bell; split inlet screen; outlet cone. This fan will be coupled to a Waukesha natural gas engine, model F554GU through a floating shaft through the fan nose as shown on the attached sketch. Engine and fan will be mounted on a structural steel common base. The engine will be provided with the following items.

1. Oil bath air filter
2. Oil pressure gauge

3. Water temperature gauge
4. Manual throttle and linkage
5. High ratio pistons
6. Radiator and cooling system
7. Oil bath oil filter
8. 12 volt starting system with generator
9. 12 volt battery
10. Tachometer
11. Tachometer drive

Also included is a Thomas size 262 SN dynamically balanced shaft and couplings. Torque will be transmitted through Twin Disc torque converter.

Additional information will be as shown on the fan and motor data sheets attached.

The performance indicated is based on there being an outlet cone on the fan which is shown on the attached Dimension Sheet 1116-1 sheet 1.

Performance is as shown on PD 1116, page 134.

Total price for the above items is - $11,720.00 net shop assembled, f.o.b. Hyde Park (Boston), Massachusetts.

Shipping weight of the above is 7150 lb. total.

Price addition for freight to Texas Gulf Coast is $465.00.

<u>SPARE PARTS</u>

We recommend the following spare parts for two years operation:

1. Two fan bearings complete, consisting of 1 Link Belt F-355 3-7/16 inch flange bearing and 1 PE-355 pillow block bearing.
2. One head gasket set.

3. One overall gasket set.
4. Twelve oil filter elements.
5. Twelve oil filter gaskets.
6. Two fan belts.
7. Four sets spark plugs.
8. Two Magneto coupling discs.

Total net price for spare parts - $540.00.

OPTIONAL EXTRAS

The following additional engine accessories are recommended by the engine manufacturer.

1.	Engine housing	- $ 92.00
2.	Gas pressure regulator	- 25.00
3.	Overspeed governor	- 85.00
4.	Vacuum gauge	- 10.00
5.	Safety shut-down	- 10.00
	Total net selling price	- $222.00

WHEEL REMOVAL

The fan wheel will be removable through the inlet after disconnecting the floating shaft and couplings. However, please note that our unique adjustable blade design permits easy replacement of blades without the necessity of removing the wheel hub from the shaft and without need to rebalance the wheel if blades are replaced. The attached bulletin 1116 illustrates our blade arrangement.

INLET SCREEN

We take exception to the specifications which call for inlet screen wire to be 1/8 inch. Inlet screen we will furnish will be our standard #12 gauge (.109 inch) wire.

COUPLING

A Fast gear type coupling is not recommended because it will have a tendency to transmit tortional vibrations generated by the internal combustion engine. Our proposal includes Thomas couplings and a hydraulic torque converter which will absorb the tortional vibrations making for smooth operation. We are proposing a "Twin-Disc" converter, but suggest that a "Power-Glide" automotive torque converter might be applied successfully. This can be negotiated later and probably would reflect a price reduction of between $200 and $300.

ROTOR AND SHAFT

Fan is designed for continuous operation at a maximum speed of 1600 RPM. The engine is capable of 2000 RPM intermittent service and 1600 RPM continuous service, but it must be noted that the fan brake horsepower increases by the cube of the speed ratio. Therefore, the engine speed maximum must be restricted to that speed at which its' horsepower capabilities is equal to the fan horsepower required. This limit would be approximately 1340 RPM where the fan brake horsepower is -

$$\left(\frac{1340}{1170}\right)^3 \text{ X } 55 = 82.5$$

whereas the continuous rating of the motor is approximately 80 HP.

In any fan with adjustable blades there is a small clearance necessary where the blade base seats in the socket of the hub. It is possible for small particles to become inbeded in this base therefore we must take exception to this part of your specifications. However, it should be noted that centrifugal force would tend to resist such an accumulation and further we feel that if such an accumulation did occur the amount would be too insignificant to affect balance providing fan is handling relatively clean air.

MOTOR DATA

For your information enclosed you will find Waukesha bulletins 47887A and 1079E which further describe the engine we are offering.

SHIPMENT AND TERMS AND CONDITIONS

We estimate shipment at approximately 16 weeks after receipt of approved drawings. Drawings can be submitted for approval within 6 weeks after receipt of order. At time order is to be placed we will review the above intervals with you and make improvements where possible.

This proposal is firm for 15 days and is subject to our terms and conditions shown on the reverse side.

Thank you for the opportunity of quoting. We look forward to a more thorough discussion of this offering at your convenience.

Very truly yours,

B. H. Stern
Sales Representative
Sturtevant Division

mav

F. D. FAN DATA SHEET

(see notes below where marked with *)

	1.	Type and Model Number	Vaneaxial; Axiflex L1060
*	2.	Flow (#/hr)	298,800 #/hr
*	3.	Pressure rise (in. H_2O) at 100° F	3.5 Static; 3.93" Fan Total
	4.	Speed (RPM)	1170 Nominal
*	5.	Width, length, height (ft.)	5' dia. X 3' - 11 3/16"
*	6.	Weight of fan housing complete (#)	3773
*	7.	Housing discharge size (ft.)	5'
	8.	Intake size (ft.)	5'
	9.	Fan tip speed operating (FPM)	18,850
	10.	Fan tip speed maximum (FPM)	25,000
	11.	Bearing type	Anti-Friction (Ball)
*	12.	Lubricating requirements	Grease
	13.	Bearing cooling requirements	None

* EXPLANATORY NOTES

2. 70,200 CFM

3.

	FAN STATIC PRESSURE	FAN BHP
With outlet cone at 100° F	3.5	55
@ 32° F	3.76	62.5

5. Add 31¼" length for outlet cone. See D.S. 1116-1

6. Includes fan, base, inlet bell, screen, outlet cone

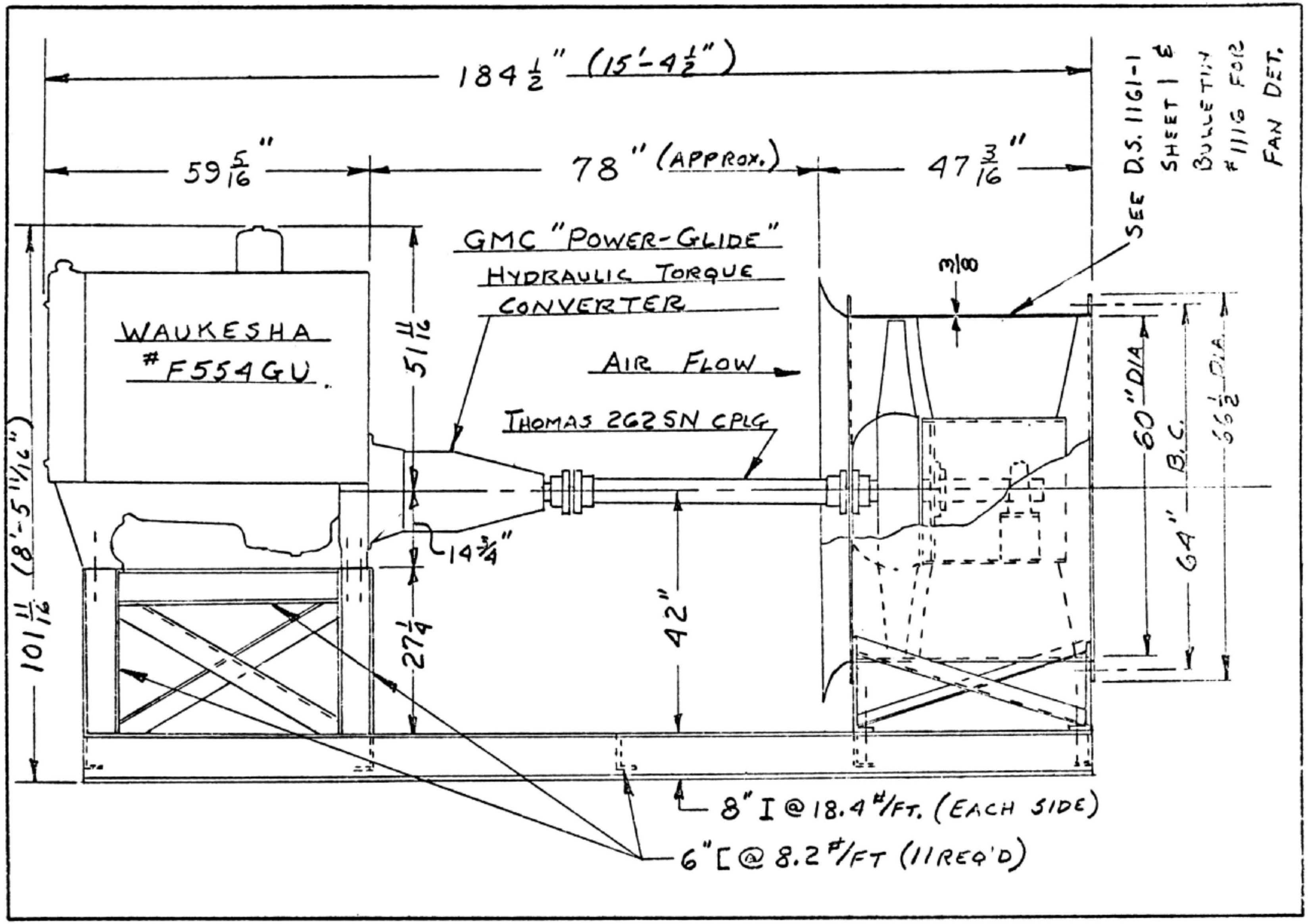
7. Outlet cone discharge size = 5'-11½". See D.S. 1116-1

12. Beacon 325 or aeroshell 11 at 6 mo. to 2 year intervals

GAS ENGINE DATA SHEET

Type and Model Number	Waukesha F554 GU
Operating H.P. with accessories	73 hp continuous Service
Operating Speed (RPM)	1200
Fuel Requirements (#/hr) @ 20430 $\frac{\text{BTU}}{\#}$ LHV	528,000 btu/hr
Engine weight (#)	2550 lbs
Overall Dimensions (inches)	W:31 9/16;H:66 7/16;L:69 15/16
Number of Cylinders	6
Cylinder Arrangement	in-line
Cylinder Bore/Stroke (In.)	4 5/8/5 1/2
Displacement (Cu.In.)	554
Compression Ratio	* 9:1

* Compression ratio with "high ratio" pistons recommended for best fuel economy.



PROPOSED FAN & DRIVE ARR'G'T

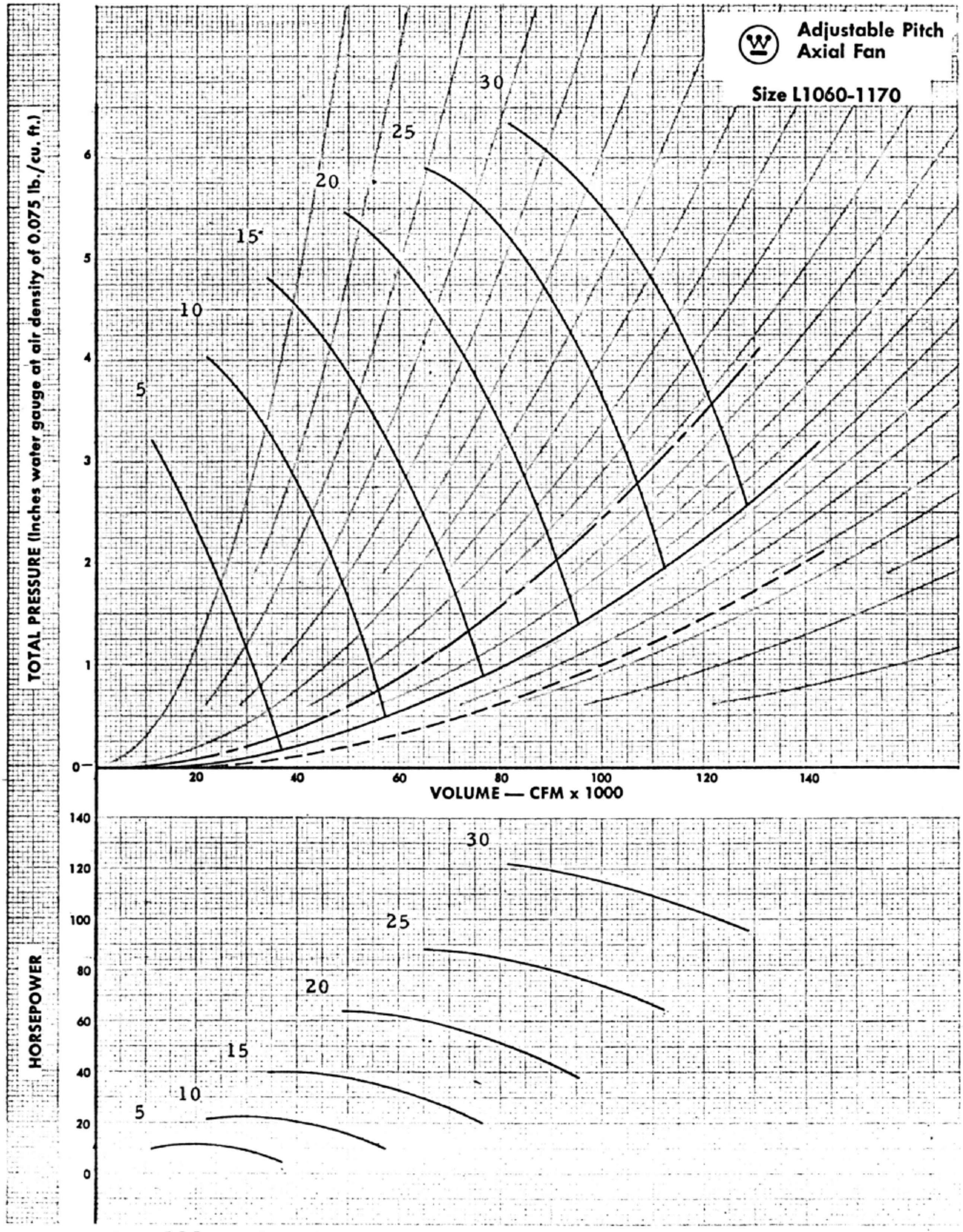
E. V. Lloyd 3-26-68

PD 1116

Adjustable Pitch Axial Fan

Size L1060-1170

PAGE 134



Effective April, 1966

Westinghouse

AIR CONDITIONING — STURTEVANT DIVISIONS
HYDE PARK, BOSTON, MASS. 02136

WORLDWIDE:
WESTINGHOUSE ELECTRIC INTERNATIONAL COMPANY
200 PARK AVENUE NEW YORK, NEW YORK 10017

IN CANADA:
CANADIAN WESTINGHOUSE COMPANY, LIMITED
STURTEVANT DIVISION GALT, ONTARIO

Aqua-Chem, Inc.

WORLD LEADER IN SEAWATER DESALTING —
SPECIALIST IN WATER PURIFICATION AND POLLUTION CONTROL SYSTEMS

VICE PRESIDENT

Please reply to:
225 NORTH GRAND AVE.
WAUKESHA, WIS. 53186

March 23, 1968

Struthers Energy Systems Division
Struthers Wells Corporation
Post Office Box 8
Warren, Pennsylvania 16365

Attention: Mr. A. G. Gaden

Subject: Your Order No. 67-50-7840-031
Our Sales Order No. 99699
MSF Plant Part of Single Purpose
Gas Turbine Powered Desalination Plant
Design and Cost Estimate Study

Gentlemen:

This will modify or supplement the information contained in our report of March 1, 1968.

1) Reference Equipment Specifications, Sheet 1. Change the tube thickness for the evaporator condensers for undeaerated seawater from 20 BWG to 18 BWG. No change in price.

2) Your specifications requested an estimate for the extra cost of keeping the entering condensate separate from that produced in the flash train. The steam that is flashed off from the condensate will mix with that flashed from the brine and condense on the flash train condenser tubes. This condensate is separated and collected in a trough below the condenser. It would be possible to maintain this mixture of condensate separate from that in the lower section of the flash evaporator. There would be no extra charge for this; however, it would be necessary to install additional pumps, and this would increase the total cost by approximately $45,000.

3) Reference Flow Diagram 722-8378. A level control would be required in the drain line from the decarbonator to the vacuum deaerator.

P.O. BOX 421, MILWAUKEE, WISCONSIN 53201 CABLE ADDRESS: AQUA

4) The air ejector system is sized for operation under all of the water temperature conditions specified in the specification enclosed with your inquiry.

5) The weights for the pumps are as follows:

Deaerated Feed	17,000 lbs. each
Distillate	6,000 lbs. each
Blowdown	8,000 lbs. each

6) The total air requirement for instrumentation is estimated to be 18 cubic feet per minute.

Yours very truly,

AQUA-CHEM, INC.

Gordon F. Leitner
Vice President

GFL:gm

Aqua-Chem, Inc.

WORLD LEADER IN SEAWATER DESALTING —
SPECIALIST IN WATER PURIFICATION AND POLLUTION CONTROL SYSTEMS

VICE PRESIDENT

Please reply to:
225 NORTH GRAND AVE.
WAUKESHA, WIS. 53186

March 1, 1968

Struthers Energy Systems Division
Struthers Wells Corporation
P. O. Box 8
Warren, Pennsylvania 16365

Attention: Mr. A. G. Gaden

Subject: Your Order No. 67-50-7840-031
Our Sales Order No. 99699
MSF Plant Part of Single Purpose
Gas Turbine Powered Desalination Plant
Design and Cost Estimate Study

Gentlemen:

In accordance with the requirements of your purchase order, we submit herewith our detailed design and cost estimate of a multi stage flash type desalting plant. The plant we have studied is intended to be a part of a single purpose gas turbine powered desalination plant which Struthers Energy Systems is studying for OSW.

The information furnished herewith does not imply or grant any rights or license under Aqua-Chem, Inc. patents.

We have received only reproductions of the original copy of your purchase order. Although terms and conditions of the order are referred to, these have not been included with the order; and we, therefore, assume that there are none.

We appreciate your confidence in placing this order with us and hope you will find the design and cost estimate to be satisfactory.

Yours very truly,

AQUA-CHEM, INC.

Gordon F. Leitner

GFL:gm
Enclosures

P.O. BOX 421, MILWAUKEE, WISCONSIN 53201 • CABLE ADDRESS: AQUA

MULTI STAGE FLASH EVAPORATOR
BRINE RECIRCULATION SYSTEM

The Multi Stage Flash Evaporator will produce distilled water from sea water by heating it until it is ready to flash. The flashed vapors are drawn to the cooler tube bundle surfaces where they are condensed and collected as distillate.

Flash evaporation is a process in which water is evaporated under vacuum. Boiling temperature for water under vacuum is less than atmospheric pressure. When hot water is injected into a vacuum chamber, some of the water will instantly flash into vapor. The remaining brine then flows to a succeeding higher vacuum chamber where further flashing takes place. It should be noted that in a flash evaporator boiling does not take place on heat transfer surfaces, an important factor in scale control. The sea water which initially serves as a coolant, flows through the condenser tubes on which the vapor condenses to distillate.

The brine recirculation system is designed to operate at temperatures at or above 185°F. In order to achieve long run operation of the unit, it is necessary to retard the formation of scale. Scale control is accomplished through the chemical treatment systems described later in this section.

The brine recirculation system was designed and developed by Aqua-Chem, Inc. and is covered by U.S. and foreign patents. It permits operation at higher evaporator temperatures and, at the same time, reduces the amount of feedwater treatment chemical as compared with that which would be required for once through circulation operation at the same temperature.

Long Tube Flash Evaporator

The Long Tube Flash Evaporator was designed and developed by Aqua-Chem, Inc. and is covered by U.S. and foreign patents. It permits substantial savings in pump power due to the reduction of required waterboxes as compared with cross-tube designs wherein a separate integral condenser tube bundle is required for each evaporator stage.

The Long Tube Flash Evaporator design is furnished when specified elsewhere in this proposal.

Sea Water System

Sea water is pumped into the evaporator at the heat rejection section of the unit. It flows through the tubes of this section and is discharged. A portion of the discharged feed water is diverted for use as makeup water. The makeup water enters the evaporator through the deaerator and flows ultimately to the last stage flash chamber of the evaporator.

The feed water now can be considered brine. The brine flows to the recirculation pump and is pumped through the heat recovery section condenser tubes toward Stage 1, from Stage 1 the brine enters the feedwater heater (Brine heater). The brine is heated to the required temperature within the heater. The brine flows on into the first stage flash chamber where a portion of it flashes off. The brine then flows progressively from stage to stage re-flashing in each stage until it reaches the last stage. At the last stage the brine flows to the recirculation pump.

The optimum concentration level is maintained by removing part of the recirculated brine as blowdown.

Steam and Condensate System

The steam supplied to a Long Tube Flash Evaporator is used for 1) the heating of the feedwater, and 2) the operation of the air ejectors. When so specified high pressure steam is first used to drive the feed and/or brine pumps, with the steam turbine exhaust used in the evaporator feedwater heater.

Low pressure steam is introduced to the shell side of the feedwater heater; it is condensed on the tubes of the heater transferring its heat to the feedwater flowing through the tubes. Thus, the feedwater temperature is elevated to the required temperature.

High pressure steam is utilized by the air ejectors to draw the initial vacuum within the evaporator shell. After the unit is on the line, it serves to withdraw the non-condensible gases, and maintain the vacuum necessary for the unit's operation. The steam and non-condensibles are discharged, from the air ejectors, into a condenser where the steam is condensed and non-condensibles are vented to atmosphere.

Condensate formed by the condensing steam in the heater and air ejector condenser is collected and returned to the condensate system. When specified a barometric type condenser is used.

Distillate System

Distillate is formed, by condensing of the flashed vapors, on the evaporator condenser tubes. The condensed vapors are collected in distillate troughs and piped from Stage 1 through the evaporator until the combined distillate production is removed from the last stage.

Venting and Air Ejector System

Venting of the evaporator is essential to the efficient operation of the distilling plant. Venting is accomplished by the utilization of air ejectors. These ejectors are steam operated. They suction air from within the evaporator and feedwater shell. The air, non-condensibles, and steam are piped into air ejector condensers where the steam is condensed and the non-condensibles are vented to the atmosphere.

Chemical Treatment (Either Chemical Pre-treatment or Continuous Acid Pre-treatment)

A. Chemical Pre-treatment

The recirculated brine of a Flash Evaporator is chemically treated with 1) AC-1, Aqua-Chem Feed Treatment Compound, 2) Acid.

The AC-1 is required to retard the hard formation of scale, which precipitates much quicker at high temperature operation. The scale that forms, forms as a sludge and does not adhere to the heat transfer surfaces.

Acid is used periodically to remove the soft scale or sludge from the evaporator heat transfer surfaces.

Both of the treatment chemicals are mixed in separate tanks and injected into the feedwater stream at the deaerator. AC-1 is injected continuously while the acid is injected periodically as required.

B. Continuous Acid Pre-Treatment

Sulfuric acid is used as a feed treatment chemical. It is introduced continuously just ahead of the deaerator and controlled to maintain the desired pH in the stream leaving the deaerator. Continuous operation can be maintained without shutdown for cleaning. Continuous acid treatment can control scale in flash type evaporators at temperatures up to 250°F.

PERFORMANCE DATA

STRUTHERS ENERGY SYSTEMS DIVISION
STRUTHERS WELLS CORPORATION

OUTPUT GUARANTEE

EVAPORATOR CAPACITY		DISTILLATE PURITY
289,000 #/Hr	832,000 U.S. GPD	50 p.p.m. T.D.S.

UTILITY REQUIREMENTS – STEAM

HIGH PRESSURE STEAM	PSIG	°F	LBS./HR.
Air Ejector	450	650	900
Steam to Brine Pump Turbine			None

LOW PRESSURE STEAM	PSIG	°F	LBS./HR.
Heating Steam Makeup			None
Evaporator Economy ①		LBS. DIST./1000 BTU	

① Does not include air ejector steam.

ELECTRICAL 4,160 440/220 VOLT 3 PHASE 60 CYCLES TOTAL KW 1004

FEED PUMP	BRINE PUMP	DISTILLATE PUMP	CONDENSATE PUMP	CHEMICAL TREATMENT	CONTROLS	OTHER
734 kw	99 kw	168 kw	None Supplied	1.0 kw	2.0 kw	-- kw

CHEMICAL TREATMENT

TYPE	QUANTITY	QUANTITY PER 1000 GAL. DISTILLATE
Continuous 93% H_2SO_4	660 #/Hr	Not applicable

CHEMICAL CLEANING

TYPE	QUANTITY	TIME BETWEEN SHUTDOWNS	DOWN TIME FOR CLEANING

SEAWATER SUPPLY

QUANTITY	MINIMUM INLET PRESSURE	SEAWATER FEED DESIGN TEMPERATURE	MAXIMUM SEAWATER TEMPERATURE	BRINE CONCENTRATION AT BRINE PUMP DISCHARGE
11,000GPM	20 PSIG	75°F	212.5°F	2.27 Max.

NOTE: Guarantees are based upon supply of "normal" seawater as defined by Sverdrup in "The Oceans," unless Aqua-Chem is furnished with copies of, and does approve, a complete seawater analysis for proposed supply. Seawater to be clean and free of sand and debris.

DISCHARGE PRESSURES AND TEMPERATURE

COOLING WATER	BRINE	DISTILLATE	CONDENSATE
72 PSIG	7.5 PSIG 93.8°F	25 PSIG 92.3 °F	None

Specification 1092 Date 2/28/68 Prepared by [illegible]

Aqua-Chem, Inc.

C19-4626-1

SPECIFICATION SHEET Aqua-Chem, Inc.

STRUTHERS ENERGY SYSTEMS DIVISION
PREPARED FOR: STRUTHERS WELLS CORPORATION

EVAPORATOR AND EQUIPMENT COMPONENT DESCRIPTION

A. Evaporator Physical Characteristics

The evaporator equipment is designed and arranged for brine recirculation and consists of the evaporating vessels containing the evaporator flash stages and integral condensers. The evaporator shells are prefabricated in the factory prior to shipment.

Each stage is provided with a manhole to provide for adequate access and ventilation.

A makeup deaerator is provided to remove noncondensable and corrosive gases from the makeup feedwater.

An observation window is also provided at each stage, so positioned that the surface of the shell side brine is visible as well as the steam separating devices.

The unit is capable of being drained to the drainage system by one common drain.

Materials of Construction:

a. Evaporator Flash Chambers:

Shell	1/2" Steel	ASTM A-36
Distillate Trough	1/4" Steel	ASTM A-36
Air Cooling Baffle	1/4" Steel	ASTM A-36
Suppression Baffle	1/2" Steel	ASTM A-36
Vapor Separator	Monel Mesh	
Vapor Piping	None, Integral Condenser	

b. Evaporator Condensers for Deaerated Seawater Section:

Tubes	Cu-Ni 90-10	O.D. 20 BWG ASTM B-111
Tube Sheets External	Cu-Ni 90-10	
Tube Supports	1/2" Steel	ASTM A-36
Waterboxes	Fabricated Steel 1/8" 90-10 Cu-Ni Lining	

c. Evaporator Condensers for Undeaerated Seawater Section:

Tubes	Cu-Ni 90-10	O.D. 18 BWG ASTM B-111
Tube Sheets External	Cu-Ni 90-10	
Tube Supports	1/2" Steel	ASTM A-36
Waterboxes	Fabricated Steel	

SPECIFICATION: 1092 DATE PREPARED 2/28/68
REVISIONS
PREPARED BY: GFL SHEET 1 OF 8

Aqua-Chem®, Inc.
WAUKESHA, WISCONSIN

PREPARED FOR: STRUTHERS ENERGY SYSTEMS DIVISION
STRUTHERS WELLS CORPORATION

Corrosion Allowance:

All parts fabricated of steel are designed with a corrosive allowance of 3/16".

Design and Temperature:

	Design Pressure	Design Temperature
Evaporator Shell	15 psig & Full Vacuum	250°F
Tube Side	75 psig	250°F

Note: Evaporator vessels operate below 15 psig. No ASME code inspection or stamp is included for these vessels.

B. Deaerator

The makeup feed water deaerator included in this proposal is of a packed column type. The deaerator performance will be as follows:

Oxygen	0.020 ppm
Carbon Dioxide	Less than 4 ppm

Materials of construction used for the deaerator are as follows:

Shell	Fabricated Steel lined with Cu-Ni 90-10
Spray Nozzles	Bronze
Deaerator Packing	Plastic Pall Rings

Decarbonator

The makeup feed water is first passed through an atmospheric decarbonator, after addition of acid. The atmospheric decarbonator is to be of wood slat construction and is to include an electric driven fan for air circulation. No steam is required. Flow from decarbonator to vacuum deaerator to be by vacuum drag.

C. Brine Heater - (Not required)

The heater is designed for multi-pass shell and tube type with removable waterboxes. Included are hotwell gauge glasses and steam impingement baffle.

Materials of Construction:

Tubes	Cu-Ni 90-10 1" O.D. 20 BWG
Tubesheets	Cu-Ni 90-10
Shell	3/8" Steel ASTM A-7
Waterboxes	Fabricated Steel

Design Pressure and Temperature:

	Design Pressure	Design Temperature
Shell Side	50 PSIG	300°F
Tube Side	75 PSIG	250°F

D. Air Ejectors and Barometric Condensers

Description and Function of the Venting System

A hogging ejector for fast start-up will evacuate the evaporator to the final vacuum within one hour. The hogging jet will take suction from the last stage and discharges the air to atmosphere.

In operation, the liberated gases from the deaerator are passed to a built-in precondenser, where they are subcooled with cold sea water. Then they are removed with the 1st stage air ejector and discharged into the intercondenser and from there into the inter-condenser with the 2nd stage ejector, and then to atmosphere.

The air leakage through manholes and other flanged connections is vented from stage to stage and is sent to the vacuum system for removal by the air ejectors. Removal is made by the 1st stage ejector which discharges to inter-condenser. The second air ejector stage discharges to the after-condenser for final vent to atmosphere.

The air ejectors are of conventional power plant design complete with strainers. Twin ejector elements are provided; each designed to handle full 100% ejecting load.

Ejector Material:

Steam Chest	Bronze.
Diffuser	Bronze
Nozzle	Stainless Steel

Inter-Condenser and After Condenser:

Design	Direct contact spray condenser

Materials of Construction:

Shell	Reinforced fibreglass
Nozzle	Bronze

Manufacturer: Schutte & Koerting, Graham Manufacturing, or equal

E. Instrumentation and Control Valves

The evaporator distilling plant control system is designed for fully automatic operation with manual preset control. The system includes controllers, recorders and indicators and all necessary alarm devices for maintaining normal continuous operation.

All control valves are designed with pneumatic control topworks. Instrument air supply to be provided by the customer.

The instruments and controls to be furnished are:

Level control for brine service controlling the brine level in the last evaporator flash chamber.

Level control for distilled water service controlling the distillate level in the pump section hot well.

Flow control for the sea water flow rate.

Flow measurement and totalizing meter of the distilled water capacity.

Flow rate measurement of the seawater stream.

Salinity indicator and monitor with diversion valve and alarm to measure conductivity of the distilled water prior to discharge to the fresh water storage tanks.

F. **Piping and Fitting Materials**

Piping is to be steel except as noted below. Terminal points are as shown on the flow diagram.

Deaerated Sea Water Feed - Epoxy lined steel up to 160°F. Fibreglass reinforced epoxy pipe above 160°F.

Vents - Stainless Steel - Type 316

G. **Hand Valves**

Hand valves will be furnished as shown on the flow diagram.

H. **Insulation**

Insulation is to be furnished by Aqua-Chem for the evaporator vessels and pipe work as required to meet the performance specifications.

Piping and vessels which operate at above 125°F will be insulated for protection of personnel.

I. **Scale Control System - Chemical Treatment System**

The evaporator system is designed for once through circulation with continuous acid feed treatment followed by deaeration.

The chemical treatment system consists of one acid storage tank and proportioning acid feed pump providing complete standby equipment.

Treatment rate is based on neutralization of the incoming sea water makeup steam. Acid injection pump is to be controlled by the pH recorder installed in the effluent stream of the deaerator protecting the evaporator plant from acid overdosing. The pH of the brine leaving the deaerator is to be maintained at a pH of 7.5.

Pumps: Two (2) Lapp Microflo Pulsafeeders or equal. Complete with 1/2 HP, 3 phase, 60 cycle, 120 volt, totally enclosed motor.

Tank: One (1) tank will be provided. 1/4" steel construction.

PREPARED FOR: STRUTHERS ENERGY SYSTEMS DIVISION
STRUTHERS WELLS CORPORATION

J. Anti-Foam Injection System

To control the foaming of water due to the presence of organics and other foam-producing materials in the feed water, an anti-foam feed rate of about 1/2 ppm of anti-foam may be required. This is to be fed in a solution of 3 to 5% anti-foam at a feed rate of the solution of about one gallon per hour.

Equipment will consist of:

1 - 50-gallon storage tank (steel drum with polyethlene liner).

2 - Lapp LS-3 "Microflo" Pulsafeeder with 1/20 HP, 1750 RPM motor.

Included are:

Suction strainer, suction shutoff valve, and discharge shutoff and check valves.

K. Pumps and Drivers

Deaerated Seawater Feed Pump

Three (3) half capacity pumps motor driven, are to be furnished and installed.

Capacity	5500 GPM
Total Dynamic Head	260 Feet
Pump Effiency	.85
Brake Horsepower	440
Pump Manufacturer	Worthington or equal.

Materials of Construction:

Casing and Bowls	Type II Ni-Resist.
Impeller	Stainless Steel - 316
Shaft Sleeve	Stainless Steel - 316

SPECIFICATION SHEET Aqua-Chem, inc.

PREPARED FOR: STRUTHERS ENERGY SYSTEMS DIVISION
STRUTHERS WELLS CORPORATION

Distillate Pump

Three (3) half capacity pumps, electric motor driven, are to be furnished and installed.

Capacity	3000 GPM
Total Dynamic Head	112
Pump Efficiency	.85
Brake Horsepower	100
Pump Manufacturer	Worthington or equal

Materials of Construction:

Casing	Cast Iron
Impeller	Bronze
Shaft Sleeve	Stainless Steel

Brine Blowdown Pump

Three (3) half capacity pumps, electric motor driven, are to be furnished and installed.

Capacity	3400 GPM
Total Dynamic Head	58
Pump Efficiency	.85
Brake Horsepower	58.5
Pump Manufacturer	Worthington or equal

Materials of Construction:

Casing	Type II Ni-Resist
Impeller	Stainless Steel - 316
Shaft Sleeve	Stainless Steel - 316

SPECIFICATION: 1092 DATE PREPARED 2/28/68

REVISIONS

PREPARED BY: GFL SHEET 7 OF 8

Aqua-Chem®, Inc.
WAUKESHA, WISCONSIN

C19-943A

PREPARED FOR: STRUTHERS ENERGY SYSTEMS DIVISION
~~STRUTHERS WELLS CORPORATION~~

L. Electrical Controls

Aqua-Chem will furnish and install the power supply system, motor starters, miscellaneous electrical devices and lighting system, consisting of the following equipment:

a. Transformer - Included only when specified in proposal.

b. Main switch gear, consisting of:

1 - Main Breaker
1 - Tie Breaker
Feeder Breakers as Required

Aqua-Chem will supply and install all electrical equipment:

c. Motor Control Center

A motor control center of NEMA Class I Type B construction.

All starters will be NEMA Size 2 minimum full magnetic combination type, with fusible disconnect switch, overload protection in all three lines, and complete with 440/110 volt control transformer, and protective devices required for each motor controller.

Safety ringed Stop buttons with red lights are provided for each starter.

Remote Start-Stop pushbutton with lights will be provided at motor located out of sight of the control panel.

Starter for 110 volt motor will be manual and include all protection devices.

d. Lighting System

Lights are to be provided by others unless specified in the proposal.

PROPOSAL

Aqua-Chem, Inc.

AFFILIATED WITH CLEAVER-BROOKS COMPANY
225 N. GRAND AVENUE, WAUKESHA, WISCONSIN 53186
CABLE ADDRESS – AQUA

Page 1 of 1 Pages

To Struthers Energy Systems Division
Struthers Wells Corporation
Address P. O. Box 8, Warren, Pennsylvania 16365

Proposal No. 6048
Date March 1, 1968

SUBJECT: MSF Plant Part of Single Purpose Gas Turbine Powered Desalination Plant - Design and Cost Estimate Study

Your Order No. 67-50-7840-031
Our Sales Order No. 99699

The following is a cost estimate and is furnished for estimating purposes only as part of the work under the design and cost estimate study furnished under your Order No. 67-50-7840-031.

Item	Quantity	Description
1	1 Set	Aqua-Chem multi stage flash evaporator with prefabricated piping complete with accessories, all as described in Aqua-Chem Specification No. 1092. Total Price, FOB Milwaukee, Wis. . . . . . $1,350,000 Shipping Weight -- 1,500,000 Lbs.
2	1 Set	Field Erected Vessels, FOB Factory . . . Not Offered
3		Erection of plant (Item 1) on customer's foundations, including freight to job site at a Texas Gulf Coast location . . . . $ 600,000
4		Start-up services can be furnished at a rate of $90 per day, plus travel and living expenses.

Shipping Terms See above
Current Characteristics See specifications
Approximate Shipping Weight See specifications
Payment Terms Progress payments
Approximate Shipment after Receipt of Order and Complete Details 14-18 months

THE TERMS AND CONDITIONS OF SALE PRINTED ON THE REVERSE SIDE OF THIS SHEET, UNLESS EXPRESSLY EXCEPTED HEREIN, ARE PART OF THIS PROPOSAL.

THIS PROPOSAL IS SUBJECT TO CHANGE OR WITHDRAWAL WITHOUT NOTICE. PRICES QUOTED SHALL BE FIRM FOR THIRTY (30) DAYS FROM DATE OF PROPOSAL UNLESS OTHERWISE SPECIFIED. ANY EXTENSION OF TIME IS SUBJECT TO APPROVAL OF COMPANY. IF ACCEPTED BY THE PURCHASER IT SHALL BECOME A CONTRACT WHEN APPROVED AT MILWAUKEE, WISCONSIN OR AT WAUKESHA, WISCONSIN, BY AN AUTHORIZED COMPANY REPRESENTATIVE AND MAY THEN BE MODIFIED BY WRITTEN AGREEMENT ONLY. NO STATEMENTS OR UNDERSTANDINGS RELATING TO THE SUBJECT MATTER, OTHER THAN THOSE SET FORTH HEREIN, SHALL BE BINDING ON AQUA-CHEM, INC., (HEREINAFTER REFERRED TO AS THE "COMPANY").

PROPOSAL FURNISHED BY:

Gordon F. Leitner
Vice President

Date ACCEPTED ____________ 19____.

Waukesha, Wis. ____________ 19____.

ACCEPTED FOR AQUA-CHEM, INC.

By ____________
PURCHASER

Printed in U.S.A.

C.9

MPC

MOTIVE PARTS COMPANY OF PENNSYLVANIA
6399 PENN AVENUE • PITTSBURGH, PA. 15206 • 412 – 441-1000

April 25, 1968

STRUTHERS ENERGY SYSTEM, INC.
P.O.Box 8
Warren, Pa. 16365

Attention: Mr. Hal Wightman

Gentlemen:

Our quotation to you for the 100 KW Natural Gas Engine Stand-by Set is as follows:

1 - Waukesha Motor Company Model F817GU 100 KW Stand-By-Continuous Natural Gas Engine Driven Emergency Generator Set rated 277/480 volts, 3 phase 4 wire, 60 cycles.
Unit to contain the following equipment:
- Air cleaner, oil bath type
- Base, structural steel H beam
- Carburetor, natural gas
- Unit mounted radiator with fan and air duct adapter.
- Governor, vacuum compensated
- Engine instrument panel
  - water temperature gauge
  - oil pressure gauge
  - vacuum gauge
- Jacket water heater
- Ignition, low tension with one spark plug and one coil per cylinder
- Lubrication, full pressure, positive pump
  - Shunt type oil filter
- Safety shutdowns for low oil pressure, high jacket water temperature and overspeed. (overcrank located in control panel)
- Electric starting motor 24 volt
- Flexible exhaust section, not mounted
- Silencer, industrial type, not mounted
- Tachometer
- Gas solenoid valve, 12 volt
- Unit mounted generator control panel having the following:
  - 1 - main circuit breaker
  - 1 - ammeter
  - 1 - voltmeter
  - 1 - combination ammeter-voltmeter selector switch
  - 1 - frequency meter
  - 1 - battery charger, 120 volt A.C. input 12 volt, 10 amp output.
  - 4 - pilot lights to indicate shutdown of low oil pressure, high jacket water temperature, overspeed and overcrank

WAUKESHA MOTOR CO

WAUKESHA MOTOR COMPANY DISTRIBUTOR • PARTS - SALES - SERVICE

1 - voltage regulator
1 - voltage adjusting rheostat
1 - audible alarm
1 - set of engine controls to include a 3-position selector switch, off-on-auto (auto. not used unless automatic start is required), overcrank controls, crank limiting with 10 sec. crank and 15 sec. rest with an overall crank of 90 seconds.

Generator, close coupled to engine flywheel, single bearing, Class B insulation, 20 degree C. rise above an ambient of 40 degree C., brushless rotating excitation, synchronous. Frame is drip-proof self-ventilated.

1 - Battery set, 12 volt, lead acid type, 150 ampere hours complete with electrolyte

Total Net Price $ 9,536.00

A. Shipping point is Waukesha, Wisconsin and is assembled and tested at this location.

B. Total shipping weight is 6000 pounds.

C. Shipping cost is approximately $ 3.60 per hundred weight by motor freight.

D. To supervise installation and demonstrate operation of unit will cost $80.00 per day, plus travel expenses. We will have a local dealer handle this service in Texas.

E. You have stated this emergency set to be for stand-by service. For this duty, we do not recommend a set of spare parts other than oil filter changes.

ALTERNATE

To increase the KW capacity from 100 KW to 150 KW, we must use a larger engine, model F1197GU. This model will require a 24 volt electric system and a larger breaker in the generator panel. All other items supplied will be sized to correspond with larger engine size.

Total Net Price $ 14,560.00

Freight rate will be approximately the same as the 100 KW and the total weight is approximately 9000 pounds.

Thank you for this opportunity to quote. Let us know if we can be of further help.

Very truly yours,

MOTIVE PARTS CO. OF PA.,

John Libroth,
Sales Engineer

JL:jg

GAS ENGINE GENERATOR DATA SHEET

100 KW

Gas Engine

Type and Model No.	Four Cycle - Model F817GU
Operating HP	Max. 195 H.P.
Operating Speed	1800
Fuel Requirements, #/hr	61 at full load
Overall Dimensions	111" L x 36" W. x 68" H.

Generator

Type and Model No.	Electric Machinery - Bemac
Output	100 KW
Speed	1800
Power Factor	0.8
Voltage	277/480 volts
Voltage Regulation	plus or minus 2%
Frequency Regulation	3-5%

GAS ENGINE GENERATOR DATA SHEET

150 KW

Gas Engine

Type and Model No.	Four Cycle Model F1197GU
Operating HP	275 H.P. Max.
Operating Speed	1800
Fuel Requirements, #/hr	78.8 at full load
Overall Dimensions	128" L. x 48" W. x 89" H

Generator

Type and Model No.	Electric Machinery - Bemac
Output	150 KW
Speed	1800
Power Factor	0.8
Voltage	277/480
Voltage Regulation	plus or minus 2%
Frequency Regulation	3 - 5%

Onan

We build our future into every Onan Product!

PROPOSAL

Prepared for:

STRUTHERS ENERGY SYSTEMS
P.O. BOX 8
WARREN, PENNA, 16365
ATT: HAL WIGHTMAN
PROJECT ENGINEER

Prepared by:

J.C. SCHULTZ
2123 PARADE ST
ERIE, PENNA. 16503
PHONE 814-455-0502
DISTRIBUTOR FOR ONAN

Litho in U.S.A.

Equipment Check List

STANDARD ACCESSORIES

In addition to the main components this proposal includes the following standard equipment:

Onan 115WA 4XR8 AS SHOWN
on Brochure A465-J ENCLOSED.
100KW 125KVA @ 0.8PF CONTINOUS
SERVICE RATING
STANDARD CONTROLS AS LISTED
BURGESS-MANNING 5" RESIDENTAIL
TYPE MUFFLER, BATTERY CABLES
AND 2-168 A.H. 12V STARTING
BATTERIES. NATURAL GAS
CARBURATION, PRIMARY GAS
REGULATOR FUEL STRAINER.

OPTIONAL ACCESSORIES

This proposal [redacted] the following optional equipment: is extra as shown.

ELECTRIC GAS FUEL SOLENOID $87.00
STEEL HOUSING ENGINE ONLY $150.00
COMPLETE HOUSING ENG + GEN + CONTROLS
$595.00

BROCHURE # A 466K ENCLOSED
ONAN MODEL 170WB 4XR8
WITH SAME EQUIPMENT AS
LIST ON LEFT $12,900 FOB MINN.
ENGINE HOUSING ONLY $290.00
COMPLETE HOUSING - $795.00
SHIPPING WT. UNHOUSED 7250 LB
" " HOUSED 8000 LB

SHIPPING WT. UNHOUSED 5200 LB F.O.B. MINN. APPROXIMATE
" " HOUSED 6000 LB " " " " FREIGHT $250.00-$300.00

PRICE F.O.B. MINN. 8821.00 + FREIGHT + ANY OPTIONAL EQUIPMENT AS LISTED.

TERMS - 5% 30 DAYS.

DELIVERY - 160 DAYS AFTER RECIEPT OF ORDER.

ITEMS 3+4 Section E of your request are not clear enough to quote on a firm basis. Exact location of unit. Length of time involved in installation, number of hours of standby operation expected, ect. are essentail to pricing.

J C Schultz. Distr for Onan.

INDUSTRIAL SALES DIVISION
GENERAL ELECTRIC
COMPANY
HEADQUARTERS, SCHENECTADY, N. Y. 12305

QUOTATION NO. 419-24434-1

on form 13004-ISD 4th rev.

NOTICE: This quotation on the equipment described below is subject to the terms and conditions on the face and back of this letter, and is void unless accepted within 15 days from date hereof and, in the meantime, is subject to change upon notice. It supersedes all previous quotations and agreements relating to this transaction. Please refer to this quotation by number in any order placed with us for this equipment, and address all letters to our office at:

1001 State Street
Erie, Pennsylvania
March 25, 1968

Struthers Energy Systems, Inc.
P. O. Box 8
Warren, Pennsylvania 16365

Attention: Mr. Hal Wightman, Project Engineer

Reference: Your Letter of Inquiry, dated February 21, 1968
Our Quotation 419-24434, for switchgear

Gentlemen:

We are pleased to quote on steam turbine generator unit as requested in your letter of February 21st. We quote as follows:

1 - Steam turbine generator unit rated 1500 KW, 1875 KVA, 480 volt, 3 phase, 60 cycle, 0.8 PF, for operation with steam conditions of 400 PSIG, 650° FTT inlet, 19 PSIG exhaust. Steam rate at these conditions will be 22.5 lb/KWH at 1875 KW and 23 lb/KWH at 1500 KW load.

This turbine generator set will include speed reducing gear between the turbine and generator. All to be mounted on a common fabricated steel base. It is recommended that a roof or enclosure be provided to protect this equipment from the elements. A drip proof air cooled generator as called for in the specifications is not adequate protection for outdoor installation.

The generator will be provided with a brushless exciter and static voltage regulator with field forcing, for separate mounting. The generator will be designed for solid neutral grounding. Space heaters are included. Bushing CTs are not included. Six leads are brought out to allow installation of current transformers for differential protection and for making up the neutral connections.

Your specifications called for a DC auxiliary oil pump. We have substituted a turbine driven auxiliary oil pump.

In other respects, this equipment will be in accordance with specifications submitted with your letter of 2/21/68.

ESTIMATED PRICE $230,000.00

The price quoted includes freight to destination within the confines of the Continental United States, exclusive of Alaska. The price also includes technical direction of installation. Labor for installation is not included.

If you have any question concerning information contained in this quotation, we would be pleased to discuss this proposal with you at your convenience. We hope you are successful in securing an order for this plant and that we may have an opportunity to serve you by providing the turbine and switchgear equipment.

Yours very truly,

G S Tabolt

Gerald S. Tabolt
SALES ENGINEER

GST/b

INDUSTRIAL SALES DIVISION
GENERAL ELECTRIC
COMPANY
HEADQUARTERS, SCHENECTADY, N. Y. 12305

QUOTATION NO. 419-24434

on form 13004-ISD 4th rev.

NOTICE: This quotation on the equipment described below is subject to the terms and conditions on the face and back of this letter, and is void unless accepted within 15 days from date hereof and, in the meantime, is subject to change upon notice. It supersedes all previous quotations and agreements relating to this transaction. Please refer to this quotation by number in any order placed with us for this equipment, and address all letters to our office at: 1001 State Street
Erie, Pennsylvania
March 21, 1968

Struthers Energy Systems, Inc.
P. O. Box 8
Warren, Pennsylvania 16365

Attention: Mr. Hal Wightman, Project Engineer

Reference: Your Letter of Inquiry, dated February 21, 1968

Gentlemen:

As requested in your letter of February 21st, we are preparing a quotation on a steam turbine generator and on associated switchgear equipment. We are forwarding herewith specifications for the switchgear portion, and will supplement this with an estimated price for a turbine generator set at a later date.

We are pleased to quote on the switchgear portion as follows:

1 - Set of switchgear equipment in accordance with the attached specification 419-24434, as prepared by R. L. Smith on March 18, 1968.

TOTAL ESTIMATED PRICE	$23,198.00
PRICE ADDITION for Option #1	220.00
PRICE ADDITION for Option #2	1,900.00

We recommend solid grounding for this system and have requested that our turbine people quote the generator suitable for solid grounding.

We are pleased to have the opportunity to work with you on this proposal. We will supplement this portion of the quotation with a quotation on the steam turbine as soon as it becomes available from our factory. If, in the meantime, you have any question concerning the information contained in this letter, or in the specifications, please call me.

Yours very truly,

GSTabolt

Gerald S. Tabolt
SALES ENGINEER

GST/b
Enclosure

GENERAL ELECTRIC
COMPANY
SPECIFICATIONS

Specifications No.
Proposition No. 419-24434

STRUTHERS ENERGY SYSTEMS
2500 KVA Generator Control

1 - Indoor low voltage drawout switchgear equipment per Sketch #1 and including:

Units 1 and 2 - Generator Equipment

1- Low voltage drawout power circuit breaker, Type AK-75, TPST, 3000 amperes, electrically operated, 48 V DC control with shunt trip and no series overcurrent trip devices.
7- Current transformers (3 for circuit relaying and metering, 3 for differential relays, one for voltage regulator)
3- Overcurrent relays with voltage restraint, Type IJCV #51V
3- High speed differential relays, Type CFD #87T
1- Lockout relay, Type HEA #86T
1- Field lockout relay, Type HEA #41
3- Potential transformers (2 for metering, one for voltage regulator)
1- Control power transformer (for voltage regulator)
1- Provision for mounting voltage regulator and field forcing panels
1- Overvoltage relay, Type IAV71 #59
1- Over frequency relay, Type CFK12 #81
1- Ground relay, Type IAC #51G
1- Field ammeter Type DB-40
1- Ammeter, Type AB-40 and switch
1- Voltmeter, Type AB-40 and switch
1- Wattmeter, Type AB-40
1- Varmeter, Type AB-40
1- Frequency meter, Type AB-40
1- Temperature meter, Type DB-40 with transfer and test switch
1- Voltage adjusting rheostat
1- Control switch and indicating lamps
1- Set of terminals for incoming cable

Unit 3 - Feeders

2- Low voltage drawout power circuit breakers, Type AK-50, TPST, 1600 ampere, manually operated, with static power sensor overcurrent trip devices including both short time and long time delay phase overcurrent trips and time delay ground fault trips.

Unit 3 - continued

2- Sets of terminals for incoming cable
1- Breaker lifting device

For Remote Mounting

4- Current transformers (at generator neutral terminals for differential and ground relaying)
1- 48 V DC plante' type battery and automatic voltage regulated charger

Options: (Not necessarily recommended)

Option #1 - 3- Lightning arresters, 650 volts
3- Surge capacitors, 650 volts

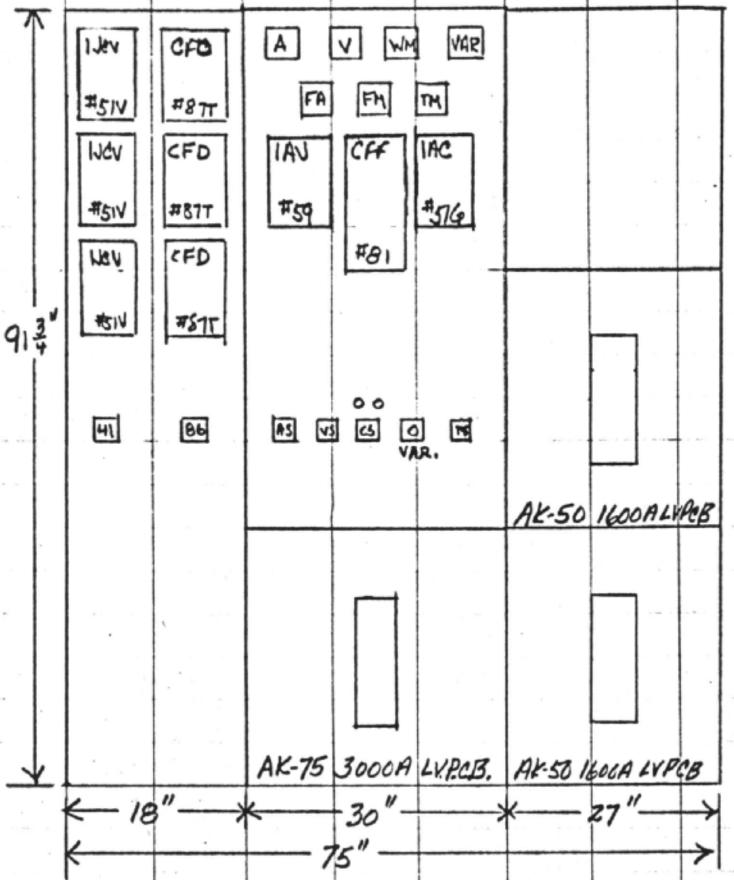
Option #2 - Omit 48 V DC battery and add 125 V DC battery

Assumptions:

1. Generator is braced for solid grounding
2. Field forcing is included with voltage regulator
3. RTD's are available
4. Both sides of each phase winding available
5. Turbine self-protected against motoring

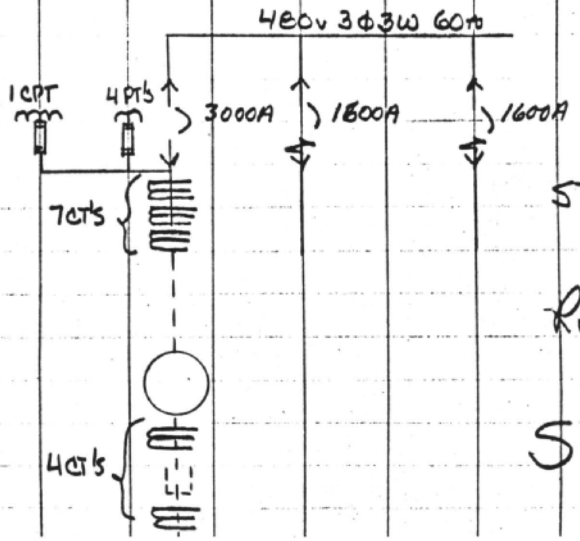
R. L. Smith
March 18, 1968

INDOOR LOW VOLTAGE DRAWOUT SWITCHGEAR



60" DEEP

FRONT VIEW



STRUTHERS ENERGY SYSTEMS
PROP. 419-24434

RLSmith 3-15-68

SKETCH #1

W. L. BADGER ASSOCIATES, INC.
CONSULTING CHEMICAL ENGINEERS
300 SOUTH THAYER STREET
ANN ARBOR, MICHIGAN 48104

TELEPHONE
665-8835
AREA CODE
313

CABLE
ADDRESS
BADGERENG
ANN ARBOR

May 6, 1968

Mr. Hal Wightman
Struthers Energy Systems, Inc.
P.O. Box 8
Warren, Pennsylvania 16465

Our Ref: E-247

Subject: <u>OSW 8 MGD Thermo Compression Plant</u>

Dear Mr. Wightman:

The $32,500 price of the sulfuric acid tank includes shipment and erection on site -- foundation by customer.

Very truly yours,

W.L. BADGER ASSOCIATES, INC.

Howard F. Bjork

HFB:er

3.0 Calculations

3.1 Vertical Tube Evaporator - Tubesheet Thickness

1. Use TEMA Standard, but provide adjustment for end conditions.

2. Equivalent shell thickness, t

$\frac{\pi}{4}(12.75^2 - 10.75^2) \times 4 \times r^2 = \pi \times 145 \times t \times r^2$

$t = \frac{23.5 \times 2}{145} = .324"$

3. Tubesheet Weight, W_1

$W_1 = \frac{\pi}{4}(290^2 - 5076 \times 3^2) \times 1.5 \times \frac{490}{1728} = 12,900$ lbs.

4. Half weight of tubes, W_2

$W_2 = 5076 \times 6.25 \times \frac{\pi}{4} \times (3^2 - 2.902^2) \times \frac{490}{144} = 51,000$ lbs.

5. Total area of tubesheet, A

$A = \frac{\pi}{4} 290^2 = 66,000$ in.^{2}

6. Total inside area of tubes, C

$C = 5076 \times \frac{\pi}{4} \times 2.902^2 = 33,600$ in.^{2}

7. Total metal area, A-C

$A\text{-}C = 66,000 - 33,600 = 32,400$ in.^{2}

8. Total weight acting on one tubesheet, W

$W = W_1 + W_2 = 12,900 + 51,000 = 63,900$ lbs.

9. Tube-sdie pressure due to weight, Pw

$Pw = \frac{W}{A\text{-}C} = \frac{63,900}{32,400} = 2$ psig

10. Ratio $\frac{C}{A\text{-}C} = \frac{33,600}{32,400} = 1.038$

11. Pick the worst condition

P_T = Tube-side pressure, psig

P_S = Shell-side pressure, psig

Effect	Location	$P_T = P + Pw + P_{Nozzle}$ Top $P_T = P - Pw$ Bottom	P_T	P_S	$P_T - P_S$
1	Top	22.5 + 2. + 8 x 1.038 =	32.8	18.7	+14.1
1	Bottom	14.5 - 2.	12.5	18.7	- 6.2
2	Top	20 + 2 + 9.1 x 1.038 =	31.5	14.5	+17.
2	Bottom	10.9 - 2. =	8.9	14.5	- 5.6
3	Top	16.5 + 2 + 9. x 1.038 =	27.9	10.9	+17.
3	Bottom	7.5 - 2	5.5	10.9	- 5.4
4	Top	13.2 + 2 + 8.8 x 1.038 =	24.4	7.5	+16.9
4	Bottom	4.4 - 2	2.4	7.5	- 5.1

12. Top tubesheet of second effect = worst condition.

13. Follow TEMA, Fifth Edition, 1968

$F = 1$

$J = 1$

$$K = \frac{27.9 \times .324}{17.8 \times .049 \times 5076} \frac{289.7}{2.951} = 2.0$$

$$Fq = .25 + .4 \left(\frac{300 \times .324 \times 27.9}{2 \times 150 \times 27.9} \times \left(\frac{289.3^3}{1.5}\right)\right)^{1/4}$$

$$= .25 + .4 \times (233 \times 10^4)^{1/4} = .25 + 15.65 = 15.9$$

$$fs = 1 - 5076 \left(\frac{3}{289.3}\right)^2 = .455$$

$$Ps^1 = 14.5 \; .4 \times \frac{(1.5 + 2 \times 1.955)}{1 + 2 \times 15.9} = 14.5 \times .066 = .96 \text{ psig}$$

$$ft = 1 - 5076 \left(\frac{2.902}{289.3}\right)^2 = .492$$

$$P_T{}^1 = 31.5 \frac{1 + .4 \times 2 \times 1.992}{1 + 2 \times 15.9} = 31.5 \times \frac{2.595}{32.8} = 2.5 \text{ psig}$$

$$P = P_T{}^1 - P_S{}^1 = 2.50 - .96 = 1.54 \text{ psig}$$

$$T^2 = .25 \frac{G^2P}{S} = .25 \times 289.3^2 \frac{1.54}{13750} = 2.35$$

$$T = \sqrt{2.35} = 1.54 \text{ in.}$$

14. To provide proper adjustment, compare flat plate formulas (Roark, Formulas for Stress and Strain, 4th edition).

Stress in a simply supported circular plate

$$S = 1.25 \frac{a^2}{T^2} W \qquad (a = \text{radius})$$

Stress in a beam with fixed ends (a = span)

$$S = .5 \frac{a^2}{T^2} W$$

Adjustment coefficient for thickness, k

$$k = \sqrt{\frac{1.25}{.5}} = \sqrt{2.5} = 1.58$$

15. Thickness adjusted for support in center of tubesheet (Assume that corners of the quadrants are fixed to the vertical supporting pipes):

$$T = \frac{1.54}{1.58} \approx 1.0 \text{ in.}$$

16. Include corrosion allowance 3/8" T = 1 3/8"

17. Use T = 1 1/2 in.

3.2 Economic Calculations - Refer to Section VI

1. Gallons per day as per heat and material balance; Fig. V-1

$$(2781.761 \ \#/\text{hr})(.016106 \ \frac{\text{Ft}^3}{\#}) \ (\frac{7.48 \text{ gal.}}{\text{Ft}^3}) \ (\frac{24 \text{ hr}}{\text{day}}) =$$

@ 92.3°F

$$= 8.04 \quad \times 10^6 \text{ gal/day}$$

2. Gallons per year at 90% load factor

$$= 8.04 \quad \times 10^6 \frac{\text{gal}}{\text{day}}) \ (\frac{\text{day}}{24 \text{ hr}}) \ (8760 \ \frac{\text{hr}}{\text{year}}) \ (.90)$$

$$= \quad 2642. \quad \times 10^6 \text{ gal/year}$$

3. Average annual daily production rate (based on 90% load factor):

$$(8.04 \times 10^6 \frac{\text{gal}}{\text{day}})\ (90\%)$$

$$= 7.239 \times 10^6 \text{ gal/day}$$

4. Acid usage rate: (refer to heat and material balance, Figure V-1)

$$\frac{(555\ \#/\text{hr})\ (24\ \text{hr/day})}{8.04 \times 10^3\ \text{gal/day} \times 1000\ \text{gal}}$$

$$= 1.656\ \#/1000\ \text{gal.}$$

5. Annual cost of chemicals, refer to Table VI-8

$$\frac{(\$0.034491)}{1000\ \text{gal}} \quad (2642. \times 10^6)\ \frac{\text{gal}}{\text{year}} = \$91{,}125.$$

6. Interest on Working Capital: (Refer to Table VI-3)

Total Direct Operating Costs	$507,325
Payroll Extras	+ 24,440
G. and A.	+ 37,845
	$569,610

$$(\$569{,}610)\ (.06\ \frac{\text{percent}}{\text{annum}})\ (\frac{2\ \text{months}}{12\ \text{months}})$$

$$= \$5{,}695$$

7. Interest of 4.25%

$$\text{Capital recovery factor} = \frac{r(1 + r)^n}{(1 + r)^n - 1}$$

$$(1 + .0425)^{30}$$

$$30 \log 1.0425$$

$$= 30\ (0.0181)$$

$$= 0.5430\ (\text{anti-log } 0.5430 = 3.4915)$$

$$\text{therefore, } \frac{.0425\ (3.4915)}{(3.4915 - 1)} = 5.9557\%$$

8. Overall Performance Ratio:

$$\frac{2781761\ \#/\mathrm{hr}}{145.8 \times 10^{6}\mathrm{btu/hr}} = 19.05\ \#/1000\ \mathrm{btu}$$

3.3 Process Calculations - Refer to Section IV

1. Deaerated seawater flow rate at design conditions:

$$\frac{(5{,}000{,}000\#/\mathrm{hr})(.1209\ \frac{\mathrm{gal}}{\#\mathrm{fw}^{*}}\ (\frac{62.4\#\mathrm{fw/ft}^{3}}{64.2\#\mathrm{sw/ft}^{3*}})}{60\ \mathrm{min/hr}}$$

= 9790 gpm

2. Raw seawater flow rate at design conditions:

$$\frac{(5{,}800{,}000\#/\mathrm{hr\ sw})(.1202\ \frac{\mathrm{gal}}{\#\mathrm{fw}_{75^{\circ}\mathrm{F}}})\ (\frac{62.4\#\mathrm{fw/ft}^{3}}{64.2\#\mathrm{sw/ft}^{3}})}{60\ \mathrm{min/hr}}$$

= 11,295 gpm

3. Blowdown brine flow rate at design conditions:

$$\frac{(2{,}212{,}389\#/\mathrm{hr})(.1206\ \frac{\mathrm{gal}}{\#\mathrm{fw}}\ (\frac{1}{1.06}\ \mathrm{specific\ gravity})}{60\ \mathrm{min/hr}}$$

= 4195 gpm

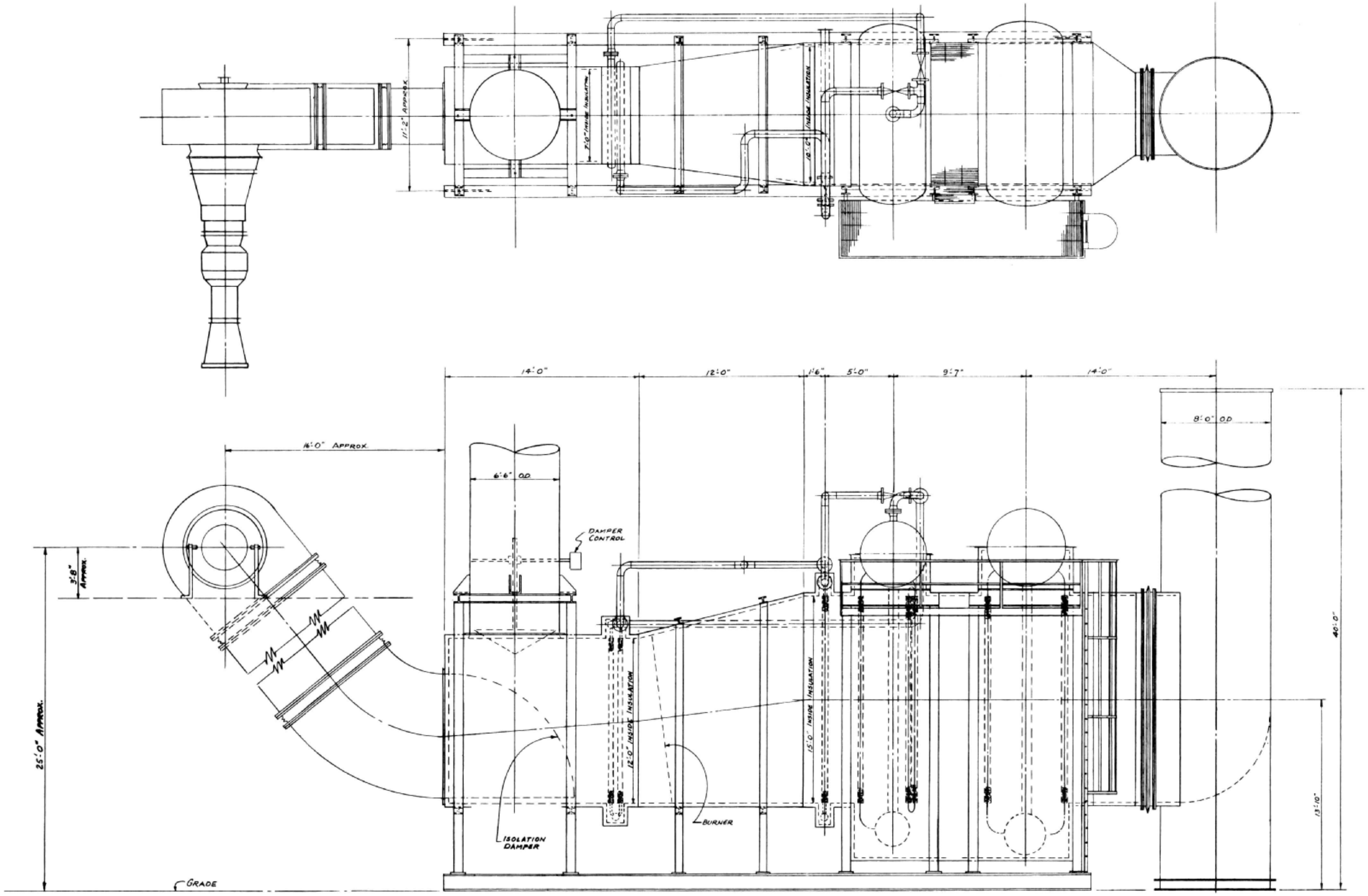
4. Distillate flow rate at design conditions

$$\frac{(2{,}781{,}761\#/\mathrm{hr})(.1205\ \mathrm{gal}/\#)\ 923^{\circ}\mathrm{F}}{60\ \mathrm{min/hr}}$$

= 5585 gpm

* fw = Fresh water
sw = Seawater

★ U.S. GOVERNMENT PRINTING OFFICE : 1968 O—309-337
1969 O-323-951



APPROX. WT. 431,000*

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

8.0 MGD GAS TURBINE POWERED
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442

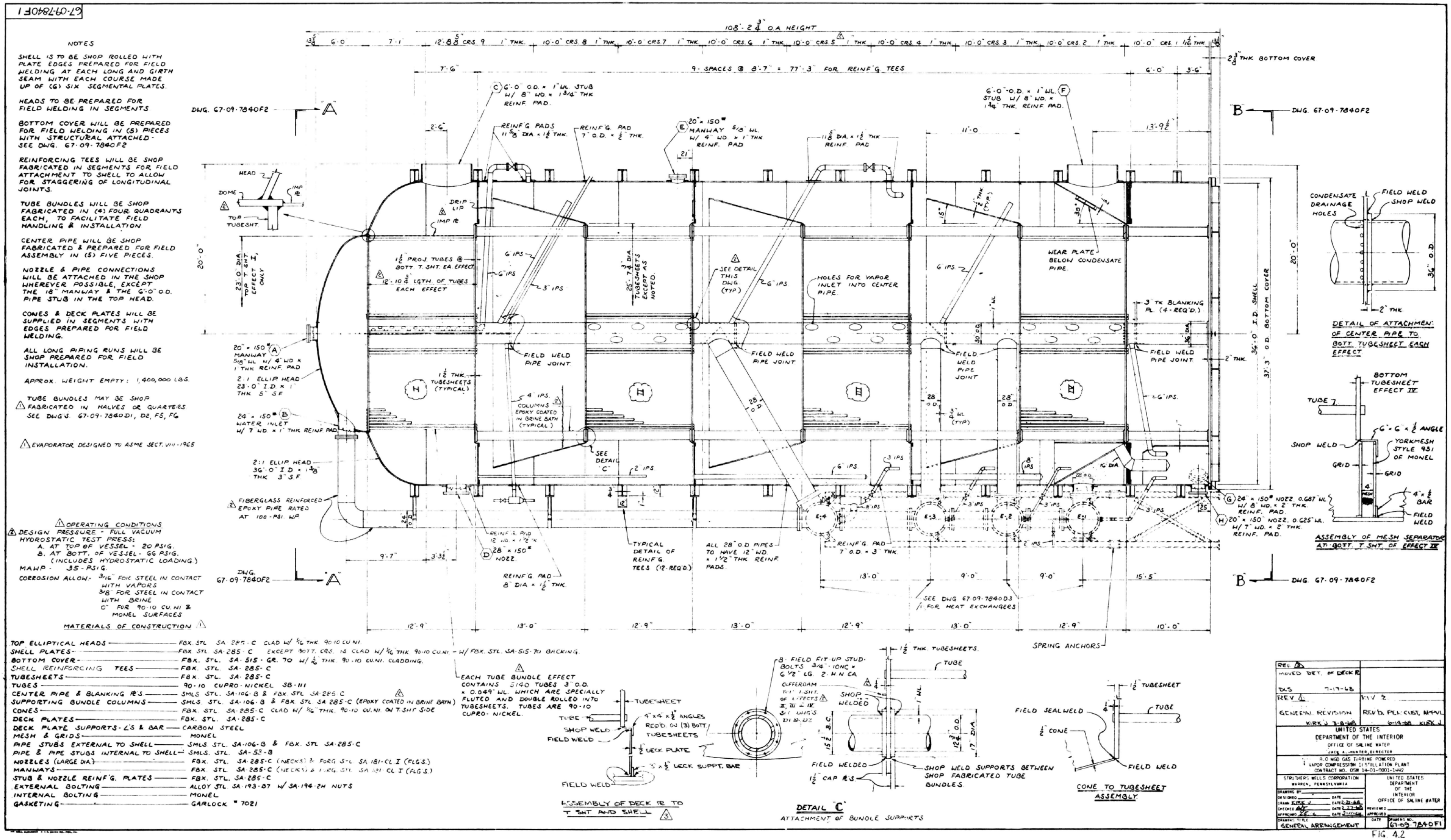
STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA

DRAWING BY
DESIGNED DATE
DRAWN Fgm DATE 3-18-66
CHECKED HAJ DATE
APPROVED DATE

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

DRAWING TITLE
Heat Recovery Boiler
DATE
DRAWING NO.
67-03-7040-DS

FIG. 4.1



NOTES

SHELL IS TO BE SHOP ROLLED WITH PLATE EDGES PREPARED FOR FIELD WELDING AT EACH LONG AND GIRTH SEAM WITH EACH COURSE MADE UP OF (6) SIX SEGMENTAL PLATES.

HEADS TO BE PREPARED FOR FIELD WELDING IN SEGMENTS

BOTTOM COVER WILL BE PREPARED FOR FIELD WELDING IN (5) PIECES WITH STRUCTURAL ATTACHED - SEE DWG. 67-09-7840F2

REINFORCING TEES WILL BE SHOP FABRICATED IN SEGMENTS FOR FIELD ATTACHMENT TO SHELL TO ALLOW FOR STAGGERING OF LONGITUDINAL JOINTS.

TUBE BUNDLES WILL BE SHOP FABRICATED IN (4) FOUR QUADRANTS EACH, TO FACILITATE FIELD HANDLING & INSTALLATION

CENTER PIPE WILL BE SHOP FABRICATED & PREPARED FOR FIELD ASSEMBLY IN (5) FIVE PIECES.

NOZZLE & PIPE CONNECTIONS WILL BE ATTACHED IN THE SHOP WHEREVER POSSIBLE, EXCEPT THE 18" MANWAY & THE 6'-0" O.D. PIPE STUB IN THE TOP HEAD.

CONES & DECK PLATES WILL BE SUPPLIED IN SEGMENTS WITH EDGES PREPARED FOR FIELD WELDING.

ALL LONG PIPING RUNS WILL BE SHOP PREPARED FOR FIELD INSTALLATION.

APPROX. WEIGHT EMPTY: 1,400,000 LBS.

△ TUBE BUNDLES MAY BE SHOP FABRICATED IN HALVES OR QUARTERS. SEE DWG'S. 67-09-7840D1, D2, F5, F6

△ EVAPORATOR DESIGNED TO ASME SECT. VIII-1965

△ OPERATING CONDITIONS

△ DESIGN PRESSURE - FULL VACUUM
HYDROSTATIC TEST PRESS:
A. AT TOP OF VESSEL - 20 PSIG.
B. AT BOTT. OF VESSEL - 66 PSIG. (INCLUDES HYDROSTATIC LOADING)
MAWP - 35-PSIG.
CORROSION ALLOW. - 3/16" FOR STEEL IN CONTACT WITH VAPORS
3/8" FOR STEEL IN CONTACT WITH BRINE
0" FOR 90-10 CU. NI & MONEL SURFACES

MATERIALS OF CONSTRUCTION △

TOP ELLIPTICAL HEADS	FBX. STL SA 285-C CLAD W/ 1/16 THK. 90-10 CU NI.
SHELL PLATES	FBX STL SA-285-C EXCEPT BOTT. CRS. IS CLAD W/ 1/16 THK 90-10 CU.NI. - W/ FBX. STL. SA-515-70 BACKING.
BOTTOM COVER	FBX. STL. SA-515-GR. 70 W/ 1/16 THK. 90-10 CU.NI. CLADDING.
SHELL REINFORCING TEES	FBX. STL. SA-285-C
TUBESHEETS	FBX. STL. SA-285-C
TUBES	90-10 CUPRO-NICKEL SB-111
CENTER PIPE & BLANKING PL'S	SMLS STL. SA-106-B & FBX STL SA-285 C
SUPPORTING BUNDLE COLUMNS	SMLS. STL. SA-106-B & FBX. STL. SA 285-C (EPOXY COATED IN BRINE BATH)
CONES	FBX. STL. SA-285-C CLAD W/ 1/16" THK. 90-10 CU.NI. ON T.SHT SIDE
DECK PLATES	FBX. STL. SA-285-C
DECK PLATE SUPPORTS - L'S & BAR	CARBON STEEL
MESH & GRIDS	MONEL
PIPE STUBS EXTERNAL TO SHELL	SMLS. STL. SA-106-B & FBX. STL SA-285-C
PIPE & PIPE STUBS INTERNAL TO SHELL	SMLS. STL. SA-53-B
NOZZLES (LARGE DIA.)	FBX. STL. SA-285-C (NECKS) & FORG. STL. SA-181-CL. I (FLG'S.)
MANWAYS	FBX. STL. SA-285-C (NECKS) & FORG. STL. SA-181-CL. I (FLG'S.)
STUB & NOZZLE REINF'G. PLATES	FBX. STL. SA-285-C
EXTERNAL BOLTING	ALLOY STL. SA-193-B7 W/ SA-194-2H NUTS
INTERNAL BOLTING	MONEL
GASKETING	GARLOCK # 7021

△ EACH TUBE BUNDLE EFFECT CONTAINS 5140 TUBES 3" O.D. × 0.049" WL. WHICH ARE SPECIALLY FLUTED AND DOUBLE ROLLED INTO TUBESHEETS. TUBES ARE 90-10 CUPRO-NICKEL.

REV. 3 MOVED DET. OF DECK PL DLS 7-17-68	
REV 1 GENERAL REVISION KIRK J 3-8-68	REV 2 REV'D. PER CUST. APPVL. 6-19-68 KIRK J

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

8.0 MGD GAS TURBINE POWERED
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442

STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA

DRAWING BY
DESIGNED DATE
DRAWN KIRK J DATE 2-22-68
CHECKED DATE 2-27-68
APPROVED DATE 2-11-68

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

DRAWING TITLE
GENERAL ARRANGEMENT
DATE
DRAWING NO. 67-09-7840F1

FIG. 4.2

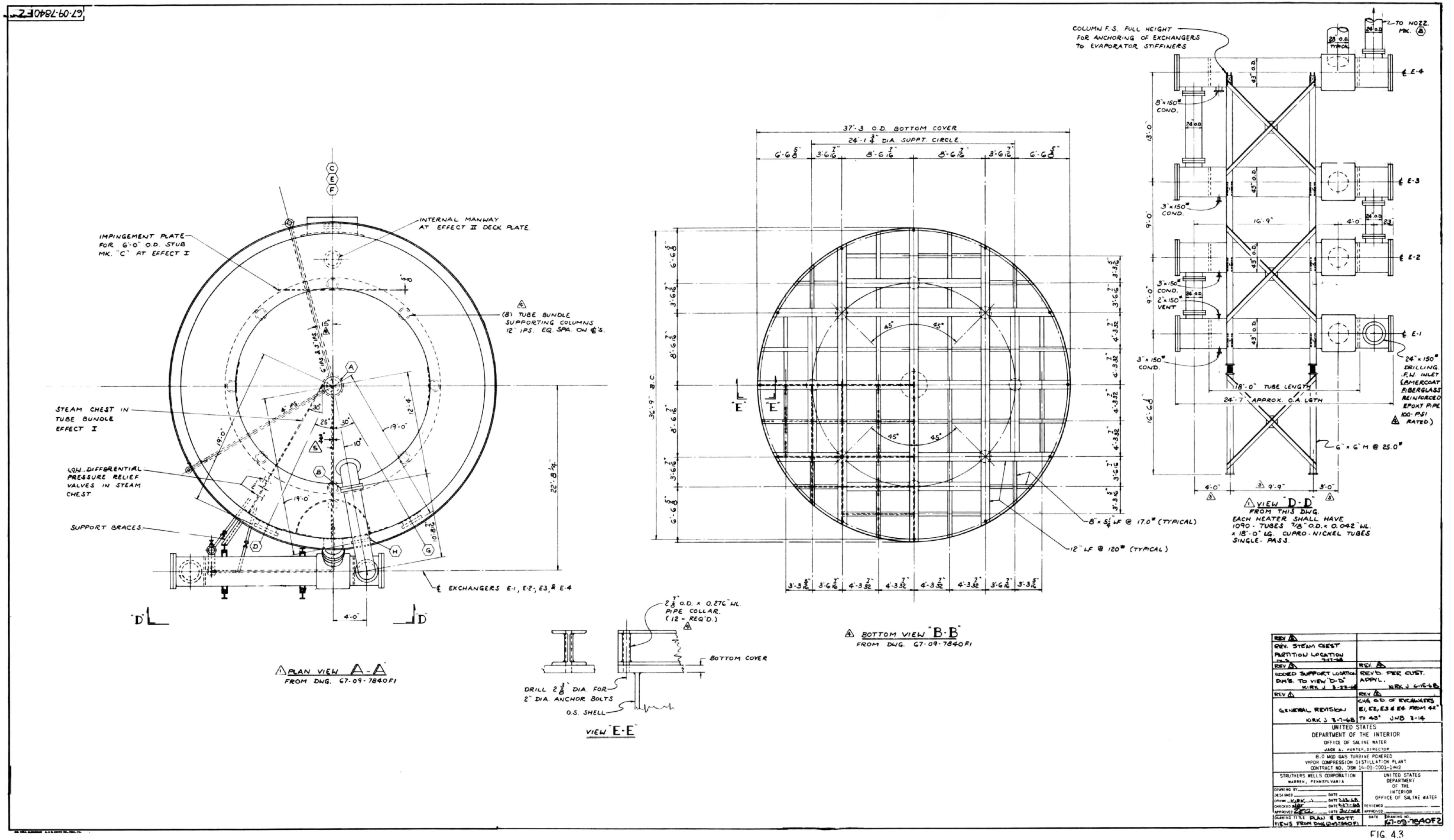
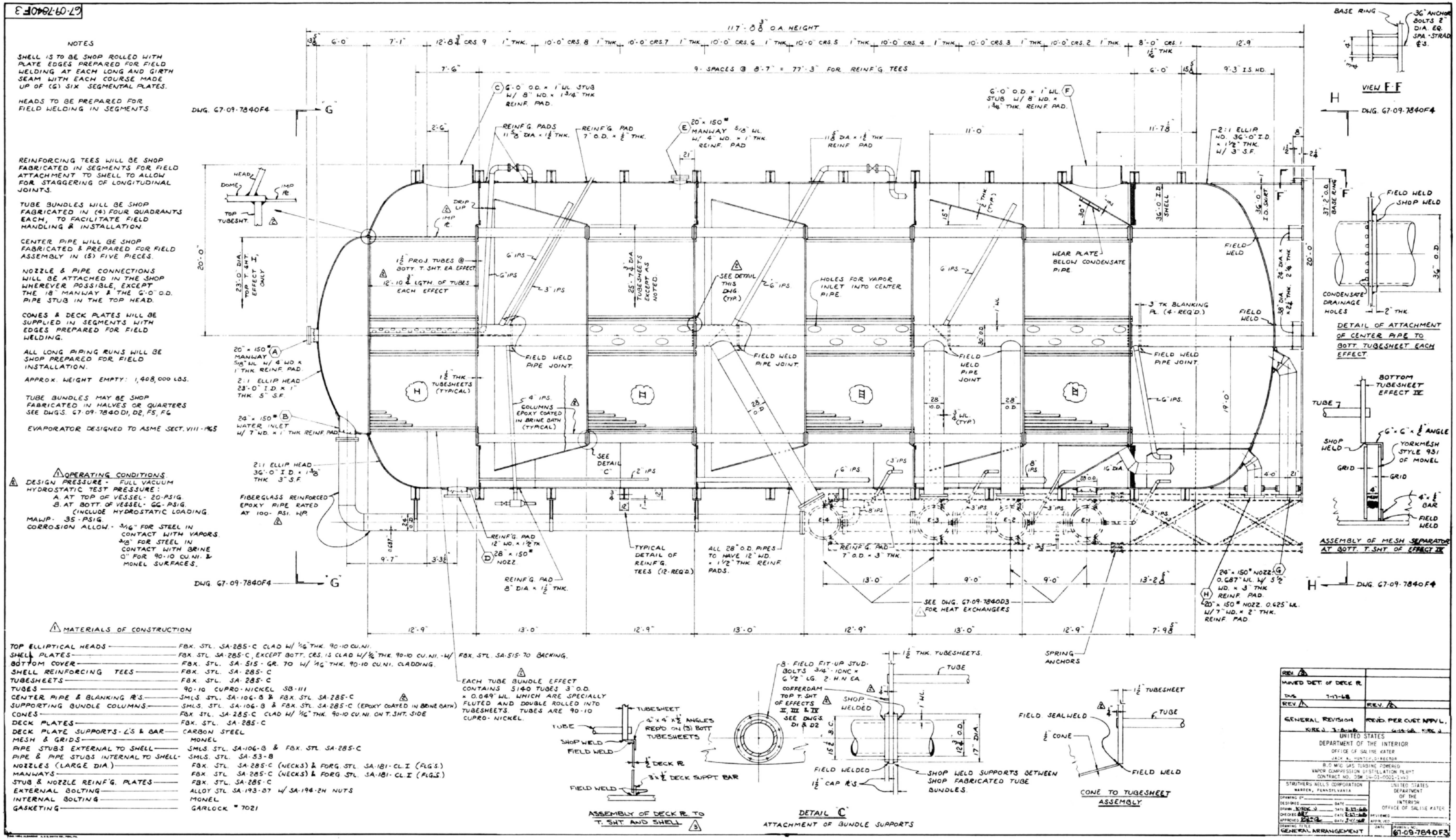

67-09-7840F2
IMPINGEMENT PLATE FOR 6'-0" O.D. STUB MK. "C" AT EFFECT I
INTERNAL MANWAY AT EFFECT II DECK PLATE
(8) TUBE BUNDLE SUPPORTING COLUMNS 12" IPS. EQ. SPA. ON ℄'S.
STEAM CHEST IN TUBE BUNDLE EFFECT I
LOW DIFFERENTIAL PRESSURE RELIEF VALVES IN STEAM CHEST
SUPPORT BRACES
6" IPS & 3" IPS
4" IPS
19'-0"
12'-4"
10'-8 1/2"
22'-8 1/4"
4'-0"
15°
25°
30°
10°
℄ EXCHANGERS E-1, E-2, E3, & E-4
PLAN VIEW A-A
FROM DWG. 67-09-7840F1
2 7/8" O.D. x 0.276" WL. PIPE COLLAR. (12 - REQ'D.)
BOTTOM COVER
DRILL 2 3/8" DIA. FOR 2" DIA. ANCHOR BOLTS
O.S. SHELL
VIEW "E-E"
37'-3 O.D. BOTTOM COVER
24'-1 3/4" DIA. SUPPT. CIRCLE.
36'-9" B.C.
6'-6 5/8"
3'-6 7/16"
8'-6 7/16"
3'-3 5/16"
4'-3 7/32"
45°
8" x 5 1/4" WF @ 17.0# (TYPICAL)
12" WF @ 120# (TYPICAL)
BOTTOM VIEW "B-B"
FROM DWG. 67-09-7840F1
COLUMN F.S. FULL HEIGHT FOR ANCHORING OF EXCHANGERS TO EVAPORATOR STIFFINERS
TO NOZZ. MK. B
28" O.D. TYPICAL
24" O.D.
℄ E-4
℄ E-3
℄ E-2
℄ E-1
8" x 150# COND.
3" x 150# COND.
2" x 150# VENT
43" O.D.
13'-0"
9'-0"
16'-6"
16'-9"
4'-0"
23"
18'-0" TUBE LENGTH
24'-7" APPROX. O.A. LGTH
6" x 6" M @ 25.0#
9'-9"
3'-0"
24" x 150# DRILLING. F.W. INLET (AMERCOAT FIBERGLASS REINFORCED EPOXY PIPE 100 PSI RATED)
VIEW "D-D"
FROM THIS DWG.
EACH HEATER SHALL HAVE 1090 - TUBES 7/8" O.D. x 0.042" WL. x 18'-0" LG. CUPRO-NICKEL TUBES SINGLE-PASS.
REV. STEAM CHEST PARTITION LOCATION 7-17-68
ADDED SUPPORT LOCATION DIM'S. TO VIEW "D-D" KIRK J 3-27-68
REV'D. PER CUST. APPVL. KIRK J 6-15-68
GENERAL REVISION KIRK J 3-7-68
CHG O.D. OF EXCHANGERS E1, E2, E3 & E4 FROM 42" TO 43" JNB 3-14
UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR
8.0 MGD GAS TURBINE POWERED
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442
STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA
UNITED STATES DEPARTMENT OF THE INTERIOR OFFICE OF SALINE WATER
DRAWN KIRK J DATE 2-23-68
DRAWING TITLE PLAN & BOTT. VIEWS FROM DWG 67-09-7840F1
DRAWING NO. 67-09-7840F2

FIG. 4.3



NOTES

SHELL IS TO BE SHOP ROLLED WITH PLATE EDGES PREPARED FOR FIELD WELDING AT EACH LONG AND GIRTH SEAM WITH EACH COURSE MADE UP OF (6) SIX SEGMENTAL PLATES.

HEADS TO BE PREPARED FOR FIELD WELDING IN SEGMENTS.

REINFORCING TEES WILL BE SHOP FABRICATED IN SEGMENTS FOR FIELD ATTACHMENT TO SHELL TO ALLOW FOR STAGGERING OF LONGITUDINAL JOINTS.

TUBE BUNDLES WILL BE SHOP FABRICATED IN (4) FOUR QUADRANTS EACH, TO FACILITATE FIELD HANDLING & INSTALLATION.

CENTER PIPE WILL BE SHOP FABRICATED & PREPARED FOR FIELD ASSEMBLY IN (5) FIVE PIECES.

NOZZLE & PIPE CONNECTIONS WILL BE ATTACHED IN THE SHOP WHEREVER POSSIBLE, EXCEPT THE 18" MANWAY & THE 6'-0" O.D. PIPE STUB IN THE TOP HEAD.

CONES & DECK PLATES WILL BE SUPPLIED IN SEGMENTS WITH EDGES PREPARED FOR FIELD WELDING.

ALL LONG PIPING RUNS WILL BE SHOP PREPARED FOR FIELD INSTALLATION.

APPROX. WEIGHT EMPTY: 1,408,000 LBS.

TUBE BUNDLES MAY BE SHOP FABRICATED IN HALVES OR QUARTERS SEE DWG'S. 67-09-7840 D1, D2, F5, F6

EVAPORATOR DESIGNED TO ASME SECT. VIII-1965

△1 OPERATING CONDITIONS.

△2 DESIGN PRESSURE - FULL VACUUM

HYDROSTATIC TEST PRESSURE:
A. AT TOP OF VESSEL - 20-PSIG.
B. AT BOTT. OF VESSEL - 66-PSIG.
(INCLUDE HYDROSTATIC LOADING.

MAWP - 35-PSIG.

CORROSION ALLOW. - 3/16" FOR STEEL IN CONTACT WITH VAPORS.
3/8" FOR STEEL IN CONTACT WITH BRINE
0" FOR 90-10 CU. NI. & MONEL SURFACES.

△1 MATERIALS OF CONSTRUCTION

TOP ELLIPTICAL HEADS	FBX. STL. SA-285-C CLAD W/ 1/16" THK. 90-10 CU.NI.
SHELL PLATES	FBX. STL. SA-285-C, EXCEPT BOTT. CRS. IS CLAD W/ 1/16" THK. 90-10 CU. NI. - W/ FBX. STL. SA-515-70 BACKING.
BOTTOM COVER	FBX. STL. SA-515-GR. 70 W/ 1/16" THK. 90-10 CU.NI. CLADDING.
SHELL REINFORCING TEES	FBX. STL. SA-285-C
TUBESHEETS	FBX. STL. SA-285-C
TUBES	90-10 CUPRO-NICKEL SB-111
CENTER PIPE & BLANKING PL'S.	SMLS. STL. SA-106-B & FBX. STL. SA-285-C △2
SUPPORTING BUNDLE COLUMNS	SMLS. STL. SA-106-B & FBX. STL. SA-285-C (EPOXY COATED IN BRINE BATH)
CONES	FBX. STL. SA-285-C CLAD W/ 1/16" THK. 90-10 CU. NI. ON T. SHT. SIDE
DECK PLATES	FBX. STL. SA-285-C
DECK PLATE SUPPORTS - L'S & BAR	CARBON STEEL
MESH & GRIDS	MONEL
PIPE STUBS EXTERNAL TO SHELL	SMLS. STL. SA-106-B & FBX. STL. SA-285-C
PIPE & PIPE STUBS INTERNAL TO SHELL	SMLS. STL. SA-53-B
NOZZLES (LARGE DIA.)	FBX. STL. SA-285-C (NECKS) & FORG. STL. SA-181-CL. I (FLG'S.)
MANWAYS	FBX. STL. SA-285-C (NECKS) & FORG. STL. SA-181-CL. I (FLG'S.)
STUB & NOZZLE REINF'G. PLATES	FBX. STL. SA-285-C
EXTERNAL BOLTING	ALLOY STL. SA-193-B7 W/ SA-194-2H NUTS
INTERNAL BOLTING	MONEL
GASKETING	GARLOCK # 7021

REV. △3	
MOVED DET. OF DECK PL. DVS 7-17-68	
REV. △1	REV. △2
GENERAL REVISION KIRK J. 3-8-68	REV'D. PER CUST. APPV'L. 6-19-68 KIRK J.

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

8.0 MGD GAS TURBINE POWERED
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442

STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA

DRAWING BY
DESIGNED DATE
DRAWN KIRK J. DATE 2-27-68
CHECKED ART DATE 2-27-68
APPROVED DATE 3-11-68

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

DRAWING TITLE GENERAL ARRANGEMENT
DATE
DRAWING NO. 67-09-7840F3

FIG. 4.4

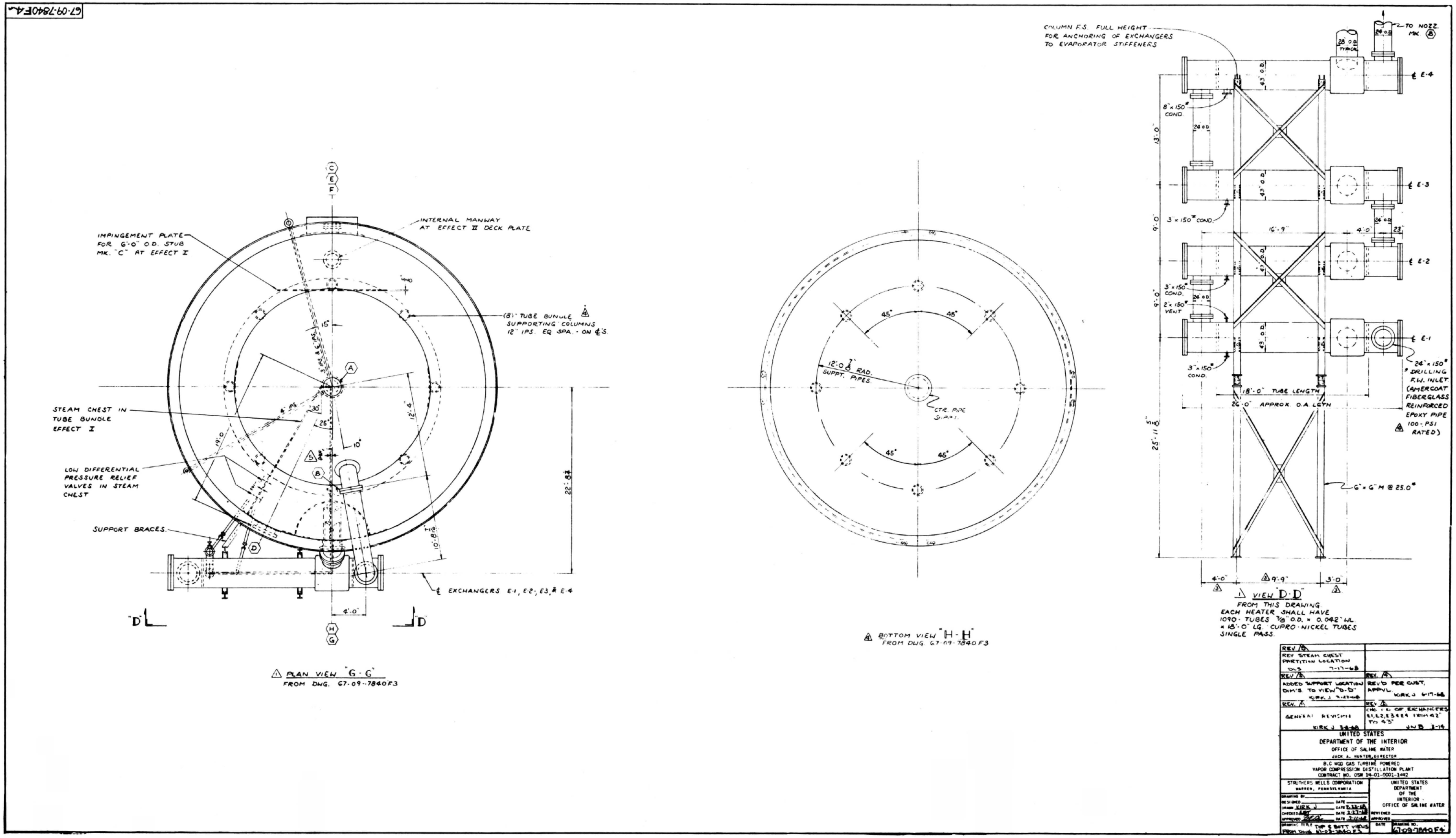

67-09-7840F4
IMPINGEMENT PLATE FOR 6'-0" O.D. STUB MK. "C" AT EFFECT I
INTERNAL MANWAY AT EFFECT II DECK PLATE
C
E
F
(8) TUBE BUNDLE SUPPORTING COLUMNS 12" IPS. EQ SPA. - ON ℄'S.
STEAM CHEST IN TUBE BUNDLE EFFECT I
LOW DIFFERENTIAL PRESSURE RELIEF VALVES IN STEAM CHEST
SUPPORT BRACES.
A
B
D
15°
30°
25°
10°
3" IPS. & 6" IPS.
8" IPS.
19'-0
12'-4"
10'-8 7/16"
22'-8 7/8
4'-0"
℄ EXCHANGERS E-1, E-2, E3, & E-4
"D"
"D"
H
G
PLAN VIEW "G-G"
FROM DWG. 67-09-7840F3
12'-0 7/8" RAD. SUPPT. PIPES.
CTR. PIPE SUPPT.
45°
45°
45°
45°
BOTTOM VIEW "H-H"
FROM DWG. 67-09-7840F3
COLUMN F.S. FULL HEIGHT FOR ANCHORING OF EXCHANGERS TO EVAPORATOR STIFFENERS
28" O.D. TYPICAL
24" O.D.
TO NOZZ. MK. B
℄ E-4
℄ E-3
℄ E-2
℄ E-1
8" x 150# COND.
3" x 150# COND.
3" x 150# COND.
2" x 150# VENT
3" x 150# COND.
24" O.D.
43" O.D.
13'-0"
9'-0"
9'-0"
16'-9"
4'-0"
23"
24" x 150# DRILLING F.W. INLET (AMERCOAT FIBERGLASS REINFORCED EPOXY PIPE 100-PSI RATED)
18'-0" TUBE LENGTH
26'-0" APPROX. O.A. LGTH
25'-11 5/16"
6" x 6" M @ 25.0#
4'-0"
9'-9"
3'-0"
VIEW "D-D"
FROM THIS DRAWING.
EACH HEATER SHALL HAVE 1090 - TUBES 7/8" O.D. x 0.042" WL. x 18'-0" LG. CUPRO-NICKEL TUBES SINGLE PASS.
REV 5
REV STEAM CHEST PARTITION LOCATION
DLS 7-17-68
REV 3
ADDED SUPPORT LOCATION DIM'S. TO VIEW "D-D"
KIRK J 3-27-68
REV. 4
REV'D PER CUST. APPVL.
KIRK J 6-17-68
REV. 1
GENERAL REVISION
KIRK J 3-8-68
REV 2
CHG. O.D. OF EXCHANGERS E1, E2, E3 & E4 FROM 42" TO 43"
JNB 3-14
UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR
8.C MGD GAS TURBINE POWERED
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442
STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA
DRAWING BY
DESIGNED
DATE
DRAWN KIRK J
DATE 2-23-68
CHECKED
DATE 2-27-68
APPROVED
DATE 3-11-68
DRAWING TITLE TOP & BOTT VIEWS
FROM DWG. 67-09-7840F3
UNITED STATES DEPARTMENT OF THE INTERIOR - OFFICE OF SALINE WATER
REVIEWED
APPROVED
DATE
DRAWING NO. 67-09-7840F4

FIG. 4.5

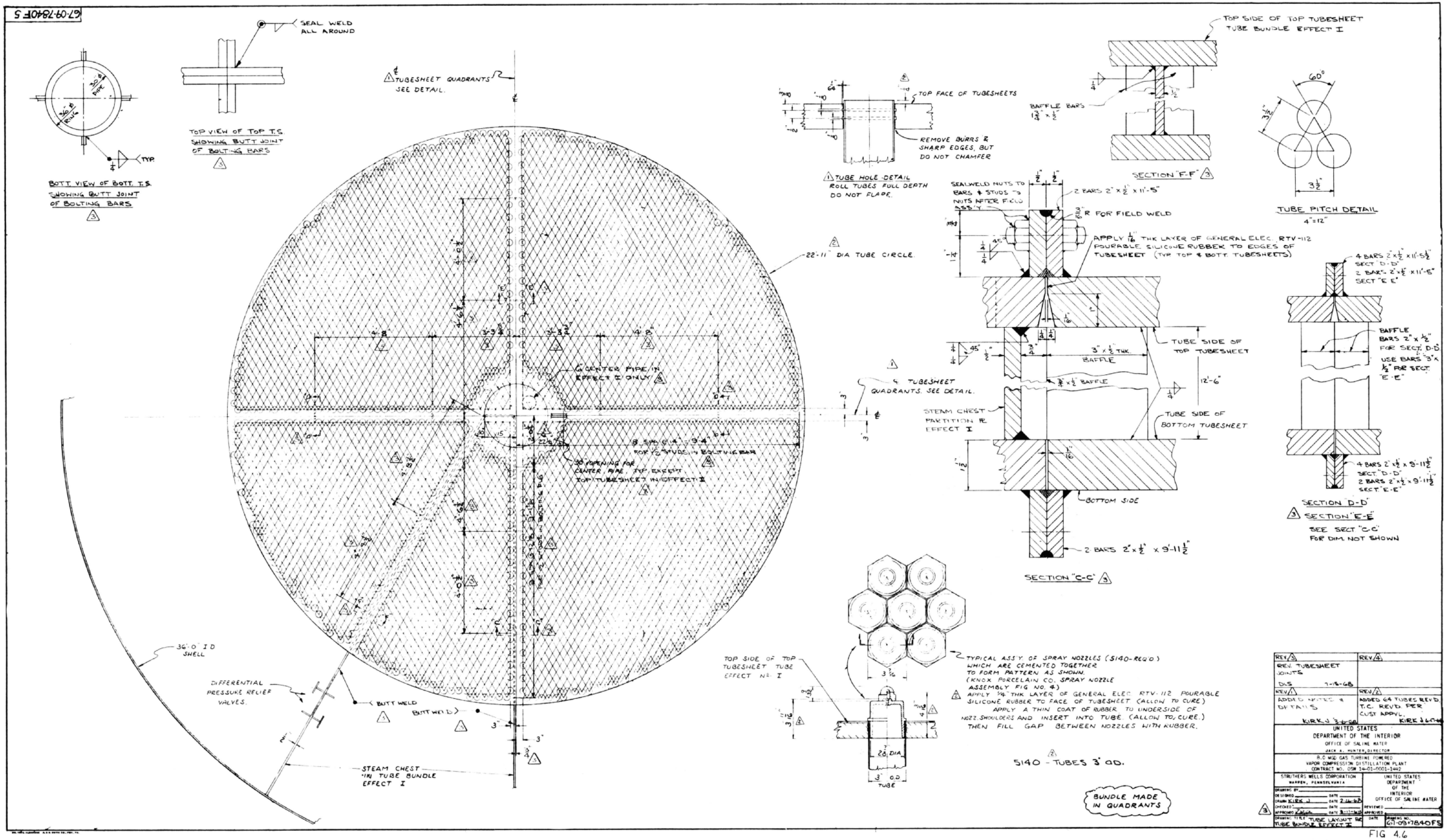
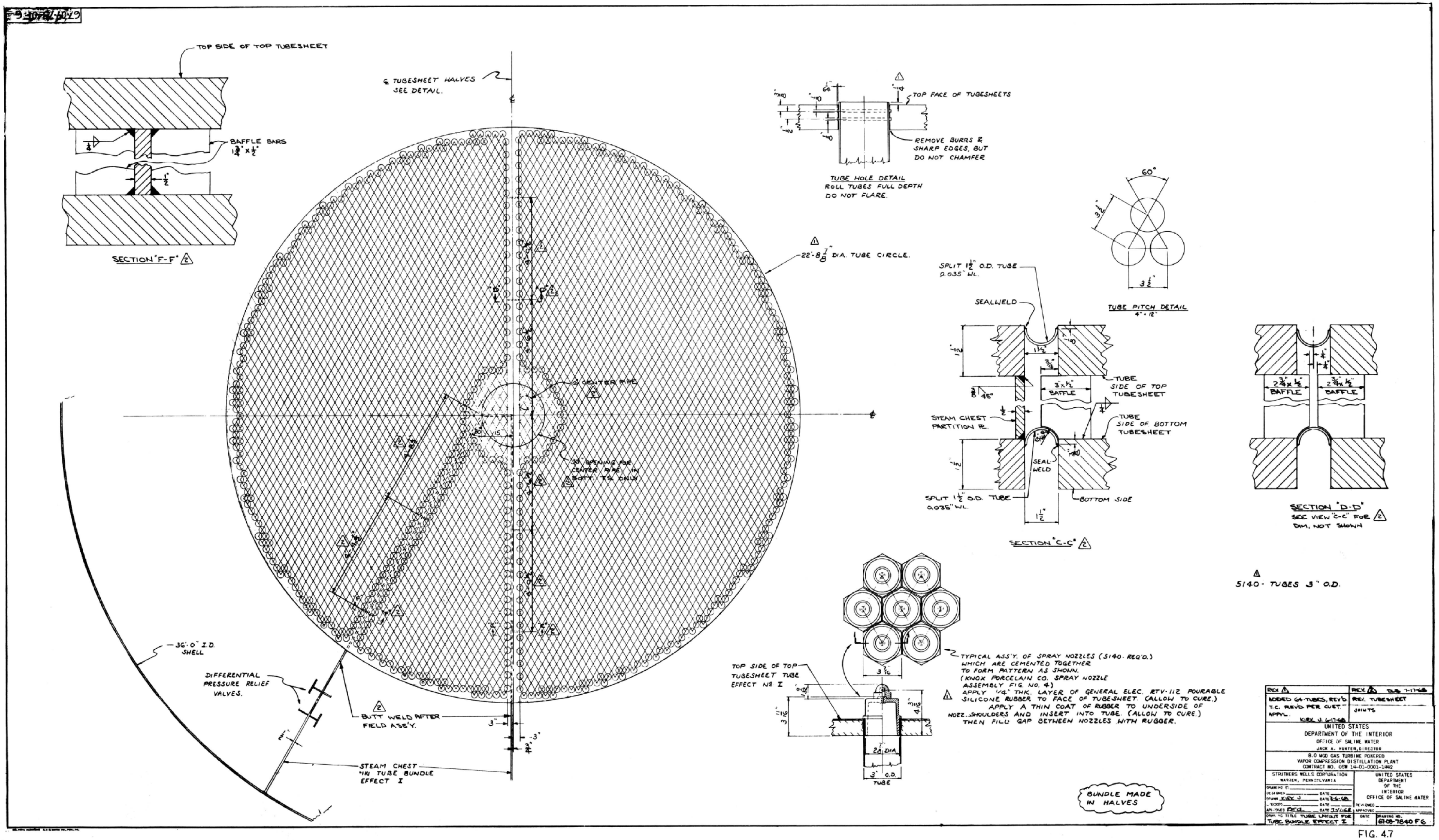

67-09-7840F 5
SEAL WELD ALL AROUND
TYP.
30" ⌀ PIPE
36" ⌀ RING
BOTT. VIEW OF BOTT. T.S. SHOWING BUTT JOINT OF BOLTING BARS 3
TOP VIEW OF TOP T.S. SHOWING BUTT JOINT OF BOLTING BARS 3
1 ℄ TUBESHEET QUADRANTS SEE DETAIL.
2 22'-11" DIA TUBE CIRCLE.
1 4 TUBESHEET QUADRANTS. SEE DETAIL.
6" CENTER PIPE IN EFFECT I ONLY 3
30" OPENING FOR CENTER PIPE. TYP. EXCEPT TOP TUBESHEET IN EFFECT I
8 SPA @ 14" = 9'-4" FOR 1/2" STUDS IN BOLTING BAR
4'-8"
3'-3 3/4"
4'-6 1/2"
4'-0 1/2"
2'-0 1/4"
22 1/2"
15"
30"
3"
36'-0" I D SHELL
DIFFERENTIAL PRESSURE RELIEF VALVES.
BUTT WELD
STEAM CHEST IN TUBE BUNDLE EFFECT I
1 TUBE HOLE DETAIL ROLL TUBES FULL DEPTH DO NOT FLARE.
TOP FACE OF TUBESHEETS
REMOVE BURRS & SHARP EDGES, BUT DO NOT CHAMFER
TOP SIDE OF TOP TUBESHEET TUBE BUNDLE EFFECT I
BAFFLE BARS 1 3/4" x 1/2"
SECTION "F-F" 3
60°
3 1/2"
TUBE PITCH DETAIL 4"=12"
SEALWELD NUTS TO BARS & STUDS TO NUTS AFTER FIELD ASS'Y
2 BARS 2" x 1/2" x 11'-5"
3/16" R FOR FIELD WELD
APPLY 1/16" THK LAYER OF GENERAL ELEC. RTV-112 POURABLE SILICONE RUBBER TO EDGES OF TUBESHEET (TYP. TOP & BOTT. TUBESHEETS)
3" x 1/2" THK. BAFFLE
3/4" x 1/2" BAFFLE
TUBE SIDE OF TOP TUBESHEET
TUBE SIDE OF BOTTOM TUBESHEET
12'-6"
STEAM CHEST PARTITION PL EFFECT I
BOTTOM SIDE
2 BARS 2" x 1/2" x 9'-11 1/2"
SECTION "C-C" 3
4 BARS 2" x 1/2" x 11'-5 1/2" SECT. "D-D" 2 BARS 2" x 1/2" x 11'-5" SECT. "E-E"
BAFFLE BARS 2" x 1/2" FOR SECT. D-D. USE BARS 3" x 1/2" FOR SECT. "E-E"
4 BARS 2" x 1/2" x 9'-11 1/2" SECT. "D-D" 2 BARS 2" x 1/2" x 9'-11 1/2" SECT. "E-E"
SECTION "D-D"
3 SECTION "E-E"
SEE SECT. "C-C" FOR DIM. NOT SHOWN
TOP SIDE OF TOP TUBESHEET TUBE EFFECT Nº I
3 7/16
9/32
3 1/16
2 7/8 DIA
3" O.D TUBE
TYPICAL ASS'Y. OF SPRAY NOZZLES (5140-REQ'D.) WHICH ARE CEMENTED TOGETHER TO FORM PATTERN AS SHOWN. (KNOX PORCELAIN CO. SPRAY NOZZLE ASSEMBLY FIG NO. 4)
2 APPLY 1/4" THK LAYER OF GENERAL ELEC. RTV-112 POURABLE SILICONE RUBBER TO FACE OF TUBESHEET (ALLOW TO CURE) APPLY A THIN COAT OF RUBBER TO UNDERSIDE OF NOZZ. SHOULDERS AND INSERT INTO TUBE. (ALLOW TO CURE.) THEN FILL GAP BETWEEN NOZZLES WITH RUBBER.
2 5140 - TUBES 3" OD.
BUNDLE MADE IN QUADRANTS
REV. 3 REV. TUBESHEET JOINTS DLS 7-18-68
REV. 4
REV. 1 ADDED NOTES & DETAILS KIRK J 3-6-68
REV. 2 ADDED 64 TUBES REV'D. T.C. REV'D. PER CUST APPVL. KIRK J 6-17-68
UNITED STATES DEPARTMENT OF THE INTERIOR OFFICE OF SALINE WATER JACK A. HUNTER, DIRECTOR
8.0 MGD GAS TURBINE POWERED VAPOR COMPRESSION DISTILLATION PLANT CONTRACT NO. OSW 14-01-0001-1442
STRUTHERS WELLS CORPORATION WARREN, PENNSYLVANIA
DRAWING BY
DESIGNED DATE
DRAWN KIRK J DATE 2-26-68
CHECKED DATE
APPROVED DATE 3-11-68
UNITED STATES DEPARTMENT OF THE INTERIOR OFFICE OF SALINE WATER
REVIEWED
APPROVED
DRAWING TITLE TUBE LAYOUT RE TUBE BUNDLE EFFECT I
DATE
DRAWING NO. 67-09-7840F5

FIG 4.6



REV. 1	REV. 2 DLS 7-17-68
ADDED 64-TUBES, REV'D T.C. REV'D PER CUST. APPVL. KIRK J. 6-17-68	REV. TUBESHEET JOINTS

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

8.0 MGD GAS TURBINE POWERED
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442

STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA

DRAWING BY
DESIGNED ____ DATE ____
DRAWN KIRK J DATE 3-6-68
CHECKED ____ DATE ____
APPROVED RCQ DATE 3/1-68

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

DRAWING TITLE TUBE LAYOUT FOR TUBE BUNDLE EFFECT I
DATE
DRAWING NO. 61-08-7840 F6

FIG. 4.7

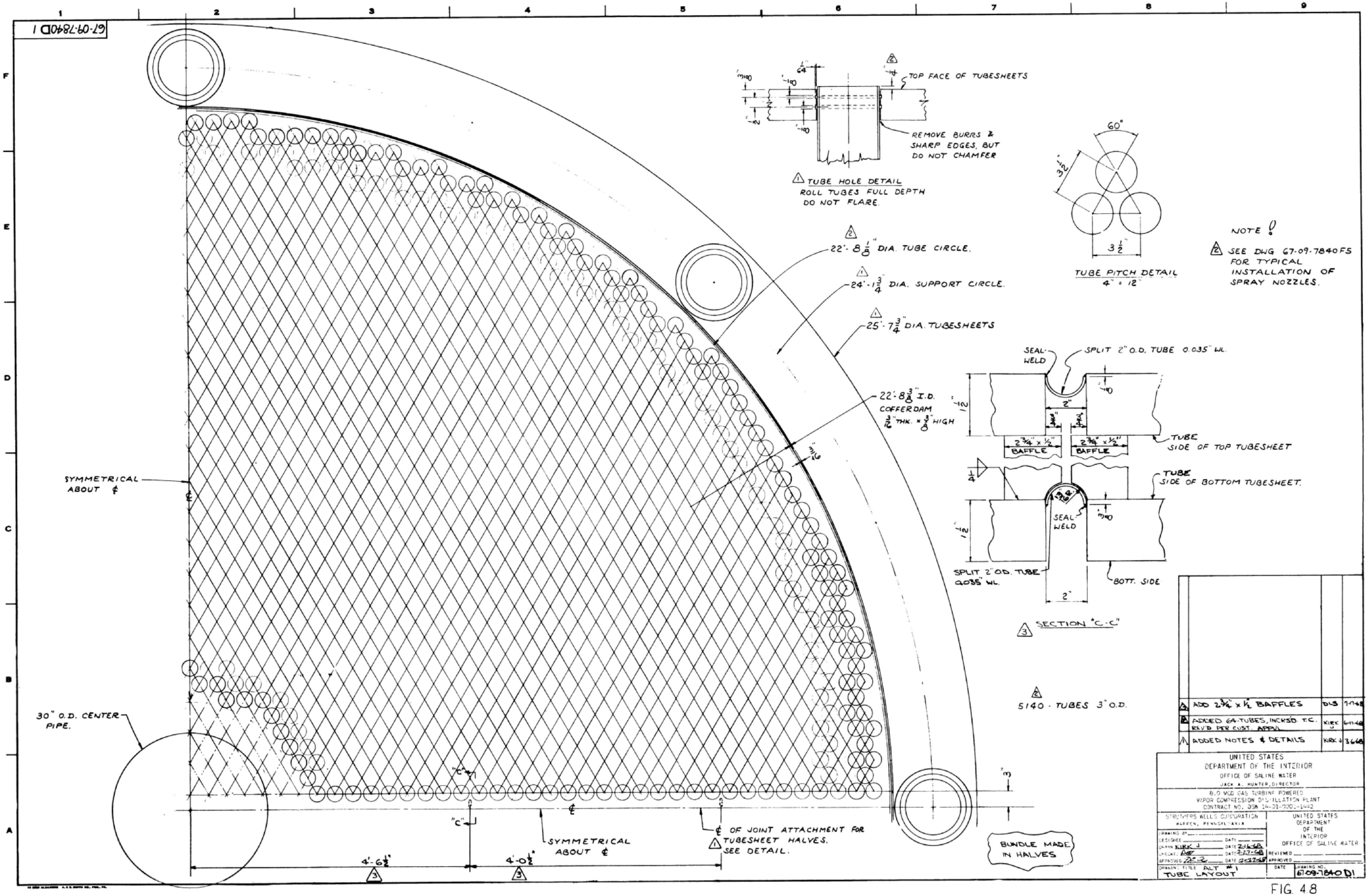
67-09-7840D1
TOP FACE OF TUBESHEETS
REMOVE BURRS & SHARP EDGES, BUT DO NOT CHAMFER
TUBE HOLE DETAIL
ROLL TUBES FULL DEPTH
DO NOT FLARE.
60°
3 1/2
3 1/2"
TUBE PITCH DETAIL
4" = 12"
NOTE
SEE DWG 67-09-7840FS FOR TYPICAL INSTALLATION OF SPRAY NOZZLES.
22'-8 1/8" DIA. TUBE CIRCLE.
24'-1 3/4" DIA. SUPPORT CIRCLE.
25'-7 3/4" DIA. TUBESHEETS
22'-8 3/8" I.D. COFFERDAM 3/16" THK. x 3/8" HIGH
3/16"
SEAL WELD
SPLIT 2" O.D. TUBE 0.035" WL.
2"
1 1/2"
2 3/4" x 1/2" BAFFLE
2 3/4" x 1/2" BAFFLE
TUBE SIDE OF TOP TUBESHEET
TUBE SIDE OF BOTTOM TUBESHEET.
1/4
SEAL WELD
SPLIT 2" O.D. TUBE 0.035" WL.
BOTT. SIDE
SECTION "C-C"
5140 - TUBES 3" O.D.
SYMMETRICAL ABOUT ℄
30" O.D. CENTER PIPE.
"C"
"C"
SYMMETRICAL ABOUT ℄
℄ OF JOINT ATTACHMENT FOR TUBESHEET HALVES. SEE DETAIL.
4'-6 1/2"
4'-0 1/2"
3"
BUNDLE MADE IN HALVES
ADD 2 3/4" x 1/2" BAFFLES DLS 7-7-68
ADDED 64-TUBES, INCRS'D. T.C. REV'D PER CUST. APPVL KIRK J 6-11-68
ADDED NOTES & DETAILS KIRK J 3-6-68
UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR
8.0 MGD GAS TURBINE POWERED
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442
STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA
DRAWING BY
DESIGNED
DATE
DRAWN KIRK J
DATE 2-16-68
CHECKED
DATE 2-27-68
APPROVED
DATE 2-27-68
UNITED STATES DEPARTMENT OF THE INTERIOR OFFICE OF SALINE WATER
REVIEWED
APPROVED
DRAWING TITLE ALT #1
TUBE LAYOUT
DATE
DRAWING NO. 67-09-7840D1

FIG. 4.8

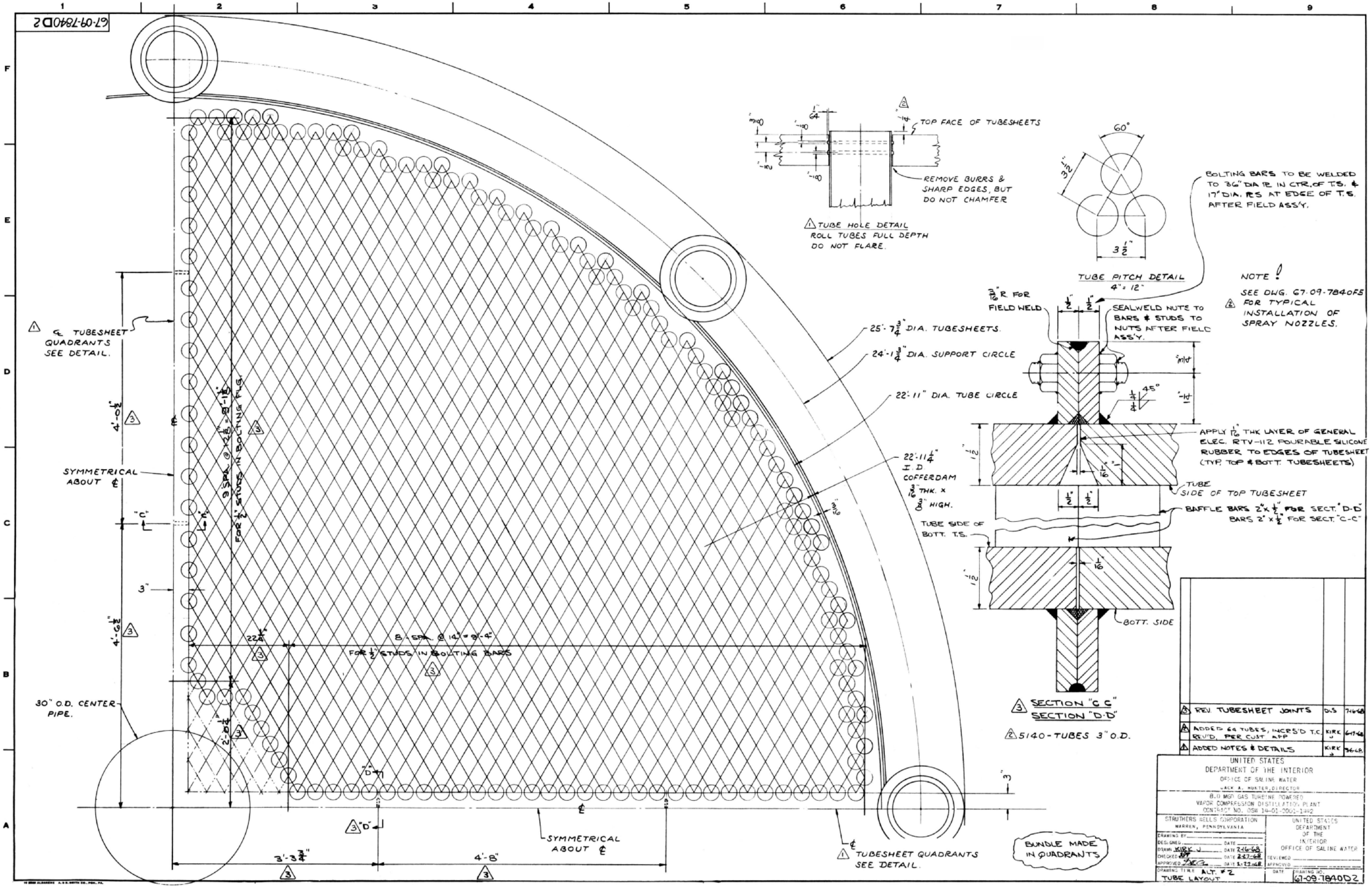
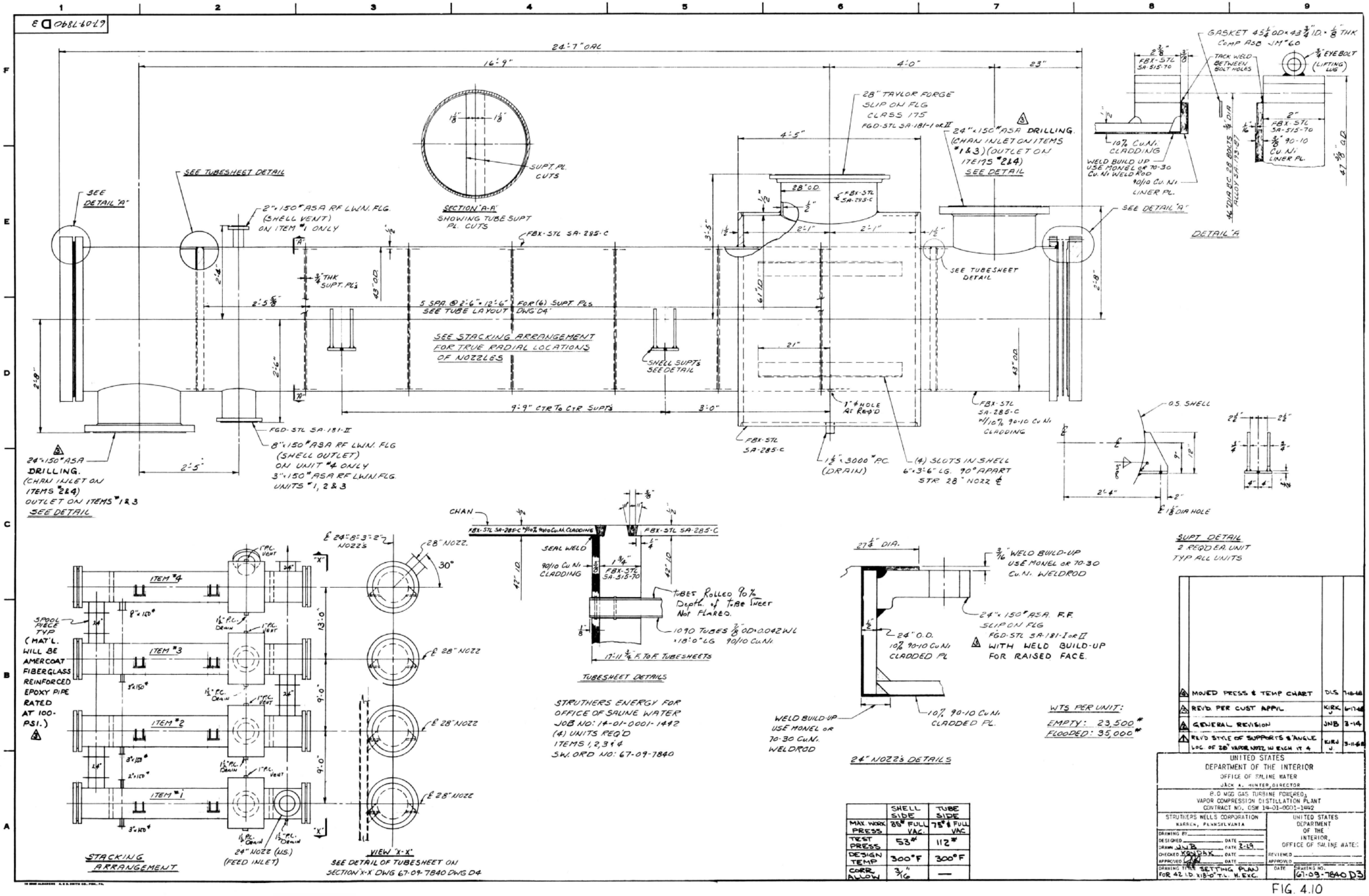

67-09-7840D2
TOP FACE OF TUBESHEETS
REMOVE BURRS & SHARP EDGES, BUT DO NOT CHAMFER
TUBE HOLE DETAIL
ROLL TUBES FULL DEPTH DO NOT FLARE.
60°
3 1/2"
TUBE PITCH DETAIL 4" = 12"
BOLTING BARS TO BE WELDED TO 36" DIA ℞ IN CTR. OF T.S. & 17" DIA. ℞S AT EDGE OF T.S. AFTER FIELD ASS'Y.
NOTE 1
SEE DWG. 67-09-7840F5 FOR TYPICAL INSTALLATION OF SPRAY NOZZLES.
℄ TUBESHEET QUADRANTS SEE DETAIL.
25'-7 3/4" DIA. TUBESHEETS.
24'-1 3/4" DIA. SUPPORT CIRCLE
22'-11" DIA. TUBE CIRCLE
22'-11 1/4" I.D. COFFERDAM 3/16" THK. x 3/8" HIGH.
3/16"
3/16" R FOR FIELD WELD
1/2"
SEALWELD NUTS TO BARS & STUDS TO NUTS AFTER FIELD ASS'Y.
45°
APPLY 1/16" THK LAYER OF GENERAL ELEC. RTV-112 POURABLE SILICONE RUBBER TO EDGES OF TUBESHEET (TYP. TOP & BOTT. TUBESHEETS)
TUBE SIDE OF TOP TUBESHEET
BAFFLE BARS 2" x 1/2" FOR SECT. "D-D" BARS 2" x 1/2" FOR SECT. "C-C"
TUBE SIDE OF BOTT. T.S.
BOTT. SIDE
1 1/2"
1/16"
SECTION "C-C"
SECTION "D-D"
5140-TUBES 3" O.D.
4'-0 1/2"
SYMMETRICAL ABOUT ℄
9 SPA. @ 12 1/8" = 9'-1 1/8"
FOR 1/2" STUDS IN BOLTING FLG.
"C"
3"
4'-6 1/2"
22 1/4"
8 - SPA. @ 14" = 9'-4"
FOR 1/2" STUDS IN BOLTING BARS
30" O.D. CENTER PIPE.
2'-0 1/4"
"D"
℄
SYMMETRICAL ABOUT ℄
3'-3 3/4"
4'-8"
TUBESHEET QUADRANTS SEE DETAIL.
BUNDLE MADE IN QUADRANTS
REV. TUBESHEET JOINTS | D.S | 7-16-68
ADDED 64 TUBES, INCRS'D T.C. REV'D. PER CUST. APP | KIRK J | 6-17-68
ADDED NOTES & DETAILS | KIRK J | 3-6-68
UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR
8.0 MGD GAS TURBINE POWERED
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442
STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA
DRAWING BY
DESIGNED
DATE
DRAWN KIRK J
DATE 2-16-68
CHECKED
DATE 2-27-68
APPROVED
DATE 2-27-68
UNITED STATES DEPARTMENT OF THE INTERIOR OFFICE OF SALINE WATER
REVIEWED
APPROVED
DRAWING TITLE ALT. #2 TUBE LAYOUT
DATE
DRAWING NO. 67-09-7840D2

FIG. 4.9



STRUTHERS ENERGY FOR
OFFICE OF SALINE WATER
JOB NO: 14-01-0001-1442
(4) UNITS REQ'D
ITEMS 1, 2, 3 & 4
S.W. ORD NO: 67-09-7840

WTS PER UNIT:
EMPTY: 23,500#
FLOODED: 35,000#

	SHELL SIDE	TUBE SIDE
MAX. WORK PRESS	35# FULL VAC.	75# & FULL VAC
TEST PRESS	53#	112#
DESIGN TEMP	300°F	300°F
CORR ALLOW	3/16"	—

4	MOVED PRESS & TEMP CHART	DLS	7-18-68
3	REV'D PER CUST APPVL	KIRK J	6-17-68
2	GENERAL REVISION	JNB	3-14
1	REV'D STYLE OF SUPPORTS & ANGLE LOC. OF 28" VAPOR NOZZ IN EXCH IT 4	KIRK J.	3-11-68

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

8.0 MGD GAS TURBINE POWERED, VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442

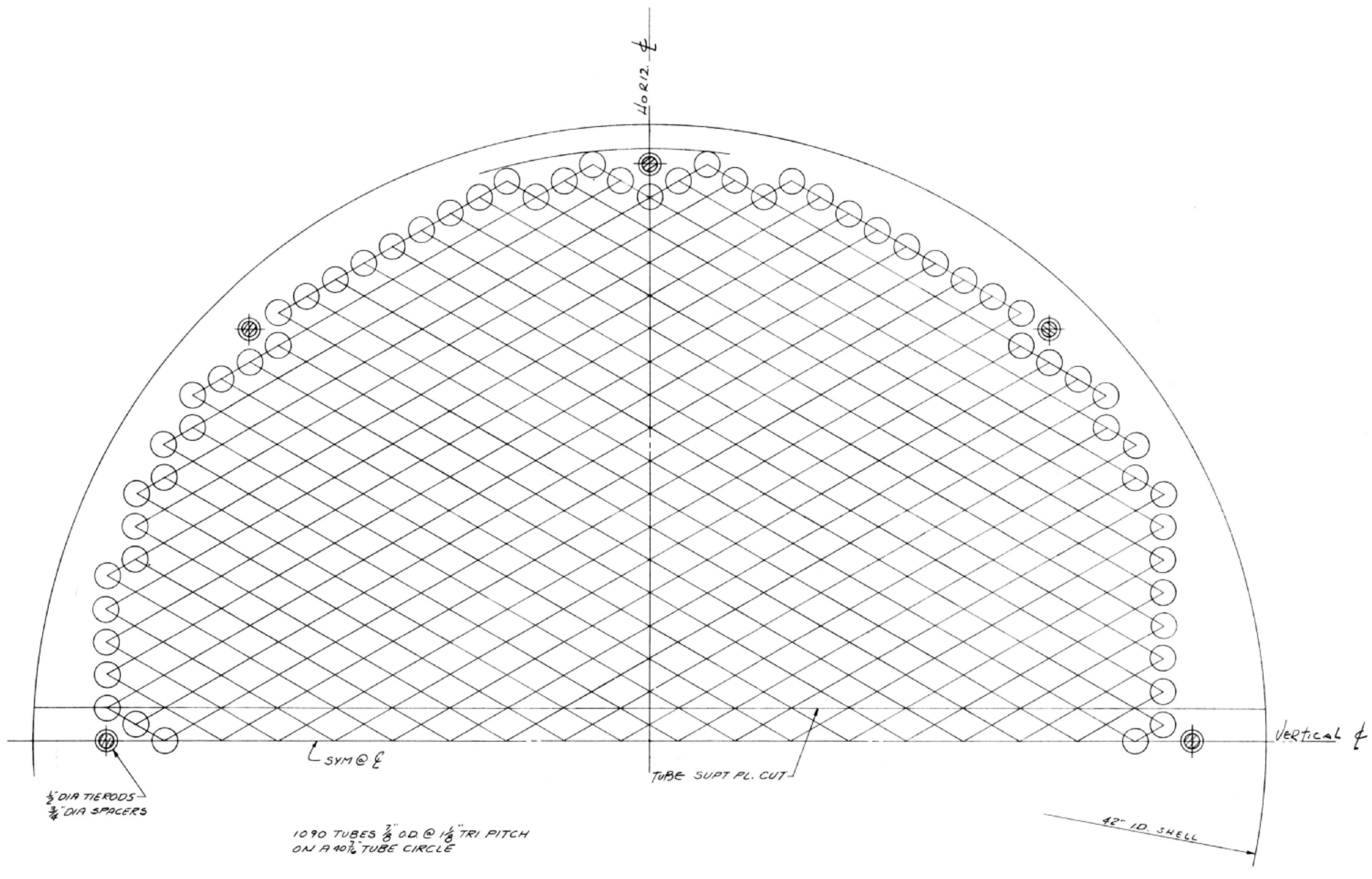
STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA

UNITED STATES
DEPARTMENT
OF THE
INTERIOR,
OFFICE OF SALINE WATER

DRAWING BY
DESIGNED DATE
DRAWN JNB DATE 2-29
CHECKED KONDAK DATE
APPROVED DATE
REVIEWED
APPROVED
DRAWING TITLE SETTING PLAN FOR 42 I.D. × 18'-0" T.L. H. EXC.
DATE
DRAWING NO. 67-09-7840 D3

FIG. 4.10

67-09-7840 D4



VIEW "X"-"X"
TAKEN FROM DWG. 67-09-7840 D3

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

8.0 MGD GAS TURBINE POWERED:
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442

STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA

DRAWING BY ____
DESIGNED ____ DATE ____
DRAWN BOSKO DATE 2-23
CHECKED KONDAK DATE ____
APPROVED ____ DATE ____
DRAWING TITLE TUBE LAYOUT
FOR 42" I.D. x 18'-0" T.L. H. EXC.

UNITED STATES
DEPARTMENT
OF THE
INTERIOR,
OFFICE OF SALINE WATER
REVIEWED ____
APPROVED ____
DATE
DRAWING NO. 67-09-7840 D4

FIG. 4.11

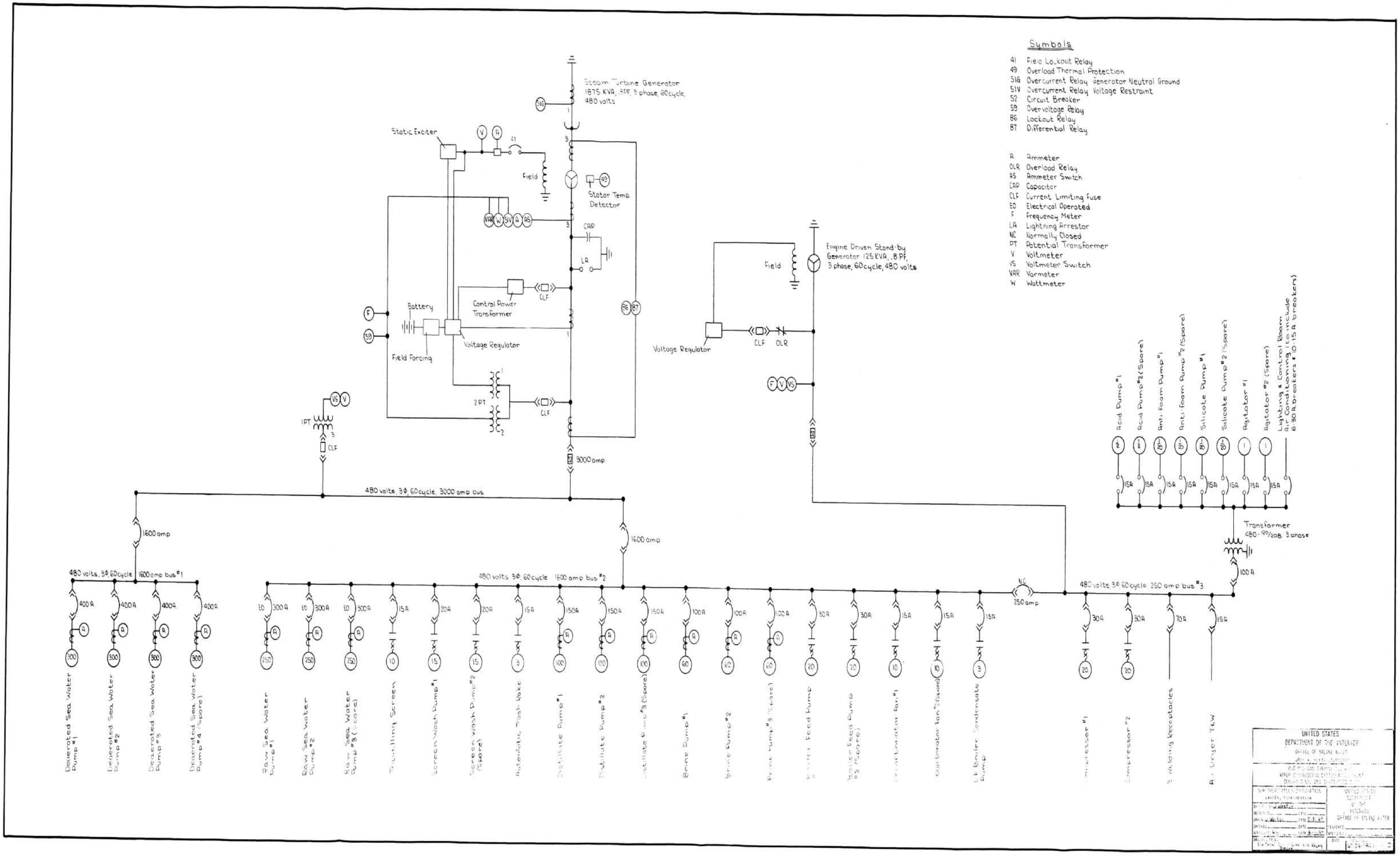


FIG. 4.12

FIG 4.12

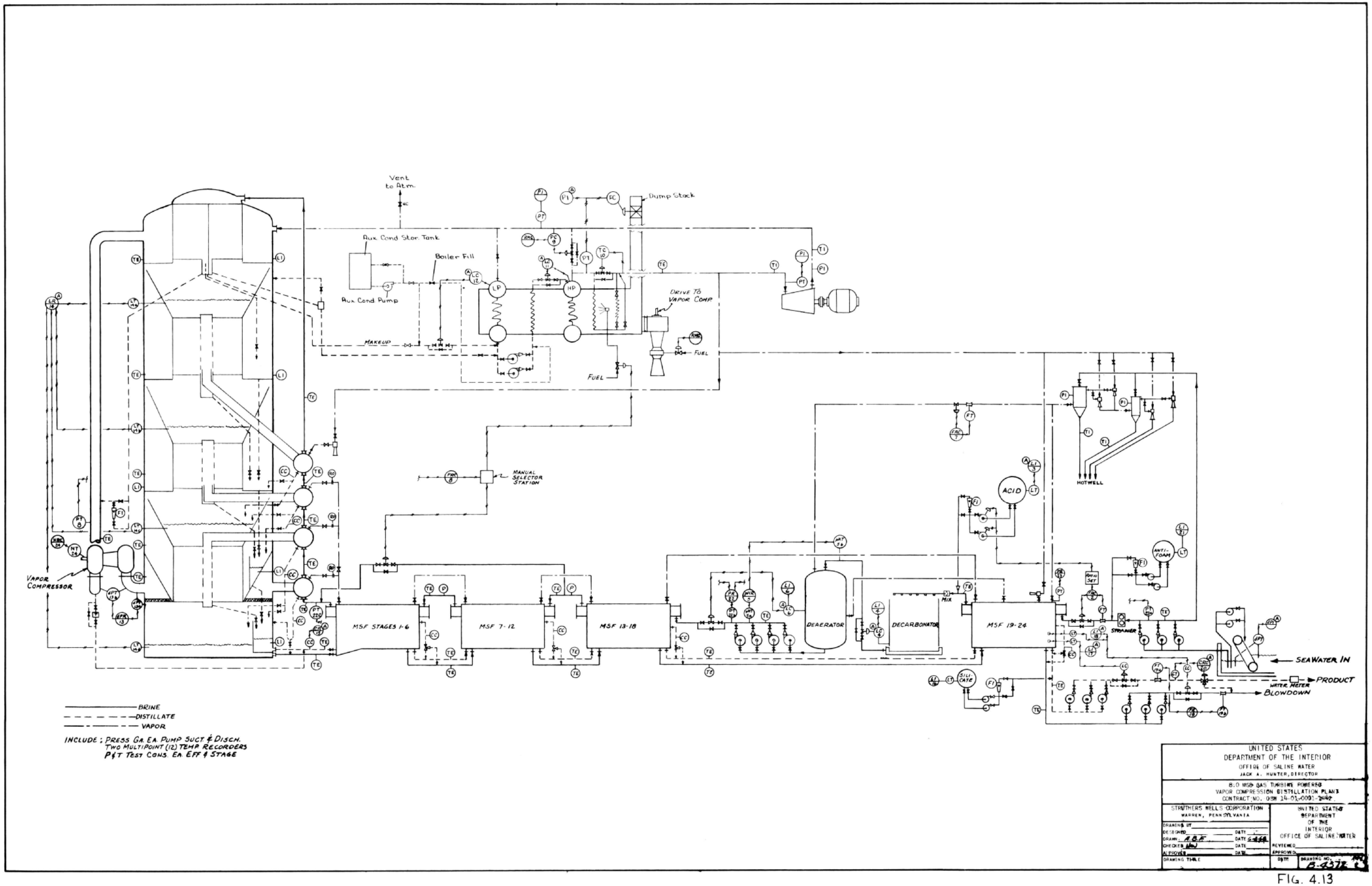
VAPOR COMPRESSOR
Vent to Atm.
Aux Cond Stor Tank
Boiler Fill
Aux Cond Pump
MAKEUP
LP
HP
Dump Stack
DRIVE TO VAPOR COMP
FUEL
FUEL
MANUAL SELECTOR STATION
MSF STAGES 1-6
MSF 7-12
MSF 13-18
DEAERATOR
DECARBONATOR
MIX
MSF 19-24
ACID
ANTI-FOAM
SILICATE
STRAINER
HOTWELL
SEAWATER IN
WATER METER
PRODUCT
BLOWDOWN
BRINE
DISTILLATE
VAPOR
INCLUDE; PRESS GA. EA. PUMP SUCT. & DISCH.
TWO MULTIPOINT (12) TEMP RECORDERS
P&T TEST CONS. EA. EFF & STAGE
UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
JACK A. HUNTER, DIRECTOR
8.0 MGD GAS TURBINE POWERED
VAPOR COMPRESSION DISTILLATION PLANT
CONTRACT NO. OSW 14-01-0001-1442
STRUTHERS WELLS CORPORATION
WARREN, PENNSYLVANIA
DRAWING BY
DESIGNED
DATE
DRAWN A.B.F
DATE 6-4-68
CHECKED
DATE
APPROVED
DATE
DRAWING TITLE
UNITED STATES DEPARTMENT OF THE INTERIOR
OFFICE OF SALINE WATER
REVIEWED
APPROVED
DATE
DRAWING NO.
B-4372

FIG. 4.13