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OCEAN THERMAL ENERGY CONVERSION
(OTEC) PLATFORM CONFIGURATION AND INTEGRATION

FINAL REPORT

VOLUME II

MASTER

CONCEPTUAL DESIGN

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REFERENCES

- (1) D'Arcangelo, A. M., Ed.; Ship Design and Construction; Society of Naval Architects and Marine Engineers; New York, 1969.
- (2) "OTEC Platform Configuration and Integration, Tasks I, IIA and IIB - Final Report, Volumes I and II;" Gibbs and Cox, Inc. Report 18351-1/2 (W-8400), dated October 1977..
- (3) Rules for Building and Classing Steel Vessels, 1975; American Bureau of Shipping, New York.
- (4) "OTEC Platform Configuration and Integration, Task IV - Final Report, Volumes I and II;" Gibbs and Cox, Inc. Report 18351-4 (W-8600), dated December 1977.
- (5) "Ocean Thermal Energy Conversion (OTEC) Power Plant;" Lockheed Missiles and Space Company Report, File NSF/RANN/SEC/01-0937/FR/75/1, LMSC D056566, dated April 12, 1977.
- (6) "OTEC, Analysis of Electric Power Conditioning Equipment Weight and Space Requirements for a Range of Module and Plant Sizes;" Simplex Wire and Cable Company Development Engineering Report No. 20, dated November 4, 1977.
- (7) Frequency domain cold water pipe computer simulation developed by Professor J. Randolph Paulling, University of California, Berkeley, 1977.
- (8) "Losee, L. K.; Design Data Sheet DDS 1100-3, Strength of Structural Members;" Department of the Navy, Bureau of Ships, Washington, D.C., 1956.
- (9) "Structural Design Manual for Naval Surface Ships;" Department of the Navy, Naval Ship Engineering Center, Washington, D.C., December, 1976.
- (10) "Rules and Regulations for Cargo and Miscellaneous Vessels, Subchapter 1;" Department of Transportation, U. S. Coast Guard, April 1973.
- (11) Rules for Building and Classing Offshore Mobile Drilling Units 1973; American Bureau of Shipping, New York.
- (12) Thomas, D. L. and Brown, W. H.; "Potential Use of Profile Wire Screens for OTEC;" paper presented at the Fifth OTEC Conference, Miami Beach, February 1978..
- (13) Department of Energy letter from Jr. J. Horowitz, to Mr. D. Price, NOAA, dated January 10, 1978.

REFERENCES

(Continued)

- (14) Department of Commerce (National Oceanic and Atmospheric Administration) letter from Mr. D. Price to Mr. R. Scott of Gibbs & Cox, Inc., dated February 15, 1978.
- (15) "OTEC, Preliminary Analysis of Allowable Movement of Plant as It Affects Power Cables; Simplex Wire and Cable Company Development Engineering Report No. 18;" dated October 11, 1977.
- (16) "OTEC, Preliminary Approach to Riser Cable Attachment and Emergency Development at OTEC Plant;" Simplex Wire and Cable Company Development Engineering Report No. 21, dated October 31, 1977.
- (17) Lofft, R. F. and Price, W. G.; "Ocean Wave Statistics: Frequency of Occurrence of Sea States;" Admiralty Experiment Works Technical Memorandum No. 19/73, July 1973.

1. INTRODUCTION

This report summarizes studies conducted by Gibbs & Cox, Inc. under Department Of Energy Contract No. EG-77-C-01-4064 relating to the OTEC Platform Configuration and Integration study.

1.1 The OTEC Concept

The Offshore Thermal Energy Conversion (OTEC) power system is based on the Rankine thermodynamic cycle, utilizing working fluids such as ammonia capable of boiling and condensing over small temperature ranges in a closed system. Solar energy, stored in warm ocean surface waters, is transferred to the working fluid in a large heat exchanger, thereby causing evaporation of the working fluid. The vapor phase fluid passes through a low pressure turbine and then to a condenser cooled by waters pumped from ocean depths up to 3,000 feet. The condensed working fluid is then returned to the warm water heat exchanger (evaporator), and the cycle is renewed. Energy extracted by the turbine is used to generate electric power either for transmission to shore or for direct usage in an associated, energy-intensive manufacturing, chemical processing use.

1.2 OTEC Program

The OTEC Program schedule calls for the deployment and at-sea test of the OTEC plant facilities. The first test is called OTEC-1, signifying a test of the 1 MWe power cycle module. OTEC-1 is planned for FY 1980-81. OTEC modular experiment plants are planned for FY 1982-83 to test a power module between 10 MWe and 20 MWe in size. There are contracts currently awarded that deal with three major subsystems of the OTEC plant. One set of contracts is involved with the design of various size power cycle modules. Another set of contracts is involved with the configuration of the electric cable subsystem of both the riser/umbilical and bottom transmission cable. A third set of three contracts is involved with the configuration analysis of the OTEC Commercial Plant platforms. This report describes the Gibbs & Cox, Inc. studies conducted under one of these three contracts.

1.2 OTEC Program (Continued):

A comprehensive study of the Cold Water Pipe (CWP) is planned for FY 78 involving preliminary design of the CWP for the OTEC Modular Experiment. Other programs planned for FY 1978 besides the proposed effort of this RFP are an analysis of the stationkeeping subsystems for the modular experiment OTEC plant and an analysis of large system construction techniques.

After the major subsystem configuration studies have been completed, a system integration design contract will be awarded. It will be the responsibility of the systems integration contractor to design all OTEC subsystems (except the Power System and Energy Transmission System) into one integrated Ocean System. A separate contractor will integrate all the OTEC components into the working OTEC plant, and then deploy the plant and operate it at sea.

1.3 Project Overview

The purpose of this project is to evaluate six candidate hullforms as candidates for the OTEC Commercial Plant. The six hullforms will be systematically evaluated to rank them in order of preference considering factors such as cost, schedule and risk. Conceptual designs of two of these plants will then be conducted, and a plan for development of a Demonstration Plant will be prepared.

The project is being conducted under the following nine (9) tasks:

- Task I Data Assembly and Synthesis: Development of a data bank of OTEC-related documentation.
- Task IIA Systems Evaluation and Requirements: Definition of Top Level Requirements and an assessment of factors critical to the selection of hull configuration and size; quantification of payload requirements and characteristics; sensitivity of system characteristics to site selection.
- Task IIB Evaluation Plan: Development of a methodology for systematically evaluating the candidate hullforms, based on interrelationships and priorities developed during Task IIA.

1.3 Project Overview (Continued):

- Task III Technology Review: Assessment of current technology and identification of deficiencies in relation to OTEC requirements; development of plans to correct such deficiencies.
- Task IV Systems Integration Evaluation: Formal evaluation of the six (6) candidate hullforms in relation to site and plant capacity (gross megawatts) to quantify cost/size/capability relationships, leading to selection of an optimum Commercial Plant.
- Task V Conceptual Design: Development of Conceptual Design documentation for two selected Plants to identify plant characteristics to the level of detail required to quantify cost and schedule.
- Task VI Facilities and Equipment: Identification of the facilities and equipment necessary to build and deploy the OTEC Commercial Plant.
- Task VII Development Plan: A plan for the development of an OTEC Demonstration Plant including funding, key milestones, fallbacks, etc.
- Task VIII Cost, Schedules: Detailed assessment of cost and scheduling requirements for the OTEC Commercial Plant.
- Task IX Site Sensitivity: Assessment of the sensitivity of Plant characteristics to the specific environmental characteristics of potential deployment sites.

Gibbs & Cox, Inc. was assisted in this study by four (4) subcontractors:

- Giannotti & Buck Associates, Inc. for evaluation of platform motions, cold water pipe dynamics and environmental analysis.
- Alan C. McClure Associates, Inc. for development of positionkeeping systems and general input related to offshore technology.
- Santa Fe Corporation for systems analysis, cost-benefit analysis, and the Development Plan.
- Worthington Corporation for the design of Seawater Pumps.

1.4 Final Report Organization

This Final Report is divided into three (3) volumes:

- Volume I, Systems Requirements and Evaluation, summarizing Tasks II, III, and IV.
- Volume II, Conceptual Designs, summarizing Tasks V, VI, VIII, and IX.
- Volume III, Development Plan, summarizing Task VII.

This volume, Volume II, is a summary of the Conceptual Design effort, including facility requirements, cost, schedule and site sensitivity.

1.5 Definitions

Throughout this volume, reference will be made to the OTEC Platform System, Cold Water Pipe System, Power System and Transmission System. For this study, the Platform system consists of those functional elements necessary to support the payload which generates and transmits electrical power from the platform to shore. These elements are defined on the Work Breakdown Structure shown in Figure 1.5-1 which was invoked by DOE after completion of Task IV. This WBS differs from that used in earlier studies, as defined in Volumes I and III; therefore, Figure 1.5-1 only applies to this Volume.

The Power System consists of those elements necessary to convert the seawater system temperature differentials into electrical power, and consists of the following:

- Evaporator System
- Condenser System
- Turbogenerator System
- Ammonia and Nitrogen Transfer and Storage System

Figure 1.5-2 defines the interfaces between the Power System and the Seawater System as used throughout this study.

Figure 1.5-1

DTEC PLANT WORK BREAKDOWN STRUCTURE

1.5 Definitions (Continued)

The Transmission System consists of the power conditioning equipment and cable necessary to transmit the generated power ashore. Both the Power and Transmission System characteristics reflected in this study reflect DOE input. The Gibbs & Cox, Inc. scope of work did not involve any design effort relative to these systems.

At the completion of Task IV, DOE provided updated Power System data based upon a basic 25 to 50 MW NET power module. As noted throughout Volume I, all studies during Tasks II through IV were based on a GROSS rating. Since the normal reference to OTEC system capability is in terms of net or useable MW, DOE directed that this change in definition be made for Task V and all subsequent tasks. The 25 or 50 MW net rating reflects an assumed parasitic loss of 30 percent, corresponding to gross module ratings of 32.5 and 65 MW respectively. This means that any comparison between the results presented in this volume and those of Volume I must include a correction factor to equate plant outputs.

1.6 Conceptual Design Baseline

The basic requirements established by DOE for the Gibbs & Cox, Inc. Conceptual Designs include the following:

- Two Commercial Plant configurations - Ship and Semi-Submersible
- 400 MW net output per Plant
- Hawaii is the prime site, with New Orleans and the West Coast of Florida as alternatives to be studied in Task IX.
(NOTE: The West Coast of Florida site was substituted for Key West at the beginning of Task V.)
- 8 Plants located in a 3200 MW energy park
- Both internal and external heat exchangers are to be considered
(NOTE: Tasks I-IV only dealt with the internal version.)

2. TASK V CONCEPTUAL DESIGN - SHIP

2.1 Approach

2.1.1 General

The conceptual design process applicable to the two OTEC Commercial Plant configurations being considered in this study (Ship and Semi-Submersible with net outputs of 400 MWe) may be divided into the following major phases:

- Platform Trade-Off Studies
- Platform Design
- Cold Water Pipe (CWP) Trade-Off Studies
- Cold Water Pipe Design

In the case of both the platform and CWP, logical structured evaluation processes are used to determine the configurations that best meet the program goals as defined in the Top Level Requirements (TLR) (see Section 2.2). These configurations are then developed to the conceptual level of detail as described throughout this volume.

Figure 2.1-1 illustrates in a simplified fashion the relationship of the above phases to the overall development of the conceptual design and serves to place the various aspects in perspective.

In this case, the design of the two Commercial Plant configurations presents some unique problems to the naval architect because of the paucity of available information concerning the payload, i.e., the Power System. Power System development is proceeding concurrently with that of the Ocean System; therefore, it becomes difficult to insure that the Ocean System is developed to meet all the needs of its payload. Whereas some general characteristics of the Power System are known, this knowledge is relatively soft, and since the Power System has such a significant impact on the overall Commercial Plant design, changes in the payload could invalidate any designs developed using this data. On the other hand, program constraints dictate a relatively high level of optimization with respect to the Ocean System and overall Commercial Plant; consequently, the Commercial Plant designs fit the payload data quite closely, leaving little or no room for change.

FIGURE 2.1-1

2.1.1 General (Continued):

The development of the Commercial Plant conceptual designs follows standard ship design practices; i.e., a "design spiral" (Reference (1)) is utilized to converge on the final design. The process begins with the initial design data, which in this case is contained in the TLR, and proceeds through a series of iterations each more detailed or better defined than the previous. The end is reached when the level of detail and/or confidence satisfies the goals of the program at hand, and in this case it is defined as the point that will permit an initial cost estimate for the purpose of further defining the future path of the OTEC program and also demonstrate that the Power and Ocean Systems may be integrated in a viable manner.

In entering the design spiral described above, the naval architect normally will rely on previous designs of a similar type to establish the principal dimensions, weights, etc, for the initial integration, but in the case of this study, such an approach cannot be followed because of the lack of a developed parametric data base. The uniqueness of the designs requires a synthesis approach where the Commercial Plant is developed by building around the particular requirements of the Power System using standard ocean engineering practices.

2.1.2 Trade-Off Studies

The details of the processes that evaluate the candidate platform arrangements and CWP materials and configurations may be found in Section 2.3. In essence, these studies comprise the first iteration of the conceptual designs for the ship, semi-submersible, and CWP. The large number of alternatives that must be considered preclude the detailed development of the Commercial Plants at this stage; however, the designs are carried to the point where a realistic evaluation based on technical and economic factors may be made. As mentioned earlier, certain guidelines with regard to the overall Ocean System cost were imposed; therefore, the trade-off studies are directed towards arriving at a solution that possesses minimum life cycle costs and maximum revenues. These of course, must be tempered by technical considerations such as constructability, flexibility, maintainability, and survivability to arrive at an optimum configuration.

2.1.3 Design Process

The full development of the conceptual designs of both the ship and semi-submersible proceeds from the outcome of the trade-off studies through a series of design iterations until the desired degree of detail and confidence is reached. The design of these platforms is driven by the unique requirements of the Power System with respect to configuration, seawater requirements, and finally, operational and maintenance considerations. The Power System, Hull System, Seawater System, CWP, Positionkeeping System, and Support System must all be integrated such that their various aspects complement rather than conflict with each other. For example, the structural configuration of the hull must provide adequate strength, yet at the same time it must be sensitive to the arrangement of the Power System in both the operational and maintenance modes (equipment removal paths, etc.). This may appear to be an obvious point, but all too often a designer will neglect the synergistic effects inherent in the make-up of such a system as the OTEC Commercial Plant. In keeping with this total integration approach, construction and deployment play a significant role in the development of the designs. Overall dimensions, displacements, modularity, and materials of construction all have their effects on where and how the Plants may be built which in turn can have a significant effect on costs and technical viability. These considerations are also included in the evaluation criteria used in the trade-off studies, but not to nearly the same level of detail. The details of the development of the conceptual designs are further covered in Sections 2 and 3.

2.2 Top Level Requirements (TLR)

The Top Level Requirements, or TLR, assembles in one document all of the design requirements, criteria, definitions, and assumptions necessary to develop the conceptual designs of the ship and semi-submersible Commercial Plants. It is constructed around the work breakdown structure developed during Task II (Reference (2)) and is included in this report along with a detailed discussion as Appendix A. This TLR is an expansion of the one developed for the Feasibility Studies of Task II, and provides more detailed design guidance and requirements as required for the Conceptual Design process.

2.3 Trade-Off Studies

2.3.1 Approach

The configurations selected for further development by Gibbs & Cox, Inc. are the nominal 400 MW (net) Ship and Semi-Submersible platforms. The following section summarizes a number of trade-off studies which were performed in an attempt to define characteristics of the baseline Ship designs which demonstrate an apparent advantage from the standpoint of cost, construction, operation and maintenance. Corresponding studies for the Semi-Submersible are described in Section 3.

The approach taken to demonstrate the combination of characteristics which best satisfies the operational requirements of the Commercial Plant, involves the generation of a series of point designs. Prior to the development of these point designs it is necessary to identify features which have a significant impact on platform integration. Each point design then represents a unique combination of these features. These designs are developed to a sufficient level of detail to define the relative impact on platform configuration with corresponding effects on platform volumes, weights, and ultimately costs.

In an effort to maintain a workable number of alternatives, related variables are, whenever possible, considered in sequence (e.g., the selection of a CWP material preceeds the selection of CWP length) and independant variables are considered separately (e.g., the selection of platform configuration and the selection of the CWP configuration).

The primary selection criterion in all of these trade-off studies is the Figure Of Merit (FOM) as presented in Volume 1, Section 5. Where F.O.M. comparisons indicate minimal differences among alternatives, secondary criteria are addressed and used to reinforce the design decision. Among the secondary considerations are: risk, constructability, modularity, positionkeeping, and maintenance. Where appropriate, these are discussed in the following sections.

As mentioned above, trade-off studies related to the platform configuration were developed independant of the Cold Water Pipe trade-off studies. Sections 2.3.2 and 2.3.3 address the selection of the hull material/configurational concept and the subsequent hullform proportion analysis of the ship platform, respectively.

2.3.1 Approach (Continued):

Section 2.3.4 summarizes the selection of the CWP material, and structural configuration.

2.3.2 Hull Material/Configurational Trade-Off Studies

The features identified as having significant impact on platform integration and cost are the hull material, heat exchanger orientation, hydraulic considerations in the sea water distribution system, and heat exchanger size and location. The following paragraphs discuss the alternatives considered for each of these features.

Hull Material - Reinforced concrete and mild steel were the only materials considered applicable for hull structure. Because of the volume limited nature of previously developed OTEC concepts, the increased weight of reinforced concrete was not considered undesirable. The general size of the platforms being considered was well within current State-Of-the-Art in steel construction, but precluded the use of aluminum or any other material as a primary hull structure material.

Heat Exchanger Orientation - As directed by DOE, both horizontally and vertically oriented heat exchangers are considered, as defined in Appendix A.

Hydraulic Considerations - A finite decrease in parasitic power is available through the incorporation of wide radius bends, diffuser sections and other features which reduce the pressure drop in the S. W. System. These features, however, result in an increase in required volume and thus an increase in platform acquisition costs. Two sets of arrangements were developed to analyze the relative magnitude of the costs incurred and benefits derived from the incorporation of these features. The first concept utilizes bend radii in the S.W. piping runs of approximately 150 percent of the nominal pipe diameter. This corresponds roughly to a minimum head loss bend radius considering both redirection of flow and increased frictional loss. The second concept utilizes a minimum volume arrangement with lengths of piping and bend radii as short as practical with consideration for fabrication and provision for supporting structure.

2.3.2 Hull Material/Configurational Trade-Off Studies (Continued):

Heat Exchanger Size and Location - As directed by DOE, both internal and external heat exchangers are considered. Both 25 and 50 MW (net) power systems components are available, however, only the 50 MW (net) units are used in these studies because of their obvious superior volumetric efficiency.

The twelve point designs generated to demonstrate these alternatives are presented in Figures 2.3-1 through 2.3-6. Characteristics of the designs are presented in Tables 2.3-1 and 2.3-2. Various assumptions made during the course of the study are discussed below as they relate to weights, acquisition costs, and operating costs.

Platform System - The structural weights reflected in the point designs represent preliminary sizing of scantlings to meet primary strength requirements of Reference (3). It was assumed that the use of reinforced concrete would not require any change to the overall dimensions of the corresponding steel platform except as the resulting displacements effect the operating drafts. The unit costs which were extracted from the Task IV report, Reference (4), are \$2,500/L.T. and \$250./L.T. for steel and reinforced concrete, respectively.

All other major platform system component costs and weights are developed from values quoted in the Task IV report, Reference (4). The values used are summarized in Table 2.3-3.

CWP System - To facilitate the estimation of acquisition costs prior to the availability of results of the CWP conceptual design, it is necessary to estimate the cost of the CWP. Figure 2.3-7 depicts the relationship between the dynamic bending stress and the operating displacement for the concrete CWP designs presented in the Task IV report, Reference (4). This data is generated for a one foot wall thickness at various diameters. By increasing the wall thickness by the ratio of dynamic bending stress to allowable stress of 2 KSI, and making no correction for the discrepancy in diameter, the results received are considered to be conservative. This thickness is used to generate a CWP cost by assuming a fabricated cost of \$500/cubic yard.

FIGURE 2.3-1

FIGURE 2.3-2

400 MW SHIP PLATFORM
EXTERNALLY MOUNTED HORIZONTAL
HEAT EXCHANGERS
MINIMUM LENGTH OF PIPING
(OPTION C)

FIGURE 2.3-3

400 MW SHIP PLATFORM
INTERNALLY MOUNTED VERTICAL
HEAT EXCHANGERS
MINIMUM SW PUMPING POWER
(OPTION D)

FIGURE 2.3-4

FIGURE 2.3-5

FIGURE 2.3-6

TABLE 2.3-1
Hull Trade-Off Study
CONCRETE CONSTRUCTION

REFERENCE I.D.	A	B	C	D	E	F
OPTION	HORIZONTAL			VERTICAL		
	INTERNALLY MOUNTED		EXTERNALLY MOUNTED	INTERNALLY MOUNTED		EXTERNALLY MOUNTED
	PARASITIC POWER	MIN. SW. PIPING		PARASITIC POWER	MIN. SW. PIPING	
LENGTH	1,050'	340'	700'	880'	825'	660'
BEAM	330'	330'	330'	330'	330'	330'
DEPTH	150'	150'	90'	200'	170'	110'
DRAFT	95'	100'	45'	135'	120'	45'
Δ(LIGHTSHIP)	601,900	523,300	355,700	531,500	449,000	325,400
S.W. IN SYS.	225,300	218,500	70,000	347,500	246,400	164,500
BALLAST				40,000	144,600	3,300
Δ OPERATING	857,200	742,400	425,700	918,500	840,000	493,100
ACQUISITION COST (\$M)	930	900	880	760	750	740
FACILITIES IMPROVEMENT COST (3200 MW PARK)	780	620	520	660	620	500

TABLE 2.3-2
Hull Trade-Off Study
STEEL CONSTRUCTION

REFERENCE I.D.	A	B	C	D	E	F
OPTION	HORIZONTAL			VERTICAL		
	INTERNALLY MOUNTED		EXTERNALLY MOUNTED	INTERNALLY MOUNTED		EXTERNALLY MOUNTED
	MIN. PARASITIC POWER	MIN. SW. PIPING		MIN. PARASITIC POWER	MIN. SW. PIPING	
LENGTH	1,050'	840'	700'	880'	825'	660'
BEAM	330'	330'	330'	330'	330'	330'
DEPTH	150'	150'	90'	200'	170'	110'
DRAFT	80'	80'	40'	135'	120'	40'
Δ(LIGHTSHIP)	238,300	235,900	206,900	215,700	194,500	170,000
S.W. IN SYS.	255,300	218,500	70,000	347,500	246,400	164,500
BALLAST	199,400	115,700	140,100	355,300	399,100	128,200
Δ OPERATING (L.T.)	713,000	570,200	417,000	918,500	840,000	462,700
ACQUISITION COST (\$M)	1,080	1,040	960	900	860	800

TABLE 2.3-3
PLATFORM SYSTEM WEIGHT AND
ACQUISITION COST ASSUMPTIONS FOR
SHIP TRADE OFF STUDIES

WBS	DESCRIPTION	WEIGHT (L.T.)	COST (\$M)	COMMENTS
1.0	Platform System			
1.2	Hull Structure			
	Steel		\$2500/LT.	Task IV
	Concrete		\$250/LT.	Task IV
1.3	Position Control	2000		Costs proportioned from Task IV by operating displacement
1.4	Platform Support	700	\$3.7/M	Task IV for 350 MW ship
1.5				
1.7	Seawater Systems			
	Warm Water Pumps	3300	\$3.5M	Proportioned from Task IV by flow requirements
	Cold Water Pumps	4000	\$4.1M	
	Piping	1.5LT/Ft.	\$3000/Ft.	36' Diameter Steel

2.3.2 Hull Material/Configurational Trade-Off Studies (Continued):

Figure 2.3-7
CWP DYNAMIC BENDING STRESS

Power System - Characteristics of the Power System Components are summarized in Tables 2.3-4 and 2.3-5. All figures presented with the exception of heat exchanger costs, are developed from information provided by DOE. Heat exchanger costs are developed from previous work by Lockheed, Reference (5) on a dollars/ton basis with a 40-percent allowance for inflation (1973 - 1978). It should be noted that this results in a significant variation in Power System costs for horizontal or vertical heat exchangers. In addition, an allowance of 25 pounds/square foot of shell is provided on external heat exchangers to allow for the increase in loads and corrosion anticipated for the external mounting.

TABLE 2.3-4

HEAT EXCHANGER WEIGHT AND ACQUISITION
COST ASSUMPTIONS
(WBS 3.2 & 3.3)

	HORIZONTAL		VERTICAL	
	WEIGHT	COST	WEIGHT	COST
INTERNAL	LT.	\$M	LT.	\$M
Heat Exchanger	1610	23.6	1070	15.7
Water in Heat Exchanger	4460		2950	
EXTERNAL				
Heat Exchanger	1800	24.0	1225	16.0
Water in Heat Exchanger	4460		2950	

TABLE 2.3-5

POWER SYSTEM WEIGHT AND ACQUISITION COST ASSUMPTION FOR
SHIP TRADE OFF STUDIES

WBS	DESCRIPTION	WEIGHT	COST	COMMENTS
3.4	Working Fluid System	3760	22.67	Proportioned from DOE information
	Piping	0.43Lt/Ft.	\$850/Ft.	10' Diameter Steel
3.5	Working Fluid Storage	4320	4.48	Proportioned from DOE information
3.7	Generation System	2160	31.06	
3.11	Biofouling & Corrosion	240	0.80	

Energy Transfer System - A weight of 2240 LT and a cost of \$112M are estimated for the Power Conditioning System, based on information provided by Simplex, Reference (6).

Facilities Improvement Costs - To make the acquisition costs for steel and reinforced concrete comparable, it is necessary to include in the reinforced

2.3.2 Hull Material/Configurational Trade-Off Studies (Continued):

concrete cost an estimate of facilities improvement costs. Based on data presented in Reference (4), a cost per square foot of dock platform area can be generated. A clearance margin of 20% on platform shadowed area is then used to generate the cost of one facility. Assuming that two facilities are required to construct an eight platform energy park in approximately six years the facilities improvement costs listed in Table 2.3-1 are generated.

Construction time - Steel construction would allow completion of the hull structure in less time because of the existing technology in steel shipbuilding. Assuming long lead items are available, on schedule, this would permit a shortening of the entire construction sequence. A seventy-four (74) month construction schedule is anticipated in Task IV for concrete construction. This figure is arbitrarily reduced by nine (9) months for steel construction to in some way quantify the relative levels of technology related to floating platforms.

Operation Costs - All operation costs which are used in these trade-off studies are derived from Reference (4). Crew costs are taken from the 350 MW ship. Insurance costs are taken as 0.8 percent of acquisition cost. The cost included for mini-submarine operation is doubled for platforms utilizing externally mounted heat exchangers. For the concrete hulls, the remainder of the operation and maintenance costs are assumed to be equal to the corresponding costs from Reference (4), for an equivalent lightship displacement. Operating costs for a steel platform, excluding insurance costs, reflect a ten percent increase over the corresponding operating cost of the comparable concrete platform to account for the increase in maintenance required by the steel hull.

Energy output - An estimate of the parasitic load corresponding to various sea water distribution piping run configurations is included in the FOM analysis. As discussed in Section 2.9, the difference in pressure drop when one tight radius bend is substituted for one long radius bend is estimated to be 1% of the total head loss through an individual sea water system path. Assuming the sea water pumping power requirement to be ninety (90) percent

2.3.2 Hull Material/Configurational Trade-Off Studies (Continued):

of the total parasitic load, and the parasitic load to be thirty (30) percent of the module output; the increase in parasitic power for the use of each tight radius bend is 0.07 MW.

The results of the FOM analysis assuming a ten (10) percent rate of return are presented in Table 2.3-6 for the twelve alternatives considered. A comparison of alternatives A and B or D and E indicates that by minimizing platform size and accepting the resultant increase in pumping power, the life-cycle costs as well as the capital investment costs are lower. This result is applied to all subsequent trade-off studies.

A comparison of alternatives B and C or E and F demonstrates the advantage gained through the use of externally mounted heat exchangers and the corresponding improvement of platform volumetric efficiency. This conclusion is dependent on the assumptions provided in preceeding paragraphs regarding the cost of externally mounted heat exchangers.

TABLE 2.3-6
COMPARISON OF FIGURES OF MERIT-
HULL TRADE-OFF STUDIES

OPTION	A	B	C	D	E	F
DESCRIPTION:						
H/X Orientation (1)	Hor	Hor	Hor	Vert.	Vert.	Vert.
H/X Location (2)	Int	Int	Ext	Int	Int	Ext
Hydraulic Considerations (3)	Min	Max	Max	Min	Max	Max
F.O.M. 3200 MW Park						
Steel	2.568	2.655	2.912	3.060	3.152	3.448
Concrete (w/facilities)	2.645	2.765	2.881	3.194	3.215	3.377

1. Hor=Horizontal, Vert=Vertical
2. Int=Internal, Ext=External
3. Min=Minimum Parasitic Pumping Power Regmt.
Max=Minimum Volume S.W. Distribution

2.3.2 Hull Material/Configurational Trade-Off Studies (Continued)

Similarly, a comparison of A and D, B and E, or C and F demonstrates an apparent advantage of vertical heat exchangers. This result is extremely dependent on the assumptions pertaining to equivalence of unit costs (\$/L.T), of horizontal and vertical heat exchangers.

Finally, a comparison of steel and concrete platforms shows a very slight difference between platforms of a given configuration (less than four percent in each case). As might have been expected, as platform size and weight decreases, the relative advantage of steel increases. The differences however, are not adequate to justify selection of hull material without consideration of secondary criteria. Steel offers an obvious advantage from risk and constructability standpoints, because of the well developed steel shipbuilding technology. Steel would, however, require additional maintenance to handle the problem of corrosion. Several steel offshore platforms are currently operating successfully with cathodic protection systems. The advantages of steel in terms of risk, constructability and cost are more than adequate to offset the disadvantages encountered in hull maintenance.

Taking into account all of the preceding observations, a joint decision by DOE and Gibbs and Cox, Inc., has selected Alternative F (Vertical External Heat Exchangers with Minimum Piping Runs), to be built of steel as the baseline configuration for subsequent conceptual design studies.

2.3.3 Hull Form Parametric Analysis

Prior to a full evaluation of the cold water pipe, it is possible to qualitatively assess the cost of the CWP for various platforms by predicting and ranking their motions. In an effort to minimize CWP cost, the features selected in the preceeding paragraphs should be arranged in a platform with proportions which result in minimum motions. Figures 2.3-8 and 2.3-9 present a comparison of motion induced forces for several platforms with adequate size to accommodate the selected features, and various length-beam ratios. A typical example of how these forces are reflected in CWP dynamic bending stress is demonstrated in Figure 2.3-10. It is evident from these figures that at the design sea spectrum, a length: beam ratio of approximately two results in consistently lower motions and corresponding lower CWP dynamic bending stresses. (This varies from normal naval architectural trends because of the unique nature of the hull form) Although the CWP is addressed in greater detail in subsequent sections, this analysis justifies the development of the ship platform with a length: beam ratio of approximately 2.1.

2.3.4 Cold Water Pipe Trade-Off Studies

As with the hull material/configuration trade-offs, several features can be identified which have a significant effect on CWP performance and cost. These features and the alternatives considered for each include:

CWP/Hull interface fixity: Rigid, Pinned (zero rotational stiffness)

CWP Material: Mild Steel, High Tensile Steel (HTS),
Aluminum, Reinforced Concrete (RC) and Glass
Reinforced Plastic (GRP)

CWP Diameters: 60, 80, 100, and 120 feet

CWP Buoyancy: Where justified to allow reduction in weight.

CWP Length: 2500 - 3500 feet

FIGURE 2.3-8

SURGE FORCE vs. HEADING ANGLE FOR VARIOUS L/B SHIP PLATFORMS

FIGURE 2.3-9

ROLL MOMENT vs. HEADING ANGLE FOR VARIOUS L/B SHIP PLATFORMS

FIGURE 2.3-10

TYPICAL DYNAMIC BENDING STRESS DISTRIBUTION

2.3.4 Cold Water Pipe Trade-Off Studies (Continued):

The nature of the CWP/Hull interface cannot be evaluated simply on the basis of loads transmitted through the connection. Although the value of the dynamic stress at the joint is greater for a rigid connection, preliminary analysis of stress distribution along the length of pipe indicates that the maximum anticipated stress is not significantly affected by the degree of fixity at the interface. The nature of the CWP/Hull interface then is driven by considerations for maintenance, construction, deployment and the possibility of CWP detachment/recovery. As presented in Section 2.10, the method of CWP attachment currently proposed by Gibbs and Cox, Inc., involves the use of a universal joint which is supported by a shaft which in turn is supported by the platform structure thus decoupling the platform and pipe in roll and pitch motions. Investigation into the availability of bearings in the size range required indicates that loads of 20,000 to 30,000 long tons can be supported with little development of the current State-Of-the-Art. In addition, this type of connection eliminates the necessity for the production of a complex underwater weld, provides for the possibility of a "shirt sleeve environment" in the bearing housing and provides for a simpler detachment procedure should detachment ever be required. For this reason, all subsequent CWP studies are conducted assuming a joint at the hull/CWP interface with zero rotational stiffness in roll and pitch.

The results of a series of analyses using the model described in Reference (7) which evaluated the effect of various combinations of CWP diameter, thickness and material on CWP dynamic bending stress, are presented in Figures 2.3-11 through 2.3-14. These relationships were used to develop a series of minimum weight point designs for each diameter-material combination. The mild steel, HTS, aluminum and GRP designs all use a structural configuration consisting of a series of externally mounted ringframes and axial stiffeners supporting a CWP shell. The uniform equivalent wall thickness used to enter the appropriate figure reflects a uniform wall thickness with a moment of inertia equal to that of the corresponding point design. In addition to the dynamic bending stress read from the figures, stresses resulting from the dead weight of

FIGURE 2.3-11

FIGURE 2.3-12

FIGURE 2.3-13

FIGURE 2.3-14

2.3.4 Cold Water Pipe Trade-Off Studies (Continued):

the structure and the pressure differential across the pipe wall are estimated. The pressure differential is considered to be the sum of the head loss and velocity head resulting from flow through the CWP, together with the stagnation pressure of the assumed current profile acting against the exterior of the CWP.

Each point design is evaluated for failure in tension, panel buckling and plate buckling using Reference (8). Initially, all designs are considered to have no special provision for buoyancy. In certain cases using mild steel where the resulting designs are limited by the allowable tensile stress, distribution of buoyancy along the length of the pipe is considered. Various combinations of axial and ring stiffener spacings are evaluated in an attempt to produce a minimum weight configuration. A typical example of the results of this methodology performed for various diameters is presented in Figures 2.3-15 and 2.3-16 for HTS.

Reinforced concrete was treated differently because of its unique properties compared to the other alternative materials. The enormous weight of the concrete required necessitates the use of buoyancy to relieve the vertical load at the bearing. The difficulty in providing and maintaining water tight voids along the entire pipe length requires the provision that buoyancy be concentrated at the top of the pipe. High strength reinforcing wire (150 KSI yield stress) is assumed in an attempt to limit the required amount of steel. Sufficient reinforcing wires are provided to support the weight of the CWP below the point being designed, prestress the concrete to 2 KSI, and support a portion of the dynamic bending stress proportional to the relative stiffness of the steel and the concrete.

The results of the structural analyses are presented in Table 2.3-7. In addition to the weight per foot values, an estimate of the relative unit costs of the various materials has been applied to reduce the weight comparisons to relative cost comparisons. Where buoyancy is required, it is assumed to be provided by 30 foot diameter pressurized steel tanks 100 feet long of a sufficient number to provide the required buoyancy. The resulting

FIGURE 2.3-15

FIGURE 2.3-16

18351-10 (W-10,010)

2.3.4 Cold Water Pipe Trade-Off Studies (Continued):

CWP Relative Cost Factors represent normalized costs related to the 100 foot diameter mild steel minimum.

TABLE 2.3-7
CWP COST/WEIGHT RELATIONSHIPS

Diameter (feet)	60		80		100		120	
Material	Wt/Ft	Rel. Cost Factor	Wt/Ft	Rel. Cost Factor	Wt/Ft	Rel. Cost Factor	Wt/Ft	Rel. Cost Factor
Mild Steel (w/o buoy)	19.0	2.639	18.4	2.556	7.2	1.000	9.4	1.306
Mild Steel (w/buoy)	17.1	2.439	7.7	1.090				
HTS	16.3	3.396	5.8	1.208	6.0	1.250		
Aluminum			3.17	1.101	3.01	1.045	3.34	1.160
GRP			2.47	2.058	2.47	2.058	2.97	2.475
R.C.			111.3	2.85	102.1	2.61	53.5	1.343

The power required to pump the necessary volume of water through the CWP is inversely related to the CWP diameter. To properly evaluate the cost effectiveness of the CWP system, some estimate of this variation in this power requirement must be included in the FOM analysis. For each diameter considered a power requirement can be generated which can then be used to modify the output of the platform.

The results of both the CWP relative cost analysis and the pumping power requirement analysis are summarized in Table 2.3-8 and Figure 2.3-17. The Acquisition Cost Modifier assumes an average deployed cost over an eight ship procurement plan of \$450M, 20 percent of which is directly applicable to CWP engineering, fabrication, assembly and deployment (See Volume I).

2.3.4 Cold Water Pipe Trade-Off Studies (Continued):

TABLE 2.3-8
CWP FIGURES OF MERIT

Diameter (feet)		60	80	100	120
Power Output Modifier		.7664	.8036	.8131	.8159
Mild Steel (w/o buoy)	Cost Mod	1.3278	1.3112	1.0000	1.0612
	FOM Mod	.5772	.6129	.8131	.7688
Mild Steel (w/buoy)	Cost Mod	1.287	1.018		
	FOM Mod	.5955	.7894		
HTS	Cost Mod	1.4792	1.0416	1.0500	
	FOM Mod	.5181	.7715	.7744	
Aluminum	Cost Mod		1.0202	1.0090	1.0320
	FOM Mod		.7512	.8058	.7906
R.C.	Cost Mod		1.3700	1.3220	1.0686
	FOM Mod		.5866	.6151	.7636
GRP	Cost Mod		1.2116	1.2116	1.2950
	FOM Mod		.6633	.6711	.6300

As shown by these results, the 100 foot diameter mild steel pipe represents the most cost effective CWP system. Although the aluminum pipe has approximately the same FOM modifier at 100 foot diameter and would reduce the load on the bearing, the potential difficulty arising from dissimilar metals (steel hull-aluminum CWP) in an electrolytic solution along with the more difficult quality control procedures precluded the recommendation of aluminum.

FIGURE 2.3-17

FORM MODIFIERS FOR VARIOUS MATERIAL/DIAMETER CWP ALTERNATIVES, SHIP PLATFORM

2.3.4 Cold Water Pipe Trade-Off Studies (Continued):

A preliminary analysis indicates that a highly tuned relationship exists between the length of the CWP and the maximum dynamic bending stress. For a preliminary evaluation of this trade off, the ratio of peak dynamic bending for a 0.1 foot wall thickness of a 100 foot diameter mild steel CWP is used as typical of the response of the CWP. Corresponding variations in power output, resulting from the variation in thermal resource, are developed and another F.O.M. modifier is determined. The results presented in Table 2.3-9 are calculated only for the 100 foot diameter mild steel CWP. It is recognized that this analysis is approximate and should be further investigated during the preparation of the preliminary design.

TABLE 2.3-9
CWP FIGURE OF MERIT vs LENGTH

Length	2500	3000	3500
CWP Stress Modifier	2.821	1.071	1.429
CWP Cost Modifier	2.821	1.071	1.429
Platform Cost Modifier	1.345	1.000	1.071
Power Output Modifier	.798	.813	.865
F.O.M. Modifier	.563	.813	.808

Summary - The conclusion of the CWP trade-off studies can be summarized in the recommendation of a CWP of mild steel, 100 foot inside diameter, and 3000 foot length with no provisions for buoyancy and a pinned connection (zero rotational stiffness) to the ship platform. This recommendation is further developed in Sections 2.10 and 4.3.

2.4 Platform Integration

2.4.1 Arrangements

The baseline arrangement for the development of the conceptual design of the 400 MW (net) Ship OTEC Platform is the Alternative F point design presented in Section 2.3.2 and depicted in Figure 2.3-6. The results of the subsequent design procedure are the arrangements presented in Appendix B. A summary of principal characteristics is presented in Table 2.4-1, and Figure 2.4-1 illustrates the profile.

TABLE 2.4-1

Principal Characteristics of the 400 MW (net) Ship OTEC Platform

Length	620 Feet (189 m)
Beam	300 Feet (91 m)
Depth	85 Feet (25.9 m)
Draft	45 Feet (13.7 m)
Operating Displacement	310,000 L.T. (314,900 mT.)
Principal Hull Material	Mild Steel
Cold Water Pipe System	
Inside Diameter	100 Feet (30.5 m)
Material	Mild Steel
Connection	Pinned (Zero Rotational Stiffness)
Power System	
H/X Rating	65 MW (gross) (nominally 50 MW (net))
H/X Type	Externally mounted, Vertical
Working Fluid	Ammonia

The arrangements represent an attempt to combine several features considered desirable for the efficient performance of functions related to maintenance and operation of the Power System. The following features are given priority in the development of the arrangement:

- Minimum length of ammonia piping. The length of piping from the turbine to the condenser is considered more critical.

FIGURE 2.4-1

400 MW_e SHIP, PROFILE

2.4.1 Arrangements (Continued):

- Simplified sea water distribution system to minimize parasitic losses.
- Provision for withdrawal of internally mounted major equipment for maintenance or replacement. Equipment considered major includes pump motors, turbines, generators, ammonia pumps, compressors, and vacuum pumps.
- Provision for attachment of the externally mounted equipment on site to simplify deployment.
- Maximum use of shore-side support facilities to provide services not required on a continuous basis.
- Maximum use of symmetry to simplify design and construction.

In the event that several alternatives provide the desired features, minimum acquisition cost is used as the decision criterion.

The conceptual design addresses each of these features in such a manner that the resulting arrangement provides a functional grouping of power system, platform, and personnel support related equipment. Significant features of the arrangement are described in the following paragraphs.

The use of a platform composed of four identical quadrants achieves a highly uniform arrangement with resultant simplification of design and construction. The overall dimensions are driven by the size of the heat exchangers, foundations, interface with the CWP and provision for ammonia storage tanks. Internally, the equipment related to the Power System is contained in two adjacent spaces per module. Laydown areas adjacent to major equipment is provided as noted below. The CW pump motors are clustered in four spaces on centerline amidships to minimize the size of the CW plenum while simultaneously simplifying the CW distribution system. The location of each WW pump motor in an individual space is driven by the size and arrangement of the WW intakes located immediately below each pump. Power conditioning equipment is consolidated outboard amidships on both the main deck and second deck. In this location it is convenient to each generator served and also provides a centralized location for the currently undefined attachment to the riser cable. Auxiliary equipment including fan rooms, circulating water pumps and air conditioning units are provided convenient to the equipment or spaces served.

2.4.1 Arrangements (Continued):

Provision for major maintenance of the sea water pump motors, turbines, and generators is provided by a series of hard patches. Removal of the pump motors, turbine casings and rotors requires a vertical lift straight through the main deck using the 150 ton capacity gantry crane. It is assumed that the generator rotor must be withdrawn through the end of the generator casing. This necessitates the use of an additional hard patch in a transverse bulkhead. To remove the rotor, it must then be swung clear of the generator casing and lifted vertically through the same hard patch used to access the corresponding turbine. Laydown area to provide space for temporary storage of the casings or on-site inspection and maintenance of the rotating components is provided adjacent to each piece of major equipment. These access envelopes are illustrated in the arrangement drawings in Appendix B. Removal of smaller equipment, i.e., compressors, feed pumps, and vacuum pumps, is provided by a series of hard patches and/or equipment handling hatches as required.

A scheme for handling the heat exchangers during the deployment operation has been developed and is presented in Section 4.1.2. Although direction provided by DOE indicates that no subsequent removal is required, the deployment scheme has been developed in such a manner that removal can be accomplished by reversal of the deployment operation. This feature adds flexibility to the operation of the platform without increasing its cost or complexity.

The arrangement also incorporates a six foot wide cofferdam running longitudinally along centerline. This feature permits construction of the two halves in existing shipbuilding facilities. A detailed discussion of the construction and deployment sequence of the Platform System is contained in Section 4.2.

2.4.2 Hull Form

The ship platform utilizes a symmetric barge-type hull to provide a volume-efficient envelope for the internally mounted Power System components, a consistent structural configuration to permit integration of various equipment foundations, and a simplified arrangement for minimum fabrication costs. The selection of the proportions reflects the results of the Hull Form Parametric

2.4.2 Hull Form (Continued):

Analysis of motions presented in Section 2.3.3 together with consideration of the arrangements of major Power System components. The motions of the selected hull are summarized in Section 6.

2.4.3 Manning

The platform is located a sufficient distance offshore to necessitate the provision for a full time crew of adequate size to provide 24 hour supervision of the platform, power system and related support functions. Although current practice in offshore drilling rig manning is for two twelve hour shifts, the watch standing nature of the majority of crew responsibilities on the OTEC platform is comparable with the duties performed by the members of a merchant ship crew. For this reason three shifts working eight hour days, is anticipated to be the most reasonable approach to normal operation. The use of the park concept permits the use of a transient crew to perform major maintenance and overhaul operations.

The full-time crew is functionally divided into Deck, Plant Supervision, and Platform Maintenance Departments. Manning levels in each department are developed from industrial operations which require the performance of similar functions. A summary of the recommended crew size is presented in Table 2.4-2. The principal duties anticipated for each rating are discussed in the following paragraphs. For comparison, the manning levels projected by several previous OTEC concepts are presented in Table 2.4-3.

Deck Department - A minimum of three men, one per shift, is currently provided on offshore moored platforms to maintain a 24 hour bridge look-out. Normally this crew is composed of two able-bodied (AB) seamen, and one ordinary seaman. One of the AB seamen is designated as an unlicensed master to serve as maritime crew supervisor.

In addition to their watch standing functions, the Deck Department would be responsible for operation of the ship-to-shore radio, the supervision of replenishment operations from the supply ship, and, in the event of an emergency, the supervision of life boat handling.

2.4.3 Manning (Continued)Deck Department (Continued)

The operation of the OTEC platform does not require the performance of any deck related functions in addition to those required on an off-shore oil platform, therefore, a deck department of three is recommended for the OTEC platform.

TABLE 2.4.2
RECOMMENDED OTEC 400 MW (NET) MANNING LEVELS

Rating	No. per Shift	No. of Shifts	Total	Accommodations
Deckhands	1	3	3	
Deck Total	1		3	5
Plant Superintendant	1	1	1	
Shift Supervisors	1	3	3	
Control Room	3	3	9	
Roving Watch	2	3	6	
Plant Supervision Total	7		19	20
Mechanical Foreman	1	1	1	
Mechanics	4	1	4	
Electrical Foreman	1	1	1	
Electricians	4	1	4	
Instrumentation Foreman	1	1	1	
Instrumentation Specialists	4	1	4	
Cook	2	1	2	
Janitor Messmen	3	2	6	
Clerical	2	1	2	
Platform Maintenance Total	22		25	25
Spares for transient Personnel	10	1	10	10
Total	40		57	60

TABLE 2.4-3
OTEC PLATFORM MANNING
ESTIMATE SUMMARY

	<u>LOCKHEED (1)</u>			<u>JOHNS HOPKINS UNIVERSITY (2)</u>			<u>TRW (3)</u>		
<u>Platform:</u>									
Type:	Spar			Ship			Cylinder		
Capacity, MW	160 (Net)			100 (Net)			100 (Net)		
Displacement, L.T.	355,000			141,650			213,500		
Dimensions (Ft.)	200 dia. x 432 deep			476 x 196 x 90			340 dia. x 170 deep		
	No. per Shift	Shifts	Total Aboard	No. per Shift	Shifts	Total Aboard	No. per Shift	Shifts	Total Aboard
<u>Manning:</u>									
Ship's Master				1	1	1	1	1	1
1st Mate/Medical				1	2	2	2	1	2
2nd Mate				1	3	3	1	1	1
Deck Hands (AB's)				2	3	6	0	0	0
Sub-Total:	0	0	0	5	-	12	4	-	4
Plant Superintendent	1	1	1	1	1	1	1	1	1
Staff Supervisor	1	3	3	0	0	0	1	2	2
Control Rm. Opertr.	2	3	6	0	0	0	1	2	2
Plant Operators	2	3	6	1	3	3	3	2	6
Chemistry/Testing	2	1	2	1	3	3	1	2	2
Sub-Total:	8	-	18	3	-	7	7	-	13
Mechanic	1	3	3	1	2	2	2	2	4
Electrician	1	3	3	2	2	4	2	2	4
Diver	0	0	0	1	1	1	3	1	3
Cook	0	0	0	2	1	2	1	2	2
Messmen/Janitor	1	1	1	0	0	0	1	2	2
Misc. Repair	2	1	2	2	1	2	0	0	0
Clerk	1	1	1	1	1	1	0	0	0
Sub-Total:	6	-	10	9	-	12	9	-	15
TOTAL (4) (5):	14	-	28	17	-	31	-	-	32

NOTES:

- 1) Lockheed Report LSMC-0056566 "OTEC Power Plant Technical and Economic Feasibility - Volume I - Technical Report" dated 12 April 1975.
- 2) Johns Hopkins Report PB-257-444 Detailed Report - "Maritime and Construction Aspects of OTEC Plant Ships" dated April, 1976.
- 3) TRW Report PB-246-180 "OTEC Research on an Engineering Evaluation and Test Program - Volume III - Baseline System Concept" dated June, 1975.
- 4) Does not reflect men on rotating shore leave.
- 5) Assumes all non-routine maintenance performed by shore-based personnel.

2.4.3 Manning (Continued)

Plant Supervision Department - The use of a centralized control room permits consolidation of watch standing duties and consequential reduction in manpower requirements. Typical shore-based power plants of a similar capacity have demonstrated the practicality of a three man watch to monitor the necessary instrumentation. Additionally, a roving watch is generally provided to maintain an intermittent local watch, confirm certain vital operational parameters and perform minor unautomated operational duties. Two men per watch allows for approximately one man hour to be devoted to each 50 MW (net) unit during each four hour shift. To supervise the overall operation of the plant and perform routine watch related administrative duties, a shift supervisor, in addition to control room staff of three, is required. The nature of each of these duties necessitates full-time manning of each position, therefore three full shifts composed of a shift supervisor, three control room personnel and two roving watch-standers are recommended for the plant supervision of the 400 MW (net) OTEC platforms. To coordinate overall administration and serve as ultimate authority for matters concerning plant operation, the position of Plant Superintendent is also recommended, bringing the total staff of the Plant Supervision Department to 19.

Platform Maintenance Department - This department is composed of all of the day working specialists required to perform maintenance of a routine or preventative nature. It can be further subdivided into mechanical, electrical, instrumentation, steward and administrative subgroups. A member of each group is designated as foreman to coordinate scheduling of work and report significant developments to the Plant Superintendent. The specific responsibilities of the mechanical, electrical and instrumentation groups are the rotating equipment (pumps, motors, deck equipment, etc.), transformers and riser cable connection, and the automated equipment and control circuitry, respectively. The recommended staff sizes reflect current land based power plant practice. Under normal operating conditions, it is anticipated that all routine maintenance can be accomplished in a single eight hour shift, five days per week with a rotating skeleton weekend crew to respond to monitor alarms. The stewards department responsibilities, in

2.4.3 Manning (Continued)

addition to the preparation of meals for the platform complement, includes routine janitorial duties in all habitable spaces on the platform. It is anticipated that each individual will work eight hour days and seven day weeks. Administrative personnel are required to maintain records of personnel, plant availability, maintenance, accidents, logistics shipments, and financial matters. A staff of two is considered sufficient to perform these functions. The workload is anticipated to be sufficient to require a single eight hour shift five days per week.

As mentioned previously, all major maintenance and overhaul operations will be performed by a transient crew of specialists which services all of the platforms within the energy park. Accommodations for up to ten transient crew are provided on the platform.

Because of the remote location of the platform and the inconvenience of providing commuting boat service to shore, it is anticipated that all crew members will be assigned to duty for a specified period of time to be followed by a scheduled period of shore leave. This work sequence is typical of offshore platforms which work on 10-day on-10-day off or 14-day on-14-day off work cycles. The specific cycle designated may vary for different responsibilities and work loads.

2.4.4 Weights

Table 2.4-4 gives a one digit WBS summary of weights for the 400 MW (net) ship. The level of detail reflected in any individual entry in this table varies according to its impact on the Ocean System configuration or cost. The following section describes generally the procedures used to estimate the individual line item weights listed in the detailed weight report of Appendix E.

Platform System (WBS 1.0) - Hull and Structure (WBS 1.2) account for 50 percent of the total Platform System weights and 20 percent of the total operating displacement of the ship. For this reason, the structural weight estimate is based on a detailed analysis of the structural configuration developed in Section 2.5. The weight included for the Position Control System (WBS 1.3) is developed from vendor supplied characteristics of a recommended suit of equipment. Where possible, weights for specific items of equipment are used in developing estimates for the Platform System (WBS 1.4) and Outfit and Furnishings (WBS 1.5). Where the identification of individual components of these groups requires the development of details beyond the scope of a conceptual design, parametric relationships are used to provide sufficiently accurate estimates. The major components of the Sea Water System (WBS 1.7) are the pumps and motors. Weights for these items are developed from vendor information and algorithmic relationships. The remaining weights are developed for this specific arrangement based on assumptions regarding structural requirements. The weight for Biofouling and Corrosion Control (WBS 1.8) is proportioned from a similar system on floating nuclear power plants.

The CWP System (WBS 2.0) - This section reflects a level of detail comparable to the Hull and Structure estimate. The configuration of the CWP is presented in Section 2.10.

The Power System (WBS 3.0) and Energy Transfer System (WBS 4.0) Weights are developed from information provided by DOE. As mentioned in Section 2.3.2, the weight for an externally mounted heat exchanger was modified to reflect some estimate of the increase in structure required to resist the additional loads which would be experienced by an external unit.

TABLE 2.4-4

WEIGHT SUMMARY FOR
400 MW (net) OTEC SHIP PLATFORM

WBS	DESCRIPTION	WEIGHT	
		(L.T.)	(M.T.)
1.0	Platform System (Note 1)	187400	190400
2.0	CWP System	25000	25400
3.0	Power System (Note 2)	71900	73000
4.0	Energy Transfer System	2200	2200
	Light Ship W/O Margin	286500	291000
	Margin (Note 3)	23900	24300
	TOTAL LIGHT SHIP DISPLACEMENT	310400	315300
	Load Items	1000	1000
	TOTAL OPERATING DISPLACEMENT	311400	316300

- NOTES: 1. Includes seawater in pumps and internal piping, plus ballast.
2. Includes seawater in heat exchangers. Water in discharge tubes and CWP not included. Also includes ammonia in power loop and storage tanks.
3. 10 percent on light ship minus permanent ballast.

2.4.5 Stability

The platform configuration and weight distribution of the 400 MW (net) Ship OTEC platform provide a more than adequate metacentric height (GM) of approximately 84 feet. A high value for GM as a measure of intact stability however, implies a large restoring force to any heeling moment with a corresponding short roll period. The hydrodynamic coefficients and high displacement which are characteristic of this hull form result in small motion amplitudes and consequently acceptable motion accelerations.

A damage stability analysis of the design assuming the worst case flooding condition depicted in Figure 2.4-2, indicates trim and heel values after damage of approximately 10.8 feet and 2°, respectively. This worst case flooding condition assumes that the damage would extend transversely past the wing wall bulkhead and longitudinally over two adjacent compartments with the inner longitudinal bulkhead remaining intact. This corresponds to a longitudinal extent of damage of approximately 12% of the platform length and transverse extent of 27% of the platform beam. The small values of trim and heel reflect the large amount of freeflooded or ballasted volume together with the provision of numerous subdivision bulkheads. Although the angles of trim and heel are small, the possibility of interference between the CWP and plenum is increased; therefore, the ballast system provided incorporates the ability to counter-flood to eliminate trim and heel. The additional parallel sinkage and free-surface do not significantly reduce the metacentric height in the damaged condition.

In the event of failure of the pinned joint at the CWP/hull interface, the loss of the CWP would result in a parallel rise of 4.5 feet and a four foot decrease in GM, neither of which would endanger the platform.

FIGURE 2.4-2
DAMAGED WATERLINES FOR 400 MW SHIP

2.4.6 Logistic Support Concept

2.4.6.1 General

An environmental impact study considers the effects of an engineering system on the ecology and environment. In a sense, the logistic support concept examines a situation from a reversed perspective i.e., the effect of the ecology and environment and its impact on successful use of a system. In this light, the following study begins by examining the ecology and environment.

The purpose of this study is to define a logistics support concept for the 3200 MW energy park located off Keahole Point, Hawaii, as a basis for total system cost estimates in Task VIII. The study also defines the desired characteristics of the platforms in relation to their logistic support facilities. It is noted that this study is based strictly on the Keahole Point site. If the location is moved elsewhere, the Logistic Support concept will bear re-examination.

2.4.6.2 Environmental Considerations

(a) Location:

The logistic support concept is based on eight platforms, which will ultimately have an optimum arrangement vis-a-vis platform to platform, but for the purposes of this document are considered to be deployed in a straight southerly line from Keahole Point southward. The deployment line is assumed to follow a 4000 foot depth contour line roughly parallel to, and two to three miles off the so-called Kona Coast of the Big Island. The platforms are located 3000 feet apart, so the total length of the line would be almost four miles.

(b) Climate:

The climate is warm and semi-tropical. The prevailing winds are North East Trade Winds, which precipitate large quantities of rain on the North East Coast of the Big Island. The very high volcanic mountains prevent this source of rainfall from reaching the Kona Coast where the platforms are deployed. In the winter time southerly winds usually bring very humid wet weather in what is referred to as a "Kona" wind.

2.4.6.2 Environmental Considerations (Continued):

(b) Climate: (Continued)

The Hawaiian Islands are presently experiencing a general drought which is in its fourth year. This shortage is attributed to the failure of the "Kona winds" to bring rain, and results in a chronic shortage of fresh water which is typical of many tropical islands. This fact is of importance with respect to possible utilization of excess power to operate desalinization plants.

(c) Seabed:

The seabed in this area drops rapidly from sea level to a depth of 6000 feet approximately three miles off the coast. Since the seabed is the flank of a volcano it can be assumed to consist of volcanic material and debris. There is little coral formation around the Big Island because it is geologically the youngest island in the Hawaiian group and it is still building from volcanic activity.

(d) Coastal Area:

The coastal area is not as precipitous in the Keahole Point locale as it is elsewhere in the Island. For this reason a new jet air field has been constructed near the point. Much of the coastal area appears to be a succession of bare lava flows with little or no sand or soil. The point itself is relatively deserted and uninhabited but there are resort hotels north and south of the Point, and a number of hamlets and towns along the main circumferential Island highway.

(e) Water Supplies:

Potable water is usually obtained from watersheds or by the drilling of deep wells. There are no streams or rivers which can be used for water supply.

(f) Sewage Treatment:

Existence of municipal facilities in the Keahole Point area is not known. It is known that resort hotels in the area have installed sewage treatment plants for their own use.

2.4.6.2 Environmental Considerations (Continued):(g) Electrical Power:

Electrical power on the island is supplied by the Hawaii Electric Light Company, Inc., a subsidiary of the Hawaiian Electric Company, Inc. Electric power is generated from fossil fuels, primarily residual fuel, oil, bagasse (the fibrous waste from the sugar extraction process), and hydro sources. It will be noted in Figure 2.4-3 that there is a seasonal effect on sources of generating capacity.

FIGURE 2.4-3
BIG ISLAND GENERATING CAPACITY - 1976

2.4.6.2 Environmental Considerations (Continued):

(g) Electrical Power: (Continued)

This figure indicates that during periods of peak production of sugar cane, which coincide with the availability of hydro power, the plantations are dumping excess power from their own generators into the system, and the fossil fuel requirement is reduced.

A geothermal test well has been drilled on the Island and is assessed as capable of producing 2.8 megawatts of electricity for thirty-five years. The geothermal field itself is evaluated as capable of producing the equivalent of 500 megawatts.

(h) Deep-Water Ports:

The main port on the Big Island is Hilo, which is about one hundred and twenty five miles from Keahole Point by sea. The port of Hilo can handle container ships and barges. Kawaihae, which is twenty seven miles north of Keahole Point, is equipped to handle barges. Entrance depth is forty feet and basin depth is thirty five feet. Water depths suggest that this port could be developed.

(i) Transportation:

There is a good highway around the Island. This is used for tanker or trailer trucks to haul fuel and provisions to the resort hotels.

(j) Fresh Provisions:

These are delivered to Kawaihae by barges and are distributed along the highway by trucks.

(k) Natural Hazards:

Being a volcanic area, there is always a possibility of eruptions or earthquakes. The last lava flows in the Keahole Point area were deposited in 1801. Tidal waves or tsunami occur occasionally and there is a warning system established for the protection of life. In deep water, the tidal wave is barely perceptible to ships which encounter it. When it reaches shallow water or a funnel-like coast line, the wave's kinetic energy is converted into classic

2.4.6.2 Environmental Considerations (Continued):

(k) Natural Hazards: (Continued)

tidal waves which would pose a serious threat to shore facilities and personnel.

2.4.6.3 Logistics Support Concept Considerations

Examining the environment justified the concept of platform independence. It also drives certain design alternatives in one direction, and tends to eliminate alternatives which might be feasible in other locales. Basic pricing information has been obtained from reliable sources, and has been adjusted as necessary to suit the specific application under consideration. In nearly every case pricing was adjusted upwards to compensate for shipping requirements to site of use. Due to the desired level of the study, these adjustments are based on experience and judgment.

The energy park has been examined from the point of view of the platforms, and their interfaces with the shore, and the shore facilities and related support. The following paragraphs define the proposed Logistics Support concept.

The Platforms...

There is a primary requirement to move operating and maintenance personnel, heavy and light spare parts, operating fluids (including gases) and provisions to the platforms from shore, and conversely, a need to remove personnel from the platforms together with replaced parts going to overhaul or scrap, and waste products which can not be disposed of aboard. Treatment aboard of waste products is most attractive, because of the lack of soil and water ashore and the close proximity of resort hotels.

It is concluded therefore, that the platforms should be as self-contained as possible.

2.4.6.3 Logistics Support Concept Considerations (Continued)

The Platforms (Continued)

(a) Movement of Heavy Equipment:

Heavy equipment aboard the platforms can be moved by the use of material handling equipment plus the 150 ton gantry crane on the ship and the 200 ton gantry on the semi-submersible. Any lift at sea above these values requires the chartering of heavy lift barges and cranes from Honolulu.

Heavy equipment up to 150 tons can be transferred from a carrier to a 200 foot class supply boat in Hilo. The supply boat has a clear after deck approximately 130 feet long with a width equivalent to the beam. The cranes on the platforms can unload the supply boat.

(b) Movement of Light Equipment and Provisions:

These may be transported from the shore to the platform by the supply boat, the general purpose tug or the crew boats.

(c) Movement of Fluids and Gases:

All the platforms require an initial filling of tanks and cylinders prior to start up. They are subsequently self-sufficient as potable water is concerned but need "topping up" periodically with fuel, lubricants, hydraulic fluid, and gases. In the event of shut downs for maintenance, the platforms require all of the above plus a capability to dispose of waste products such as sewage, oily water, and packaging materials.

Fluids such as diesel oil and potable water can be moved out quickly in the supply boat or by the tug moving general duty ocean-going barges alongside. Three of these barges are proposed.

The movement of gases depends on whether they are required in large bulk quantities such as with anhydrous ammonia or nitrogen, or whether the quantities required can be satisfied by commercial gas cylinders such as with hydrogen or carbon dioxide. So far as it is known, no compressed gases of this type are made or bottled in the State of Hawaii. They are all shipped from the Continental United States.

2.4.6.3 Logistics Support Concept Considerations (Continued)

The Platforms (Continued):

(c) Movement of Fluids and Gases: (Continued)

So far as anhydrous ammonia is concerned, there are commercial ammonia tankers in service but their availability is not known. On initial start up, one of these commercial tankers can fill all systems and all storage tanks; thereafter, a periodic visit to top up all storage can be arranged.

Bulk nitrogen can be shipped in cryogenic type tanks with a boil off to atmosphere. Arrangements for such deliveries to the site can be made. Otherwise ammonia can be dissociated into one volume of nitrogen and three volumes of hydrogen. This is a standard procedure used in heat treatment and hydrogenation of fats. The hydrogen can be burned or utilized in the generator cooling system and the nitrogen used for system purging.

It should be noted that even the oxygen/helium tanks for the divers have to be sent to the mainland for filling.

(d) Movement of Laundry:

It is anticipated that all bedding will be changed on a daily basis. This includes mattress covers, pillow cases, sheets and bedspreads. In addition, there are cooks' mess person uniforms and items such as dish towels. These are picked up by the tug or crew boats, weather permitting, and returned the next day.

Heavy duty commercial washers and dryers are installed on each platform for the use of platform employees to wash out personal items of clothing. This is the usual routine on MSC ships. Arrangements can be made for personnel who do not wish to use such facilities to send their personal laundry ashore for commercial laundering at their own expense.

(e) Movement of Waste Products:

The platforms are self sufficient with respect to the disposal of oily water, sewage sludge, and galley waste. Metal containers are compacted and sent ashore for recycling or loaded on the tug for disposal in an oceanic dump as approved by the Federal and State Governments. These conditions apply so long as the platform is on line.

2.4.6.3 Logistics Support Concept Considerations (Continued)

The Platforms (Continued):

(f) Movement of Personnel - Shift Change (Proposed):

Shift change is tentatively established at every fourteen days for platform personnel. To provide continuity of information on the status of the platform in operation it is desirable to change one-half of the personnel on each platform every seven days. Thus, each person would put in a full fourteen days but half of them are changed every seven days. The criteria used for a change of personnel is that it should be completed within one hour's time from start to finish. This can be accomplished with two, 100 passenger crew boats designed for a maximum speed of 25 knots but achieving an average speed of 15 knots on a daily basis.

(g) Movement of Personnel - Scheduled Passenger Runs (Proposed):

One of the crew boats works for 7 days as a passenger boat, visiting the platforms on a scheduled run during the mornings and afternoons. It carries passengers, mail, machinery, data records and miscellaneous small light cargo. Two trips per platform in the morning and again in the afternoon are advisable to ensure that shore support personnel are not tied up on one platform too long when they may be required elsewhere. At night this boat is on a stand-by status to provide medical evacuation or search and rescue as required. The basic configuration is intended for modification to carry up to ten stretchers.

(h) Movement of Provisions and Laundry:

The other crew boat works for seven days in the movement of provisions, laundry, etc. It is secured at night for preventive maintenance. Every seven days the boats in (g) and (h) exchange functions.

(i) Search and Rescue:

A search and rescue boat, approximately 65 feet long, with a top speed of at least thirty-five knots is a necessity to provide added protection to personnel in watercraft and on the platforms. In addition, there is a requirement for a search and rescue function in connection with helicopter operations. The boat is also intended to intercept inadvertent intrusion into the

2.4.6.3 Logistics Support Concept Considerations (Continued)

The Platforms (Continued):

(i) Search and Rescue (Continued)

energy park area by shipping and, in case of need, to carry up to ten armed peace officers on anti-terrorist or anti-sabotage operations.

It is believed that such a vessel is required from the point of view of insurance rates on personnel in transit or on the platforms, or in connection with the platforms and equipment. In addition, the Head of the Federal Bureau of Investigation has warned recently of the possibility of more widespread terrorist activity world-wide.

Such a boat would work with the U. S. Coast Guard and would supplement its functions in an area of very intensive financial and human investment.

(j) Submersible and Support Barge:

A work boat submersible with a rated depth of 2000 meters is available to carry out current surveys and temperature measurements. It is also equipped to survey moorings and the intake of the cold water pipes, and can carry out simple manipulative tasks such as cutting moorings.

The craft works with a portable modularized support barge from which it is deployed and recovered. The barge is fitted with a decompression chamber and a small diesel generator, and is self propelled by a Harbor Master unit or equivalent.

(k) Diving Tender:

One diving tender, 75 feet long, is available to support wet suit divers, working from the surface down to 300 feet around the platforms. This vessel is only used during diving operations and is equipped with a gas mixer and decompression tank for divers.

(l) Start-Up Generator Barge:

Start-up power for placing each platform in operation is required. It is estimated that at least 10,000 horsepower is required for this purpose. Three

2.4.6.3 Logistics Support Concept Considerations (Continued)

The Platforms (Continued)

(1) Start-up Generator Barge (Continued)

16 cylinder diesel engines, each rated at 8000 HP and driving an appropriately sized generator are required. Consideration has been given to fitting three such generators on each platform (cost approximately \$4.2 per platform). This is not considered to be a cost effective solution.

The other two alternatives are to fit the diesel generators in the supply boat or have a designated start-up barge.

The start-up power barge is the preferred selection because:

- The supply boat may be in Hilo or Honolulu on a pick-up of heavy machinery when such start-up services are required.
- The space below the main deck on the supply boat can be used as a fuel and water reserve for platforms and for stowage of cargo.
- The start-up time has not been determined. If this period is lengthy on initial start-up it is not desirable to tie up the supply boat for such long periods.

The barge carries enough fuel to operate the diesel generators at required output for two full day's operations. Ancillary equipment required to run the diesels, and necessary fluids are carried on the barge.

The power start-up barge is moved from platform to platform by the Service Tug.

(n) Fluids/Supply Barges:

There are two fluid/supply barges. These are built to ABS standards, and are 200 feet long with a flat deck.

2.4.6.3 Logistics Support Concept Considerations (Continued):

Shore Facilities

The natural hazards inherent in the region are considered in the arrangement and construction of the shore facilities and buildings.

(a) The Pier

The pier consists of a concrete slab at the approach end, which is built into the lava flows. Because of the rapid drop off of the seabed and the possibility of tidal waves, the remainder of the pier consists of reinforced concrete pontoons for a total length of 250 feet and is 30 feet wide. The pontoons are secured in position by piles at regular intervals along the length of the pier. The piles are intended to allow the pier to rise and fall with the tide but prevent rotation of the pontoon under high loading from a portable crane. In addition, if observations predict the possibility of a tidal wave, the pontoons will be released from the piles and towed out to sea by the supply boat.

(b) Power Station Control and Distribution

This station is primarily the responsibility of others but logically it performs the Command and Control function for the Energy Park and peripheral area. This study is concerned with the Command and Control of the following:

- Platforms
- Ships
- Helicopters
- Security

2.4.6.3 Logistics Support Concept Considerations (Continued)

Shore Facilities (Continued):

The following functions are an inherent requirement in the Power Station Control and Distribution:

Communications

Platform Position Surveillance

Radar and Marine Traffic Control

Surveillance of Energy Park and Prevention of Intrusions

Security of Afloat and Ashore Facilities

Accident Control Center

(c) Warehouse and Assorted Buildings

The warehouse and other buildings are Butler type prefabricated construction.

The warehouse is 200 feet long, 150 feet wide and 24 feet high. It provides security for both large and small spare items of equipment and is erected on a concrete slab poured to size.

The smaller buildings are erected in a similar manner and incorporate the following functions:

Electrical Shop

HVAC Shop

Building Maintenance

Machine and Pipe Shop

(d) Medical Protection

A clinic is located on the perimeter of the Shore Facility. It is manned 24 hours per day by a paramedic on shift. During the day, a doctor is in attendance and is on call at all times. In the event of an accident, the paramedic on duty proceeds to the scene on a crew boat, surveillance boat, or helicopter (chartered). Depending on the situation,

2.4.6.3 Logistics Support Concept Considerations (Continued)Shore Facilities (Continued):

backup support may be called in from off-duty personnel. Serious casualties can be transported to the Hilo or Honolulu Hospitals from Keahole Airport.

(e) Fire Fighting Protection - Afloat

In addition to regular fire fighting equipment required by Coast Guard Regulations, all mobile craft including the Offshore Supply Boat, the Start-up Generator Barge, the Service Tug, the Surveillance Craft and the Crew Boats incorporate fire fighting capabilities to back up the platforms. These include excess fire pump capacity, fire fighting monitors, foam generating equipment, and oxygen breathing apparatus. Distribution is as follows:

<u>Type of Boat</u>	<u>No.</u>	<u>Excess Fire Pump Capacity</u>	<u>Foam Generating Equipment</u>	<u>Monitors</u>	<u>OBA's</u>
Offshore Supply Boat	1	X	X	X	X
Start-up Generator Barge	1	X	X		X
Service Tug	1	X	X	X	X
Surveillance Craft	1				X
Crew Boats	2	X	X		X

(f) Fire Fighting Protection - Ashore

Standards of Hawaii County and Insurance Underwriters are met.

OTEC Shoreside Facilities - Summary

The OTEC Shoreside Facilities required and their estimated cost are summarized in Table 2.4-5. The proposed shoreside complex is shown in Figure 2.4-4.

TABLE 2.4-5SHORESIDE FACILITIES

Item	Description	Cost, \$M
<u>Boats and Service Craft</u>		
Supply Boat	200 foot Offshore Supply Boat	5.3
Start-Up Generator Barge	3-8000 KW Generators plus fuel	5.3
Fluids/Supply Barges (2)	200 foot flat deck barges	2.0
Service Tug	125 foot/4000 HP	3.6
Surveillance Craft	65 foot/35 Knot	0.8
Crew Boats	100 foot/100 person	2.1
Submersible Support	2000 M Sub with Support Boats	5.2
Barges (3)	General Duty	5.0
SUB-TOTAL		29.3
<u>Ground Transportation</u>		
Cranes	T-60 Ton, 1-5 ton capacity	.30
Fork Lift	50 ton capacity	.28
Fork Lift	5 ton	.05
Miscellaneous	cars, pick-up truck, bus	.17
SUB-TOTAL		0.8
<u>Buildings, Piers, Etc.</u>		
Warehouse (2)	200 x 75 foot, 24 foot high	0.4
Office/Shop Building	120 x 40 foot, 1 story	0.2
Garage, Misc. outbuildings	40 x 30 foot garage, 2 or 3 sheds	0.1
Roads, parking		3.0
Pier	30 x 250, concrete @ \$100/SF	1.0
Fuel storage	Fuel supplied by truck or tractor	0.2
Building equipment	Office equipment, etc.	0.5
Supplies	Initial inventory	0.1
Communications, Data Proc.		0.3
Incinerator		0.1
SUB-TOTAL		5.9
<u>Other Facilities</u>	10% of above	3.6
TOTAL		39.6

1. Office/Shops
2. Power Station
Controls & Distribution
3. Warehouse
4. Garage
5. Fuel Storage
6. Water Distiller
7. Cold Water Inlet
8. Cold Water Pumphouse
9. Hot Water Discharge
10. Clinic
11. Sewage Treatment/Incinerator
12. Gatehouse
13. Parking
14. Pontoon Pier

Approx. Scale 1" = 300.0'

FIGURE 2.4-4
PROPOSED SHORE INTERFACE FACILITIES

2.5 Hull Structure

2.5.1 Structural Design

Currently available Ship structural design methods are employed in the design of the OTEC platform hull. In general, ABS Rules, Reference (3), are used as a guide in the design process. It should be noted that the Rules do not strictly apply in that the proportions of the OTEC platform exceed those values for which the Rules are valid. In general, they apply to vessels having depths not less than one fifteenth of their lengths, and breadths which do not exceed twice the depths to the strength decks. The OTEC hull form meets the depth-length criteria; however, the beam to depth ratio is exceeded with proportions of 300' to 85'. Thus, the Rules are useful as a baseline guide only, since in most cases specifications within the Rules are greatly exceeded.

In addition to the ABS Rules, Navy structural design methods are integrated into the hull structural analysis (Reference (9)). The Navy design manual is used to evaluate local panel loading conditions. The result is a conservative analysis procedure which employs State-Of-the-Art structural design techniques of both the Navy and the commercial shipbuilding industries.

The structural design process begins with establishment of hull girder bending moments. From the bending moments, preliminary hull scantlings (structural members) are determined. The final step in the design procedure involves secondary (hydrostatic) loading analyses. Preliminary hull scantlings are checked as to their ability to resist secondary loads, as are bulkheads and decks.

Special considerations are given to structure unique to the OTEC platform. The cold water plenum and the heat exchanger discharges are examples of structure requiring specialized design.

2.5.2 Longitudinal Strength

For longitudinal strength purposes the ship hull is treated as a beam with non-uniform loading. This non-uniform loading results from weight-buoyancy differences along the hull. Two loading conditions are considered: hogging - where the design wave crest is centered amidships; and sagging - where the design wave trough is centered amidships. The design wave height for the OTEC platform was taken as $1.1\sqrt{L}$ or 27.4 feet. On the basis of the loading curves, shear and bending moment curves were established for hogging and sagging. In addition, a bending moment due to the acceleration of the cold water pipe is superimposed on the wave-induced bending moments. An assumed acceleration of 0.2 g's results in a force of approximately 8200 tons. The CWP hull-girder moment is then determined using the relationship for a concentrated load on a simply-supported beam. The total hull-girder bending moments are shown in Figure 2.5-1.

The required hull midship section modulus is calculated by dividing the bending moment by allowable stress. The allowable design primary stress is 10.36 TSI* as specified in Section 6.3.2a of Reference (3). On the basis of the required section modulus, an approximate plating area is calculated by treating the hull bottom and main deck as flanges of a beam. Preliminary scantlings are then selected by spreading the approximate plating area over the midship section, this involves assigning plating sizes to the shell, decks and bulkheads with an allowance of 25% for longitudinal stiffeners. Several iterations of this process are required to obtain a section which satisfies the primary stress requirements. Once the midship section is established, secondary stresses must be checked. The evaluation of secondary stresses yields the actual sizes of the longitudinal stiffeners. A final check of longitudinal strength is required to account for longitudinal stiffeners as well as any changes in plating sizes incurred by secondary stress requirements.

The hull midship section for the OTEC platform is shown in Figure 2.5-2. The large openings through the bottom complicate the longitudinal strength design. Heavy plating is required to compensate for this loss of area. The final midship primary stress is 10.05 TSI; however, the maximum stress of 10.15 TSI occurs 27 feet from midships.

(*Tons per Square Inch)

TOTAL HULL-GIRDER BENDING MOMENTS

D= 85.0 FT L= 620 FT.

SCALE - MOMENT $1'' = 1.0 \times 10^4$ FT-TONS
 MAX. MOMENT - HOGGING 6.56×10^4 FT-TONS
 MAX. MOMENT - SAGGING 4.42×10^4 FT-TONS
 SCALE - STRESS $1'' = 5.0$ TSI
 MAX. DESIGN PRIMARY 10.36 TSI

FIGURE 2.5-1

OTEC PLATFORM: SHIP HULL GIRDER BENDING MOMENTS

FIGURE 2.5-2
MIDSHIPS SECTION 400 MW_e SHIP

TYPICAL MIDSHIPS SECTION 400 MW SHIP

2.5.3 Structural Configuration

A longitudinal framing structural system is used for OTEC platform hull. This system utilizes deep transverse web frames to support the shell plating. The deep webs are spaced on 18-ft. centers. This large spacing necessitates the placement of intermediate swash bulkheads between the web frames to reduce the size of the longitudinal stiffeners. These members are designed for hydrostatic loading based on a design head of 45 ft. plus $0.68\sqrt{L}$ (61.9 ft). In addition to the deep transverse webs, nine transverse watertight bulkheads are employed. These bulkheads are used to divide the platform into specific spaces, i.e., pump rooms, turbo-generator rooms, and to provide damage control zones.

Longitudinal structure is comprised of the shell plating with its longitudinal stiffeners, the inner bottom and two longitudinally continuous decks. The main deck, 85 feet above the baseline, plays a major role in the longitudinal strength of the ship. The second deck is located approximately at the hull's neutral axis and therefore adds very little to the longitudinal strength; however, the second deck is designed to be watertight. Both decks are supported by transverse girders on 9-ft. centers, in line with the transverse webs and swash bulkheads, and they are also longitudinally stiffened. The inner bottom is located 10 ft. above the baseline, and like the bottom shell, has numerous large openings. For this reason, the inner bottom is constructed of heavy plating.

Six longitudinal bulkheads are also provided. Two bulkheads, each located 133 ft. off center-line, create wing tanks which run the entire length of the platform. These wing tanks provide collision protection as well as storage area where required. For longitudinal strength purposes, a flat running the ship's length is added to each wing tank. Two longitudinal bulkheads are situated at each quarterline (68' off centerline). The final two bulkheads are located three feet off centerline thus forming a cofferdam. The quarterline and cofferdam bulkheads combine to divide the platform into 32 main compartments. In addition, the cofferdam bulkheads and the amidships transverse bulkheads are designed to carry the load of the CWP. This double centerline bulkhead

2.5.3 Structural Configuration (Continued)

arrangement is a consequence of the construction technique postulated for the Ship, and is not driven by any structural requirements. The fabrication process postulated involves building the Ship hull in two longitudinal sections and then joining the two halves at sea. During this period the cofferdam bulkheads serve as functional elements of the Ship's hull.

Ring frames are located around each opening in the bottom shell. This provides a continuous transition for longitudinal members around the openings, thus insuring smooth and even shear flow.

As mentioned previously, plating sizes tend to be rather large. The side shell and decks have an average thickness of about 1.25 inches, with 1.50 inch - thick plating in a few areas. One inch plating is generally used for longitudinal bulkheads. See Appendix C for the Ship hull structural drawings.

2.6 Position Control

The position keeping system must meet the operational requirements imposed by the other systems that comprise the Commercial Plant in addition to insuring the overall safety of the platform and CWP by preventing groundings or a collision with adjacent floating structures. The actual requirements placed on this system are delineated in the TLR, Appendix A, and this section will discuss the trade-offs involved in the selection of a position keeping scheme and its subsequent conceptual development. Since the drag loads are similar for both the ship and Semi-Submersible, the discussion that follows applies to both.

2.6.1 Trade-Off Studies

In determining the optimum system to be used for the Keahole Point site, a number of factors must be considered, the more important of which are:

2.6.1 Trade-Off Studies (Continued):

- Station Keeping Tolerance - The OTEC plant must be maintained in sufficiently deep water to avoid grounding the cold water pipe. This imposes a maximum excursion limit of about 500 feet in the easterly direction. The electrical power transmission line to shore does not limit the horizontal excursion as severely as does the CWP clearance, but it requires yaw is kept to ± 5 degrees which necessitates a tight mooring system.
- Water Depth and Bottom Conditions - Depth of water at the proposed site is 3,150 feet, however, the bottom slopes very steeply from a narrow shelf down to abyssal depths. The seaward anchors are therefore in water as deep as 9,000 feet while the inshore anchors are located in as little as 900 feet. A bottom profile through the site perpendicular to the shore line is shown in Figure 2.6-1.
- Environmental Conditions
 - Wind. Normally the wind west of Hawaii does not exceed 40 knots. This velocity is used for defining normal loads in relation to margins and safety factors for normal operating conditions. Maximum expected wind velocity is 66 knots sustained, with gusts to 95 knots. This velocity is used to define conditions under which minimum survival range safety factors are appropriate. Although the prevailing winds are from the northeast, the design wind velocity could occur from any direction; therefore, the system must be designed to be omnidirectional.
 - Current. Normal current is 1.13 knots. The flow is normally parallel to the shore. Maximum current is 2.18 knots, and since this is generated partly by wind, it will vary with the wind direction. For purposes of this study we have assumed that the wind and current act co-linearly. This results in conservative environmental force estimates; however, this is not necessarily overly conservative since current is generated

FIGURE 2.6-1
BOTTOM PROFILE KEAHOLE POINT

2.6.1 Trade-Off Studies (Continued):

by wind shear over a long period of time and is deflected from the wind direction by Coriolis forces. The wind direction may change abruptly and hence may not be in the same direction as the wind which generated the current. This being the case, it is necessary to admit the possibility of the wind and the current being co-linear. Current velocity diminishes with depth, and the current profile differs from the normal to the maximum condition.

- Waves. Conventional semisubmersibles are relatively transparent to waves. The steady drift forces experienced in moored ships are negligible in the case of Semi-Submersibles. The large size and great draft of the OTEC Semi-Submersibles render wave drift forces even less significant. This is not to say that the structural loads induced by waves are not substantial; however, in view of these facts wave forces have not entered into the mooring calculation but were considered in determining structural loads on the Semi-Submersibles.
- Earthquake, Tsunamis. The Hawaiian Islands are located in an area of intense earthquake activity. An average of over 100 earthquakes, greater than 3 on the Richter scale, are experienced on the island of Hawaii every year. Severe earthquakes, greater than Richter 6 have been experienced 7 times over a recent 34 year period; consequently, we can expect many minor earthquakes and several major ones during the 40 year lifetime of the OTEC plant..

Earthquakes will, of course, have no direct effect on the OTEC Plant but may have drastic effect on the anchors. Pile type anchors could be dislodged by even moderately severe earthquakes. Embedment type anchors could be dislodged but would probably re-establish themselves. Deadweight type anchors would be least affected by earthquakes but they could be buried by mud slides making retrieval difficult or impossible. For this reason

2.6.1 Trade-Off Studies (Continued):

it is advisable particularly when using deadweight anchors to provide a means of changing out the expendable parts of a mooring system without having to retrieve the anchor.

Tsunamis are ultra high velocity low-amplitude waves generated by major earthquakes or volcanic explosions. In deep water, their amplitude is in the order of a foot, and in view of their great length, is scarcely discernable. The destructive effects of the Tsunami occur when it encounters a shore. In expanding the wave energy against the shore, waves reach enormous heights. In the depth of water in which the OTEC plant will be moored Tsunamis will have negligible effect; however, some of the inshore mooring lines will be in depths which will begin to feel their effects, and anchors could be moved or dislodged. From this viewpoint a deadweight anchor is probably most satisfactory since it will still be effective even after being moved or rotated.

Given the above conditions and assuming the maximum current and wind act simultaneously, the combined total drag loadings that the position keeping system must withstand are as follows:

• Ship:	Fore and aft (lbs)	Abeam (lbs)
Normal Conditions	1,268,000	1,500,000
Extreme Conditions	2,260,000	2,639,000
• Semi-Submersible		
Normal Conditions	1,114,000 lbs	
Extreme Conditions	2,103,000 lbs	

Three conceptual systems that can meet these demands have been developed, i.e., a static mooring system, a pure dynamic position keeping system, and a system that combines both of these, and the advantages and disadvantages of each have been critically evaluated to determine the optimum system for the Commercial Plants under consideration.

2.6.1.1 Static Mooring System

- Chain - Chain is highly advantageous for mooring systems in many respects. It is available in long lengths in large sizes and strengths, and forms a springy, energy-absorbing mooring system. Chain corrodes slowly since it consists of massive pieces of metal with a relatively small surface area. In very deep water, however, chain is very inefficient since its ponderous weight produces a large vertical force component at the ship; a component which does not contribute to station-keeping. In fact, a length of 4-inch oil rig quality chain will reach a load equal to its proof strength just reaching bottom in 9300 feet of water with no horizontal component! The deepest mooring lines for the Hawaiian site will extend to about 9000 feet.
- Wire Rope - Wire rope has much greater strength per unit weight than chain. In contrast to chain, a 4 inch 6 x 37 wire rope will reach half its breaking strength when suspended 28,000 feet in sea water. One disadvantage of wire rope is its susceptibility to corrosion. Galvanized wire is expected to have a useful life of about 10 years if conservative design practices are followed. This falls short of the OTEC plant life unless periodic replacement can be effected.
- Chain Wire Combination - Combined wire chain systems can utilize both materials in parts of the system to which they are best adapted. The recommended system consists primarily of wire rope which has the desired weight and strength properties. To minimize corrosion in the upper end of the wire at the air water interface, a short length of chain can be inserted. Chain will also facilitate adjustment and securing of the mooring line, since a simple chain stopper can be used, obviating the need for a winch for each mooring line. In order to permit replacement of the wire rope without the necessity of retrieving the anchor or to resorting to deep diving, the use of a chain pendant on each anchor slightly longer than the depth

2.6.1.1 Static Mooring System (Continued):

of water at the anchor location is proposed. The entire wire segment can thus be examined above water and can be replaced without resorting to underwater operations. In order to facilitate handling the chain and to reduce the stress because of the chain's own weight, two or more sizes of chain may be used in the anchor pendant.

- Synthetics - Synthetic lines have been used successfully to moor small objects such as deep sea oceanographic buoys. There is no long term history, however, of mooring using synthetic materials. A high incidence of severed lines believed to be from shark bites has plagued oceanographic buoy development. Although the larger sized lines suitable for mooring OTEC Plants could not easily be severed by a shark, there is no assurance that even these large lines would be immune to attack. Deterioration resulting from other causes may occur in view of the lack of experience with similar applications, and because of the availability of satisfactory alternatives the use of synthetics has been ruled out.
- Anchors - Anchors may be characterized as one of three types: deadweight, embedment and driven piles. Deadweight anchors provide a large part of the holding force from the pure weight of the anchor and a secondary holding capability from friction on the bottom. Friction may be augmented by drag skirts or some embedment surfaces. This type of anchor has the advantages of being most easily set, not being easily disturbed, and not losing holding power by being dislodged due to earthquakes or storms. Also it is not sensitive to bottom conditions or materials. The latter feature makes it most attractive at the Hawaii site particularly for the anchor lines since the bottom is a confused array of rock and coral outcroppings. Also, this type of anchor is least affected by earthquakes which are rampant in the vicinity of the proposed Hawaiian site.

2.6.1.1 Static Mooring System (Continued)

Embedment anchors combine weight with surface area designed to penetrate the bottom and augment the weight of the anchor with the weight of entrained soil. Successful application of this type of anchor depends upon correct emplacement and correct adjustment of flukes to suit the bottom materials. The latter is difficult in areas such as the slopes off Hawaii because the bottom material changes from rock, to coral, to sand, and in the excessive water depths involved it would be difficult to be certain that the anchor was placed in suitable bottom material and that it was properly embedded in the preload operation. Embedment anchors could be used in the lines farthest offshore; however, owing to the long length of those lines, there is a strong incentive to reduce length giving rise to the possibility of uplift on the anchor. Embedment anchors are also prone to being dislodged by earthquakes.

The third category is driven or drilled and grouted pile. This type of anchor is not considered suitable for the Hawaiian site because:

- (1) it is extremely expensive to install in the great depths of water where the anchors are required, and
- (2) the bottom material and non-uniformity of material render driving or drilling difficult, and
- (3) piles are the most susceptible of all the anchor types considered to failure due to earthquake activity.

For the reasons stated above, deadweight anchors are recommended for the Hawaii site. Those for the deeper depths, i.e., below 3000 feet, will have sufficient chain attached to obviate the possibility of uplift. These anchors must be designed therefore to solely prevent sliding on the ocean bottom. They should be provided with effective skirts to entrain bottom material. Anchor weight must be sufficient

2.6.1.1 Static Mooring System (Continued):

to generate a horizontal holding power of about 800,000 pounds. The anchors will be expected to weigh about 400,000 pounds.

They should be designed to be capable of floating so that they can be towed to the site for convenient deployment.

The offshore anchors have the advantage of the tendency to drag uphill. The inshore anchors on the other hand will be pulled in the down-slope direction although uplift will be largely eliminated due to the large scope chosen. These anchors must be somewhat heavier than those offshore.

- Tensioning and Attachment - After installation, the mooring lines must be correctly tensioned so that the loads will be evenly shared between lines, and to insure that excursions will stay within limits. A chain pendant constituting the upper 200 to 300 feet of each line will make this operation much simpler and less expensive than an all wire system. One wire line winch can service a group of mooring lines. Each line runs from its fairlead through a chain stopper to a second fairlead aligned with the adjusting winch. The lines are shackled to the winch line one at a time. Adjustment in length is made, and the chain pendant is set in the chain stopper. A means of measuring tension is desirable to facilitate correct adjustment of the mooring lines. This can be built into the winch, or the chain stoppers can be mounted on load cells. Either method will enable proper tension to be applied, but the individual load cells on each chain stopper will have the additional advantages of signalling a change in tension during operation indicating incipient overload, enabling the tensioning to be done more quickly.

A wire line winch is required for each group of mooring lines on deck. Two winches, one at the bow and one at the stern, will suffice for the ship. The semisubmersible will require four, one on each column. These winches should have a line

2.6.1.1 Static Mooring System (Continued):

pull capacity of 400,000 lb at slow speed, about 20 fpm, and about 100,000 pounds at about 100 fpm. Reel capacity should be about 1,000 feet of 3½ inch wire rope. Examples of suitable winches are Skagit Model AED-295 or Model DMW-250.

Chain stoppers, wire rope fairleads, and roller chain fairleads are required in accordance with the arrangement. All of these items are of standard manufacture.

- Safety Factors - Under normal conditions the mooring line is not allowed to exceed one-half of the breaking strength of the line. This load will be reached on only rare occasions since the "normal" conditions in the calculations are the upper limit of the normal weather range. The "maximum" conditions would be encountered only during unusual storms. Line loads in these conditions are permitted to range up to two-thirds of the breaking strength. In determining the number and size of lines required to resist a given total force, only the horizontal component of the line tension is used.

The above minimum safety factors apply only to the renewable parts of the mooring system. The lower end of the lines consisting of chain attached to the anchors has a factor of safety 50% greater than the minimum.

- Endurance - The mooring system is designed to hold the OTEC platform on station for the expected 40 year plant life. Parts which can be inspected and replaced above water are designed for 5 to 20 year lives. Those parts which are inaccessible, such as anchors and lower line segments are designed for the full 40 year life.
- Configuration - A suitable arrangement for the mooring system components is shown in Figure 2.6-2 and the arrangement of the overall system is depicted in Figure 2.6-3. It should be noted that a fourteen point moor is utilized to insure

FIGURE 2.6-2
TYPICAL ANCHOR ARRANGEMENT

FIGURE 2.6-3

MOORING ARRANGEMENT AT KEAHOLE POINT

2.6.1.1 Static Mooring System (Continued):

compliance with the design requirements contained in the TLR along with the safety and environmental considerations discussed above.

2.6.1.2 DYNAMIC POSITIONING

- Thrust Requirements - The use of dynamic positioning for providing the stationkeeping has several advantages with respect to a "moored" system. Specifically, the dynamic positioning system provides controlled vessel dynamics, and the system can be automated to maintain the vessel at a given relationship with respect to the required reference. Assuming the extreme conditions of wind, waves, and current, the total lateral environmental force acting on both platforms will be approximately 2,000,000 pounds. Assuming 30 pounds per horsepower thrust conversion, this would require 67,000HP. To make use of the electrical energy available on board the vessel, the thrusters would normally be controlled by electric motors. Assuming an overall conversion efficiency of 90%, a total of 56MW would be required. This total is within the capabilities of the OTEC Power System when it is operating. However, since the vessel position must be maintained irrespective of the operational condition of the Power System, a separate additional power source must be provided.
- Thruster Units - For the total thrust required, the units should be as large as possible to keep the number to a minimum. 2,000 HP rotatable units are readily available and have a history of good reliability. A minimum of 34 such units would be required.

3,000HP rotatable units have been built and could be considered for this application, although not much reliability data is available as of this date. A minimum of 22 such units would be required.

2.6.1.2 Dynamic Positioning (Continued):

The number of units could be reduced by considering larger units that are of the fixed type similar to the main propulsion systems used on ships. For example, 6,000HP units using three 2,000 HP motors could be designed for this purpose.

2.6.1.3 Combined System

While it appears impractical to provide the total station-keeping requirements with a dynamic positioning system, the operation of the mooring line station-keeping system can be enhanced by the use of thrusters. The thrusters used to augment the mooring lines would provide an additional safety factor for the critical environmental situations, would reduce the maximum excursions within the normal station-keeping circle and would provide system damping to a highly under-damped spring-mass system.

Four 3000HP rotatable units would provide about 15% of the maximum required holding force. This would provide a small but important safety factor at the critical environmental limit. Also for the mooring depth under consideration, the lateral restoring force of the lines is relatively small at the "center" of the mooring circle and the 360,000 pounds of controlled thrust can be used to significantly reduce the "wander" of the vessel within the mooring circle. Finally, the system damping can be increased so that "good" system dynamics can be obtained which will significantly reduce the transient loading of the mooring lines.

For this augmentation, a total independent power source of 12,000HP would be required.

2.6.2 Recommendations

Based on the considerations discussed in the previous section along with system costs, the recommended position control system is the fourteen point static moor. A pure dynamic system is considered impractical because of the large number of thruster units required and the power demands of such a system. The parasitic power drain of up to 79MW depending upon the types of thruster chosen is totally unacceptable to the economics of commercial electrical power production, and the addition of fossil-fuelled prime movers is not considered appropriate for a solar energy generating station. The installation of the thrusters also presents arrangements difficulties especially with respect to the semi-submersible configuration; in fact, this aspect alone is almost sufficient to preclude the active system from consideration.

The combined system possesses attributes of both the active and passive systems, but some of the more significant disadvantages also remain. For example, the electric power required for the four 3000HP thusters is in the vicinity of nine megawatts which is still an appreciable drain on the plant output. Also, the installation of the units on the semi-submersible cannot be carried out without some degree of platform reconfiguration even though their number has been reduced drastically. Acquisition cost also directs the decision towards a totally static system since it can be seen from the following figures that the cost of the combined system is approximately 25% higher:

	<u>Acquisition Cost (materials only)</u>
Static mooring system	\$13,338,000
Combined system	\$16,600,000

In conclusion, the static system emerges as the best all around candidate for the Commercial Plants developed in this study. While further design efforts may modify the details or configuration of this system somewhat, the general concept and attendant costs developed herein are considered a reasonable estimate at this point in the design process.

2.7 Platform Service System

2.7.1 Auxiliary Electrical Subsystem

The auxiliary electrical systems supplies power to ship support services such as general lighting, ventilation and hotel facilities including emergency services as specified by regulatory agencies. The ships service and emergency load analysis is summarized in Table 2.7-1. A schematic of the auxiliary and power module distribution schemes is shown as Figure 2.7-1.

During normal operations with module power available, the auxiliary electrical system load is to be included with the parasitic load of one of the power system modules. An automatic bus transfer is provided so that a second module can be utilized as an alternate power source in the event of loss of the primary power source due to module shutdown or disruption of the power interface with the Ship Service/Emergency Switchboard.

In addition, two diesel generators, each rated at 2000 KW are furnished as reserve power sources for the electric system. It is considered that the operation of these units, the ratings of which will permit one unit to be kept in the standby mode, would be limited to the platform power system startup period and to those occasions when both of the module power sources are not available. A standby unit precludes the loss of power to the auxiliary system which would occur should only a single diesel generator be provided and be down for repair or required maintenance at the same time that both module power supplies become unavailable.

A bus unloader is provided as part of the auxiliary electrical system control scheme to monitor diesel generator loading, thus assuring that sufficient generator capacity is available for connected emergency services.

The impact on required power system output of including the auxiliary electric system loads with the parasitic loads during normal plant operation is considered minimal. The total platform parasitic load is summarized in Table 2.7-2, and is equal to 147.6 MW. The impact of the 1.8 MW total platform ships service auxiliary systems loads on this total is only 1%.

FIGURE 2.7-1
400 MW OTEC PLATFORM
AUXILIARY ELECTRICAL
SYSTEM - DISTRIBUTION
SCHEMATIC

TABLE 2.7-1

PLATFORM SHIPS SERVICE/EMERGENCY ELECTRICAL
LOAD ANALYSIS

<u>ESTIMATED LOAD (KW)</u>			
<u>EQUIPMENT</u>	<u>CONNECTED</u>	<u>SHIPS SERVICE BUS</u>	<u>EMERGENCY BUS</u>
Machinery Auxiliaries	770	120	260
Commissary	240	100	--
Workshops	30	5	--
Electronics, Alarms & Controls	80	--	70
Air Conditioning	110	100	--
Ventilation	720	650	--
Lighting	400	20	50
Deck Machinery	<u>2220</u>	<u>--</u>	<u>--</u>
Totals	4560	995	380
with approximately 30% margin		<u>1300</u>	<u>500</u>

Grand Total Ships Service/Emergency Load with
 30% margin is: 1800 KW

TABLE 2.7-2PLATFORM PARASITIC POWERSUMMARY

<u>Equipment</u>	<u>Total Operating Electric Load Per Module (MW)</u>	
<u>Major Power System Support Loads</u>		
Cold Water (CW) Pump Motor	7.6	} 13.8 KV
Warm Water (WW) Pump Motor	5.6	
NH ₃ Feed Pumps	1.4	
NH ₃ Reflux Pumps	.4	} 480V
CW Chlorine Generators	1.35	
WW Chlorine Generators	.7	
Power Conditioning Transformer Losses	1.0	
Subtotal	<u>18.05</u>	Transmission cable losses and internal cable losses not included

Minor Power System Support Loads

CW Pump Motor Cooling Pump	.0068	} 480V
WW Pump Motor Cooling Pump	.0049	
Power Conditioning Transformer Cooling Pumps	.0240	
Generator Cooling Pump	.0197	
Turbine-Generator LO Pumps	.0236	
Turbine-Generator LO Cooling Pumps	.0236	
Auxiliary Transformer Cooling Pumps	.0012	
CW Chlorine Generator Circ Pumps	.0260	
WW Chlorine Generator Circ Pumps	.0176	
AMERTAP	--	
Cathodic Protection System	--	Negligible
Auxiliary Transformer Losses	.0264	Negligible
Subtotal	.174 MW	
Total	18.22 MW/Module	
x 8	= 145.8 MW/Platform	
+ 1.8 MW Ships Service Load =	147.6 MW	
	Total Platform Parasitic Load	

2.7.1 Auxiliary Electrical Subsystem (Continued)

The reason for the large (147.6 MW) parasitic power load is the high head losses (presumably due to 1 in. tubes) in the evaporator and condenser, which greatly increase the motor horsepower required for the warm and cold water pumps. Evaporator head losses constitute approximately 79% of all warm water system head losses, and condenser head losses constitute approximately 70% of all cold water system head losses. Total platform parasitic power requirements could be reduced by approximately 46 MW to 101.6 MW, if 2 inch heat exchanger tubes were utilized. A trade-off study of the cost effectiveness of various heat exchanger tube sizes is in order.

A detailed description of the physical characteristics of the major pieces of equipment in the Ships service electric system is given in WBS Section 1.4.40, of the List of Machinery in Appendix D.

Platform start-up is accomplished by feeding power into the first module to be started from the start-up power connection as indicated on Figure 2.7-1. Start-up power would be provided by start-up generators located on a barge as described in Section 2.4.6. Trade-off studies indicate it would be more cost effective to provide one set of start-up generators on a barge or ship to service all platforms, then to have a full set of start-up generators on each platform.

2.7.2 Fluid and Gas & Environmental Control Subsystems

The fluid and gas and environmental control subsystems are designed to provide all required auxiliary services to the platform and the Power System. Equipment characteristics are described in the Ship List of Machinery, Appendix D, and brief system descriptions are provided below.

2.7.2.1 Fire Detection and Extinguishing System

The Fire Detection System consists of smoke detectors in all machinery, living, storage and control spaces, infrared radiation (IR) detectors in all machinery and control spaces (and the galley), ammonia vapor detectors in all spaces containing ammonia piping and equipment, and hydrogen detectors (in addition to the generator enclosure hydrogen concentration meter provided with the generator control panel) in all turbine-generator spaces. The detectors sound alarms in the space served and in the Central Control Room.

2.7.2.1 Fire Detection and Extinguishing System (Continued)

The Fire Extinguishing System consists of a centralized fixed CO₂ flooding system serving the cold and warm water pump motor rooms, turbine-generator rooms, and ships service diesel generator (SSDG) rooms. CO₂ flooding of a space may be activated in or near the space served and from the Central Control Room. The Central CO₂ bank consists of 108 100 lb. CO₂ cylinders connected to mains and distribution branches leading to the distribution piping and nozzles serving each space. All CO₂ piping is copper conforming to ASTM B42. An FP-1000 foam proportioner is provided near the helicopter landing area to provide a foam fire fighting capability (monitors and/or deck nozzles), with seawater being provided by the firemain through a 4 in. seawater supply line. All foam piping is copper-nickel conforming to ASTM B466.

Portable CO₂ and dry chemical fire extinguishers are provided throughout the platform as required by ABS and USCG requirements.

Additional firefighting capability is provided by the firemain, which is described in a separate paragraph below (Section 2.7.2.8).

2.7.2.2 Ventilation Systems

Machinery Space Ventilation Systems - The machinery space ventilation system consists of a suite of centrifugal and vaneaxial exhaust and supply fans (as required) with associated ductwork to provide the necessary air flow to the spaces served. Air quantities for all compartments containing ammonia equipment comply with USCG requirements for "Classified" compartments and a negative pressure is maintained in all ammonia compartments in compliance with USCG requirements. Consideration was given to the removal of ammonia vapor due to large ammonia leaks, to the heat dissipation of equipment in the compartment, and to the required rate of air change, in the design of each compartment's ventilation system.

Deckhouse Ventilation System - All areas of the deckhouse not air conditioned (see Air Conditioning System Description, Section 2.7.2.3) are provided with a suitable ventilation system consisting of a set of centrifugal supply and exhaust fans and associated ductwork.

2.7.2.3 Air Conditioning System

The air conditioning system consists of two 40 ton reciprocating air conditioning plants with compressor and motor, condenser, chiller, and associated seawater and chilled water circulating pumps. A chilled water piping system is provided to circulate chilled water between the chillers and the 4-7500 CFM air conditioning, recirculation air handling units. The chilled water system is segregated into two individual zones, each containing a complete loop including a chilled water circulating pump and an air conditioning plant. The system consists of 3 in. supply and return mains extending port and starboard within the deckhouse and cross connected into the applicable zones. The chilled water piping is copper conforming to ASTM B88. The air conditioning plants are sized to provide sufficient air conditioning capacity (with margin) for all air conditioned areas, including the living accommodations, offices, control rooms, medical spaces, labs (all at 75°F DB, 50% RH), mess room(s), galley, recreation room(s) and shops (all at 80°F DB, 55% RH). In addition to the 4 7500 CFM air handling units, 8-1400 CFM replenishment fans are provided for air replenishment.

2.7.2.4 Ships Stores Refrigeration System

The ships stores refrigeration systems consists of two 1-ton reciprocating refrigeration plants serving a 150 ft³ chill box (33°F) and 150 ft³ freeze box (0°F). The chill and freeze boxes are sized to provide storage for a 60 day supply of chilled and frozen stores for the platform's crew. The 1-ton capacity refrigeration plants are sized so that a single plant can handle the full refrigeration load (chill and freeze box), except during pull down, when both plants would be on the line. The chill and freeze boxes and the two refrigeration plants are located in the deckhouse adjacent to the galley. Cooling water for the refrigeration plants is taken from the firemain.

2.7.2.5 Plumbing Drains, Deck Drains and Scuppers

Plumbing drainage piping is provided as required to handle all soil drainage (waterclosets and urinals) and gray water drainage (sinks, lavatories, showers, laundries, certain deck drains, etc.). The plumbing drainage piping is led from the applicable fixture to a collecting tank for treatment by a Type II MSD (Marine Sanitation Device) or an incinerator in accordance with USCG requirements.

Sufficient deck drains and scuppers are provided to keep all weather deck areas and compartments free from standing water. Double check valves or screwdown automatic non-return valves are provided as required by USCG and ABS requirements.

2.7.2.6 Vents, Overflows, and Sounding Tubes

Vents, overflows, and sounding tubes are provided for all tanks in accordance with ABS requirements. Sounding tubes (1 1/2 in.) are provided for all ballast tanks, potable water storage tanks, fuel oil storage tanks, lube oil storage tanks, and voids. Vents are provided for the potable water tanks (1 1/2 in.), ballast tanks (2 in.), and fuel and lube oil storage tanks (2 1/2 in.). Overflows are provided for the potable water storage tanks (2 1/2 in.), lube oil storage tanks (4 in.), and the ballast and fuel oil storage tanks (6 in.). Vents and overflows for the ballast, fuel and lube oil storage tanks extend above the waterline and overboard and are provided with non-return valves. Vents and overflows for the potable water tanks extend above the main deck.

2.7.2.7 Emergency Drainage and Ballast System

The emergency drainage and ballast system consists of 4-1500 gpm @ 50 psig emergency drainage and ballast pumps connected via risers to 8 inch port and starboard drain and ballast mains extending the length of the platform and inboard of 20% of the beam. Connections are provided to dewater all machinery spaces and to ballast and deballast all ballast tanks. Provision is made to utilize the pumps to pump sea water into the machinery spaces to dilute large ammonia spills. A description of the bilge stripping system which would routinely be used to pump bilges is provided below in a separate paragraph (Section 2.7.2.12, Pollution Control Systems).

2.7.2.8 Firemain and Flushing System

The firemain and flushing system supplies seawater at sufficient pressure to the firemain for fire-fighting and washdown purposes and to auxiliary systems which take their seawater supply from the firemain. The latter includes flushing water for the urinals and water closets and cooling water for the L.P. and H.P. air compressors, refrigeration units, and emergency cooling for the air conditioning plants. The firemain consists of a single horizontal loop piping system employing four fire pumps, each rated at 200 gpm and 125 psig. The system includes 4" port and starboard mains which are cross-connected to form two independent zones employing two fire pumps each. The fire and flushing system piping is copper-nickel conforming to ASTM B466.

2.7.2.9 Freshwater Systems

Distilling Water System - The function of this system is to supply the potable water storage tanks with fresh water via distillate transfer pumps and a distiller brominator..

Feedwater is supplied to two 30 KW distilling plants by two distiller feed pumps rated at 5 gpm and 50 psig. Each electric distilling plant is capable of desalinating incoming seawater at a rate of 60 gallons/man-day plus that required for helo washdown. Two 4800 gpd units are installed since this is the commercially available size that comes closest to meeting these demands. During normal operations, one plant will be down while the other plant will supply the required distillate.

Distillate from the distilling plant discharges into a 150 gallon distillate collecting tank where the contents are transferred to the potable water storage tanks by a distillate transfer pump. A second pump is provided in parallel as emergency backup for the primary pump. The pumps, rated at 10 gpm and 40 psig, transfer distillate from the collecting tanks through a distiller brominator, with a 4000 gpd capacity, and discharge the treated distillate into the potable water storage tanks.

Piping from the distilling plants to the distillate collecting tanks is ½" copper tubing and the transfer pump discharge piping will be ¾" copper tubing. All piping conforms to ASTM B88.

2.7.2.9 Freshwater Systems (Continued)

Potable Water Systems - The function of the potable water system is to provide a continuous supply of fresh water from the storage tanks to the hot potable water system and to cold potable water outlets throughout the plant. The system receives potable water from a supply ship or from the distilling plants for filling the storage tanks. Fresh water is supplied for the hotel services, laundry, and expansion tanks in the closed loop chilled water cooling systems.

The two potable water storage tanks have a combined capacity of 7200 gallons (based on 120 gal. per accommodation). Potable water is supplied to the system by two horizontal, centrifugal potable water pumps rated at 20 gpm and 60 psig. The pumps discharge through risers to a 2" potable water main forming a partial loop in the deckhouse. A connection off the combined pump discharge supplies a 200 gallon hot potable water accumulator tank. A bromine disinfection system employing a recirculating bromine feeder unit transfers water from the potable water storage tanks through the brominator for proportioning treatment and returns the brominated water back to the tanks. The brominator is sized to provide an adequate bromine residual after a 60 minute contact time in the tanks based on a 7200 gallon capacity.

The 200 gallon hot water tank is electrically heated using 35000 BTU/hr. elements for a 50-gal/hr recovery rate. Incoming cold potable water forces the hot water out through a riser to a 1½" hot potable water main. The main forms a complete loop extending throughout the deckhouse. Hot water is continuously recirculated by a centrifugal pump rated at 5 gpm and 15 psig. All potable water piping is copper conforming to ASTM B88.

2.7.2.10 Fuel Oil Systems

Fuel Oil Fill, Transfer & Stripping Systems

The functions of the fuel oil fill, transfer and stripping systems are to receive fuel in bulk from a supply ship, to discharge fuel from the storage tanks via the fueling-at-sea connections, transfer fuel from the storage tanks to the ships service diesel generator and small boat service tanks, and to transfer stripped fuel from the fuel tanks to the contaminated oil settling tanks.

2.7.2.10 Fuel Oil Fill, Transfer & Stripping Systems (Continued)

Fuel is transferred from the 250,000 gal (total capacity) fuel storage tanks to the service tanks by a two speed rotary type fuel pump rated at 50/25 gpm and 50 psig. A 50 gpm filter/separator is installed between the transfer pump and the service tank.

The fuel transfer pump, operating at the lower speed, strips the fuel storage and service tanks via a separate 1½" suction line and discharges the residual fuel into the contaminated oil settling tanks.

The fuel storage tanks are capable of receiving fuel from a supply ship via the port and starboard fueling stations on the main deck at a rate of 500 gpm through a 6" supply pipe. In addition, the transfer pump is capable of delivering fuel to the deck fueling system via a 2" pipe. All fuel transfer and stripping piping conforms to ASTM B106 for steel pipe.

Fuel Oil Service Systems

Separate fuel oil service systems are provided for helo fueling, small boat fueling, and for the ships service diesel generators. The helo fuel service system consists of a 900 gal helo aviation fuel service tank with a fuel service pump, fuel filter/separator, and piping and fueling fittings located adjacent to the helo landing area. The small boat fuel service system consists of a fuel oil service pump with associated piping and fuel oil fillings. The ships service diesel generator fuel oil service system is described in Section 2.7.1.

2.7.2.11 Compressed Air System

The compressed air system consists of two totally independent systems, namely the low pressure air systems for normal ship services and a high pressure air system for starting the ships service diesel generators.

The low pressure compressed air system consists of two cross-connected low-pressure compressors rated at 100 SCFM and 125 psig, servicing a 1 1/2" split main running within the deckhouse with ½" branches extending throughout the vicinity of the power system modules.

2.7.2.11 Compressed Air System (Continued)

The low pressure air system provides compressed air for control air, charging compression tanks, cleaning electrical machinery, standby sewage tank aeration, pneumatic tools, personnel support services, and piping blow-out requirements. Low pressure air piping is copper material conforming to ASTM B42.

Two high pressure air compressors rated for 15 CFM at 600 psig are provided for charging 2-55 ft³ air flasks. The flasks have been sized to provide for six consecutive starts of the ships service diesel generators. The compressor capacity is based on a 45 minute charging time for increasing the pressure from 150 psig to 600 psig. The high pressure air piping is copper conforming to ASTM B42.

2.7.2.12 Pollution Control System

Oily Waste System

The oily waste system consists of 2 oily waste holding tanks, 16 bilge stripping pumps, 2 oil water separators, 2 waste oil tanks, 2 oily waste transfer pumps, and 2 contaminated oil settling tanks. The 16-100 GPM @ 60 psig bilge stripping pumps (rotary sliding vane) are used to strip oily bilge water from the machinery spaces and transfer this waste to the 2 oily waste holding tanks. This oily waste is then processed by the oil water separators, with clean water being pumped overboard and concentrated oil being transferred to the waste oil tanks. The waste oil is then held for pick-up by the service ship, or used in the platforms incinerator, with the oily waste transfer pumps being used to transfer the oil. The contaminated oil settling tanks are used to settle out contaminated fuel from the fuel oil transfer and service systems. After the fuel has settled the water may be stripped overboard and the fuel returned to the fuel oil storage tanks.

Sewage Treatment System

The sewage treatment system consists of a Type II Marine Sanitation Device (MSD) and two sewage transfer pumps which will handle all soil waste and gray water drains. The soil waste may also be transferred to the platform's incinerator for processing.

2.7.2.12 Pollution Control System (Continued)

Solid & Chemical Waste System

The solid and chemical waste system consists of 2 garbage grinders in the scullery, 1 trash compactor, and 1 trash, garbage, and sewage (if required) incinerator.

2.7.2.13 Auxiliary Seawater Systems (Power System Support)

Various auxiliary seawater systems are provided throughout the platform to provide circulating and cooling seawater to the power and transmission systems. The systems are as follows:

	<u>WBS Section</u>
1) Cold Water Pump Motor Cooling System	1.7.1
2) Warm Water Pump Motor Cooling System	1.7.2
3) Power System Auxiliary Support Transformer Cooling System	3.8
4) Power Generator Cooling System	3.10
5) Power Turbine-Generator Set Lube Oil Cooling System	3.10
6) Chlorine Generator Circulating System	3.11
7) Power Conditioning Transformer Cooling System	4.3

Each system consists of dedicated pumps and piping. The principal characteristics of each system's major equipment is provided in the applicable WBS section of the List of Machinery in Appendix D. A possible alternative means of providing seawater would be to utilize a large, central seawater system providing seawater to all areas requiring seawater service, instead of providing individual systems to serve each load. This should be studied in a later stage of design.

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2.8 Outfit and Furnishings

2.8.1 Personnel Support

The area of personnel support is comprised of those systems and sub-systems that provide for the living, messing, recreation, and welfare of the embarked personnel. Section 2.4.3 Manning, describes the manning levels for the various categories of personnel, and the TLR presents the criteria used to develop the accommodations.

Habitability - In general, the habitability standards on the OTEC Plants parallel those of the offshore industry and current maritime practice with approximately 100 ft² of living area per man. The type of accommodations for the different categories of personnel are shown in Table 2.8-1.

TABLE 2.8-1
ACCOMMODATIONS SUMMARY

Rating	No.	Type Accommodations			Accommodations Area (ft ²)	
		Private	Semi-Private	Bunkroom	Per Man	Total
Master (AB)	1	X			140	140
Deckhand (AB)	2*		X		90	180
Deckhand (Seaman)	2*		X		90	180
Deck Subtotal	5	1	2		100	500
Plant Superintendent	1	X			200	200
Shift Supervisors	3	X			160	480
Control Room	10*		X		100	1000
Roving Watch	6		X		100	600
Operating Subtotal	20	2	8		114	2280

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TABLE 2.8-1 (Continued)
ACCOMMODATIONS SUMMARY

Rating	No.				Accommodations Area (ft ²)	
		Private	Semi-Private	Bunkroom	Per Man	Total
Mechanical Foreman	1	X			160	160
Mechanics	4		X		100	400
Electrical Foreman	1	X			160	160
Electricians	4		X		100	400
Instrumentation Foreman	1	X			160	160
Instrumentation Specialists	4		X		100	400
Cook	2		X		90	180
Janitor Messmen	6			X	80	480
Clerical	2		X		100	200
Maintenance Subtotal	25	3	8	1	102	2540
Spare Cabins	2	X			140	280
For Transient	2		X		90	180
Personnel	4			X	80	320
Subtotal	10	2	1	1	98	780
Total	60	8	19	2	103	6100

* Includes one spare bunk

2.8.1 Personnel Support (Continued):

Habitability (Continued)

Supervisory personnel are assigned individual staterooms while all others are berthed in double rooms. All spaces have private sanitary facilities containing a water closet, wash basin, and shower, and have individual climate controls installed. Spare staterooms are provided for transient personnel such as VIPs, observers, test personnel, manufacturers' representatives, and special maintenance teams.

Messing Facilities - The galley and messing facilities are similar to those in use in the offshore industry today and are designed around cafeteria service techniques. The messing facility is divided into supervisory and non-supervisory messes, and each is sized to accommodate one-half of the appropriate embarked personnel at a seating.

Lounges are situated adjacent to each of the messes for individual activities such as reading, and a general recreation room is provided for the entire crew to accommodate group activities. In addition an exercise room is included along with such amenities as a sauna and swimming pool (optional).

Medical Facilities - A limited medical facility is provided on the platform itself, the philosophy being that major medical problems will be handled by evacuation to a shore facility. A small dispensary, including an examination room and isolation ward with accommodations for two people makes up this facility and is considered sufficient to deal with minor illnesses and injuries.

Laundry - Commercial grade self-service washing machines are provided so that the crew may do their own personal laundry. Bulk items such as linen will be taken ashore on a periodic basis for laundering.

All of the personnel support spaces are located above the main deck in the deckhouse with the exception of the swimming pool which is situated in the open on the main deck. Maximum use is made of natural light which is admitted to the interior by relatively large windows in an attempt to enhance the impression of spaciousness.

2.8.2 Lifesaving

In accordance with U. S. Coast Guard regulations, Reference (10) and American Bureau of Shipping rules applicable to offshore drilling units. Reference (11), lifesaving equipment consisting of life boats, life rafts, a rescue boat, life jackets, and life buoys are carried on the platform. Again, current offshore practice is used as a guideline in the choice of equipment which consists of the following:

- Life boats - Two twenty-eight man survival capsules such as those made by Whittaker. The capsules are enclosed and are capable of making five knots on their installed diesel engines. They are mounted port and starboard on the main deck in the vicinity of the deckhouse and can be lowered into the water by davits.
- Life rafts - Two ten-man life rafts in GRP storage capsules are mounted on the main deck in automatic release mounts.
- Rescue boat - An eighteen to twenty-foot diesel powered rescue boat is mounted in davits on the starboard side in the wing wall near the accommodation port.
- Life jackets and life buoys - These items are distributed throughout living, working, and exterior areas of the platform.

2.8.3 Platform Support

The area of platform support is comprised of the shops, laboratories and test facilities, spare parts stowage, and office space required to operate the Plant.

- Shops - Mechanical, electrical, and instrument shops are provided to support a limited amount of repair work by the embarked crew and the major maintenance performed by the rotating maintenance teams. The instrument shop has the necessary equipment for gage and meter calibration.
- Test facilities - Space for permanent test facilities is allotted but not designated in any detail since the on-board testing requirements have not yet been defined. It is assumed that as a minimum, chemical

2.8.3 Platform Support (Continued):

- Test Facilities (Continued)

analyses will be run on the Power System working fluid, but in any case adequate space exists on the platform for any anticipated needs in this area.

- Offices - A small central office complex is contained in the deckhouse.
- Spare parts stowage - Storage areas are provided for high use items and a limited number of other repair parts.

2.8.4 Material Handling

Material handling may be divided into air to sea, sea to sea, and intra-platform, and facilities are installed to handle all three cases.

- Air to sea - A helicopter landing area is designated on the after portion of the main deck, and it is designed to accommodate helicopters of up to 50,000 pounds operating weight such as the Sikorsky CH-53E. A control facility with electronic and visual communications equipment is fitted atop the deck house and can handle day or night operations.
- Sea to sea - Mooring stations are provided around the periphery of the hull near the water line to allow supply boats, barges, etc., to tie up alongside at almost any position. In addition, personnel accesses are located both port and starboard in the vicinity of the deck house with accommodation ladders leading to access openings in the side shell approximately twenty feet above the water line.

Material is brought aboard via the two electric pedestal cranes, each rated at a thirty ton over-the-side capacity. The cranes are similar to the Bucyrus-Erie MK 35 marine cranes, are mounted port and starboard, and will handle the bulk of the cargo handling. Heavy lifts will be handled by an overhead gantry crane traveling on rails running the length of the ship. These rails overhang the stern and enable lifts of up to 150 tons to be made from vessels lying alongside.

- Intra-platform - The primary item of concern with respect to this area is the movement of major pieces of machinery for either repair or replacement. More specifically the ability to service, or remove if

2.8.4 Material Handling (Continued):

- Intra-platform (Continued)

necessary, the turbines and generators is an essential requirement imposed by DOE, and the 150 ton gantry meets these needs. The turbines, generators, and pump motors, may be removed from their locations inside the plant via the hard patches shown in the arrangements of Appendix B using the gantry crane. In the case of the turbines and generators, removal will be in sections because of their extreme weight in the assembled condition.

In addition to the main gantry crane, overhead rail cranes are mounted beneath the main deck in all of the machinery spaces. These units are designed to handle routine maintenance tasks and equipment disassembly within the hull envelope and can position components beneath hard patches in preparation for lift out via the gantry crane. Minor equipment movements can be made with hand carts or fork lift trucks, and an elevator is provided in each quadrant of the hull for vertical personnel and equipment transfer.

2.8.5 Navigation and Communication

The navigation and communications installation uses standard practices for large floating platforms as a guide and is further configured to meet the unique needs of the OTEC Commercial Plant.

- Navigation - Since the OTEC Plant is considered a moored platform the requirements for navigational aids are not as stringent as those for self-propelled platforms; however, the proximity of the platform to water shallow enough to ground the CWP, and the high value of the Plant warrant systems above those normally installed on stationary platforms. All navigation and communications equipment is installed in the bridge/helo control area.

For accurate position keeping a system similar to the Raydist precision radio location systems presently available is installed. This type of unit has a positional accuracy in the vicinity of ten feet and requires a minimum of shipboard and shore based equipment. Accuracy of this magnitude could also prove valuable should the position keeping

2.8.5 Navigation and Communication (Continued):

• Navigation (Continued)

requirements dictated by the riser cable become more stringent.

In addition to the electronic position keeping equipment the Plant is outfitted with a gyrocompass and magnetic compass to provide the capability of taking visual position bearings as a backup.

It is considered prudent to provide a surface radar with a collision warning system. This would be similar to the Decca units presently available and would provide a warning in the event any ship-ping traffic presented any danger of coming too close to the platform thus giving the Plant crew a chance to either contact the vessel in question or prepare for collision. This radar would also provide a limited tracking capability with respect to low-flying aircraft such as helicopters.

• Communications - A communications suit that provides for a full range of internal and external capabilities is installed.

The internal system utilizes a dial telephone system backed up by sound powered telephones in critical locations. Basically the dial system connects all living and operating spaces including staterooms, communal living spaces, control spaces, and machinery rooms while the sound-powered units are located in the pilot house/helo control station, machinery control rooms, and the machinery spaces. In addition a public address system that reaches all accessible areas is installed.

The external system follows standard offshore practice and is made up of the following typical units:

- SSB radio telephone system with 100% redundant equipment
- VHF (AM & FM) radio telephone system
- Ship-helicopter communications
- Radio telegraph system with battery operation back-up
- Lifeboat radios
- Portable VHF (FM) radios for rescue boat and ship work crew communication

2.8.6 Biofouling and Corrosion Control

The long operating life of the OTEC Plants (40 years) coupled with the inability to drydock them for routine maintenance places severe demands on the corrosion and biofouling control systems used. In general the approach taken to combat these problems is based on two methods, i.e., one active and the other passive, and is analogous to that postulated for floating offshore nuclear power plants. The following discussion applies only to the external portions of the Plant; biofouling and corrosion control for the Seawater and Power Systems are discussed in Sections 2.9 and 2.11, respectively.

2.8.6.1 Biofouling

The primary detrimental effect of biofouling is the increased platform drag that results from extensive organism growth. This places additional demands on the position keeping system; however, the present design of the fourteen point mooring system has sufficient margin to accommodate additional loads of this order of magnitude. In the event it becomes necessary to remove some of this accumulated growth, hull cleaning systems similar to those in use today for cleaning the underwater portions of ship hulls while afloat could be utilized.

2.8.6.2 Corrosion Control

As mentioned above two approaches are considered for the protection of surfaces exposed to the environment, and they are discussed below:

- Active - An impressed current system is used to inhibit corrosion on all underwater surfaces of the Plant including pump housings, heat exchangers, discharge pipes, the hull proper, and the CWP. With the proper placement of anodes over the submerged portions of the Plant, the system should be able to keep corrosion levels within predicted acceptable values over the life of the Plant. The major potential problem with this system concerns the maintenance of the electrodes along the CWP; however, divers or a work boat submersible should be able to perform repair or replacement work in the event it is necessary. Studies to date indicate that external biofouling will have

2.8.6.2 Corrosion Control (Continued):

- Active (Continued)

no effect on the ability of a cathodic protection system to function effectively.

- Passive - In a sense the cathodic protection system is augmented by the application of corrosion allowances in the structure of the submerged components of the Plant. These allowances are considered a contingency approach and provide for a margin in the design and operation of the active system. Coatings are not used on the submerged surfaces because anticipated coating life does not meet the forty-year operating requirement for the platform, and the active system is considered sufficient for complete protection.

Coatings are used as the only method of corrosion control in the "splash zone" and on the above water portions of the platform. The splash zone is defined as the area in the vicinity of the water line that is alternately exposed to air and seawater. It is anticipated that advanced epoxy coatings should last the life of the Plant with periodic touch-up work in these areas.

2.9 Seawater System

2.9.1 Warm Water System

2.9.1.1 General System Description

The warm water system for each 50 MW module consists of a warm water pump suspended below the platform (refer to the arrangements in Appendix B), taking suction from a truncated conical inlet screen and discharging through each module's evaporator and warm water discharge pipe back into the ocean slightly above or below the bottom of the mixed layer depending on the season. A hydraulic analysis of the warm water system was conducted to determine the system head loss at the design flow rate of 5000 CFS (2.25×10^6 gpm), so that head requirements of the warm water pump could be identified. Head losses evaluated included those in the screen, entrance, pump, piping (including friction, transition, and turning losses), heat exchanger, discharge pipe (including transition), exit, and the density effect loss. A summary of these losses is presented below.

Heat Exchanger Losses	-	8.6 ft.
All other Losses	-	<u>2.3 ft.</u>
Total Head Loss		10.9 ft.

It should be noted that the heat exchanger losses account for 79% of all warm water system head losses. The high heat exchanger (evaporator) head losses are evidently due to the small tube size (1 in.) utilized. Heat exchanger head loss could be reduced to 4.1 ft. by the use of 2 in. tubes. As is discussed in greater detail in Section 2.7.1, a trade-off study of heat exchanger tube size is in order.

2.9.1.2 Inlet Configuration Description

The inlet configuration for each warm water system consists of a truncated conical inlet screen fastened directly below the warm water pump suction bell-mouth. The truncated conical shape was chosen for its relative ease of fabrication, structural strength, and uniform inlet velocity across the screen surface. The screen frame is fabricated from carbon steel (protected by a multi-coat application

2.9.1.2 Inlet Configuration Description (Continued)

of coal tar epoxy, and the platform cathodic protection system) or alternatively, by CuNi cladding. The screen surface itself is made from 90-10 CuNi (1.5 Fe, CA 706). The screen is fastened to the steel frame with inert fasteners and stand-offs to minimize galvanic corrosion problems and to maintain the anti-fouling properties of the CuNi screen. The 90-10 CuNi alloy was chosen for its excellent corrosion and anti-fouling properties. The screen surface is a profile type screen configuration of the type manufactured by the Johnson Division of UOP, Inc., and described in Reference(12). The profile type screen was chosen for its postulated superior performance characteristics in regard to clogging, the impingement and entrainment of sea life, and because it is probably the most costly static screening alternative, and therefore represents a conservative upper limit on cost for static screening configurations. The overall size of the conical screen is 56 ft. in diameter at the base of the cone with a height of 23 ft. These dimensions produce a screen area of approximately 3450 ft.² based on the design criteria of limiting screen approach velocities to 1.5 fps at a warm water system flow rate of 5000 cfs to prevent the trapping of fish and other sea life against the screen. A slot size of .375 inches was chosen for the profile screen to prevent the entry into the system of objects or sea life large enough to clog the evaporator tubes (the smallest heat exchanger tube size anticipated is 1 inch I.D.).

Screen cleaning is not anticipated to present any problems. The CuNi screen fabric has excellent anti-fouling properties, so frequent cleaning will not be required. The warm water pump motors and thrust bearings are designed so that the warm water pump can be run in the reverse direction (axial flow propeller type pumps can be reversed with very little loss in efficiency), to back flush the screens as required. Should severe fouling problems be encountered, the warm water screen can be mechanically cleaned (while backflushing the system) by divers, but this would only be required once a year (at the most), even under the most severe fouling conditions. Screens might have to be installed on the discharge pipe (depending on the length of time required for backflushing) to

2.9.1.2 Inlet Configuration Description (Continued):

prevent the ingress of foreign objects or animal life during backflushing. This will be investigated during later design stages.

Alternative Configurations - Several different alternative inlet configurations were considered during the course of the warm water system conceptual design studies. One alternative considered was to utilize a coarse grating (say a 1 foot to 2 foot grid) at the warm water pump suction bellmouth and provide a fine screen or strainer plate between the warm water pump and evaporator to protect the evaporator from clogging. The advantages of this configuration are that there is very little possibility that the coarse grating will become clogged or fouled and there are no support problems with a simple grating as there are with a large screen structure. Additionally, the fine screen or strainer would be moved to a location where it could be more easily cleaned and maintained. The disadvantages of this configuration, however, outweighed the advantages, and are as follows. While it is true that the coarse grating would not be prone to fouling, all sea life and debris smaller than the coarse grating openings and larger than the fine screen or strainer openings drawn into the system would have to be processed and disposed of. That is, this material would somehow have to be cleaned from the upstream surface of the fine screen or strainer, and processed onboard the platform in some manner, or returned to the ocean if this is ecologically and politically acceptable. The amount of material which might have to be processed is potentially very large and it is expected that it would not be permissible to return it to the ocean. Investigation also indicated that, with the exception of vertical traveling screens, there were no practical mechanisms available or postulated that could effect complete and reliable removal and handling of debris and animal life from such large quantities of seawater. The traveling screens, however, were still not considered a satisfactory solution to the problem. The use of traveling screens would have necessitated the installation of four conventionally sized vertical traveling screens (74 feet high by 10 feet wide) in each warm water system between the warm water pump and evaporator. Three streamlined steel pillars would have to be installed in each warm water pipe to support the screens,

2.9.1.2 Inlet Configuration Description (Continued):

and handling devices would have to be installed to remove the animal life and debris picked up by the traveling screens back into the ocean or to the processing point within the platform. Traveling screens of this size (fabricated from seawater resistant materials - stainless steel) cost approximately \$100,000 each, so the cost for the screens alone would run to \$400,000 for each module, or \$3.2M for the entire platform. It was realized that these costs would be even larger when a handling system and processing plant (if required) were provided, and that the costs of the screens themselves would increase substantially if the screens were fabricated from seawater compatible materials such as Monel as opposed to merely seawater resistant materials. Also, it was realized that the traveling screens and handling system represented a potential maintenance nightmare and source of reduced system availability, even when constructed from fully seawater compatible materials. For these reasons, this alternative was discarded from further consideration, and the decision was made to utilize a "fine" screen at the warm water pump inlet.

Several alternative screen shapes were considered in addition to the truncated conical shape. The other alternatives were a hemisphere and a right circular cylinder with a closed end, and a height equal to half of the cylinder diameter. These alternatives also produced uniform screen velocities (especially for the hemisphere), and the cylindrical screen with a closed end has the additional advantage of pulling in water closer to the surface, and thus preserves the thermal resource. However, as was mentioned previously, the truncated conical shape was chosen for its ease of fabrication and structural strength.

An alternative to the profile type screen surface was also considered, i.e., ordinary woven wire cloth. This type of screen could also be fabricated from the 90-10 CuNi (1.5 Fe, CA 706) alloy, and at much less cost. The estimated cost of 2 mesh wire cloth fabricated from the 90-10 CuNi alloy is \$5/ft.², much less than the estimated \$150/ft.² required for profile wire screen. However, as was mentioned previously, the profile wire screen was chosen for its postulated superior performance characteristics.

2.9.1.2 Inlet Configuration Description (Continued)

It is recommended (see below) that the final choice of screen type be deferred until additional studies and tests can be completed due to the potential cost savings of utilizing woven wire cloth.

Recommendations for Additional Studies

Before a final decision can be made regarding the optimum inlet configuration, additional information, studies, and/or tests are required in the following areas.

(1) The nature, size, distribution, and density (including seasonal and day/night variations) of sea life at the nominal warm water inlet depth needs to be defined for all sites under consideration.

(2) Any ecological or political constraints, as opposed to engineering constraints, need to be identified. That is, from an engineering viewpoint, the fine strainer should be sized small enough to prevent clogging the evaporator, and no smaller, to prevent excessive screen size, weight, cost, and head loss; but the entrainment and possible "killing" of small organisms may result. Is this acceptable from an ecological and political viewpoint? For a coarse external grating/internal fine screen concept, the same question applies, with the quantity of animal life, and individual animal size, being much larger.

(3) Various size, surface area and shape (truncated cone, hemisphere, closed end cylinder, etc.) screens need to be tested to verify the 1.5 fps limiting approach velocity (to prevent trapping fish and other sea life against the screen), to determine whether horizontal or vertical inflows are superior as regards to fish entrapment, and to determine the inflow velocity uniformity for the various screen configurations.

(4) The woven wire cloth and profile wire screens should be extensively tested to determine their relative advantages and disadvantages with regard to freedom from clogging, sea life impingement and entrainment, ease of cleaning, etc. Unless the profile wire screen shows a marked advantage, and unless these "advantages" are worth the premium price paid for the

2.9.1.2 Inlet Configuration Description (Continued)

Recommendations for Additional Studies (Continued)

profile screen, it is recommended that the woven wire cloth screen be utilized, for its lighter weight, anticipated ease of attachment to the frame, and potential \$4M cost savings for a complete platform warm water system.

(5) Although it is felt that the 90-10 CuNi (1.5 Fe, CA 706) is the best material to be utilized for fabrication of the screen surface, due to its excellent corrosion and anti-fouling properties, test screens should be fabricated from this, and any other proposed alloys, and tested for a reasonable period of time (greater than one year) in the design environment to determine actual performance and to identify the optimum material.

(6) The effectiveness of different cleaning methods, e.g., back-flushing, water or air jets, mechanical cleaning, etc., should be tested to determine the optimum method (should cleaning be required).

(7) The effectiveness of various galvanic corrosion minimization techniques (e.g., coatings, noble alloy cladding, passive and active cathodic protection, etc.), should be evaluated to identify potential problems and to determine the optimum technique.

2.9.1.3 Warm Water Pump

Description - The warm water pumping capability for each module consists of a single axial flow propeller type pump in a vertical configuration. The pump configuration for the warm water pump is shown in Figure 2.9-1, and it is also representative of the cold water pump, the only difference being slightly different dimensions.

Capacity:	2.25×10^6 gpm (5,000 cfs)
Total Head:	10.0 Ft. (4.9 psig)
Speed:	41 rpm
Size:	26.4 Ft. long with 24 Ft. impeller diameter
Weight:	762,000 lbs. including shaft and stuffing box
Efficiency:	90%
Axial Thrust:	230,000 lbs.
Material:	Suction Bell - 316 L Stainless Steel Impeller Case - 316 L Stainless Steel Impeller - 316 L Stainless Steel Diffuser - 316 L Stainless Steel
Cost:	\$5.3 M each
Designer:	Worthington Pump Corporation

The pump materials given above are highly seawater resistant and should produce a pump with excellent performance in seawater throughout its 40 year service life. The pump should require very little maintenance and exhibit a high degree reliability and availability. The warm water pump costs can be reduced approximately 25%, to \$4.0 M each, if less expensive and less erosion resistant alloys, are used to fabricate the pump. For the \$4.0 M pumps, carbon steel would be utilized for the suction bell, carbon steel with a 316 L liner for the impeller case, 316 L for the impeller, and Ni-Resist for the diffuser. The risk of using these cheaper materials is great and their use should be studied in greater detail to determine if the cost savings of utilizing the materials is worth the increased maintenance, reduced reliability and reduced availability associated with their use. For the present study, the decision was made to use the higher cost premium materials for the pump. Pump costs could be reduced approximately

	A	B	C	D	E
Cold Water Pump	2.1	27.3	25.5	28.0	37.4
Warm Water Pump	1.9	25.9	24.0	26.4	35.6

(Dimensions in Feet)

FIGURE 2.9-1

TYPICAL SEAWATER PUMP CONFIGURATION

2.9.1.3 Warm Water Pump (Continued):

50%, to 2.65 M each, if the pumps were fabricated completely from carbon steel; however these pumps would be completely unsuitable for the marine environment.

Each of the pumps is driven directly by a vertical electric motor with principal characteristics listed below:

Capacity:	8,000 HP
Speed:	41 rpm
Size:	21 Ft. high with a 20 Ft. diameter
Weight:	239,000 lbs.
Type:	AC, 3-Phase, 60 Cycle, 13.8 KV, synchronous, TEWAC (Totally Enclosed Water/Air Cooled), with integral thrust bearing and lubrication and cooling system.
Cost:	\$1.4 M each

Alternative Configurations - Several different alternative pump and drive configurations were considered during the course of the warm water system conceptual design studies. These are as follows:

- 1) Self contained bulb type pump
- 2) Offset inline external drive pump.
- 3) Right-angle external drive pump
- 4) Vertical pit type pump in a horizontal orientation.

2.9.1.3 Warm Water Pump (Continued):

Alternative Configurations (Continued):

Early in the studies it was determined that a vertical orientation of the pump below the platform offered several advantages, these being as follows:

- 1) Good submergence of pump impeller, providing adequate net positive suction head to prevent cavitation under all operating conditions, even in high sea states.
- 2) Good submergence of pump suction bellmouth, preventing emergence of suction bellmouth under all operating conditions, even in high sea states.
- 3) Good submergence of pump suction bellmouth and inlet screen, preventing clogging or damage to screen from floating foreign objects under all operating conditions, even in high sea states.
- 4) Together with a vertical inline driver, the vertical pump orientation resulted in a compact arrangement, which allowed a minimization of platform size and cost.

These advantages eliminated any of the horizontal pump orientations from further consideration and also eliminated right angle drive arrangements, since they indicate a horizontal driver, which would require a larger platform. Another disadvantage of right angle drive is that the gears are not state-of-the-art in the high torques required. Right angle drive gears of the capacity required for the warm water pump (high horsepower, extremely low rpm) would be extremely large, and it is certain their cost would be extremely high, if they could be fabricated at all. Although this problem could be eliminated by the use of a high speed motor driving through the right angle drive into a vertical reduction gear, this would result in even greater complexity, required volume and platform size. Self-contained bulb type pumps were eliminated from further consideration because of their estimated high complexity and cost and low reliability. In general, the components most likely to require maintenance or repair on a large capacity, low head, axial flow propeller type pump are the driver and thrust bearing. In the vertical pit configuration, these components are easily accessible for

2.9.1.3 Warm Water Pump (Continued):

Alternative Configurations (Continued):

inspection, routine maintenance, or repair. In the self-contained bulb type pump, however, these components are very difficult to access for inspection or maintenance, and any repair would present major problems. Furthermore, failures would probably be more likely to occur with the self-contained bulb-type pumps, due to the additional complexity of the sealing and cooling systems, probability of water damage, etc. Discussions with various utilities indicated that they consider availability of paramount importance; therefore, the vertical pit type pump configuration was chosen as the best pump configuration due to its superior characteristics with regard to ease of arrangement, required volume, impact on platform size, simplicity, proven design and operation, and reliability.

Various combinations of drivers and transmissions were also considered during the course of the warm water system conceptual design studies. Other driver and transmission configurations that were considered are as follows:

- 1) DC Motor Drivers
- 2) AC Induction Motor Drivers
- 3) High Speed AC Synchronous Motor Drivers with Reduction Gears.

The DC motors were eliminated because of their higher weight and cost, low (relative to AC motors) efficiency, high maintenance requirements (and thus, reduced availability), and because their use would probably have required step down transformers, since the 13.8 KV voltage available from the turbine generators is too high for direct powering of DC motors. The AC induction motors were eliminated because of their higher weight and cost, and because of their low (relative to synchronous motors) efficiency. The use of high speed AC synchronous motor drivers with reduction gears, however, appeared to be a viable alternative to low speed direct drive AC synchronous motors. A high speed synchronous motor is much smaller and lighter, and less costly. In fact, due to the much lower cost of the high speed motor, it appears that the combined cost of a high speed motor/reduction gear drive system would be equal to, or lower than, the cost of a low speed direct drive motors. There are disadvantages associated with the high speed motor/reduction gear system, however. While a high speed motor is less costly (and more state-of-the-art) than a low speed motor, high torque, multi-stage, vertical reduction gears are not state-of-the-art items. It appears that there might be design and fabrication

2.9.1.3 Warm Water Pump (Continued):

problems for a gear of this type, especially since the gear would be required to operate reliably for 40 years, which might preclude the utilization of anti-friction bearings. For these reasons then, and because of the additional complexity, and losses that would be associated with the use of a reduction gear, the decision was made to use a low speed, direct drive, AC synchronous motor as the pump driver.

Recommendations for Additional Studies

Before a final decision can be made regarding the optimum pump and driver configuration, additional information, studies, and/or tests are required in the following areas:

- 1) It appears feasible to utilize the same pump for both the warm and cold water pumping applications. Detailed trade-off studies should be completed in this area, with sufficient funding to support engineering and cost estimating studies by a pump designer and manufacturer, to determine if the reduction in design and acquisition costs due to single pump procurement offset the increase in the operating costs due to off design point pump operation.
- 2) Due to the large size and cost of the warm (and cold) water pumps, it appears that, in some cases, it might be cost effective to operate the pumps at a capacity greater than the design or best efficiency capacity. That is, the reduction in acquisition cost obtained by operating a smaller, lighter and less costly pump (and driver) at a higher specific speed and capacity may offset the reduced revenue obtained because of the lower efficiency (and higher parasitic losses) of this pump. Trade-off studies should be completed in this area, with sufficient funding to support engineering and cost estimating studies by a pump and motor designer and manufacturer.
- 3) As was mentioned previously, the high speed AC synchronous motor/reduction gear drive configuration appears to be a viable alternative to the low speed, direct drive, AC synchronous motor drive configuration. Detailed trade-off studies should be completed in this area, with sufficient funding provided to insure the active participation and cooperation

2.9.1.3 Warm Water Pump (Continued)

Recommendations for Additional Studies (Continued)

of pump, motor, and reduction gear designers and manufacturers. Previous studies have indicated that there might be cost savings in this area; however, the magnitude of the numbers is such that the costs of the two alternatives are roughly comparable based on the general cost estimating techniques utilized heretofore. Therefore, it is essential that a more detailed effort, managed by a single contractor to insure coordination, thoroughness, and objectivity, and including pump, motor, and reduction gear manufacturers, to insure validity and accuracy of results, be undertaken.

- 4) Previous studies indicate that there is a large reduction in weight (and cost) for higher head warm (and cold) water pumps of identical capacities. This is because of the higher speed required for the higher head pumps, which results in a smaller size, and therefore weight. The cost of these pumps is such a large absolute number, and such a large percentage of the total platform acquisition cost, that it may be cost effective to utilize higher head pumps, even if the parasitic losses increase, due to the major reduction in acquisition cost which could be obtained. This is especially true since the higher head pumps could drive the same (or a greater) quantity of water through the heat exchangers at a higher speed, which would result in better heat transfer which would provide more gross power, or allow a reduction in heat exchanger size and cost. It is recommended that more detailed trade-off studies in these areas be completed. These efforts should be coordinated by a single contractor, and include the participation of pump, motor, reduction gear and heat exchanger designers and manufacturers.

2.9.1.4 Warm Water Piping/Evaporator Connections

Description - The warm water piping/evaporator connection for each warm water system (refer to Appendix B), consists of a 180° turn piping section from the warm water pump diffuser outlet to the evaporator inlet. The piping section turns and increases in cross sectional area from the warm water pump diffuser outlet diameter to the evaporator inlet diameter in as smooth a

2.9.1.4 Warm Water Piping/Evaporator Connections (Continued)

manner as possible to minimize system head losses. The piping is fabricated from carbon steel, protected by a multi-coat application of epoxy paint.

Alternative Configurations - An alternative warm water piping configuration considered utilizes long radius turns in order to minimize system head losses. A trade-off study was completed to determine the cost effectiveness of this alternative. The study (described in greater detail in Section 2.3.2), indicated that this alternative was not preferable because the increase in revenue associated with the lowering of parasitic losses was overshadowed by the increase in platform size required by the longer radius turns, with its consequent increase in cost. Therefore, all later arrangements utilized short radius turns and as tight an arrangement as other considerations would allow.

2.9.1.5 Discharge Configuration

Description - The discharge configuration for the warm water system consists of a discharge pipe on the outlet of each evaporator (refer to the arrangement drawings in Appendix B). The pipe is fabricated from mild steel and is 150 ft. long and 40 ft. in diameter. The pipe length was chosen to discharge the warm water below or near the bottom of the mixed layer, depending on the season. The exterior pipe is protected from corrosion by the platform cathodic protection system while the inside is protected by a multi-coat epoxy paint system.

Alternative Configurations - Several alternative configurations were considered for the warm water discharge pipe. One alternative was to provide a combined discharge pipe for two warm water outlets (evaporators) and the two cold water outlets (condensers). The problem with this alternative is that deployment of the heat exchangers is more difficult and the removal of a single heat exchanger (evaporator or condenser) for repair is impossible. With individual discharge pipes for each heat exchanger, deployment is less difficult, and an individual heat exchanger may be removed with its associated discharge pipe for repair.

Another alternative considered was the use of a rubber fabric discharge pipe for each heat exchanger. This would have simplified deployment, as the

2.9.1.5 Discharge Configuration (Continued)

Alternative Configurations (Continued)

discharge pipe could be attached to the platform prior to floating each platform half from the dry dock (refer to Section 4). This alternative was eliminated, however, when investigation determined that the cost of the rubber fabric discharge pipe would be prohibitive.

Recommended Additional Studies - It is recommended that studies be completed during the preliminary design stages to minimize discharge pipe head losses by optimizing the discharge pipe design within the existing arrangement and deployment constraints.

2.9.1.6 Biofouling and Corrosion Control

Description - The biofouling-control system for each module's main water system consists of chlorine generators with associated pumps and piping (refer to WBS Section 3.11 of the List of Machinery in Appendix D). Two chlorine generators (Engelhard 3,360 lb./day Chloropac units or equivalent), are provided for each module, which supply sufficient chlorine to maintain a chlorine concentration of .25 ppm for the 5,000 cfs of warm seawater. A seawater circulation pump takes suction from the warm water pipe and discharges 500 gpm of seawater through the chlorine generators where a very high chlorine concentration is produced. This chlorine rich seawater is then injected into the warm water intake system through a piping distribution system integral with the warm water inlet screen. Injection at this location serves to additionally protect the CuNi inlet screen from biofouling, and insures that the water is mixed well to produce a uniform chlorine concentration of approximately 0.25 ppm to protect all downstream components of the warm water system, including the evaporator, from biofouling. An AMERTAP type heat exchanger cleaning system or equal can be provided for the evaporator if specified by the Power System contractor.

The corrosion control system for each warm water system consists of a multicoat application of epoxy for all non-seawater resistant materials. The CuNi inlet screen and titanium evaporator tubes require no corrosion protection.

2.9.1.6 Biofouling and Corrosion Control (Continued)Description (Continued)

It is understood that the use of different materials (steel, CuNi, titanium) in the seawater system has the potential of causing severe galvanic corrosion problems. This could be handled by isolating or protecting different materials as indicated in Section 2.9.1.2, or by utilizing a single material (or cladding) as is suggested below. As is indicated below, further study of this potential problem is indicated.

Alternative Configurations - Several alternative configurations were considered for the biofouling and corrosion control systems for the warm water systems. The .25 ppm chlorine concentration is probably excessive, depending on the biofouling potential of the warm seawater at the actual site; therefore, the number, and/or size of chlorine generators may be reduced. The actual chlorine concentration required for full biofouling protection could be determined from the OTEC-1 tests.

An alternative means of corrosion control for the warm water system is to use a fully corrosion resistant alloy (90-10 CuNi) as sheathing or cladding on all non-seawater resistant materials instead of epoxy paint systems. This alternative was eliminated from consideration because of its high initial cost. However, should additional study indicate that epoxy paint systems will not last 40 years (as is very likely), and that substantial cost and lost revenue will result from their periodic replacement, then the use of a single fully corrosion resistant alloy might prove to be the most cost effective corrosion control system. As was indicated above, a corrosion resistant alloy such as 90-10 CuNi would also serve as an excellent anti-fouling protection, and would eliminate or ameliorate galvanic corrosion problems.

Recommendations for Additional Studies - Before a final decision can be made regarding the optimum biofouling and corrosion control system, additional information, studies, and/or tests are required in the following areas:

- 1) Conduct tests at the appropriate site(s) to determine the minimum required chlorine concentration to provide full biofouling protection.

2.9.1.6 Biofouling and Corrosion Control (Continued)

Recommendations for Additional Studies (Continued)

- 2) Determine whether an epoxy, or some other type of paint system will provide full corrosion protection for non-corrosion resistant materials for 40 years. If not, determine what the periodic maintenance and replacement costs, and lost revenue, would be. Investigate the feasibility of providing corrosion protection to the warm water system, and to eliminate galvanic corrosion fouling problems and by using a single fully corrosion resistant alloy (90-10 CuNi) throughout. The effectiveness of passive and active cathodic protection systems should also be evaluated.
- 3) Investigate the environmental impact of chlorine discharge into the sea.

2.9.2 Cold Water System

2.9.2.1 General System Description

The cold water system for each 50 MW module consists of a cold water pump taking suction from the common cold water inlet plenum surrounding the cold water pipe (CWP)/hull connection (refer to Section 2.10.3 and to Appendix C), and discharging through each module's condenser and discharge pipe back into the ocean below or near the bottom of the mixed layer, depending on the season.

A hydraulic analysis of the cold water system was conducted to determine the system head loss at the design flow rate of 6,000 cfs (2.7×10^6 gpm per module)

2.9.2.1 General System Description (Continued)

so that head requirements of the cold water pump could be identified. Head losses evaluated were screen losses, entrance losses, cold water pipe losses, (including friction and transition losses) plenum losses, pump losses, platform piping losses (including friction, transition, and turning losses), heat exchanger losses, discharge pipe losses (including transition losses), exit losses, and the density effect loss. A summary of these losses is presented below:

Heat Exchanger Losses	-	8.6 ft
Density Effect Loss	-	1.0 ft
All Other Losses	-	<u>2.8 ft</u>
TOTAL HEAD LOSS	-	12.4 ft

It should be noted that the heat exchanger losses account for 70% of all cold water system head losses. The high heat exchanger (condenser) head losses are evidently due to the small tube size (1 in) utilized. Heat exchanger head loss could be reduced to 4.1 ft by the use of 2 in. tubes. As is discussed in greater detail in Section 2.7.1, a trade off study of heat exchanger tube size is in order.

2.9.2.2 Inlet Configuration

Description - The inlet configuration for the platform cold water systems consists of a truncated conical inlet screen fastened directly below the cold water pipe suction bellmouth (refer to Appendix C). The design criteria for screen shape and material selection are identical to the criteria utilized for the warm water inlet screen and are described in Section 2.9.1.2. The overall size of the conical screen is 170 ft in diameter at the base of the cone with a truncated height of 70 ft. These dimensions produce a screen area of approximately 32,000 ft² based on the design criteria of limiting screen approach velocities to 1.5 fps at a total cold water flow rate of 48,000 cfs to prevent the trapping of fish and other sea life against the screen.

Screen cleaning is not anticipated to present any problems. The CuNi screen fabric has excellent antifouling properties, and the biofouling potential at the cold water inlet depth is estimated to be negligible (although the exact extent of the potential needs to be quantified for the site chosen). Should screen clogging or fouling occur, the screen would have to be mechanically cleaned (by the workboat submersible) since it is not feasible to backflush the

2.9.2.2 Inlet Configuration (Continued)

Description (Continued)

the cold water pipe as this would require all modules to be shut down and approximately 65 MW of power fed into the platform from an outside source to run all 8 cold water pumps simultaneously in reverse.

Alternative Configurations - The alternative configurations considered for the cold water system screens are similar to those considered for the warm water system. The reader is invited to refer to Section 2.9.1.2 for a discussion of these alternatives.

Recommendations for Additional Studies - The same studies and tests are recommended for the cold water inlet configuration as are recommended for the warm water system (refer to Section 2.9.1.2). The potential cost savings of utilizing woven wire cloth instead of profile wire screen for the cold water inlet screen is \$4.8 M.

2.9.2.3 Cold Water Pipe

The cold water pipe delivers 48,000 cfs of cold water from the ocean depths through the inlet screen and to the cold water inlet plenum. The cold water pipe is 100 ft. in diameter and 3000 ft. long. Section 2.10 provides a detailed description of the pipe structure and hull connection, and Section 2.3.4 discusses the numerous trade-off studies conducted to optimize pipe diameter, length, etc. The hydraulic impact of the cold water pipe is minimal; of the total cold water system head loss of 12.4 ft., the cold water pipe (including transition and plenum losses) accounts for only 0.2 ft.

2.9.2.4 Cold Water Pump

Description - The cold water pumping capacity for each module consists of a single axial flow propeller type pump in a vertical configuration (refer to Appendix B and to WBS Section 1.71 of the List of Machinery in Appendix D), taking suction from the common cold water inlet plenum and discharging to its respective condenser. The pump's principal characteristics are listed below, and the general configuration is depicted in Figure 2.9-1:

2.9.2.4 Cold Water Pump (Continued)

Description - (Continued)

Capacity: 2.7×10^6 gpm (6000 cfs)

Total Head: 12.4 ft (5.5 psig)

Speed: 41 rpm

Size: 28 ft long with 25.5 ft impeller diameter

Weight: 906,000 lbs including shaft and stuffing box

Efficiency: 90%

Axial Thrust: 290,000 lbs.

Material: Suction Bell - 316 L Stainless Steel
Impeller Case - 316 L Stainless Steel
Impeller - 316 L Stainless Steel
Diffuser - 316 L Stainless Steel

Cost: \$6.3 M each

Designer: Worthington Pump Corporation

As with the warm water pumps, the selection of alternate materials could reduce the acquisition costs of the cold water pumps assuming the additional risk associated with the less seawater resistant materials is acceptable (see Section 2.9.1.3). If carbon steel is substituted for corrosion resistant steel in the suction bell and the impeller case (with a 316 L liner) then the cost of the pump could be reduced to \$4.7 M while a totally carbon steel pump would price out at approximately \$3.15 M.

Each of the pumps is driven directly by a vertical electric motor with principal characteristics listed below:

Capacity: 11,000 HP

Speed: 41 rpm

Size: 24 ft long with 21 ft diameter

Weight: 295,000 lbs.

Type: AC, 3-phase, 60 cycle, 13.8 KV, Synchronous TEWAC
(Totally enclosed water/air cooled) with integral thrust bearing and lubrication and cooling systems

Cost: \$1.8 M each

Alternative Configurations - The alternative configurations considered for the cold water pump and driver are similar to those considered for the warm water pump. The reader is invited to refer to Section 2.9.1.3 for a discussion of these alternatives.

Recommendations for Additional Studies - The recommendations for additional studies for the cold water pump and driver are similar to those recommended for the warm water pump. The reader is invited to refer to Section 2.9.1.3 for a description of the studies.

2.9.2.5 Cold Water Piping/Condenser Connections

The cold water piping/condenser connections and the alternative configurations considered are similar to those for the warm water system. The reader is invited to refer to Section 2.9.1.4 for a description of these connections and the alternative configurations considered.

2.9.2.6 Discharge Configuration

The discharge configuration for the cold water system, and the alternative configurations considered, are identical to those for the warm water system, and are described in Section 2.9.1.5.

2.9.2.7 Biofouling and Corrosion Control

Description - The biofouling control system for each cold water system is similar to that provided for each warm water system (refer to Section 2.9.1.6 and WBS Section 3.11 of the List of Machinery in Appendix D), with the following differences:

- 1) Three chlorine generators (Engelhard 3360 lb./day Chloropac units or equivalent) are provided, which supply sufficient chlorine to maintain a chlorine concentration of .25 ppm for the 6000 cfs of cold seawater.
- 2) A 750 gpm seawater circulating pump is provided.
- 3) The chlorine rich seawater is injected into the cold water on the trailing edge of the cold water pump diffuser vanes, as it would

2.9.2.7 Biofouling and Corrosion Control (Continued)

be impractical (and unnecessary) to inject the chlorine at the cold water pipe inlet.

The corrosion control system and the alternative configurations and additional studies considered for both the biofouling control system and corrosion control system are similar to those for the warm water system, discussed in Section 2.9.1.6, with the following additional observations:

- 1) Chlorinators (and AMERTAP) might not be required at all for the cold water system. The actual biofouling potential of the cold water at the appropriate site(s) will have to be determined.
- 2) The oxygen concentration of seawater in the ocean depths can be substantially lower than that at the surface. If this is the case for the site in question, it is possible that the level of corrosion protection provided for the non-corrosion resistant portions of the cold water system (including the CWP) could be reduced (or eliminated), resulting in a substantial cost savings. It is understood, however, that oxygen concentration at depth is extremely site specific, so therefore, the oxygen concentration (including seasonal fluctuations) at the depth(s) and site(s) of interest should be determined before any final decisions are made.

2.10 Cold Water Pipe System

2.10.1 Pipe Structure

The CWP conceptual design for the 400 MW (net) ship is presented in Appendix C. Generally, the CWP structural configuration consists of a series of externally mounted ring stiffeners and axial stiffeners supporting a CWP shell. The recommended scantlings are the result of the CWP Trade-Off studies presented in Section 2.3.4. As developed in that section, loads considered in the structural analysis include:

- Dynamic Bending Moment resulting from wave action acting on the Hull and Pipe
- Dynamic Vertical Stress resulting from wave action on the Hull
- Current Induced Bending Moment with a pinned connection at the Hull
- Deadweight Load resulting from weight of CWP and intake screen
- Velocity head and Head Loss Pressure Differential resulting from flow through pipe
- Stagnation Pressure Differential resulting from the current profile against pipe exterior

The dynamic bending stress which results from the dynamic bending moment is estimated directly using Reference (7). Figure 2.3-12 presented in Section 2.3.4 presents the relationship between CWP diameter, equivalent wall thickness and maximum significant dynamic bending stress for a steel pipe attached to the ship platform. The actual distribution of significant bending stress along the length of the CWP indicates that points of maximum bending stress occur at the quarter points of the CWP. No effort is made to locally vary the pipe in the short region between these peaks to follow the stress distribution; therefore, for design purposes, the dynamic bending stress is considered to vary as depicted in Figure 2.10-1.

The dynamic vertical stress is also derived from Reference (7) and is shown in Figure 2.10-1.

The current induced bending moment is developed using the following analytic representation of the current profile as a function of depth (z):

FIGURE 2.10-1

ASSUMED PRIMARY STRESS COMPONENT DISTRIBUTIONS

FIGURE 2.10-2

TOTAL ASSUMED PRIMARY STRESS DISTRIBUTIONS

2.10.1 Pipe Structure (Continued)

$$\begin{aligned} V(z) &= 3.68 \text{ ft/second for } z = 35 \text{ ft} \\ &= 14.9z^{-.4} \text{ ft/second for } z > 35 \text{ ft} \end{aligned}$$

Using a drag coefficient, (C_d) of 1.1, the resulting force distribution causes an angular deflection at the top of the CWP. This results in a uniform component of the weight acting perpendicular to the axis of the pipe. The difference between this weight component and the drag force acting at any point along the length of the pipe results in the development of a bending moment. The corresponding stresses are also plotted in Figure 2.10-1.

This design was developed assuming no buoyancy other than that provided by the displacement of the structure. The expense of incorporating buoyancy, the unreliability of such buoyancy over a 40 year life, and the minor impact which it would have on reducing the scantlings of this particular design, justify of omission of buoyancy. The resulting linear increase in weight stress is also shown in Figure 2.10-1

These four stresses contribute to the axial stress acting in tension or compression on the individual panels of the CWP. The maximum compressive and tensile stresses are plotted on Figure 2.10-2.

The remaining loads act perpendicular to the pipe inducing bending of the individual panels. The head loss varies linearly up the pipe while the stagnation pressure varies as the square of the current at any given level. The values for the 100 foot diameter CWP vary as shown in Figure 2.10-3. The stresses resulting from these loads vary according to the dimensions of the panels and stiffeners.

The combined effects of the axial and bending loads are evaluated as presented in Reference (8).

An iteration of this design produced by inputting the resulting structural configuration to the analysis of Reference (7) indicates the actual stress experienced by a 0.1 foot equivalent wall thickness, 100 foot diameter CWP to be greater than the extrapolated values derived from

FIGURE 2.10-3
ASSUMED PRESSURE DIFFERENTIAL ACROSS CWP WALL

2.10.1 Pipe Structure (Continued)

Figure 2.3-11. A detailed evaluation of the cause and effect of these higher values is not presented in this report, however, the drastic variation in slope of the stress vs thickness curve indicates a highly tuned response which may be circumvented by local reinforcement of highly stressed areas. This can be accomplished by the use of more or heavier stiffeners or by local use of HTS. As a upper bound on the effect which this perturbation of the design procedure would have on the estimated cost of the CWP it can be assumed that HTS will be used over half the length of the pipe. This results in an increase of approximately \$20M or four percent of the ship acquisition cost. This is considered to be within the precision achievable for a conceptual level design effort.

2.10.2 Inlet Configuration

The configuration of the inlet is driven by consideration for minimizing the entrance loss and the pressure drop across the mesh screen. A significant decrease in pressure drop is available through the use of a profile wire screen. The factors considered in selection of such a screen are discussed in Section 2.9.2.2. The assumed maximum average velocity through the screen of 1.5 feet per second determines the required surface area. The rationale for the selection of proportions and dimensions of the actual recommended screen is discussed in Section 2.9.2.2. The bell mouth at the bottom of the CWP to interface with the inlet screen is comprised of a series of conical sections to gradually orient the radial inlet flow to the axial flow through the pipe. The entire bell mouth is limited to an overall height of 50 feet to maintain consistency with the remainder of CWP structure.

2.10.3 CWP/Hull Connection

The large inertial forces generated by both the hull and the CWP require that a significant amount of structure be provided at their interface. Because of the rotational flexibility, the nature of the reactions to be supported will be primarily shear. Vertical forces resulting from the weight

2.10.3 CWP/Hull Connection (Continued)

and acceleration of the CWP must be transmitted from the CWP shell to the centrally located bearing. Similarly, the horizontal shears induced by relative surge and sway forces must be transmitted from the bearing to the CWP shell through the connecting yoke. The necessity of providing a reasonable hydraulic flow through this area imposes additional requirements on the configuration. The cruciform yoke structure depicted in Appendix C, satisfies all structural requirements without obstructing the fluid flow excessively.

The fact that the CWP is free to rotate requires that a flexible boot be provided between the CWP and the plenum to eliminate the loss of cold water. A rubber boot will contain the seawater and since no appreciable loads will be supported by the boot, will not require exotic reinforcing schemes.

The bearing represents the critical interface between the hull and CWP. The loads anticipated are not significantly beyond the current state-of-the-art; therefore, the use of a bearing is not considered to be a considerable risk. Decoupling of roll and pitch motions is accomplished in a universal type joint located at the top of the cruciform yoke. The hull side of this bearing ties into a structure similar to a rudder stock which is in turn fixed to the platform. It is anticipated that the bearing surfaces will be roller bearings similar to the type used on the Glomar Explorer gimbal device.

The problem of bearing corrosion is dealt with by immersing the entire universal joint in an oil bath. This bath is created by a circular skirt that is attached to the bottom of the hull and surrounds the universal. It is open at the bottom and as oil is pumped from the top the water is displaced, forming a volume of oil around the entire assembly. The oil also provides a minimal amount of lubrication for the bearings.

2.11 Power System2.11.1 General System Description

The Power System for each 50 MW module consists of the following major components (quantities, dimensions, weights, etc. taken from References (13) and (14), arranged as indicated in the arrangement drawings in Appendix B.)

<u>COMPONENT</u>	<u>QUANTITY</u> (Per Module)	<u>SIZE</u> (LxWxH or LxDia (ft))	<u>WEIGHT</u> (Dry/Wet (L.Tons))
Vertical Evaporator	1	50* x 55	1071/4018
Vertical Condenser	1	50* x 55	1071/4018
Turbine	1	25 x 25	67/67
Generator	1	30 x 18	196/196
Demister	1	30 x 30	402/402
NH ₃ Tanks	2	50 x 25	-/268
NH ₃ Feed Pumps	3	13.5 x 7	12/12
NH ₃ Compressor	1	6 x 18 x 4	9/9
Vacuum Pump	1	5 x 6 x 7	3.6/3.6

(*tube bundle length)

The components were arranged so as to minimize platform size and still provide sufficient space for maintenance, auxiliary components, etc.

2.11.2 Heat Exchangers

The heat exchanger (evaporator and condenser) location and orientation were established by trade-off studies described in Section 2.3. There are various potential problems associated with the external location of the heat exchangers. They are exposed to wave and current forces, corrosive seawater, forces induced by the attached discharge pipes, and maintenance and repair are much more difficult. These potential problems need to be addressed in detail to determine the overall cost effectiveness of the external heat exchanger location. The advantages of the external configuration include a significant reduction in platform size and the potential for modular heat exchanger removal. Although this is not a DOE requirement, it is a highly desirable feature in case of tube renewal, repair of leaks, or damage during the life of the system.

2.11.3 Turbine - Generators

One 65 MW (approximate gross output capacity) ammonia turbine-generator set is provided for each module to produce approximately 46.6 MW average annual net power per module (refer to Table 2.7.2). Prior to further study, support systems and equipment for the turbine-generator sets need to be identified and defined by the Power Systems Contractor. These systems and equipment will probably include such items as generator exciters, generator cooling pumps, turbine-generator set lube oil modules (including lube oil sump tank, lube oil coolers, lube oil pumps, lube oil storage tanks, lube oil settling tanks, and lube oil purifiers and heaters), and lube oil cooler seawater circulating pumps, etc. These systems and equipment will require additional volume, which is reflected in the platform arrangements.

2.11.4 Ammonia System

The ammonia system for each module consists of sufficient ammonia handling equipment and piping to circulate the ammonia through the Power System components, and to provide ammonia pump-down and make-up capability. The ammonia feed pumps pump liquid ammonia from the condenser into the evaporator where the ammonia is evaporated. Ammonia reflux pumps (3 per module, 2 operating, 1 standby) recirculate a portion of the ammonia liquid in the evaporator. The ammonia vapor then flows into the demister through a 10 foot diameter pipe where liquid ammonia droplets are separated from the ammonia vapor. The dry ammonia vapor is fed from the demister to the ammonia turbine through a 10 foot diameter pipe, and is exhausted from the turbine into the condenser through a 14 foot diameter pipe, thus completing the cycle.

The ammonia storage tanks, compressor, and vacuum pump provide the capability for ammonia storage, make-up, pump-down and transfer.

During later stages of design, better definition of the power and ammonia handling system components must be developed. More detailed information should be provided on components already identified, and additional components which will probably be required should be identified in detail. These might include components for ammonia purifying and filtering, separating water and non-condensable gases from ammonia, turbine

2.11.4 Ammonia System (Continued)

sealing, leakoff ammonia recovery, etc. The ammonia loss rates should be established so that the ammonia make-up and storage requirements may be estimated with greater accuracy. The details of ammonia storage, handling, and replenishment should be identified, and cryogenic or refrigerated storage and handling systems for the ammonia should be considered and the impact of such systems on the platform support systems identified.

2.11.5 Purge System

The purge system consists of N_2 storage tanks and the N_2 distribution piping and equipment necessary to purge each module. Sufficient N_2 storage is provided to completely purge each module once (136,000 lb N_2 @ 1800 psig in 16 - 20 ft x 8 ft O.D. tanks). The N_2 storage tanks would be initially filled and periodically refilled, from a nitrogen tanker.

During later stages of design the need for the N_2 purge system should be more firmly established, and if the need is indicated, the system requirements should be defined in greater detail. The frequency of piping should be identified as well as the details of storage, handling, and replenishment. Cryogenic handling and storage systems should be considered for the N_2 and the impact of such systems on the platform support systems determined.

2.11.6 Start-Up System

The platform will be started by supplying power to the first module to be started from the start-up barge through the start-up power connection to the power system module switchboard (refer to Section 2.7.1 and 7.4.6). Any unusual or transient requirements which will be imposed on the seawater or ship's auxiliary systems during start-up, and the anticipated time required for start-up, need to be defined.

2.12 Energy Transfer System

The Energy Transfer System is currently under development under separate contract to DOE. References (6), (15), and (16) present preliminary results of studies into the identification of required components. The following section summarizes the currently defined aspects of the Energy Transfer System which impact the arrangement of platforms.

2.12.1 Power Conditioning Equipment

It is currently anticipated that power conditioning from the generating voltage and amperage to the transmission voltage and amperage shall be accomplished in two separate stages. The initial stage, the generator transformers, will transform the 13.8 KV output of the generators to 138 KV. The second stage, the transmission transformers, will further boost the voltage to approximately 230 KV for transmission ashore.

To allow flexibility in the layout of power conditioning equipment, provide a certain degree of redundancy, and limit the capacity of any individual piece of equipment, the output of each module will be treated individually and fed into a common bus immediately before the attachment to the riser cable.

For the selected location off Hawaii AC transmission is appropriate; however, greater transmission distances such as those at the New Orleans or West Coast of Florida sites will require that transmission be D.C. This will require AC/DC converters in addition to the transformer equipment described above. If DC transmission is to be used, the conversion will be accomplished prior to the combining the output from each module to eliminate the necessity of synchronization.

2.12.2 Riser Cable

The exact configuration of the riser cable is currently undefined. Although the motions limitations and the connections to the hull may exert a significant impact on other systems, information received to date has been insufficient to allow the development of any conceptual design level features to accommodate cable interfaces.

3. TASK V CONCEPTUAL DESIGN - SEMI-SUBMERSIBLE

3.1 Approach

The approach used in developing the Semi-Submersible design is described in Section 2.1 and is identical to that utilized for the ship because of its universal nature.

3.2 Top Level Requirements (TLR)

See Section 2.2 since the TLR applies to both the ship and the semi-submersible.

3.3 Trade-Off Studies

3.3.1 Approach

The second configuration selected for development by Gibbs and Cox, Inc. is the 400 MW (net) Semi-Submersible platform. The evolution of this design is similar to that of the Ship platform, but the entire design process lags that of the ship. For this reason, several generalized conclusions reached during the development of the Ship design are applied directly to the Semi-Submersible.

As with the Ship platform design, the impact which several key features exert on the configuration and cost are tested by the development of a series of point designs. The corresponding F.O.M. is calculated for each point design, secondary criteria are considered where no obvious economic advantage is demonstrated, and a conceptual design baseline is chosen.

3.3.2 Hull Material/Configurational Trade-Off Studies

The features identified as having a significant impact on the platform integration and cost are the hull material, heat exchanger orientation, heat exchanger location, and hull configuration. Alternatives considered for each of the first three features are identical with those considered for the ship. It should be noted that hydraulic considerations are not included

3.3.2 Hull Material/Configurational Trade-Off Studies (Continued):

because of the obvious advantage demonstrated during the Ship studies by the minimizing of the total platform enclosed volume.

The term Semi-Submersible can be applied to several other diverse hull configurations. The identifiable features are a small waterplane area consisting of several surface piercing columns connected above the waterline by a cross structure. Within this configuration, several underwater hull forms can be used. In an attempt to define the most cost effective platform system, two variations were considered:

- (1) The conventional (catamaran) Semi-Submersible with two submarine type hulls attached to the surface piercing columns and providing most of the platform buoyancy.
- (2) The column stabilized Semi-Submersible with a truss type underwater cross structure connecting the large buoyant columns.

The orientation of the column stabilized Semi-Submersible was not conducive to arrangement of the horizontal heat exchangers, therefore, only vertical heat exchangers are used in those point designs.

The twelve point designs generated to demonstrate these alternatives are presented in Figures 3.3-1 through 3.3-6. Characteristics of these designs are presented in Tables 3.3-1 and 3.3-2. All costs assumed during the course of the study are the same as presented in Section 2.3.2 except as discussed below.

Platform System - Because of the complicated nature of the Semi-Submersible configuration, higher unit costs were used for hull structure. The orientation of the column stabilized units presents an advantage in concrete because of the applicability of slip forming techniques. The following unit costs are reflected in the FOM numbers:

TABLE 3.3-1
HULL TRADE OFF STUDY
CONCRETE CONSTRUCTION

OPTION	A	B	C	D	E	F
H/X Orientation (1)	Hor	Hor	Vert.	Vert.	Vert.	Vert.
H/X Location (2)	Int	Ext	Int	Int	Ext	Ext
Platform Config. (3)	Cat	Cat	Cat	C.S.	Cat	C.S.
Length (O.A.)	700	660	600	560	600	560
Beam (O.A.)	160	160	160	560	140	560
Depth (to upper level)	140	70	220	240	100	190
Δ Light ship	512,000	390,000	525,000	443,000	353,000	273,000
Sea Water in Systems	197,000	148,000	165,000	103,000	197,000	82,000
Ballast	118,000	22,000	113,000	210,000	35,000	0
Δ Operating	827,000	560,000	803,000	756,000	585,000	355,000
Acquisition Cost(\$ M)	824	795	700	674	656	639
Facilities Improvement Costs (\$ M)	760	580	640	560	600	460
Schedule (Yrs.)	8	8	8	7	8	7

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TABLE 3.3-2
HULL TRADE OFF STUDY
STEEL CONSTRUCTION

OPTION	A	B	C	D	E	F
H/X Orientation (1)	Hor	Hor	Vert.	Vert.	Vert.	Vert.
H/X Location (2)	Int	Ext	Int	Int	Ext	Ext
Platform Config. (3)	Cat	Cat	Cat	C.S.	Cat	C.S.
Length (O.A.) (feet)	700	660	600	560	600	560
Beam (O.A.) (feet)	160	160	160	560	140	560
Depth (to upper level) (feet)	140	70	220	240	100	190
Δ Light ship (L.T.)	306,000	259,000	250,000	210,000	221,000	202,000
Sea Water in Systems (L.T.)	197,000	148,000	165,000	103,000	197,000	82,000
Ballast (L.T.)	324,000	153,000	371,000	444,000	167,000	56,000
Δ Operating (L.T.)	827,000	560,000	804,000	757,000	585,000	340,000
Acquisition Cost(\$ M)	1,086	918	889	820	761	729
Facilities Improvement Costs (\$ M)	0	0	0	0	0	0
Schedule (Yrs.)	7	7	7	6	7	6

(1) Hor = Horizontal Vert = Vertical
(2) Int = Internal Ext = External
(3) Cat = Catamaran C.S. = Column Stabilized

FIGURE 3.3-1

FIGURE 3.3-2

FIGURE 3.3-3

FIGURE 3.3-4

FIGURE 3.3-5

FIGURE 3.3-6

3.3.2 Hull Material/Configurational Trade-Off Studies (Continued):

Steel, all configurations	\$2500/LT
Concrete, column stabilized	\$ 265/LT
Concrete, catamaran	\$ 250/LT

All other Platform System costs are duplicated from Section 2.3.2.

Construction Schedule - In addition to the variation in unit costs, it is anticipated that various combinations of material and configuration will require different amounts of time to construct. The following construction times are assumed:

Steel, column stabilized	- 6 years
Steel, catamaran	- 7 years
Concrete, column stabilized	- 7 years
Concrete, catamaran	- 8 years

A sensitivity study performed to evaluate the impact which these assumptions have on the FOM, indicates that an increase of 20 percent in the unit cost of concrete results in approximately a one percent decrease in the FOM, and a one year extension of the construction time results in a six percent reduction in the FOM.

The results of the FOM analysis assuming a ten percent rate of return are presented in Table 3.3-3 for the twelve alternatives considered. As in the case of the ship platform, the significantly higher FOM values for alternatives E and F demonstrate the advantage of externally mounted vertical heat exchangers. The column stabilized configurations are consistently ten to fifteen percent higher than the similar catamaran configuration. This conclusion reflects the advantage gained from the elimination of essentially all internal runs of seawater circulating piping which can be achieved using the column stabilized configuration. The resulting arrangements have consequentially superior volumetric efficiency characteristics.

Again the steel/reinforced concrete comparison does not seem to be conclusive, especially for the more volume efficient platforms. Once again the constructability and risk aspects favor steel. The complicated nature of several of the column-truss-cross structure joints and the high loads to be

TABLE 3.3-3
FIGURES OF MERIT-HULL TRADE-OFF STUDIES-SEMI-SUBMERSIBLE

OPTION	A	B	C	D	E	F
H/X Orientation (1)	Hor	Hor	Vert	Vert	Vert	Vert
H/X Location (2)	Int	Ext	Int	Int	Ext	Ext
Platform Config. (3)	Cat	Cat	Cat	CS	Cat	CS
FOM 3200 MW Park						
Steel	2.366	2.811	2.841	2.228	3.316	3.662
Concrete w/ facilities	2.545	2.703	2.941	3.416	3.157	3.679

1. Hor = Horizontal, Ver = Vertical
2. Int = Internal, Ext = External
3. Cat = Catamaran, C.S. = Column Stabilized

3.3.2 Hull Material/Configurational Trade-Off Studies (Continued):

supported by these joints makes the feasibility of the application of concrete to these areas dubious.

Based on these conclusions, Alternative F has been selected as the baseline conceptual design.

3.3.3 Cold Water Pipe

The selection of the CWP configuration for the Semi-Submersible is simplified by assuming the result of the CWP material trade-off studies presented in Section 2.3.4 is valid for the Semi-Submersible. Having selected mild steel, the dynamic bending stress values determined for various diameter and thickness combinations are presented in Figure 3.3-7. For comparison with the ship, the curves from Figure 2.3-11, are also presented in Figure 3.3-7. It is evident from these curves that in the vicinity of the a thickness of 0.1 feet and for diameters greater than approximately 90 feet, there is no appreciable difference between the anticipated stress in the CWP for the ship and the Semi-Submersible. Without further investigation this similarity can only be attributed to the interaction of the hydrodynamics of the hull and the dynamic structural response of the CWP. The effect which this has on the resultant CWP design is demonstrated in Figure 3.3-8. As shown in this figure, the minimum weight CWP for the two platforms coincide at a diameter of approximately 100 feet. For this reason the conceptual design of the CWP for the Semi-Submersible is unchanged from the design recommended for the Ship design.

3.4 Platform Integration

3.4.1 Arrangements

The arrangement of the 400 MW(net) column stabilized Semi-Submersible OTEC platform which evolved from the baseline configuration selected in Section 2.3 is shown in Figures 3.4-1 and 2 and in more detail in Appendix B. A summary of principle characteristics is presented in Table 3.4-1.

FIGURE 3.3-7

FIGURE 3.3-8

FIGURE 3.4-1

400 Mw SEMI-SUBMERSIBLE, ELEVATION

FIGURE 3.4-2

400 MW_e SEMI-SUBMERSIBLE, PLAN VIEW

3.4.1 Arrangements (Continued)TABLE 3.4-1PRINCIPAL CHARACTERISTICS OF 400 MW (net)
SEMI-SUBMERSIBLE OTEC PLATFORM

Length/Beam Overall	436 ft (132.9 m)
Depth (Bottom of Columns to Upper Level of Platform)	328 ft (100 m)
Draft (To Bottom of Hull)	215 ft (64.01 m)
Platform Dimensions	270 ft x 270 ft (82.3m x 82.3m)
Operating Displacement	450,000 Lt (457221 mt)
Maximum Diameter of Column	100 ft (30.48 m)
Principal Hull Material	Mild Steel
Cold Water Pipe System	
Inside Diameter	100 ft (30.48 m)
Material	Mild Steel
Connection	Pinned (Zero Rotational Stiffness)
Power System	
H/X Rating	65 MW (gross) (nominally 50 MW(net))
H/X Type	Externally Mounted, Vertical
Working Fluid	Ammonia

The arrangement reflects an attempt to preserve the maintenance and operational philosophies identified for the ship by providing the same combination of desirable features. The following paragraphs present a description of the consolidation of these features into a functional, workable arrangement within the constraints of the general configuration of the baseline design.

Similar to the ship, the Semi-Submersible is composed of four identical quadrants, each supporting two 50 MW (net) units. The depth of each column is driven by the location of the evaporator inlets with sufficient submergence to avoid emersion. The diameters of the lower sections of the columns are driven by dimensions of required equipment and structural considerations. The upper portion of the columns are sized to allow removal of the turbine or generator. The spacing of the four columns provides sufficient room for efficient interface of the cold water distribution piping with the CWP.

Generally, the Power System equipment is contained in the columns between the heat exchangers to minimize the length of ammonia piping runs.

3.4.1 Arrangements (Continued)

Major Seawater System equipment, with the exception of chlorinators and pump motors, is located external to the structural envelope of the columns. Power conditioning equipment is arranged over the lower level of the cross structure to allow a consistent flow from the generators to the transmission bus via the various power conditioning transformers. As with the ship, a centrally located attachment for the riser cable is assumed. Individual features unique to the Semi-Submersible are discussed in the following paragraphs.

Unlike the Ship, the sea water circulating pumps are located downstream of the heat exchangers. Possible difficulties with this arrangement are discussed in Section 3.9. This configuration is compatible with the column stabilized arrangement, and the simplified hydraulic flow of the sea water acts to offset the potential difficulties. Maintenance of the sea water pump motors must be performed in position because of the inconvenience of providing removal accesses through the spaces located immediately above. Withdrawal space for the rotor is, however, provided vertically adjacent to each motor.

It is assumed that maintenance of the demisters will have no impact on area volume requirements.

Provision for maintenance of all remaining power and sea water system equipment is accomplished by a series of hard patches installed in each deck above Deck F of the columns. Withdrawal through the main deck is accomplished using a single 200 ton gantry crane. Access by this crane to each of the four columns is provided by a system of rails and turntables as described in Section 3.8.4. This crane also provides service to the power conditioning equipment, emergency/S.S. diesel generators, and replenishment hatches located on two sides of the platform. Typical access envelopes for most major pieces of equipment are illustrated in Appendix B.

A heat exchanger deployment scheme similar to the method described for the ship could be applied to the Semi-Submersible to facilitate removal and replacement of heat exchangers during the life of the platform. The platform deployment sequences outlined in Section 4.2 does not, however, rely on this feature for initial deployment of the platform.

3.4.2 Hullform

The selection of the Semi-Submersible for development of the OTEC Commercial Plant Conceptual Design reflects the favorable motions characteristics inherent in hull forms of this type. By reducing waterplane area and at the same time providing a significant waterplane moment of inertia, the wave generated exciting forces are minimized without a corresponding reduction of righting arm. Although the particular design presents a sizeable underwater area to the orbital velocity components of the waves, the damping and added mass effects of all of the externally mounted equipment combine to a result in reduced platform response to the seastates encountered. Semi-submersible motions are summarized in Section 6.

3.4.3 Manning

No significant variation from the manning levels developed for the Ship, presented in Section 2.4.3, are anticipated for the Semi-Submersible. An identical crew of 57 men is therefore recommended.

3.4.4 Weights

Weights for each Work Breakdown Structure (WBS) element of the Semi-Submersible were developed to the same level of detail as the corresponding WBS elements for the Ship. A general discussion of the procedures used to estimate the individual line item weights is presented in Section 2.4.4. A one digit summary of the detailed weight report presented in Appendix E, appears below in Table 3.4-2.

$$\frac{dBM}{dT} > .0$$

3.4.5 Stability

The intact metacentric height for the arrangement presented in the preceding sections is approximately 18 feet. Although this figure is not excessive, it is typical of offshore drill rigs.

A damaged stability analysis of the Semi-Submersible indicates that flooding of the two compartments adjacent to the waterline does not result in loss of the platform. The extent of flooding and resultant trim is depicted in Figure 3.4-3. Further analysis indicates that damage of the turbo-generator

TABLE 3.4-2

WEIGHT SUMMARY FOR
400 MW (net) OTEC SEMI-SUBMERSIBLE PLATFORM

WBS	DESCRIPTION	WEIGHT	
		(L.T.)	(M.T.)
1.0	Platform System (Note 1 and 4)	317600	322600
2.0	CWP System	25000	25400
3.0	Power System (Note 2)	71900	73000
4.0	Energy Transfer System	2200	2200
	Light Ship W/O Margin	416700	423200
	Margin (Note 3)	33600	34100
	TOTAL LIGHT SHIP DISPLACEMENT	450300	457300
	Load Stems	1000	1000
	TOTAL OPERATING DISPLACEMENT	451300	458300

- NOTES: 1) Includes permanent ballast, water in pumps and water in piping between pumps and heat exchangers as well as between heat exchangers and inlets
- 2) Includes water in heat exchangers and ammonia in power logs and storage
- 3) Includes 10 percent on light ship except ballast
- 4) Permanent ballast consists of sand added to the lower cross structure after deployment. Total ballast weight is approximately 81000 long tons

FIGURE 3.4-3
DAMAGED WATERLINES FOR 400 MW SEMI-SUBMERSIBLE

WL₁ NORMAL OPERATING WATERLINE

WL₂ DAMAGED WATERLINE

DAMAGED VOLUME FOR WL₂

WL₃ LOSS OF CWP WATERLINE

3.4.5. Stability (Continued)

compartment results in sinkage and trim values sufficient to immerse the main deck and lead to progressive downflooding of additional compartments and the consequent loss of the platform.

It is conceivable that some of the large amount of fixed ballast could be contained in such a manner that it could be jettisoned to counteract the effects of asymmetric flooding, but this should be considered only to correct flooding which has already been contained, and should not be relied upon to meet any stability after damage requirements.

Because of the small waterplane area, the loss of the CWP results in a considerable decrease in draft. This exposes the larger diameter position of the columns, thus increasing the waterplane moment of inertia and the metacentric height.

3.5 Semi-Submersible Structure

3.5.1 Structural Design

The structural design of the OTEC Semi-Submersible configuration, varies somewhat from that of the Ship although the same general design techniques are used. Actually, the Semi-Sub design involves three separate design phases; namely the column-leg design, the lower box girder cross-structure design, and the upper platform/deckhouse design. The ABS Rules dealing with offshore mobile drilling units serves as a guide for specific design problems (Reference (11)).

The column-legs of the platform house the power generation equipment. Like the Ship, the columns are designed for primary (wave-induced) and secondary (hydrostatic) stresses; however, for the column-legs the primary stress is considered in terms of axial strength instead of longitudinal strength. The lower box girder cross-structure is designed to tie the four column-legs together thus providing torsional strength. The box girder is designed for a combination of five (5) loadings. These loadings are:

1. Vertical acceleration of the CWP.
2. Weight of box girder and ballast.
3. Strut loads on box girder center span.
4. Moment induced in box girder by the struts.
5. Lateral "pinching" due to wave action on columns.

Hydrostatic loadings on the box girder are not considered since the box girder is assumed to be flooded.

The upper platform is 270 ft. square and is supported at each corner by the column legs. Trusses with 170 and 270 ft. spans are used to support the deck structure. These trusses are designed to a load of 300 lb/ft.² which is based on the weight of power conditioning equipment, and it is assumed that no lateral loads are transferred from the column-legs to the upper platform since they are taken out by the struts.

3.5.2 Longitudinal Strength

As stated earlier, the primary stresses of the column legs are treated in terms of axial strength. With the ship hull, wave-induced moments are caused by differences in weight and buoyancy; however, bending moments on

3.5.2 Longitudinal Strength (Continued)

the semi-sub columns are caused by wave-induced pressure differences along the length of the column. Maximum bending moments occur at about 105 Ft. below the top of the column and at the point where the neutral axis of the box girder intersects the column. While these moments are rather high (Max. moment = 222,850 Ft.-Tons) the axial (longitudinal) stresses are low because of the large cross-sectional area of the columns. The maximum axial stress is 5.5 TSI with an average stress of about 2.3 TSI.

The loading on the lower cross-structure can be treated as a longitudinal strength problem. In this case, the box girder has primary stresses in two directions. Lateral loading due to "pinching" produces the highest primary stress of 6.7 TSI; while vertical loads cause a primary stress of 2.6 TSI. The box girder also has an axial compressive load of 0.98 TSI; thus the total primary stress on the box girder is 10.2 TSI. The box girder is also designed for a secondary stress of 1.8 TSI due to local panel loading of the ballast material.

3.5.3 Structural Configuration

The column-legs are designed to a damage head of 256 ft. above the baseline, 46 feet above the normal waterline, based on damage that would be caused by a typical offshore workboat. This damage head indicates that at lower sections stresses due to hydrostatic loading greatly exceed the primary stresses of the columns.

Structurally, the platform columns are very similar to the ship-hull configuration. Circumferential ring frames replace the deep transverse frames, and column decks are equivalent to the transverse bulkheads of the ship. Axial stiffeners are used between ring frames to support the shell plating. Ring frames are designed to carry circumferential compression and act as supports for axial stiffeners; the ring frames are spaced on about 10-12 ft. centers. All column decks above the turbo-generator level are designed to be watertight; the turbo-generator deck and all decks below that level are designed for equipment loadings only. Designing lower decks for watertightness would result in a cumbersome structure. Deep girders transfer deck loads to the shell ring frames, and in addition, stanchions are used to give intermediate support.

3.5.3 Structural Configuration (Continued)

The box girder cross-structure is a very complicated structure. Its purpose is to connect the four platform columns together as well as to support the CWP. As stated earlier the box girder is designed for five loading conditions. Each box girder is 29 ft. by 90 ft. with a average length of 46.4 ft., and the box girder flares to a width of 36 ft. at the intersection of the two box girders to compensate for the high bending moment at that point. The outer shell plating is supported by transverse and longitudinal deep web girders along with intermediate stiffeners. Six swash bulkheads are provided to support the deep web girders. Each box girder has three (3) bulkheads, and a centerline bulkhead extending from the internal column bulkheads is designed to carry the compressive loading and provide shear continuity. The two outer bulkheads, each 4 ft. from the outer shell, are furnished to provide additional strength for lateral bending. Two decks are also provided to resist vertical bending.

The upper platform is a grid structure with truss members acting as the major grid elements. The trusses are 38 ft. deep with spans of 170 and 270 ft. The upper and lower chord members of trusses are box-shaped and are designed to carry the bending stresses of each truss. Diagonal truss members are composed of both box and rolled sections. Diagonal truss members are designed to handle shear stresses. Locally, deck plating is supported by a grid system of T-shaped sections.

Like the ship configuration plating sizes are rather large. Shell plating of the columns has a average thickness of 1.00 inch, while the column decks have an average size of 0.75 inches. Shell plating on the box girder ranges between 1.25 and 1.38 inches. The trusses of the upper platform have a unit weight of 3720 lbs./ft. Plating for the two decks of the upper platform is 1.00 inches with 0.25 inch plate used for side plating. See Appendix C for the Semi-Submersible structural drawings.

3.6 Position Control

Refer to Section 2.6 since that discussion refers to both the Ship and Semi-Submersible.

3.7 Platform Service System

3.7.1 Auxiliary Electrical Subsystem

The auxiliary electrical system for the Semi-Submersible is almost identical to that for the ship, as the ship's service and emergency electrical loads are almost identical. The reader should refer to Section 2.7.1 for a description of the ship auxiliary electrical system, which also applies to the semi-submersible auxiliary electrical system.

3.7.2 Fluid and Gas and Environmental Control Subsystems

The fluid and gas and environmental control subsystems on the Semi-Submersible are, for the most part, similar to those on the Ship. In some cases equipment numbers, capacities, discharge pressures, arrangements, etc., are different to suit the arrangements on the semi-submersible, but the system design philosophies remain the same. Equipment characteristics are described in the Semi-Submersible List of Machinery, Appendix D., and brief system descriptions are provided below.

3.7.2.1 Fire Detection and Extinguishing System

The Semi-Submersible fire detection and extinguishing system is similar to that of the Ship, described in Section 2.7.2.1. The major difference is that 300-100 lb. CO₂ cylinders are provided in the Semi-Submersible central CO₂ bank in the deckhouse, due to the large spaces in each column served by the bank.

3.7.2.2 Ventilation Systems

The Semi-Submersible ventilation systems are similar to those of the Ship, described in Section 2.7.2.2.

3.7.2.3 Air Conditioning System

The Semi-Submersible air conditioning system is similar to that of the Ship, described in Section 2.7.2.3.

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3.7.2.4 Ship's Stores Refrigeration System

The Semi-Submersible ship's stores refrigeration system is similar to that of the Ship, described in Section 2.7.2.4.

3.7.2.5 Plumbing Drains, Deck Drains and Scuppers

These systems for the Semi-Submersible are similar to those for the Ship, described in Section 2.7.2.5.

3.7.2.6 Vents, Overflows, and Sounding Tubes

These systems for the Semi-Submersible are similar to those for the Ship, described in Section 2.7.2.6, except no provisions for ballast tanks are provided, as the Semi-Submersible has no liquid ballast.

3.7.2.7 Emergency Drainage System

The emergency drainage system consists of 8-350 gpm @ 80 psig pumps, two located in each column. Each column has an independent drainage system consisting of a vertical loop with a primary and back-up drainage pump and a priming unit for both pumps. No cross connections between columns is provided. Provision is made to utilize the pumps to pump seawater into the machinery spaces to dilute large ammonia spills. A description of the bilge stripping system which would be routinely (non-emergency) used to pump bilges is provided below in a separate paragraph (Section 3.7.2.12).

3.7.2.8 Firemain and Flushing System

The system consists of 4-200 gpm firepumps, one located in each column. The pumps are cross-connected via risers through the upper and lower cross structures. The system provides each column and the upper cross structure with firemain and flushing water.

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3.7.2.9 Fresh Water Systems

Distilling Plants

The distilling plants on the Semi-Submersible are identical to those on the ship (Section 2.7.2.9), with the distilling plants and their associated piping located entirely above the waterline with the potable water storage tanks. The distiller feed pumps are located in one of the columns to supply seawater to the plants.

Potable Water Systems

The Semi-Submersible potable water systems are similar to those on the Ship, described in Section 2.7.2.9. The cold potable water system is primarily located within the deckhouse with branches from the main extending into the machinery spaces of each column. The system consists of two 3200 gallon potable water tanks located topside, two 20 gpm @ 30 psig potable water pumps and the associated bromine system.

The hot potable water system is primarily located within the deckhouse with branches from the main extending into the machinery spaces of each column. The system consists of a 200 gallon hot water accumulator tank supplying two hot water system loops each equipped with a 5 gpm @ 15 psig hot water circulating pump.

3.7.2.10 Fuel Oil Systems

The Semi-Submersible fuel oil systems are similar to those of the Ship, described in Section 2.7.2.10.

3.7.2.11 Compressed Air Systems

The Semi-Submersible compressed air systems are similar to those of the Ship, described in Section 2.7.2.11.

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3.7.2.12 Pollution Control System

Oily Waste System

The oily waste system consists of 4 oily waste holding tanks (one per column), 8 bilge stripping pumps (two per column), 8 oil water separators (two per column), 4 waste oil tanks (one per column), 8 oily waste transfer pumps (two per column), and 2 contaminated oil settling tanks. The two 50 gpm @ 60 psig bilge stripping pumps (rotary sliding vane) in each column are used to strip oily bilge water from the machinery spaces and transfer this waste to the oily waste holding tank in each column. This oily waste is processed by the oil water separators, with clean water being pumped overboard and the concentrated oil being transferred to the waste oil tank. The waste oil is then held for pickup by the service ship, or used in the platform's incinerator, with the oily waste transfer pumps being used to transfer the oil. No cross connections between columns is necessary since each system is totally independent of the other columns. The contaminated oil settling tanks are used to settle out contaminated fuel from the fuel oil transfer and service systems. After the fuel has settled the water may be stripped overboard and the fuel returned to the fuel oil storage tanks.

Sewage Treatment System

The sewage treatment system consists of a Type II Marine Sanitation Device (MSD) and two sewage transfer pumps which will handle all soil waste and gray water drains. The soil waste may also be transferred to the platform's incinerator for processing.

Solid and Chemical Waste System

The solid and chemical waste system consists of 2 garbage grinders in the scullery, 1 trash compactor, and 1 trash and garbage (and sewage, if required) incinerator.

3.7.2.13 Auxiliary Seawater Systems (Power System Support)

The Semi-Submersible auxiliary seawater service systems are similar to those of the ship, described in Section 2.7.2.13.

3.8 Outfit and Furnishings

In general, this area is identical to that for the Ship because of the similarities in requirements. Only the differences are addressed below; therefore, for a complete discussion refer to Section 2.8.

3.8.1 Personnel Support

See Section 2.8.1

3.8.2 Lifesaving

The equipment requirements are the same as those for the Ship, the only differences being in the location of the equipment on the platform. The two twenty-eight man survival capsules are located on opposite sides of the upper cross structure upper level on cantilevered platforms, and can be lowered into the water by davits. The two ten-man life rafts are also located on opposite sides of the cross structure upper level but on the sides not occupied by the survival capsules. The rescue boat is stowed inside the upper cross structure on its lower level near the edge of the platform and can be lowered into the water through the use of a high speed hoist.

3.8.3 Platform Support

See Section 2.8.2

3.8.4 Material Handling

The configuration of the Semi-Submersible dictates material handling equipment configurations and routes that differ significantly from the Ship. The emphasis in this case is on the vertical movement of equipment and personnel, and the limited deck area found in the columns require a different approach towards equipment maintenance.

- o Air to Sea - A helicopter landing area equal in capabilities to that on the Ship is located on the upper level of the upper cross structure.

3.8 Outfit and Furnishings (Continued)

3.8.4 Material Handling (Continued)

- o Sea to Sea - Mooring stations are provided on two of the diametrically opposed column legs to allow for personnel and light material transfer. They consist of landing stages cantilevered out from the legs far enough to keep conventional offshore supply boats from contacting the columns' sides and have access to the interior of the columns via watertight doors.

Material too heavy to hand carry aboard will be lifted on by the 200 ton capacity gantry crane via one of two access openings that extend through the entire height of the upper cross structure. These openings are sized to accept the most dimensionally restrictive piece of equipment that would be expected to be transhipped from the platform (a complete main generator), and are positioned such that a vessel with sufficient deck area could tie up stern to directly below either one.

- o Intra-Platform - The major intra-platform materials handling will be done using the rail-mounted gantry crane that can access almost any portion of the OTEC Plant through either hatches or hard patches. The crane travels along the periphery of the upper cross structure on a system of rails and turntables and if necessary the inner outrigger can be supported by a temporary pylon to allow power conditioning equipment to be lifted out. This type of arrangement was selected because it permits the use of only one crane of a relatively small main span to serve the entire platform and was considered a more cost effective approach than either one crane spanning the entire platform or two cranes running on parallel tracks. It should be noted that the gantry has a capacity of 200 long tons; whereas, the one for the Ship is rated at 150 long tons. The extra capacity is required to lift the main generators, the heaviest single piece of Power System equipment, from the columns in the event major maintenance is required since adequate room for rotor removal in place does not exist. Personnel/equipment elevators are fitted in

3.8 Outfit and Furnishings (Continued)

3.8.4 Material Handling (Continued)

each one of the columns for rapid and convenient access, especially for the roving watchstanders. Equipment interference prohibits a single elevator shaft running the entire height of the platform; therefore the trip is made in three separate segments.

Chain hoists and overhead rail cranes are found in each of the major machinery areas of the Plant to allow local teardown of equipment or transferral of smaller items to the elevators. In addition, forklift trucks are used for stores handling on the upper deck of the cross structure.

3.8.5 Navigation and Communication

See Section 2.8.5.

3.8.6 Biofouling and Corrosion Control

See Section 2.8.6.

3.9 Seawater System

3.9.1 Warm Water System

3.9.1.1 General System Description

The warm water system for each 50MW module consists of a warm water pump suspended below the column (refer to the arrangements of Appendix B) taking suction through a truncated conical inlet screen and the evaporator and discharging through the combined warm and cold water discharge diffusers for each column back into the ocean, below or near the bottom of the mixed layer, depending on the season. Total head losses for the warm water system are similar to those for the ship, described in Section 2.9.1.1.

3.9.1.2 Inlet Configuration

Description - The inlet configuration for each warm water system consists of a truncated conical inlet screen fastened to the 55 ft diameter inlet pipe above each evaporator (see Appendix B). A 52 ft. long inlet pipe is provided between the inlet screen and evaporator so that the warm water inlet is no deeper than 60 ft below the surface, thus preserving the thermal resource. The design criteria for the inlet screen size, shape, and material selection are identical to the criteria utilized for the ship warm water inlet screen, and are described in Section 2.9.1.2. Provisions for screen cleaning are similar to those for the ship inlet screen, and are also described in Section 2.9.1.2.

Alternative Configurations - The alternative configurations considered for the Semi-Submersible warm water system screens are similar to those considered for the Ship warm water screens, except that traveling screens would have been even more impractical for the Semi-Submersible, due to the greater submergence of the Semi-Submersible warm water system. The reader is invited to refer to Section 2.9.1.2 for a discussion of these alternatives.

3.9 Seawater System (Continued)

3.9.1.2 Inlet Configuration (Continued)

Recommendations for Additional Studies - The additional studies recommended for the Semi-Submersible warm water systems are similar to those recommended for the Ship, described in Section 2.9.1.2.

3.9.1.3 Warm Water Pump

The warm water pumps utilized for the Semi-Submersible are similar to those used on the Ship, described in Section 2.9.1.3. The major difference is that the Semi-Submersible pumps pull water through the evaporators, away from the pump driver, which places the drive shaft in compression. The pump size, weight, cost and performance characteristics remain unchanged, however, and the description of the pumps, along with the alternative configurations considered and the additional studies recommended, are well described by Section 2.9.1.3.

3.9.1.4 Warm Water Piping/Evaporator Connections

The warm water piping and evaporator/pump connection on the Semi-Submersible were designed to minimize thermal resource loss, head loss, and pump inlet turbulence, while maintaining as compact an arrangement as possible.

3.9.1.5 Discharge Configuration

The warm water system discharge configuration consists of a combined warm and cold water discharge diffuser for each column. The diffuser is 60 ft long and 103 ft in diameter at the discharge end and is designed to minimize total discharge head losses (combined exit, frictional, and transition losses).

3.9.1.6 Biofouling and Corrosion Control

The Semi-Submersible biofouling and corrosion control systems are similar to those provided for the Ship, described in Section 2.9.1.6.

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3.9 Seawater System (Continued)

3.9.2 Cold Water System

3.9.2.1 General System Description

The cold water system for each 50MW module consists of a cold water pump taking suction from the common cold water inlet plenum at the top of the cold water pipe (refer to Appendix B), through the condenser and discharging through the combined warm and cold water discharge diffuser for each column back into the ocean below or near the bottom of the mixed layer, depending on the season. Total head losses for the cold water system are similar to those for the Ship, described in Section 2.9.2.1.

3.9.2.2 Inlet Configuration

The Semi-Submersible cold water inlet configuration is identical to that provided for the Ship, described in Section 2.9.2.2.

3.9.2.3 Cold Water Pipe

The cold water pipe delivers 48,000 cfs of cold water from the ocean depths through the inlet screen and to the cold water inlet plenum. The cold water pipe is 100 ft in diameter and 3000 ft long. Section 3.10 provides a detailed description of the pipe structure and hull connection, and Section 3.3.4 describes the numerous trade-off studies conducted to optimize pipe diameter, length, etc. The hydraulic impact of the cold water pipe is minimal; of the total cold water system head loss of 12.4 ft, the cold water pipe (including transition and plenum losses) accounts for only 0.2 ft.

3.9 Seawater System (Continued)

3.9.2.4 Cold Water Pump

The cold water pumps utilized for the Semi-Submersible are similar to those used on the Ship, described in Section 2.9.2.4. The major difference is that the Semi-Submersible pumps pull water through the condensers, away from the pump driver, which places the drive shaft in compression. The pump size, weight, cost, and performance characteristics remain unchanged, however, and the description of the pumps, along with the alternative configurations considered and the additional studies recommended, are well described by Section 2.9.2.4.

3.9.2.5 Cold Water Piping/Condenser Connections

The cold water piping and condenser/pump connection on the Semi-Submersible, were designed to minimize head loss and pump inlet turbulence, while maintaining as compact an arrangement as possible.

3.9.2.6 Discharge Configuration

The cold water system discharge configuration consists of a combined warm and cold water discharge diffuser for each column. The diffuser is 60 ft long and 103 ft in diameter at the discharge end and is designed to minimize total discharge head losses (combined exit, frictional, and transition losses).

3.9.2.7 Biofouling and Corrosion Control

The Semi-Submersible cold water biofouling and corrosion control systems are similar to those provided for the Ship, described in Section 2.9.2.7, with the following difference:

- 1) The chlorine rich seawater is injected into the cold water by a piping distribution network at each module's connection to the plenum.

3.10 Cold Water Pipe

As discussed in Section 3.3.3, the Cold Water Pipe conceptual design for the Semi-Submersible is identical with the CWP designed for the Ship, except for the fact that the circular cross section continues to the top of the pipe since the cold water plenum is round instead of elliptical. Although minor weight savings may be possible in the area at the joint, their impact on total system costs is negligible. The potential increase in structure required for the Ship CWP as discussed in Section 2.10.1, does not effect the structural design presented for the Semi-Submersible.

3.11 Power System

The suite of Power System Components is independent of the platform configuration; therefore, the Power System required for the Semi-Submersible is identical to that required for the Ship as described in Section 2.11.

3.12 Energy Transfer System

The suite of power conditioning equipment and the riser cable are independent of the platform configuration, therefore the Energy Transfer System required for the Semi-Submersible is identical to the system described in Section 2.12.

4. TASK VI FACILITIES AND EQUIPMENT

4.1 Introduction

This section reviews the methods proposed for building and deploying the 400 MW ship and Semi-Submersible to be sited off the island of Hawaii, about 2200 NM from the West Coast of the Continental United States. A number of assumptions have been made relative to the philosophy of construction and deployment which are summarized below:

1. Construction of main platform modules in West Coast shipyards. East or Gulf Coast yards are available and have somewhat lower construction costs, but the total tow from say the Gulf Coast to Hawaii via the Panama Canal is about 6300 NM versus 2200 from a West Coast facility. This would add several million dollars to the cost of deployment and severely restrict the size of modular components based on Panama Canal dimensions.
2. Construction in existing facilities, to avoid the high cost of modifying or building a special facility to suit the large size and unusual proportions of the two platforms under consideration. This means that platform modules must suit the following limits, based on the Task II A studies:

<u>Facility</u>	<u>Capabilities</u>	<u>Limiting Dimensions (Ft.)</u>		
		<u>Length</u>	<u>Width</u>	<u>Sill Height</u>
Bethlehem Steel Corp., San Francisco Yard	Repair	900	148	39.5
National Steel and Shipbuilding Co., San Diego	Construction	1000	176	27
Triple "A" Machine Shop, Inc. Hunters Point, Calif.	Repair	1092	143	50.3

3. Towing of the largest modular component permitted by West Coast facilities to sheltered waters either adjacent to the yard or on-site at Hawaii for assembly into a complete platform.
4. Maximum preoutfitting prior to leaving the yard.

4.1 Introduction (Continued)

5. Maximum use of modularity for final assembly on-site or in deep waters, since the cost of doing any operation on-site will be far greater (up to twice) than to perform a similar operation in the shipyard.
6. Assembly of the CWP on-site from prefabricated modules, and deployment after assembly as a unit. The concept of towing a completed CWP of the type being considered as a unit is not considered practical at this time.

Naturally, there are as many ways to perform these operations as there are people addressing the problem, and many alternative approaches probably deserve consideration. During the development of the concepts discussed below, literally dozens of alternatives were brainstormed, but all appeared to have more flaws or risks and fewer benefits than the selected method. This is not to say that there are not better concepts, and the search for better answers to this problem should continue and in fact increase in intensity. However, for the present, the proposed methods are considered viable, and within the state-of-the-art.

4.2 Platform Construction and Deployment-Ship

The hull of the Ship is to be built in two halves split along the center line, resulting in a pair of hull modules 150 feet wide, 85 feet deep and 620 feet long, or about the size of a 150,000 ton tanker. This is well within the existing state-of-the-art, and within the facilities limits cited above for the West Coast. For the purposes of this study the National Steel building dock is used as a control since that yard has the best potential of the three for OTEC plant construction. In order to accomplish this, the ship design incorporates a centerline water-tight cofferdam which acts as a side shell prior to joining the two halves afloat.

A major problem results from the use of external heat exchangers and pumps. In the normal afloat configuration, these appendages hang as much as 60 feet below the bottom of the hull, which precludes their installation during initial construction due to limiting drafts. In order to resolve this problem three options were initially considered as illustrated in Figure 4.2-1:

OPTION 1

Build hull halves in a conventional manner in a building dock with bottom openings sealed off.

Float halves to open water, assemble, remove temporary covers over bottom openings, and add pumps, heat exchangers, and the cold water plenum.

OPTION 2

Build hull halves in a building dock; include pumps, heat exchangers, and the cold water plenum. Additional flotation in the form of a barge is required.

OPTION 3

Build hull halves in a building dock on their sides; include pumps, heat exchangers, and the cold water plenum. Float out to deep water with the aid of a flotation barge and rotate 90°.

FIGURE 4.2-1
SHIP CONSTRUCTION OPTIONS

4.2 Platform Construction and Deployment-Ship (Continued):

- 1) Build the halves of the hull in a conventional manner, and add the bottom appendages after launch. This would involve addition of 16 pumps (8 with warm water inlet filters), 16 heat exchangers and the cold water plenum, a total of 33 components. The time and cost of such an operation was considered excessive, leading to alternative 2:
- 2) Build each half in a building or graving dock with the appendages in place, with the pumps and heat exchangers sealed to provide buoyancy, and additional buoyancy tanks or pontoons provided as required to permit floatout at a 40 foot draft. The total buoyancy available from the pumps, heat exchangers and CW plenum is about 15,000 tons (one half) versus a half light ship with no fluids of 37,817 tons. The cost of the additional buoyancy required to achieve float-out at a 25 foot draft would be both costly and difficult to properly locate for adequate buoyancy and stability. This then led to consideration of Option 3:
- 3) Build each half on its side, with the cofferdam side down, adding the external appendages before launching, and rotate the assembly 90° after float-out. Additional buoyancy would be required both for stability and buoyancy control during rotation.

The advantage of Option 3 is that the heat exchangers and pumps can be added near the end of the building cycle, which is in keeping with the long lead time required for their procurement. It also simplifies the float-out problem as noted above. The disadvantages include the following:

- The heat exchangers and pumps would be suspended as cantilevers prior to rotation, inducing abnormal loads in their structure and attachment; however, these stresses appear acceptable.
- The cofferdam structure would experience higher hydrostatic loads than it would see under normal conditions.
- High transient loads will be experienced during rotation.

4.2 Platform Construction and Deployment-Ship (Continued):

- A very carefully controlled ballasting sequence will be required during rotation to maintain positive control throughout the operation.
- It would be necessary to defer installation of much of the equipment on board until after rotation.

The selection of the optimum approach came about by virtue of a decision to incorporate modular heat exchanger replacement. As noted in the TLR, Appendix A, this is not a DOE requirement. It was intended to leave the heat exchangers in place throughout the 40 year life of the platform; however, several events occurred which changed this concept. First, the arrangement of heat exchangers and seawater ducts does not permit tube withdrawal into the hull. Second, the concept of using nylon or steel reinforced rubber boots for seawater discharge ducts proved uneconomical, thus it became apparent that a rigid discharge would be required, and that they could not be attached during construction in the building dock. This led to the concept of a modular heat exchanger/discharge duct unit which could be installed and, if necessary, replaced with the platform afloat.

On the basis of the foregoing considerations, it was decided to use a variant on Option 2, in which each platform half would be built atop four flotation barges located between the ends of the hull, the warm water pumps, and the CWP plenum. The large barges are 170 feet wide, 130 feet long and 40 feet deep while the small barges are 170 feet wide, 60 feet long and 40 feet deep. The net buoyancy required for one half the ship minus the cranes, deckhouse, and heat exchangers is 37,800 tons. With the addition of ballast necessary for stability at launch the required buoyancy equals 47,200 tons. This will allow a float-out at about a 25 foot draft.

The selected ship construction concept is illustrated in Figure 4.2-2 and reflects the following procedures, for each half of the hull:

1. The dock should be flooded and the barges for the construction of one side of the hull plus those for one half of the other side positioned. Next the dock should be drained, and the portions of the plenums for the half hulls that are to be constructed put into place.
2. Drop in place and weld up major hull modules. Provide temporary shoring as required to prevent excessive loads.

PHASE 1

Flotation barges emplaced and first half hull along with first portion of second half hull fabricated. Pumps and cold water plenum emplaced.

PHASE 2

Flood dock, move completed half hull out, reposition completed portion of second hull half, drain dock, and complete second half. Construction may start on first half of next plant at far end of the dock.

FIGURE 4.2-2
SHIP CONSTRUCTION PROCEDURE

4.2 Platform Construction and Deployment-Ship (Continued):

3. Insert the pumps through their sleeves, align and bolt in place. Weld the plenum to the bottom shell.
4. Proceed with outfitting in the usual manner until the maximum float-out weight is reached.
5. Flood the dock and float out the completed half hull. The other half hull should be at an equivalent point in construction so that it may be moved into the position previously occupied by the portion that was floated out.
6. Drain the dock and complete the remaining half hull. At this time construction could start on the first half of one side of the following platform.

After assembly of the second half of the hull, the units would be towed to deep water and joined together. Two approaches exist for this evolution; the first involves performing the mating procedure after the flotation barges have been removed with the hull halves afloat on their own, while the second has the operation taking place while the units are still on the flotation barges. The second method permits the entire welding operation to take place in air thus simplifying the preparation requirements and enhancing quality control; however, it requires that the centerline of the half hull being constructed in the building dock be coincident or slightly overlap the flotation barge so that the barges will not interfere with the mating process. This in turn would require some modification of the barge proportions given previously to insure that no angle of heel exists at float-out. Both methods are described below.

Method 1 (See Figure 4.2-3)

- 1) Ballast the two units to an even keel and equal draft. Bring them together.
- 2) Join them at the Main Deck using hydraulic linking devices such as those currently used for joining tug-barges.
- 3) Ballast the wing tanks with enough weight to put the linking rods in tension and to force the bottom joint together.
- 4) Install a cofferdam along the centerline. After pumping out and preparation, weld the two halves of the hull together. This

- ① Ballast down and remove flotation barges, align hull halves.
- ② Join hull halves along the main deck using alignment pins and hydraulic jacks. Bring the bottom edges together by ballasting the hull halves.
- ③ Weld halves together, remove jacks.

FIGURE 4.2-3
SHIP DEPLOYMENT PROCEDURE
METHOD 1

- ① Align barges and half hulls by ballasting.
- ② Join hulls and barges using hydraulic jacks and alignment pins; weld hull halves.
- ③ Ballast down and remove flotation barges.

FIGURE 4.2-4
SHIP DEPLOYMENT PROCEDURE
METHOD 2

4.2 Platform Construction and Deployment-Ship (Continued):

would be an extension of current technology used in joining the two halves of tankers afloat using a transverse girth weld.

An option to the above procedure which has not been investigated in detail would eliminate the below-water welding entirely by simply welding the two halves together from the waterline up. In effect this would generate a catamaran with a hull "separation" equal to the width of the cofferdam. The proportions of the hull suggest relatively high transverse and torsional bending, so that this concept must be investigated in greater detail.

Method 2 (See Figure 4.2-4)

- 1) Ballast the flotation barges to approximately align the hull halves.
- 2) Bring the two halves together with the aid of alignment pins and hydraulic linking devices on the barges and main deck.
- 3) Weld the halves together.
- 4) Ballast down and remove the flotation barges leaving the completed hull behind.

A problem that exists with the mating procedure irrespective of the choice of method is the final alignment of the welding surfaces which include the hull plating, interior decks and bulkheads, and transverse stiffeners. Two approaches are used in conjunction to alleviate this difficulty.

The first leaves all the structure in the vicinity of the final weld (in this case inside the cofferdam) reasonably soft so that a relatively precise alignment process can be undertaken just prior to the welding operation. Much of the transverse structure would merely be tack welded in place during fabrication in the building dock and hydraulic jacks and sledges could be used to align it prior to final welding at the deepwater site.

The second utilizes flat bars welded to all plates that form the mating surfaces on one half of the hull as shown in Figure 4.2-5.

4.2 Platform Construction and Deployment-Ship (Continued):

FIGURE 4.2-5

MATING SURFACE CONFIGURATION

This bar would provide a wider surface to weld to thus allowing for any minor misalignments between hull structural components. The potentially large transverse and torsional bending moments that could be present in a hull of these proportions would require a detailed analysis of the permissible degree of misalignment, but the overall concept is believed to be viable.

The final steps would involve final outfitting of the CWP, internal equipment, deckhouse, deck cranes, and finally the heat exchanger/discharge duct units. The latter operation is illustrated in Figure 4.2-6, and involves the following steps:

1. The unit, consisting of a heat exchanger and integral steel discharge pipe with both ends temporarily sealed, would be either towed to the site or barged in and lifted into the water by cranes. Since the dry weight of such a unit would be in the order of 910 tons, the towing concept appears preferable. A third option would utilize a floating dry dock to bring several units to the deployment site.
2. The unit would be "launched" and rotated to a vertical configuration by controlled ballasting of the discharge plenum, until it was close to submergence.

- ① Heat exchanger and seawater discharge pipe is brought to the deployment site.
- ② Unit is floated off and rotated to vertical position.
- ③ Unit is attached to a barge crane and platform gantry crane and is ballasted to a point of slight negative buoyancy. The unit is then winched into position using the gantry, barge crane, and tugs as necessary.

FIGURE 4.2-6
HEAT EXCHANGER DEPLOYMENT

4.2 Platform Construction and Deployment-Ship (Continued):

3. A tether line and bar would be attached to the unit, leading to a winch or the crane on the platform. The unit would be further ballasted until it was slightly negatively buoyant, and would be drawn into position by the tether line. Alignment guides and pins on the platform would result in proper positioning of the unit under the hull. After alignment, the unit would be deballasted to a slightly positively buoyant condition.
4. Crews working in a pressurized chamber would bolt the unit to the hull from within the double bottom as shown on Figure 4.2-6. Temporary plugs could then be removed.

Modular refit would be accomplished by reversing and then repeating this process.

4.3 Platform Construction and Deployment - Semi-Submersible

The Semi-Submersible presents problems similar to those encountered with the Ship since it is too large to be built as one unit in any of the facilities described in Section 4.1. Instead it will be fabricated in four quarters each consisting of one of the column legs, with final assembly including the addition of the upper box structure being done in deep water. Each column will have an overall diameter of approximately 150 ft., including the externally mounted heat exchangers, and a length of 392', including the warm and cold water pumps. This implies that two columns could be built at a time in a given building dock on the West Coast, and allows slightly more flexibility in construction than the ship because of the decreased length. Again as with the ship the construction scheme will be tailored to the National Steel facilities in San Diego.

Actually three approaches were considered for the construction and deployment of the semi-submersible, and they are briefly discussed below:

- 1) Build all four columns and the lower cross structure to the top of lower cross structure; float this unit out; and continue construction vertically on site. While this method is most attractive in that it minimizes the amount of reorientation of the platform, it is infeasible because of the limited building dock widths and depths. Additionally, unacceptable amounts of high priced at-sea construction work is required with this approach.
- 2) Build the four columns individually on their sides in a building dock without the warm and cold water inlet pipes, heat exchangers, pumps, and discharge pipes. Auxiliary flotation would be used where necessary to meet draft restrictions. The four columns would be uprighted and assembled offshore in deep water, the upper cross structure added, and the heat exchangers, seawater piping, and pumps attached. This method does offer some additional flexibility with regard to width and draft during the construction and float out of the four columns, but it results in an excessive amount of offshore construction work especially in the area of pump installation and alignment.

4.3 Platform Construction and Deployment - Semi-Submersible (Continued)

- 3) Build the four columns individually on their sides in a building dock with a maximum amount of pre-outfitting. In this case the heat exchangers, some external seawater piping, and the pumps would be installed prior to floatout, and as a result, extensive floatation aids would be required. The four columns would then be rotated and joined at the operational site and the upper cross structure added.

The third method was finally selected because, although a significant amount of offshore work still exists, it primarily involves a relatively small number of large units being joined at the operational site. At the same time the draft and dimensional restrictions of presently existing drydocks can be met with the aid of reasonably sized floatation pontoons; therefore, since it maximizes the effort that can be accomplished in a building facility, it is felt that this method is the most viable at the present time.

As outlined above, the construction sequence requires the use of a barge approximately 300 feet in length by 160 feet in beam and 35 feet in depth with a maximum draft of 25 feet. This barge would provide a net positive buoyancy of 20,600 tons and enable the column to be floated out of the building dock at a draft of 15 feet. In addition, the barge would have sufficient reserve buoyancy and ballasting capacity to allow the installation of one quarter of the lower cross structure to the column while at an outfitting pier.

The basic construction and deployment sequence of the semi-submersible is depicted in Figure 4.3-1 and 4.3-2 and is described below:

- 1) Emplace the two floatation barges in the building dock to allow simultaneous construction of two columns, and fabricate the columns installing major pieces of equipment including pumps, pump motors, demisters, turbine generators, heat exchangers and discharge pipes.

Fabricate two columns atop the flotation barges in the building dock.

When the columns are completed, flood the dock and move to an outfitting pier where the seawater intake ducts and a quarter of the lower cross structure may be fitted. Maintain zero list on the unit by ballasting the barge. Complete outfitting.

FIGURE 4.3-1
CONSTRUCTION SEQUENCE SEMI-SUBMERSIBLE

4.3 Platform Construction and Deployment - Semi-Submersible (Continued)

- 2) Flood the dock and move the barges to an outfitting pier where the seawater intake piping and screens would be installed. At this time, assemble and attach one quarter of the lower cross structure to each of the columns. The cross structure sections would be cantilevered out over the edge of the barges, and this would require the shifting of ballast to maintain a zero angle of list. At this time the major items of machinery would have temporary bracing installed since the permanent foundations are designed for loadings in a different plane.
- 3) While the first two columns were being outfitted, construction of the second two could commence in the vacated building dock. Additionally, construction of the upper cross structure in modular form could be taking place concurrently with these operations.

Once outfitting has been completed, the columns would be towed to the site off Keahole Point where the deployment process as outlined below would take place. The complexity of the offshore work involved in this effort will require relatively calm sea conditions; therefore, the process will be somewhat dependent on weather conditions with the critical evolutions taking place only during certain "windows". If necessary, some of these critical items could be done at a site other than the actual operational site if the environment there proved too hostile. Preferably this alternate location would be nearby and in the lee of a portion of one of the islands. The relatively short tow of the assembled plant through areas of deep water should present no undue problems if this approach proves necessary.

The deployment sequence is as follows:

- 1) Ballast down the floatation barges and float off the column sections and their associated sections of lower cross structure.
- 2) At this point the lower heat exchanger opposite the lower cross structure would be ballasted rotating the cross structure out of the water. By shifting ballast between heat exchangers the columns could be oriented at the proper angle (45° to the water's surface) to permit welding two sections of the cross structure together.

- ① Ballast down the flotation barges and float off the column legs.
- ② Ballast down heat exchangers to rotate columns in preparation for joining lower cross structure sections. Use jacks and alignment pins to position weld surfaces; weld lower cross structure sections; add portions of upper cross structure trusses to form a unit.

NOTE: UNITS ROTATED
90° FROM VIEW
② ABOVE

Ballast the units in order to rotate them 90°; align the two units using jacks and alignment pins; and weld units together.

Ballast platform down, complete upper cross structure.

FIGURE 4.3-2
DEPLOYMENT SEQUENCE SEMI-SUBMERSIBLE

4.3 Platform Construction and Deployment - Semi-Submersible (Continued)

The sections would be aligned for welding through the use of hydraulic jacks similar to those discussed in Section 4.2 along with cables run between the two columns. At this point one half of the cold water plenum structure would be fitted along with the upper cross structure joining the tops of the two columns.

- 3) Once this work is completed, the sub-assembly consisting of the two columns and half of the lower cross structure would be rotated to the vertical position by controlled ballasting. Once vertical the two sub-assemblies would be positioned at the top, sides, and bottom by jacks, and the welds at the center of the cross structure made. Cofferdams will be required for the underwater portions of the weld, but the extent of the underwater work will be minimized by deballasting the platform once the subassemblies are mechanically joined.
- 4) Attach the CWP (see Section 4.4), ballast the plant to its operating draft, finish assembling the upper cross structure, and complete outfitting. Portions of the upper structure would be brought out to the site in pre-fabricated sections on barges and lifted into place using floating barge cranes, while other sections such as the entire center section of the cross structure could be floated in below their final locations and lifted into place using synchronized winches. The largest section that would require a crane lift would weigh in the vicinity of 2000 tons which, since at least two cranes would be employed, is within the capabilities of cranes presently used in the offshore industry.

Another procedure that eliminates the complex ballasting evolution required to align the quarter sections of the lower cross structure to form the two column subassemblies has been developed. It parallels the one described above with the following exceptions:

4.3 Platform Construction and Deployment - Semi-Submersible (Continued)

- 1) The flotation barges would be only 150 feet in beam and 30 feet in depth, since they would not be required to carry the quarter sections of the lower cross structure.
- 2) The entire lower cross structure would be fabricated in the building facility and towed to the final assembly site at or near the operating site at Keahole Point. The structure could be towed upright from the shipyard to deep water then rotated on its side to minimize the power required for the tow.
- 3) The four columns would be towed to the assembly site, floated off their barges, and rotated to the vertical position. Then through the use of jacking mechanisms, alignment pins, and ballasting, they would be mechanically mated to the lower cross structure. At this time the entire structure would be deballasted to expose as much of the welding surface as possible, permitting a maximum of the welding to be done above water.
- 4) After the welds were made, attach the CWP, ballast the platform down to the operating draft, and proceed with the upper cross structure.

The first method is the preferred one because it minimizes the extent of the underwater work required (two versus eight exterior welds). It is felt that the problems and complexity of subsurface welding make it prudent to espouse alternatives that permit the maximum amount of above water effort.

4.4 CWP Construction and Deployment

The construction of the CWP can be considered in three separate phases: fabrication, assembly, and deployment. Fabrication refers to any shore side work performed to construct sub-assemblies. Assembly refers to the on-site construction of the CWP from the prefabricated sub-assemblies. Deployment is the actual rigging of the completed CWP in position on the platform.

4.4 CWP Construction and Deployment (Continued)

4.4.1 Fabrication

It is anticipated that the entire fabrication process will be accomplished in a shipyard or similar heavy industry facility. The completed sub-assemblies are 50 feet in length and approximately one-eighth of the circumference of the CWP. For a 3000 foot long CWP, 480 such sub-assemblies are required. The details of the CWP configuration and welding arrangement are shown in Appendix C. A proposed sequence for fabrication of the sub-assemblies is presented below:

1. Roll and prepare shell segments, each the full one eighth circumference (approximately 40 feet) and up to 10 feet wide.
2. Perform circumferential welds(double sided) to form a single 40'x50' panel.
3. Locate and weld axial & ring frame backing bars on shell panels.
4. Roll and prepare axial stiffeners.
5. Weld ring frame insert plate and butt backing bar to axial stiffeners.
6. Weld axial stiffeners to panel; two axial welds and one weld along the insert plate will be required. These stiffeners terminate two feet from each end of each panel.
7. Weld ring stiffeners in place.
8. Coat all surfaces with specified coatings.

These sub-assemblies are stock piled and shipped to the site either on barges or on the platform itself.

4.4.2 Assembly

This process must be accomplished on a specially constructed barge as described in Section 4.4.4. This barge has a large notch built into it to allow the CWP to be passed down through the center of the barge, and when completed, slipped out of one side. The actual sequence is presented below:

4.4 CWP Construction and Deployment (Continued)

4.4.2 Assembly

1. Erect one sub-assembly and align with adjacent stiffeners below. Support panel from king posts.
2. Perform two sided circumferential weld.
3. Layout axial stiffener spacer sections and weld in place.
4. Erect, align and support adjacent sub-assembly.
5. Perform two sided vertical butt weld and ring stiffener butt weld.
6. Repeat steps 2 and 3.
7. Repeat steps 4 through 6 until entire 50 foot ring is completed.
8. Area around each weld is prepared and coated.
9. Lower entire 50 foot ring and repeat procedure.

Some modification to this procedure is required to handle the special configurations at the top and bottom of the CWP, but the general approach is the same.

The final section includes the universal joint together with the stock assembly.

4.4.3. Deployment

For deployment all deck mounted equipment on the assembly barge must be removed to an auxiliary barge. A high capacity barge crane (600-800 LT.) is towed to the site. The top of the stock is rigged to both the barge crane and the gantry crane on the completed platform as shown in Figure 4.4.1. Sufficient length of the CWP must be exposed above the assembly barge to prevent interference with the heat exchangers in the deployed condition. Additional control lines to the assembly barge are provided to a minimum of four tugs.

FIGURE 4.4-1
COLD WATER PIPE DEPLOYMENT SCHEME

4.4 CWP Construction and Deployment (Continued)

4.4.3 Deployment

After all connections are made, the CWP/assembly barge unit is ballasted to slightly negative buoyancy and lowered beneath the surface. Positive control is maintained by the crane barge and the gantry crane. The load of the CWP is gradually transferred to the gantry crane as the CWP is moved horizontally under the platform. Compressed air may be used to deballast the CWP/assembly barge unit to neutral buoyancy, once the CWP has been aligned on centerline amidships of the platform. After releasing the line to the crane barge, the CWP stock is then brought into the mating bearing on the ship and secured. The line from the crane barge is connected to the assembly barge using divers or the mini-sub. The mechanical connection between the assembly barge and the CWP is released and the barge is towed out from under the platform, still negatively buoyant; deballasted; and brought to the surface. Control on the barge is maintained throughout the operation by the fleet of tugs.

As a final procedure, the rubber boot is installed by divers, completing the CWP deployment sequence.

4.4.4 Special Facilities and Equipment

Because of the highly uniform and repetitive nature of several of the cutting and welding operations, several specially designed jigs and welding machines are appropriate to the fabrication and assembly portions of the CWP construction sequence. The technology for highly automated ship building procedures is available, although the use of such equipment in U.S. yards is somewhat behind the state-of-the-art at the present time.

In addition to the acquisition of specialized equipment to accomplish individual processes of the fabrication sequence, the construction of the special deployment barge is required for the deployment procedure presented in the preceding section. As described in Section 4.4.3, during the deployment sequence, this barge is ballasted and submerged, but the use of a ballasting system similar to that used on submarines where internal tank and external sea pressures are equalized could reduce the scantlings required.

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4.4 CWP Construction and Deployment (Continued)

4.4.4 Special Facilities and Equipment

The jacking apparatus required during the assembly procedure is not an identifiable off-the-shelf item, but several jack up drill rigs demonstrate the principal. Depending on details of this apparatus, lifting pads or other special fittings may be required on the CWP.

5. TASK VIII COST AND TIME SCHEDULE

5.1 Introduction

The purpose of Task VIII is to define the total cost and construction/deployment schedule for the two 400 MW conceptual designs described in Sections 2 and 3. Within the context of the Task, costs are defined as including the following DOE Work Breakdown Structure elements, as defined in Section 5.2.

- 1.0 Platform System
- 2.0 Cold Water Pipe System
- 3.0 Power System
- 4.0 Energy Transfer System
- 5.0 System Engineering and Integration
- 6.0 System Test and Evaluation
- 7.0 Operational Support
- 8.0 Deployment Systems and Services
- 9.0 Industrial Facilities
- 10.0 Environmental, Legal, Licensing, Regulatory, Insurance
- 11.0 Project Management

Costs are to be defined for these elements in accordance with the following time sequence breakdown:

- Engineering (Preliminary, Contracts, Detail)
- Fabrication/Construction
- Deployment/Installation
- Operation

The schedules are to be broken out in a similar manner, thereby permitting the development of cashflow curves as a guide for long range planning.

5.2 Cost Analysis

5.2.1 Criteria and Assumptions

The following criteria and assumptions define the cost input for each WBS element and the interrelationships between elements, and apply to the cost

5.2.1 Criteria and Assumptions (Continued):

estimating worksheets used in Appendix F.

1. GENERAL

- 1.1. All cost figures are selling prices to the Government in 1978 dollars with no escalation.
- 1.2. Estimates indicated as "B" or "bottom-up" reflect the summation of estimates at lower levels of the WBS. Supporting rationale for such estimates is attached.
- 1.3. Estimates indicated as "P" or "parametric" are assumed allocations reflecting judgement rather than detailed estimating.
- 1.4. All costs are non-recurring unless indicated. All such costs are for the first platform. The effects of learning curves for later platforms are separately considered in Section 5.2.4.
- 1.5. All non-recurring costs which are applicable to all plants in a park are charged against the first plant. These include:
 - Integration/Engineering (WBS 1.1, 2.1, 3.1, 4.1, 5.0)
 - Test Planning (WBS 6.1)
 - Special Test Facilities (WBS 6.2)
 - Common Support Equipment at depot facilities
 - Deployment equipment (floatation devices, special handling equipment, etc. which are not leased for each deployment) (WBS 8.0)
 - Industrial Facilities (WBS 9.0)
- 1.6. All recurring costs are indicated by the symbol (R) which are included as average annual costs over the 40 year life of the plant, with no correction for long-term inflation.
- 1.7. WBS elements which are split between non-recurring and recurring are indicated by double entries in the form, where the non-recurring entry refers to initial installation, and the recurring (R) entry refers to average annual follow-on costs. Items in this category include:

5.2.1 Criteria and Assumptions (Continued):

1.7 (Continued)

- Spare Parts (WBS 7.1)
 - Expendable Materials (WBS 7.2)
 - Labor by embarked personnel is included with Plant Personnel (WBS 7.5.1)
 - Labor by shore-based personnel is included with Support Personnel (WBS 7.5.2) and is amortized over the 8 plants
 - Labor by subcontracting firms (laundry, cleaning, etc. is lumped in with Support Personnel.
 - Material is included under either Support Equipment (tools, etc.) or Expendable Materials (paint, etc.)
- 1.8 Tooling costs are not separately identified since they cannot be distinguished from "material and other" at this point.
- 1.9 A separate cost estimate margin is not identified. All cost values reflect margins added to weights.
- 1.10 Construction labor costs are based on \$20 per hour including fringe benefits, travel, etc. but no subsistence. Corresponding labor costs for deployment are \$40 per hour to include overtime allowances, additional travel, etc.

2. PLATFORM SYSTEM

- 2.1 Platforms are assumed to be of steel construction to commercial standards.
- 2.2 Unit costs reflect prevailing market conditions, proprietary shipyard estimating factors and published data including J. A. Fetchko "Methods of Estimating Investment Costs of Ships".
- 2.3 Hull and structure costs are based on material take off from scantling drawings assuming modular construction in existing facilities with major modules joined afloat.
- 2.4 Position control system includes mooring lines, anchors, winches and fittings. System deployment is included under WBS 8.0.

5.2.1 Criteria and Assumptions (Continued):

- 2.5 Platform Systems includes procurement activity and vendor liaison. Items included in this element are defined in Appendix F.
- 2.6 Assembly support services includes staging, scaffolding, cribbing, utilities, jigs, etc. as well as normal shipyard inspection. Owner inspection services are included in WBS 11.4, Quality Assurance.
- 2.7 Seawater Systems include all shipyard-furnished or owner-furnished items related to the OTEC seawater loop except the heat exchangers, CWP, and corrosion control, which is included in WBS 1.8 as part of the overall platform system.
- 2.8 All platform system costs reflect estimated weights including margins.

3. COLD WATER PIPE

- 3.1 The CWP is of steel construction, with a flexible connection at the top. It is fabricated at the deployment site from major subassemblies pre-fabricated at the shipyard and transported to the site onboard the platform. All activities after departure from the shipyard are included under Deployment, WBS 8.0.
- 3.2 CWP Flotation is included under Deployment, WBS 8.0, since it is used only for the deployment process.
- 3.3 CWP biofouling and corrosion control are included with the platform, WBS 1.8.

4. POWER SYSTEMS

- 4.1 This element includes only the cost of installing power system equipment. Material costs are not included for any sub-elements under WBS 3.0.
- 4.2 Biofouling and corrosion control includes only the installation of chlorinators. Tube cleaning systems (Amertap or equal) are not addressed pending input from DOE on system requirements.
- 4.3 The start-up system is installed on a separate barge and is included under Facilities, WBS 9.0, as part of the overall logistic support sub-element.

5.2.1 Criteria and Assumptions (Continued):

5. ENERGY TRANSFER SYSTEMS

- 5.1 This element includes only the cost of installing the ship-board portion of the Energy Transfer System. Equipment costs and the cable are not addressed, nor is biofouling.

6. SYSTEMS ENGINEERING AND INTEGRATION

- 6.1 The estimates for this element assume commercial design practices but with additional systems engineering activity to suit Government involvement and interface with the power community.

7. SYSTEM TEST AND EVALUATION

- 7.1 All T&E activity is included under this element. None is distributed over other elements.
- 7.2 Independent T&E (WBS 6.3) is assumed to be divided into five sub-elements, and is priced accordingly:
- In-Plant Tests
 - Dockside Tests
 - Builder's Trials
 - Acceptance Trials
 - OTEC System Tests

8. OPERATIONAL SUPPORT

- 8.1 All recurring operational costs after deployment are included in this element; including the following:
- WBS 7.1 Spare Parts (Initial and follow-on)
 - WBS 7.2 Expendable Materials
 - WBS 7.2.1 Platform fuel oil, lube oil, aircraft fuel
 - WBS 7.2.2 Platform food, dry stores
 - WBS 7.2.3 Platform Miscellaneous (paint, etc.)
 - WBS 7.2.4 Logistic Support Expendables (Fuel, spares, etc. for support vessels, shoreside vehicles, etc.)
 - WBS 7.3 Peculiar Support Equipment including special equipment to operate and maintain a particular system, but excluding test equipment listed under WBS 6.0.

5.2.1 Criteria and Assumptions (Continued):

8.1 (Continued)

WBS 7.4 Common Support Equipment including equipment to operate and maintain the overall platform. Excludes equipment at shoreside facilities.

WBS 7.5 Personnel

WBS 7.5.1 Platform Personnel

WBS 7.5.2 Shoreside Personnel or equivalent subcontracted personnel

- Administration
- Maintenance and repair
- Warehouse and Materials Handling
- Transportation

WBS 7.6 Technical Manuals

8.2 The above costs are assumed to be constant for all platforms, and are amortized over the eight platforms.

8.3 All logistic support elements not included above are incorporated under Facilities WBS 9.0.

9. DEPLOYMENT SYSTEMS AND SERVICES

9.1 This element includes platform deployment, CWP assembly and CWP deployment, and covers all activities between departure from the shipyard and plant startup.

9.2 All special equipment and services required for deployment are included in this element including flotation collars, assembly barges, tugboats, cranes (if other than platform cranes), etc.

9.3 For the ship, it is assumed that the joining of the two halves in deep water is included under Deployment.

9.4 For the semi-sub, it is assumed that the joining of two columns into pairs can be accomplished at the shipyard, which is included in WBS 1.2, Hull and Structure. The joining of pairs into a fully integrated hull and adding the upper cross structure is done in deep water and is included under Deployment. This varies from the procedure postulated in Section 4.3, but it is considered sufficient for estimating purposes since the costs should not vary significantly.

5.2.1 Criteria and Assumptions (Continued):

10. INDUSTRIAL FACILITIES

- 10.1 It is assumed that major shipyard facility improvements will not be required. However, special flotation pontoons are included as a nonrecurring item under WBS 9.1, Shipyard Facilities Improvements.
- 10.2 Items included under this element include logistic support facilities including all buildings, service craft, vehicles, maintenance facilities, etc. All associated non-recurring costs are charged against the first platform.
- 10.3 Personnel associated with the operation of these facilities are included under WBS 7.5.
- 10.4 Consumables associated with the operation of these facilities are included under WBS 7.2
- 10.5 Future replacement of shoreside equipment is not included.
- 10.6 Facilities costs are allocated to the Test and Operation time frame when this will be used. However, construction may begin earlier.

11. ENVIRONMENTAL, LEGAL, LICENSING, REGULATORY & INSURANCE

- 11.1 Environmental impact statements are assumed for both the platforms and shoreside facilities.
- 11.2 Regulatory approval is included with Systems Engineering/Integration and Design Integration.
- 11.3 Legal and Licensing are included with Project Management, WBS 11.0.
- 11.4 Insurance costs are based on a yearly rate of 0.8 percent of acquisition cost.

5.2.1 Criteria and Assumptions (Continued):12. PROJECT MANAGEMENT

12.1 Project Management costs are expressed as average yearly costs and are assumed constant over the period beginning with Contract Award through Deployment of the final plant.

12.2 Project Management costs are based on \$25 per hour rate.

5.2.2 Baseline Cost Estimates

The baseline cost estimates developed using the foregoing criteria and assumptions are presented both in summary form and in detail in Appendix F with supporting backup sheets. Table 5.2-1 summarizes the results for ready reference. Recurring costs are not included. Costs are given for the first unit, against which all non-recurring costs are to be charged. The cost of later units is considered in Section 5.2-3.

TABLE 5.2-1
COST ESTIMATE SUMMARY, \$M

<u>WBS</u>	<u>TITLE</u>	<u>SHIP</u>	<u>SEMI-SUBMERSIBLE</u>
1.0	Platform System	395	396
2.0	Cold Water Pipe System	82	82
3.0	Power Systems	12	16
4.0	Energy Transfer System	5	6
5.0	System Engineer, Integration	7	8
6.0	System Test & Evaluation	7	7
7.0	Operational Support	17	17
8.0	Deployment System, Services	14	15
9.0	Industrial Facilities	57	63
10.0	Environmental, etc.	1	1
11.0	Project Management	—	—
	TOTAL	597	611

5.2.3 Multiple Procurement

The purpose of this section is to evaluate the reduction in platform cost associated with multiple unit procurement. All of the cost elements presented in Section 5.2.2 apply to the first unit, beyond which labor efficiency increases and costs reduce accordingly. J. Fetchko, "Methods of Estimating Investment Costs of Ships", indicates that available data approximates a log linear plot with a slope of about 0.93 resulting in reduction factors as shown in Table 5.2-2. If it is assumed that all non-recurring costs are applied to the lead unit, the total costs are as shown in Table 5.2-2 and 5.2-3. Recurring operating costs are not reflected in this table, and non-recurring costs are deducted before applying the learning curve factor.

TABLE 5.2-2OTEC COMMERCIAL PLANT COST SUMMARY - 400 MW SHIP

<u>NUMBER</u>	<u>TOTAL COST</u>	<u>DEDUCT NON-RECURRING COSTS (NOTE 1)</u>	<u>NET COST</u>	<u>K</u>	<u>ADJUSTED NET COST</u>	<u>ADJUSTED TOTAL COST</u>
1	597	100	497	1.00	497.	597
2	↓	↓	↓	0.93	463.	463.
3	↓	↓	↓	0.89	443.	443.
4	↓	↓	↓	0.87	432.	432.
5	↓	↓	↓	0.85	423.	423.
6	↓	↓	↓	0.83	413.	413.
7	↓	↓	↓	0.81	403.	403.
8	↓	↓	↓	0.80	398.	398.

All Costs \$ M

NOTE 1:	Engineering	17.4
	Test & Evaluation	6.7
	Operational Support	17.3
	Industrial Facilities	57.4
	Environmental, Etc.	0.7
	TOTAL:	99.5 Say 100

5.2.3 Multiple Procurement (Continued):TABLE 5.2.3OTEC COMMERCIAL PLANT COST SUMMARY - 400 MW SEMI-SUBMERSIBLE

<u>NUMBER</u>	<u>TOTAL COST</u>	<u>DEDUCT NON-RECURRING COSTS (NOTE 1)</u>	<u>NET COST</u>	<u>K</u>	<u>ADJUSTED NET COST</u>	<u>ADJUSTED TOTAL COST</u>
1	611	108	503	1.00	503.	611.
2	↓	↓	↓	0.93	468.	468.
3	↓	↓	↓	0.89	448.	448.
4	↓	↓	↓	0.87	438.	438.
5	↓	↓	↓	0.85	428.	428.
6	↓	↓	↓	0.83	417.	417.
7	↓	↓	↓	0.81	408.	408.
8	↓	↓	↓	0.80	403.	403.

All Costs \$M

NOTE 1:	Engineering	19.4	
	Test & Evaluation	6.7	
	Operational Support	17.3	
	Industrial Facilities	63.4	
	Environmental, Etc.	<u>0.7</u>	
	TOTAL:	107.5	Say 108

5.2.4 Cost Sensitivity

The costs reflected in Tables 5.2-1 through 5.2-3 reflect an element of both pessimism and optimism, depending on the perspective of the reviewer. The principal factor which might result in an increase in these costs is the potential risk associated with certain critical elements of the design. Factors which might result in reduction in cost include the seawater pumps and portions of the hull structure, where the estimated costs are higher than current trends. Each of these areas is addressed below.

Impact of Risk. The areas of major risk in the cost estimates of this Section include the following:

WBS 2.2	CWP Sections
WBS 2.3	CWP Screen
WBS 2.4	CWP-to-Hull Transfer
WBS 3.0	Power Systems installation labor
WBS 4.0	Energy Transfer Systems installation labor
WBS 8.2	CWP Assembly
WBS 8.3	CWP Deployment

The risk associated with WBS 2.2 and 2.3 is relatively low, so that a potential cost increase of 50% is considered an appropriate upper limit. The CWP assembly and deployment is a very high risk area, and it is proposed to triple those costs as an upper limit. For the remaining items, it is proposed to double the baseline estimate. Tables 5.2-4 and 5.2-5 summarizes the baseline and upper bound costs resulting from these adjustments for risk.

5.2.4 Cost Sensitivity (Continued):

TABLE 5.2-4
OTEC COMMERCIAL PLANT RISK ASSESSMENT - 400 MW SHIP*

<u>Number</u>	<u>Baseline Cost</u>	<u>Risk Modifier</u>	<u>Upper Cost</u>	<u>Percent Increase</u>
1	597	81	678	14
2	463	75	538	16
3	443	72	515	16
4	433	71	504	16
5	423	69	492	16
6	413	67	480	16
7	403	66	469	16
8	398	65	463	16

* All cost \$M

TABLE 5.2-5
OTEC COMMERCIAL PLANT RISK ASSESSMENT - 400 MW SEMI-SUBMERSIBLE*

<u>Number</u>	<u>Baseline Cost</u>	<u>Risk Modifier</u>	<u>Upper Cost</u>	<u>Percent Increase</u>
1	611	87	698	14
2	468	81	549	17
3	448	77	525	17
4	438	76	514	17
5	428	74	502	17
6	417	72	489	17
7	408	71	479	17
8	403	70	473	17

* All cost \$M

Possible Cost Reductions. As noted in Section 2.9, a pump cost of \$5.3M each (\$84.8M total) was reflected in the baseline cost estimates, which corresponds to a highly seawater resistant pump. For about \$4M each (\$64M) a pump could be developed which, though less resistant to seawater, must be satisfactory for the service with more intensive maintenance. This corresponds to a savings of \$20M per platform. In addition, it is possible to project a unit cost for flat plate structure about \$700 per ton less than the overall average cost reflected in the Tables. Assuming that this refinement could be applied to 50% of the Ship structural weight and 30% of the Semi-Submersible structural weight, the potential cost savings is \$21M for the Ship and \$10M for the Semi-Submersible. Combining the above savings results in the reduced costs shown in Table 5.2-6 corresponding to a 6 to 8 percent savings.

TABLE 5.2-6
OTEC COMMERCIAL PLANT POTENTIAL COST REDUCTIONS

Hull Number	SHIP			SEMI-SUBMERSIBLE		
	Base Cost*	Reduction	Net Cost	Base Cost*	Reduction	Net Cost
1	597	41	556	611	30	581
2	463	38	425	468	28	440
3	443	36	407	448	27	421
4	433	36	397	438	26	412
5	423	35	388	428	26	402
6	413	34	379	417	25	392
7	403	33	370	408	24	384
8	398	33	365	403	24	379

* All costs \$M

Cost Summary. Figure 5.2-1 presents a plot of the data from the foregoing Tables for the 400 MW Ship. Data for the Semi-Submersible is quite similar. The "pessimistic" curve corresponds to the added risk, Table 5.2-4, while the "optimistic" curve reflects the reductions in Table 5.2-6. This

Figure 5.2-1: Cost Summary - 400 MW Ship

5.2.4 Cost Summary (Continued):

indicates the potential for an acquisition cost of about \$1000 per KW for both the Ship and Semi-Submersible.

5.2.5 Evaluation of Costs

It is of interest at this point to compare the above baseline costs with the original cost estimates of Task IV as reported in Volume 1, and the initial trade-offs described in Section 2.3 of this Volume. This comparison is made somewhat difficult since the Task IV results reflected Gross power output whereas subsequent tasks have used Net power. In order to normalize the results, the Task IV power outputs will be reduced by an arbitrary 30 percent to account for parasitic losses, and the cost of Power System and Transmission System equipment backed out. This results in comparative Ocean System cost per megawatt as shown in Table 5.2-7.

TABLE 5.2-7
COMPARISON OF OCEAN SYSTEM COST ESTIMATES (\$/MW)

<u>Item</u>	<u>Ship</u>	<u>Semi-Submersible</u>
Task IV (Appendix C, Reference 4)	1.22M	1.42M
Task V, Early Phase Trade-Off Studies	1.22M	1.03M
Task VIII, Final Estimates (no risk)	1.00M	1.00M

(Table 5.2-2, t.2-3, for
8th Platform)

5.2.5 Evaluation of Costs (Continued):

The constant unit cost of the ship between Task IV and V represents a combination of many factors cancelling each other out. The Task IV hulls are much larger than those used in Task V due to the use of internal heat exchangers and 25 vs 50 MW components. This is offset by the use of concrete in Task IV versus steel in Task V, and increases in CWP cost.

The reduction in unit cost reflected in the Task VIII ship costs results from the reduction in hull depth, and hence a more efficient hull, following completion of the Task V trade-offs.

The sharp reduction in the Semi-Submersible costs between Task IV and V results primarily from the use of external vs internal heat exchangers in conjunction with the highly efficient column-stabilized configuration as opposed to the original twin hull configuration. In this case, both sets of designs reflected steel or a composite. The relatively slight change between Task V and VIII costs reflects the fact that the basic dimensions of the early trade-off baseline was not changed appreciably during Task V.

5.3 Schedule Analysis

The estimated schedule for all phases of design, construction and deployment is indicated in the Ship and Semi-Submersible timelines in Figures 5.3-1 and 5.3-2. These timelines were developed in essentially the same manner as those developed in Task IV (see section 5.2 of Volume I) but modified to reflect steel vs concrete construction, and the construction/deployment concepts described in Section 4 of this Volume.

Construction was assumed to take place in a West Coast shipyard, using steel production rates appropriate to large tankers. The timelines in Figures 5.3-1 and 5.3-2 represent the first unit, i.e. no learning curve, so that the schedule for later units can be expected to be reduced by factors similar to those in Table 5.2-2. Other assumptions include the following:

Figure 5.3-1: Construction Schedule - Ship

Figure 5.3-2: Construction Schedule - Semi-Submersible

5.3 Schedule Analysis (Continued):

1. Construction/deployment procedures as outlined in Section 4.
2. The construction of the Ship and Semi-Submersible (WBS 1.2) is based on shipyard fabrication, assembly and erection of a maximum of 200 tons of steel per day, assuming two building ways available. This may pose a problem on the West Coast.
3. The manhours per ton and the man-day estimate are based on the total labor dollar value of each WBS number divided by \$20/hour for onshore work, \$25/hour for offshore work, and \$40/hour for deployment.
4. The Semi-Submersible construction schedule requires the receipt of the Heat Exchangers beginning in the third month of construction. The Cold Water and Warm Water Pumps are also required in the same time frame. The lead time on these pumps is 36 to 40 months, therefore, the pump design and construction contract will have to be let well ahead of the Platform contract. Other equipment which is considered as long lead include: AC plants, compressors, turbine generators, rotary and centrifugal pumps, diesel generators.
5. The construction schedule of the Ship is different from the Semi-Submersible in that:
 - (a) The required date for the receipt of the Heat Exchanger commences in the twelfth month of construction since they will be added after the launch of the Ship.
 - (b) The cold water pumps will be required starting with the tenth month; the warm water pumps will be required in the twelfth month.
 - (c) The construction of the support pontoon structure will have to begin six months prior to the start of construction of the Ship to allow a base platform on which to land the Ship Modules.

5.3 Schedule Analysis (Continued):

6. The Cold Water Pipe construction period is based on the major portion of the pipe to be fabricated after the Ship or Semi-Submersible hull construction is completed.
7. The Cold Water Pipe Assembly is based on putting together the Cold Water Pipe at a rate of one assembly landed, fitted, aligned, tacked and production welded every three days with ten percent down time or a total of 200 days.

Figures 5.3-1 and 5.3-2 indicate total schedules for design, construction and deployment of 6 1/2 years for both the Semi-Submersible and the Ship. The actual time to construct, assemble, and deploy the two systems is about 3 1/2 years, with the remaining 3 years devoted to design and contract negotiation efforts. An additional six months is indicated for on-site test and evaluation during plant start-up.

5.4 Cash Flow Analysis

Table 5.4-1 indicates the cash flow for the first Ship and Semi-Submersible platforms, in constant FY 78 dollars. These tables were developed by assuming the lead platform costs of Tables 5.2-2 and 5.2-3 being distributed uniformly over the timelines in Figures 5.3-1 and 5.3-2 for each WBS element. Power System and Transmission System costs are not included. It is noted that "time zero" for Table 5.4-1 is the beginning of Preliminary Design.

TABLE 5.4-1
ANNUAL CASH FLOW (\$M) - OTEC COMMERCIAL PLANT

<u>Year</u>	<u>Ship</u>	<u>Semi-Submersible</u>
1	2	2
2	3	4
3	3	3
4	82	83
5	106	108
6	174	194
7	181	185
8	68	53
9	10	10
10	10	10

6. TASK IX SITE SENSITIVITY

6.1 Introduction

The two Conceptual Designs described in Sections 2 and 3 are intended for operation off Keahole Point, Hawaii, and are optimized for the specific environment and logistic characteristics of that site. The purpose of this section is to determine the impact on those designs of optimization for the other two sites to be considered by Gibbs & Cox, Inc.

- New Orleans
- West Coast of Florida

It is noted that the West Coast of Florida site was substituted for Key West by DOE at the end of Task IV. The Top Level Requirements, Appendix A, define the principal environmental parameters of these sites and illustrates their location. These characteristics are summarized as follows:

SITE	WATER DEPTH, FT.	EXTREME EVENTS (100 Yrs.)			BOTTOM COMPOSITION
		WIND, KTS.	SIG. WAVE HEIGHT, FT.	CURRENT, KTS.	
Hawaii	3,150	95.2	35.9	2.18	Volanic Sand, Silt
Florida	4,590	165.0	45.8	5.00	Calearous Sands, Silts
New Orleans	4,650	145.4	58.1	2.49	Terrigeneous Clayey Silts

The impact of optimizing the platforms for the alternate sites is expected to have far-reaching effects on design, construction and operation, as outlined in the following sections. Each site-sensitive WBS element will be separately discussed

6.2 Platform System

The elements of the platform system which are most significantly impacted by a change in site are motions, structure, position control systems, and seawater systems. Changes might occur in auxiliary system, navigation/communication, stowage and other platform components due to differences in environment, distance offshore and logistic support; however, these are expected to be minor and of negligible cost impact.

6.2.1 Motions

A reanalysis of the two selected platforms was conducted for sea spectra corresponding to the New Orleans and Florida environment, using the methods described in Section 2.3.2. Table 6.2-1 summarizes the responses to the 100 year storm.

This tabulation indicates that platform motions will be significantly worse off both New Orleans and Florida during the 100 year extreme event. Relative to exceedance of tolerable limits, the following is noted:

- (1) The limiting platform excursion is based upon restricting the motion envelope to that corresponding to the mechanical limits of the riser cable, which spans between the platform and a submerged buoy as shown in Figure 5.4-1 of Volume 1. For the three sites being considered, the actual versus limiting heave and surge motions are as follows for the ship, which is most critical:

ALLOWABLE					ACTUAL		
<u>Location</u>	<u>Depth (Ft.)</u>	<u>Vertical Displacement</u>	<u>Surge and Drift</u>	<u>Yaw</u>	<u>Heave</u>	<u>Surge</u>	<u>Yaw</u>
Hawaii	3,150	± 450	± 900	± 5.0°	± 10.5	± 3.5	± 1.1°
New Orleans	3,950	± 570	± 1100	± 5.0°	± 17.5	± 9.3	± 1.8°
Florida	4,590	± 660	± 1300	± 5.0°	± 13.6	± 5.4	± 1.4°

TABLE 6.2-1
PLATFORM MOTION COMPARISON

(Single Significant Motion Amplitudes and RMS Vert. Acc in 100-yr. Storm Conditions)

MOTION	SHIP			SEMI SUBMERSIBLE		
	Hawaii H 1/3=35.9	N. Orleans H 1/3=58.1	Florida H 1/3=45.8	Hawaii H 1/3=35.9	N. Orleans H 1/3=58.1	Florida H 1/3=45.8
Roll, deg.	3.60	6.85	5.09	.98	3.50	1.55
Pitch, deg.	2.10	4.40	3.05	.98	3.50	1.55
Yaw, deg.	1.10	1.82	1.40	.48	.75	.63
Heave, ft.	10.49	17.50	13.60	.40	1.50	.50
Surge, ft.	3.50	9.30	5.40	1.60	3.05	2.33
Sway, ft.	5.55	8.40	6.84	1.60	3.05	2.33
Vert. acceleration	.097	.181	.134	.034	.049	.043

6.2.1 Motions (Continued):

- (2) The limiting motions for crew comfort are indicated in Figure A-9 of Appendix A. This figure is reproduced as Figure 6.2-1, upon which the vertical accelerations for the Ship are plotted.

FIGURE 6.2-1
PHYSIOLOGICAL RESPONSE TO
PERIODIC VERTICAL OSCILLATIONS

6.2.1 Motions (Continued):

From this figure, it can be concluded that the ship approaches the "threshold of malaise" in the Florida and New Orleans site under severe storm conditions while it remains below it in Hawaii. The Semi-Submersible accelerations are so low and the heave periods so large that they are outside the range of Figure 6.2-1. Thus, the semi-submersible will virtually never experience uncomfortable motions. With regard to the probability of exceeding the lower limit of the tolerable acceleration curve, the following lists those probabilities for each site.

<u>SHIP</u>		<u>SEMI-SUBMERSIBLE</u>	
Hawaii:	1%	Hawaii:	0%
New Orleans:	2.0%	New Orleans:	0%
Florida:	1.5%	Florida:	0%

These percentages are computed on the basis that the ship exceeds the .09 RMS g level in a significant wave height of about 34 ft. The SSMO wave exceedance data contained in the OTEC environmental data package does not provide information beyond significant wave heights of 19 ft. Furthermore, the SSMO exceedance data has been traditionally on the low side. For these reasons, the probability of wave height exceedance (and hence RMS g's) has been obtained from a world wide sea state exceedance probability curve given by Reference (17). In order to distinguish between each site, the probability of exceeding a significant wave height of 34 ft. (1% Hawaii) has been increased proportionately for the other two sites based on the SSMO data.

6.2.1 Motions (Continued):

- (3) With regard to equipment motion limitations, none were defined during this study for the critical Power System components. However, for the OTEC-1 one megawatt heat exchangers, a limit of .10 "g" was established by DOE as part of the Request for Proposal. If it is assumed that this limit is applicable to the 50 MW heat exchangers as well, it can be seen that the limit may be met but will never be exceeded at Hawaii. At Florida and New Orleans, the limit will be exceeded but only during the 100 year event, with a probability of exceedance below two percent.

Summarizing the foregoing discussions of motions, the use of the proposed platforms at either New Orleans or Florida will result in a degradation of motion characteristics. However, the probability of exceeding established motion limitation is so small that a reoptimization of the hullform for the alternate sites is not considered necessary.

6.2.2 Structure

The loading on the platform structure will be more severe in both Gulf sites than Hawaii due both to the height of the critical 100 year wave and the total energy of the sea spectra, which indicates the long-term or fatigue-related loading which the hull will experience. The following can be derived from Figure A-11 of Appendix A.

<u>Site</u>	<u>Relative Wave Height</u>	<u>Relative Energy of Sea Spectra</u>
Hawaii	1.00	1.00
New Orleans	1.61	2.56
Florida	1.26	1.61

For the ship, approximately 25 percent of the structural weight is directly impacted by considerations of overall hull girder strength (i.e., the midship half-length of the bottom and side shell, main deck and innerbottom). For the semi-submersible, nearly 35 percent is similarly impacted, primarily in the cross-structure and struts. If it is assumed that these portions of the

6.2.2 Structure (Continued):

structure are increased in proportion to the relative wave-induced bending moment, the total increase in structural weight and cost would be approximately as follows:

	SHIP		SEMI-SUBMERSIBLE	
	Weight, L.T.	Cost, \$.M	Weight, L.T.	Cost, \$.M
New Orleans	5800	17	8500	25
Florida	2500	8	3600	11

6.2.3 Position Control System

The impact of site on the mooring lines, anchors and fittings is primarily a function of current, wind and depth of water. Bottom characteristics impact the holding power of many anchor types, but for the type of deadweight anchors being considered for the 400 MW ship and semi-submersibles (Section 2.6 of this Volume) these effects are not considered significant. As an approximation of site impact, the baseline Position Control System costs of Section 5 of this Volume can be modified in direct proportion to the average water depth and the square of current velocity. Relative wind gust ratios can be ignored for this analysis since the current differentials are more critical. In scaling up the mooring system developed for the relatively benign Hawaiian site to that required for New Orleans and more particularly the Florida site it could be assumed that the peak currents at the two sites are relatively unidirectional, and the mooring system could be reinforced in this direction only. Based on this assumption one-half of the system used in Hawaii has been modified, and the costs for either platform are as follows:

$$\begin{aligned} \text{New Orleans} &= \frac{\$15.3\text{M}}{2} \left[\frac{4650}{3150} \right] \left[1 + \left(\frac{2.49}{2.18} \right)^2 \right] = \$26\text{M} \\ \text{Florida} &= \frac{\$15.3\text{M}}{2} \left[\frac{4590}{3150} \right] \left[\left(\frac{5.00}{2.18} \right)^2 \right] = \$70\text{M} \end{aligned}$$

The extremely high current at the Florida site raises serious questions as to the feasibility of using the proposed platforms at these sites. The costs noted above assume a "brute force" approach to the position control

6.2.3 Position Control System (Continued):

problem, i.e., simply adding more anchors and lines until the average line stress is acceptable. A more realistic approach would be to totally reconfigure the two platforms for reduced drag, and to align them with the prevailing current such that they present a minimum-drag profile. In particular, it would appear preferable to use internal heat exchangers and pumps, since the current configuration has very high drag characteristics. Alternatively, non-tight fairings could be added below the hull to reduce drag coefficients.

For Hawaii, external heat exchangers are acceptable since the savings in Commercial Plant cost is about \$60M (as shown in Section 2.3). For the Florida site, this savings will be offset by the higher drag translating into higher Position Control System costs. The crossover point cannot be determined without further studies beyond the scope of this effort. However, it can be assumed that the total cost increase in hull and Position Control System, will be at least \$50M for the Florida site relative to Hawaii.

6.2.4 Seawater System

The impact of site on the seawater system (excluding CWP) is related primarily to the ability to achieve the desired ΔT and its relation to total Commercial Plant efficiency. A secondary effect is in relation to the relative biofouling characteristics of the three sites and their impact on pumping requirements through the seawater loop. However, these differences have not been addressed, since the most critical elements in this regard are the heat exchangers, which are beyond the scope of this study.

Cold Water Sub-System - The effects of site selection on the ability to achieve a desired ΔT are primarily related to the CWP, which is discussed in the next section. At this point, it is sufficient to note that Hawaii provides the ability to achieve the best ΔT with minimal seasonal fluctuations, and that any attempt to duplicate this efficiency at either New Orleans or Florida would require a combination of the following:

6.2.4 Seawater System (Continued):

- (1) Longer CWP to lower inlet temperatures
- (2) Higher pump capacity to move more water through the loop and to compensate for higher system losses

6.3 Cold Water Pipe System

The site-sensitive items of primary interest relative to the CWP are the effects of thermal resource on required length and available ΔT , and the impact of motions on CWP structure and cost.

6.3.1 Thermal Resource Considerations

The effect of thermal profiles on CWP length can be assessed from Figures 6.3-1 through 6.3-3 which plot the distance which the CWP must extend below the surface in order to achieve ΔT 's of from 35 to 40° F. Both averages and seasonal extremes are indicated, and reflect an assumed warm water intake 100 feet below the surface. The following can be derived from these figures:

	DEPTH FOR AVG. ΔT , FT.		SEASONAL FLUCTUATION, °F	
	36° F.	40° F.	36° F. Average	40° F. Average
Florida	2418	4592	-3.8, +5.20	-5.8, +5.0
New Orleans	2526	Cannot be Achieved*	-7.55, +5.94	—
Hawaii	2001	Cannot be Achieved**	-2.9, +2.1	—

* 40° F ΔT can be achieved in best month (July) at 1936 Ft.

** 40° F ΔT can be achieved in best month (September) at 2428 Ft.

It can also be seen that the maximum average temperature differential achievable, assuming a CWP within 100 feet of the bottom is as follows:

Florida (CWP Depth = 4,490 Ft.) = 39.5° F
 New Orleans (CWP Depth = 4,550 Ft.) = 38.6° F
 Hawaii (CWP Depth = 3,050 Ft.) = 38.3° F

This data favors Hawaii in terms of CWP length for a reasonably efficient ΔT , and low seasonal variations. New Orleans is a less advantageous site, since the achievable ΔT is relatively low at reasonable CWP lengths.

FIGURE 6.3-1

FIGURE 6.3-2

FIGURE 6.3-3

6.3.1 Thermal Resource Considerations (Continued):

The implication of the above discussion is that Hawaii offers the best efficiency in terms of average annual ΔT and thereby the lowest cost per megawatt at the busbar. For a design ΔT of 40°F , Figure 6.3-1 indicates a required CWP length of about 3000 feet at Hawaii. Correspondingly, a 3700 foot CWP would be required for the same efficiency at Florida, thereby increasing the CWP cost by 25 percent. At New Orleans, an average $40^{\circ}\Delta T$ cannot be achieved. Looking at the situation in a different light, a 3000 foot CWP at all three sites would result in average ΔT 's as follows:

Hawaii	=	38.2°F
New Orleans	=	37.1°F
Florida	=	37.6°F

Assuming plant efficiency is a function of $(\Delta T_1/\Delta T_2)^{1/2}$, the relative efficiencies would be as follows, related to the design ΔT of 40°F .

Hawaii	=	91.2%
New Orleans	=	86.0%
Florida	=	88.4%

With a constant parasitic loss of approximately 120 MW, the resultant power available for transmission is as follows:

Hawaii	=	$(520 \times .912) - 120$	=	354 MW_e
New Orleans	=	$(520 \times .860) - 120$	=	327 MW_e
Florida	=	$(520 \times .884) - 120$	=	340 MW_e

6.3.2 Structural Considerations

A reanalysis of the baseline CWP designs for the more severe New Orleans and Florida results in the following peak bending stresses:

	<u>Ship</u>	<u>Semi-Submersible</u>
Hawaii	25 KSI	17.5 KSI
New Orleans	45 KSI	31.3 KSI
Florida	30.2 KSI	24.8 KSI

6.3.2 Structural Considerations (Continued):

For simplicity, it can be assumed that the total cost of CWP system design construction and deployment will be proportional to the above bending stresses. These costs would be as follows:

	<u>Ship</u>	<u>Semi-Submersible</u>
Hawaii	\$ 89M	\$ 89M
New Orleans	\$160M	\$160M
Florida	\$108M	\$126M

6.4 Power System

The primary influences of site on the Power System relate to efficiency and motions as addressed previously, and transportation of components to the construction/deployment sites. Because of the size of the heat exchangers, it will be necessary to transport them by barge, thereby adding a considerable cost if an East Coast manufacturer makes the heat exchangers and a West Coast shipyard builds the plant. Because of the wide variety of options open for both platform and heat exchanger construction, it is difficult to make a meaningful comparison of sites. However, the Gulf sites would offer more options and fewer transportation problems than Hawaii.

6.5 Transmission System

The most critical site-related aspect of the Transmission System is the length of cable between the platform and shore grid. Although this consideration is beyond the scope of this study, it is obvious that either New Orleans or Florida will be considerably more costly since the distance to shore is about 57 and 150 miles further than Hawaii, respectively. The cost per foot of cable has not been firmed up, since a number of cable options are being investigated; however, the following additional cable costs are based on the most recent transmission system data from DOE and a base cost for Hawaii of \$5M.

New Orleans	=	\$60M
Florida	=	\$93M

6.6 Operational Support

The cost of operating the OTEC Commercial Plants is site-sensitive in several areas. The Hawaiian site is close to shore, which reduces transit times for supply and personnel boats. On the other hand, it is in a remote location, far from existing logistic supply lines, and will require the development of an extensive logistic support capability with its associated costs. In addition, wages for operating personnel will be somewhat higher than on the mainland. As will be discussed in Volume III, there is a strong rationale for considering a site off Oahu rather than Hawaii, since the electrical power needs of Oahu are more compatible with the power output of the Commercial Plant. Such a location would reduce the logistics problems considerably.

6.7 Deployment Systems and Services

The basic deployment concepts and associated services defined in Section 4 of this Volume would be applicable to all three sites, with minor modification. The major difference is in terms of the time and cost required to tow the platform modules from the shipbuilding facility to the deployment site, and the cost to lease derrick barges, diving services and other deployment-related elements. In addition, the wage rates for shipbuilding and offshore construction personnel are highest at the Hawaiian site. All of these factors favor the two Gulf sites over Hawaii, since the Gulf area is already deeply involved in all aspects of offshore construction and deployment. In addition, a significant differential exists between Gulf and West Coast shipbuilding costs. For purposes of discussion, it can be assumed that deployment to Hawaii will cost at least 30-40 percent more than for the Gulf sites, or approximately \$14M-\$15M vs \$11M-\$12M (see Table 5.2-1).

6.8 Industrial Facilities

The shipyard facilities, which include special flotation barges and other unique equipment, will be similar for all sites. However, the cost of shoreside support facilities is expected to differ. For Hawaii, a more expensive shoreside facility will be required than for the Gulf sites. This is expected to be offset by the shorter distances involved in transporting

6.8 Industrial Facilities (Continued):

personnel and supplies, which translates into fewer craft to supply such services. For example, two support craft could service an 8-platform energy park with one stopover per day ($\frac{1}{2}$ hour out, $\frac{1}{2}$ hour on station, $\frac{1}{2}$ hour back, $\frac{1}{2}$ hour reload = 4 trips per 8-hour day). Alternatively, a park located 60 miles offshore, such as New Orleans, would require 8 craft to perform the same function. For the purposes of this study, it is assumed that these are offsetting factors, and that total facilities costs are similar for all three sites.

6.9 Insurance

The risk of collision and platform loss is considered greatest off New Orleans, which is nearest to major shipping lanes. Most of the traffic at the west coast of Florida site is small fishing craft, which would inflict minimal damage to the platform. The Keahole Point, Hawaii site is also far removed from major shipping lanes. These factors, in combination with less severe storm conditions, should permit a lower insurance rate for the Florida and Hawaii sites. However, the other potential hazards such as fire and explosion, will be similar and the proximity of the Hawaii site to shore increases the risk of grounding. Therefore, insurance costs can be considered relatively constant.

6.10 Cost Summary

In order to quantify all of the foregoing discussions of site sensitivity, it is of interest to investigate the cost per megawatt of power produced for the two platforms at the three specified sites. The comparison appears in Table 6.10-1, which modifies the basic costs for the Hawaiian site (Section 5 of this Volume) with the changes described in this section. The baseline costs for New Orleans and Florida are less than those for Hawaii to reflect the 6 percent construction cost differential now used by the Maritime Administration between West Coast and Gulf Coast shipyards. In order to present

6.10 Cost Summary (Continued):

a complete cost figure, consistent with Task IV; an allowance of \$420M has been separately identified for the Power and Transmission System on the first platform. This value is based on the \$336M included in the hull trade-offs, Section 2.3 for the eighth unit. These costs reflect total first-unit costs, including non-recurring costs charged to that unit. The average megawatts produced are derived from Section 6.3, for a constant CWP length for all sites of about 3000 feet.

For comparison purposes, similar numbers are developed for the eighth identical unit. This comparison clearly shows the benefits of the Hawaiian site from a cost-benefit point of view.

TABLE 6.10-1

FIRST-UNIT COST SUMMARY FOR ALTERNATIVE SITES (\$M)

	SHIP			SEMI-SUBMERSIBLE		
	Hawaii	New Orleans	Florida	Hawaii	New Orleans	Florida
Baseline Cost (Table 5.2-1)	597	561	561	611	574	574
Power, Transmission System (on-board)	420	420	420	420	420	420
Increases:						
Structure	0	17	8	0	25	11
Position Control	0	26	70	0	26	70
CWP	0	71	19	0	71	37
Power System	0	-2	-2	0	-2	-2
Transmission System (Cable)	0	60	93	0	60	93
Operations	0	-2	-2	0	-2	-2
Deployment	0	-4	-4	0	-4	-4
Net Cost, \$M	1017	1147	1163	1031	1168	1197
Effective MW	354	327	340	354	327	340
\$M/MW _e	2.87	3.51	3.42	2.91	3.57	3.52
For 8th Unit:						
Baseline Cost	398	374	374	403	379	379
Power, Transmission System	336	336	336	336	336	336
Increases @ 80% of above	0	133	146	0	139	162
Net Cost, \$M	734	843	856	739	854	877
\$M/MW _e	2.07	2.58	2.52	2.09	2.61	2.58

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 General

A relatively large number of OTEC Commercial Plant configurations have been evaluated using both technical and economic criteria with two of these having been brought forward to the conceptual design level. Resources prohibited the in detail study of all options encountered; nevertheless, all of any significance were considered, if not in a formal quantitative fashion at least qualitatively with the emphasis placed on the cumulative engineering experience of the project team members. The resulting designs of the Ship and Semi-Submersible Plants represent a balanced product that more than adequately demonstrates the feasibility of the OTEC concept from an Ocean System viewpoint. Additionally, as discussed previously in this report, those areas that are cost drivers, such as hull structure, the CWP, and the Seawater System, have been developed to a greater level of detail than those that have a minimal effect; therefore, one of the primary goals of a conceptual design, i.e., a credible cost estimate, has been attained.

It should be made clear at this time that the designs presented herein do not necessarily represent the only or the optimum solution. Instead, one approach to the problem has been developed, and a more detailed analysis or different assumptions could possibly vary some of the results; however, the analysis is considered insensitive to many such variations at this stage. Perhaps the most ominous aspect of the designs is the lack of definition with respect to the payload, or Power System. Since the configuration of the Ocean System is so inexorably linked with, and sensitive to, the make up of the Power System, any changes in this area could have far-reaching effects on the present designs. For example, if the ability to mount the heat exchangers externally did not exist, the basic premise behind the OTEC Plants presented here would also no longer exist, and the entire concept would be required to be developed again from the point where the basic hull trade-off studies were conducted. This could possibly mean an increase in cost of the Commercial Plant on the order of 30 %, but of course, this is a very pessimistic example that is predicated upon one of the basic design criteria being incorrect.

7.2 Conclusions

Given the results of this study, the ship is considered the preferable configuration for the reasons delineated below:

- Cost - The ship is slightly less expensive with respect to acquisition costs. By looking at Tables 5.2-2 and 5.2-3 it may be seen that the cost differential is \$14 M for the first Plant which includes non-recurring costs and \$ 5 M for the remaining ones. While this does not appear to be significant, it is nevertheless a difference that is more likely to diverge instead of converge as more detailed and firmer costs are developed in the later stages of the design process and more of the effects of complexities inherent in the Semi-Submersible emerge.
- Constructability - The complex configuration of the Semi-Submersible, its excessive draft, and awkward planform area in the assembled condition necessitate a rather involved at sea assembly procedure requiring some critical ballasting and alignment evolutions. In comparison, the ship requires only one major structural fabrication task away from the building facility, and all of the welding can be done above water. The risks and potential for cost growth with the procedure followed in the case of the ship is considered to be notably less than that required for the Semi-Submersible. Additionally, the fabrication work done in the building facility will be accomplished with the ship oriented correctly while the Semi-Submersible is rotated ninety degrees from the vertical introducing additional fabrication difficulties.
- Operational Flexibility - The horizontal arrangement of the ship presents a more favorable environment towards Plant operation and maintenance than does the vertical of the Semi-Submersible. Access to the machinery levels in the Semi-Submersible is more difficult than on the ship for both personnel and equipment, and all of the major equipment in the Semi-Submersible's columns cannot be withdrawn without first removing extensive interferences in the form of structure and other equipment. This is especially true for such items as the pump motors located at the bottoms of the columns. Similarly, the limited deck platform area

7.2 Conclusions (Continued):

● Operational Flexibility (Continued):

in these columns necessitates removal of an entire main generator to permit rotor withdrawal, while this evolution can be carried out in place on the ship after cutting out a hard patch.

- Safety - The ship is less susceptible to total loss resulting from flooding because of its superior stability characteristics. As discussed in Section 3.4.5, the maximum extent of damage that could be reasonably expected would result only in the loss of one Power System module, and the limited angles of trim and list assumed by the ship should not prohibit the operation of the other modules. On the other hand, the maximum probable damage in the case of the Semi-Submersible could flood the major portion of one of the columns. In addition to putting two Power System modules out of commission, this would induce such a large list that the CWP would be damaged through contact with other portions of the platform structure, and the upper cross structure would be in the water on the damaged side. The severe angle on the platform would most assuredly result in the shutdown of the undamaged modules, and a high probability exists that other structural damage would result from the unusual weight distribution. In the event of high seas at the time of damage, it is very possible that the Plant could be lost.

A more probable flooding scenario would not place the Semi-Submersible in such dire straits, and no sections of the Power System would be flooded, but the angle of heel introduced would severely restrict the range of motion available to the CWP and would significantly increase the chance of it being damaged. In addition, Power System equipment operation for a period of time at such an angle may not be possible.

7.2 Conclusions (Continued):

- Motions - The final argument in favor of the ship is that it does not exhibit inferior motions characteristics as manifested in CWP bending stresses when compared to the Semi-Submersible. Considering that superior motions was the reason that the Semi-Submersible was included as a candidate for the OTEC Plant, it implies that this design no longer offers this advantage. It must be understood that this result does not necessarily apply to all Semi-Submersible forms. A different arrangement could have more favorable attendant CWP loads, but one should realize that the decrease in CWP cost in that case could be offset by an increase in platform cost.

7.3 Recommendations

As a result of this study, at the present time the OTEC Commercial Plant can be considered a viable structure from an ocean engineering standpoint; however, a number of areas need to be assessed in considerably more detail as part of a continuing effort to reduce the risk inherent with the concept. The more critical ones are those that because of their complexity, untried technology, or unverified results could not be evaluated in detail as a part of this study with some of the more critical ones being:

- Power System Definition - A rapid convergence of the configuration (or configurations) of viable Power System designs and their operational requirements is necessary to either validate the present Ocean System designs or provide a reasonably firm data base for their modification. As has been stated a number of times throughout this study, seemingly small changes in the payload could have far-reaching effects on the OTEC Commercial Plant configuration and costs.
- Transmission System Definition - The motions limitations of the riser cable must be established as soon as practicable to once again validate the present designs, this time from a motions standpoint. Based on the findings of this study, it appears that the transmission cable could impose the most severe motions requirements on the Ocean System which would either result in the modification of the hull to yield more benign motions - an unlikely and difficult approach, or the development

7.3 Recommendations (Continued):

• Transmission System Definition (Continued):

of a cable/platform interface that could impact both the present interior and exterior arrangements.

- CWP - Although what is felt to be a reasonable CWP design in both concept and cost has been developed, this very critical aspect of the OTEC Commercial Plant deserves a much more extensive analysis. First, the analytical models used to determine the CWP dynamic stresses need to be verified to ensure that their output can be used with an acceptable degree of confidence. Second, the determination of the secondary loads on the pipe is considered a vital step in its development since the possibility exists that these loads, especially those resulting from unsteady forces, could prove to be as critical as the current and wave induced primary bending.

The upcoming study concerning the CWP evaluation and preliminary design is a step in the right direction, but it does leave a number of questions open. For example, it has been determined during the analysis of the CWP's considered for the Plants developed in this study, that the CWP response appears to be highly tuned and is highly sensitive to both diameter and equivalent wall thickness. This implies that a further effort will be required since this CWP study is involved only with pipes of relatively small sizes (inside diameters = 30 ft.) to be attached to plants producing only about 20 MWe.

- Construction and Deployment - Construction and deployment are, in all probability, the most important aspects of the Commercial Plant development. All areas of Plant design, including the CWP, hinge upon a practical and cost effective fabrication scheme. Again, this has been introduced in Section 6; however, the level of effort required to adequately address the issue is far in excess of that available in this study. Issues such as whether it is more economical in both time and money to fabricate the Plants in existing facilities, in existing facilities with extensive modification, or in specially constructed facilities, must be critically evaluated and the impacts including environmental quantified.

7.3 Recommendations (Continued):

o Construction and Deployment (Continued):

Much of the offshore evolutions postulated must also be better defined along with their associated costs. Tremendous advances have been made in the offshore oil industry over the past thirty years, and with proper development, the risks inherent in the onsite fabrication and maintenance (modular heat exchanger replacement) can be converged upon and actions taken towards their reduction.

In summary, advantage should be taken of the momentum developed during this project to continue the study of the areas discussed above. A timely, continuous expenditure of effort is considered necessary to ensure the deployment of the first OTEC Commercial Plant in a time frame that satisfies the requirements of the national energy program.

18351-10(W-10,010)

DERIVED FROM 18351-5 (W-9230)

APPENDIX A

TOP LEVEL REQUIREMENTS

(TLR)

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OCEAN THERMAL ENERGY CONVERSION
COMMERCIAL PLANT
TOP LEVEL REQUIREMENTS

1. INTRODUCTION

This document establishes a set of Top Level Requirements (TLR) for the Ocean Thermal Energy Conversion (OTEC) Commercial Plant which translates the baseline goals and constraints established by the U.S. Department of Energy (DOE) into a first-level specification for the three major systems comprising the plant:

- 1.1 Ocean System, consisting of the following:
 - Hull System
 - Seawater System (Warm and Cold Water)
 - Position Control System
 - Support System

- 1.2 Power System, consisting of the following:
 - Evaporator System
 - Condenser System
 - Turbogenerator System
 - Ammonia and Nitrogen Transfer and Storage System

- 1.3 Transmission System, consisting of the following:
 - Power Conversion System
 - Power Transmission Cable

This TLR is the first step in a multi-phase development of the specification tree for the OTEC Commercial Plant, and serves as the baseline for Conceptual Design effort. After completion of Conceptual Design, a more detailed Top Level Specification or equivalent will be required to support Preliminary

1.3 (Continued)

Design, and finally a construction specification to support Contract Design and ultimately the fabrication of the Plant. This document modifies and expands the TLR developed during Task II, (Reference 1) to reflect subsequent developments and DOE direction, as well as the specific platform and configuration specified in Task V.

Each step in the specification tree develops a progressively greater level of detail for the systems and sub-systems comprising the Plant, to the level necessary to support the specific program phase in question. The Conceptual Design phase is concerned more with overall approaches to the solution of program objectives than the solution of detail design problems. In keeping with this philosophy, this TLR is presented in rather broad terms, since the design studies conducted during Conceptual Design are not at a level of detail to justify a more refined specification.

For the Conceptual Design phase of the OTEC Commercial Plant, two (2) hullforms have been specified by DOE for the Ocean System, the ship and semi-submersible (Reference 2). This TLR is applicable to both hullforms unless specifically noted, and therefore serves the added purpose of promoting a consistent approach to the evaluation of these hullforms.

The overall format for the TLR is based on the proposed Ocean System Work Breakdown Structure, Figures A-1 and A-2 (derived from Reference (1), and consists of eight main sections:

- Program Constraints
- Mission Definition
- Payload Support
- Hull System
- Position Control System
- Support System
- System Engineering Requirements
- Environment

Figure A-1
PROPOSED THIRD LEVEL OCEAN SYSTEM WORK BREAKDOWN STRUCTURE

Figure A-2
PROPOSED FOURTH LEVEL OCEAN SYSTEMS
WORK BREAKDOWN STRUCTURE (WBS)

Figure A-2 (Continued)
 PROPOSED FOURTH LEVEL OCEAN SYSTEMS
 WORK BREAKDOWN STRUCTURE (WBS)

1.3 (Continued)

The TLR reflects a number of "hard" inputs based on data provided by DOE, which are referenced as appropriate. Other inputs are based on engineering judgement, experience and current practice for offshore platforms, and are to be considered as assumptions offered for review and adjudication with DOE.

2. PROGRAM CONSTRAINTS

2.1 Cost Goals for Ocean Systems

There shall be no specific cost constraints imposed on the Ocean System. The cost goal is to produce a Commercial Plant at the lowest possible acquisition cost consistent with mission objectives and considerations of payload support, safety and long life in the anticipated environment.

2.2 Schedule Goals

The OTEC Commercial Plant is scheduled for deployment in the 1980's, based on Conceptual Design of both the Ocean System and Power System commencing in 1977. Although other intermediate milestones have been established, these milestones shall not influence the overall program development resulting from this study. Rather, the plans for Commercial Plant and Demonstration Plant development shall reflect a logical approach reflecting minimum risks and schedule overlaps. The penalties and risks associated with accelerated schedules will be identified where the need for such acceleration is established by DOE to suit interim milestones.

2.3 Platform Life

The OTEC Commercial Plant and all of its related subsystems shall have a life of 40 years, measured from the date of deployment (Reference (3)). The ability to extend this life by repair and replacement shall be considered as an optional feature, but not as a primary design requirement.

2.4 Technology Limits

The OTEC Commercial Plant shall reflect the use of state-of-the-art technology wherever possible. Where the state-of-the-art is demonstrated to be inadequate, the risk/fallback concepts of Section 2.5 apply. For this study, the state-of-the-art is defined as that which existed in 1977, plus those technological advances which can be expected to result from currently active or planned research and development programs, defined in Reference (4).

2.5 Risks/Fallbacks

Any aspect of the OTEC Commercial Plant program which exceeds the state-of-the-art shall be considered a potential risk area. Such risk areas shall fall into two categories:

- (1) Those which are relatively minor, and for which specific programs can be initiated to develop the necessary technical capabilities or knowledge.
- (2) Those which are relatively major, and for which there exists the risk that specific R&D programs might not provide the necessary technological framework for subsequent Commercial Plant development. In such cases, fallback options shall be defined which will allow the program to proceed to its ultimate goals with acceptable risk. Such fallback options shall minimize risk, schedule slippage and cost growth, and shall define the interrelationship between these three factors.

2.6 Availability

The goal for overall OTEC Commercial Plant availability is 90 percent over a 40 year life, including considerations of plant down time for maintenance and repair, and shutdown during extreme environmental events. The plant shall be able to operate in sea states corresponding to those expected at the deployment site 95 percent of the time over a typical 40 year span.

3. MISSION DEFINITION

3.1 Primary Mission

The primary mission of the OTEC Commercial Plant shall be to generate electrical power using differences in ocean temperatures and to transmit the power thus generated to shoreside electrical grids by cable. The Plant shall demonstrate the technical feasibility of the Ocean, Power and Transmission Systems and shall demonstrate that the plant can generate and transmit electrical power to shoreside grids at a cost and with a reliability which is competitive with existing generating concepts.

3.2 Secondary Mission

A possible secondary mission of the OTEC Commercial Plant is to utilize the energy generated by the Power System to feed an energy-intensive manufacturing operation located on the platform, such as aluminum or ammonia production. However, this mission shall not be considered for the platforms to be included in the studies conducted by Gibbs & Cox, Inc.

3.3 Contingent Tasks

The Plant shall be capable of satisfying the following contingent tasks:

3.3.1 Training of Plant operating personnel.

3.3.2 Research and Development related to ocean thermal energy conversion.

3.3.3 Test and evaluation of developmental equipment related to power generation and transmission to the extent that such equipment can be installed, checked out and operated without degrading overall plant reliability, and that such installation can be accomplished onsite.

3.3.4 Oceanographic and hydrographic research including data gathering, sample analysis and other activities which require limited personnel and specialized equipment.

As contingent tasks, the above shall be accomplished without degrading the primary mission of the Plant in any way.

4. PAYLOAD SUPPORT

4.1 Payload Definition

Within the context of this TLR, "payload" is defined as consisting of the following:

4.1.1 Seawater System as defined in 1.1

4.1.2 Power System as defined in 1.2

4.1.3 Transmission as defined in 1.3

The Seawater System is functionally included with the Ocean System in 1.1 to reflect the breakdown in responsibility between Power System and Ocean System contractors established by DOE. However, from the standpoint of Platform design, it is considered logical to include the Seawater System within the scope of "Payload", since its characterization and requirements are more closely associated with the Power System than the Ocean System.

4.2 Power System

The Power System shall develop a net output of 400 MW, and shall consist of either 8 - 50 MW modules or 16 - 25 MW modules. A mixture of 25 and 50 MW components is acceptable if a significant advantage in platform arrangements accrues. Heat exchangers may be oriented either horizontally or vertically, and may be located external to the water tight hull.

4.2 Power System (Continued)

Design parameters for the principal Power System components shall be as shown below, based on data in Reference (5). This data also identifies additional Power System support requirements to be provided by the platform. It is noted that Table A-1 defines the characteristics of components producing a net output of 25 or 50 MW, with an assumed allowance for parasitic electrical loads from Seawater System pumps and platform electrical loads of 30 percent, and an assumed differential temperature of 40°F.

Figures A-3 through A-6 illustrate these components as assembled into 25 and 50 MW modules, using vertical and horizontal heat exchanger configurations. These figures are presented for illustrative purposes only, and are not intended to limit the configurations to those shown.

4.2.1 Principal Dimension and Weights

Table A-1 defines Power System component characteristics for both a 25 MWe (net) and a 50 MWe (net) design. Additionally two heat exchanger configurations are presented.

TABLE A-1

POWER SYSTEM COMPONENTS

COMPONENT (One Each)	25 MWe (net)				50 MWe (net)			
	Dim's	Ft	Wghts	Kips	Dim's	Ft	Wghts	Kips
	Dia	Lgth*	Dry	Wet	Dia	Lgth*	Dry	Wet
HORIZONTAL HEAT EXCHANGERS	50	85	2600	7600	65	85	3600	13600
VERTICAL HEAT EXCHANGERS	40	80	1600	4800	55	80	2400	9000
TURBINE	20	20	100	100	25	25	150	150
GENERATOR	15	20	300	300	18	30	440	440
DEMISTER	20	20	600	600	30	30	900	900

* Includes 50-55 foot long tubes plus water box at each end

TYPICAL CLEARANCE REQUIREMENTS FOR POWER SYSTEM COMPONENTS HORIZONTAL HEAT EXCHANGERS

1-25-78 J.L.

DESCRIPTION	RATING	DIMENSIONS (FT.)	
HEAT EXCHANGER	25	50 DIA	85 LENGTH
	50	65	85
TURBINE	25	20	20
	50	25	25
GENERATOR	25	15	20
	50	18	30
DEMISTER	25	20	20
	50	30	30
TYP. MODULE	25	155 x 125	110
ENVELOP	50	180 x 155	135

Figure A-3

TYPICAL CLEARANCE REQUIREMENTS - HORIZONTAL HEAT EXCHANGERS MINIMUM S.W. PUMPING POWER REQUIREMENTS

TYPICAL CLEARANCE REQUIREMENTS FOR POWER SYSTEM COMPONENTS VERTICAL HEAT EXCHANGERS

1-23-78 JL

DESCRIPTION	RATING	DIMENSIONS (FT.)	
HEAT EXCHANGER	25	40 DIAM x 80 LENGTH	
	50	55	80
TURBINE	25	20	20
	50	25	25
GENERATOR	25	15	20
	50	18	30
DEMISTER	25	20	20
	50	30	30
TYP. MODULE ENVELOPE	25	105 x 105	164
	50	135 x 120	142

Figure A-4

TYPICAL CLEARANCE REQUIREMENTS - VERTICAL HEAT EXCHANGERS MINIMUM S.W. PUMPING POWER REQUIREMENTS

Figure A-5

TYPICAL CLEARANCE REQUIREMENTS - HORIZONTAL HEAT EXCHANGERS MINIMUM S.W. PIPING LENGTH

TYPICAL CLEARANCE REQUIREMENTS
FOR
POWER SYSTEM COMPONENTS
VERTICAL HEAT EXCHANGERS
15' WATERBOX REMOVED FROM EACH
END OF BOTH HEAT EXCHANGERS

TYPICAL MODULE DIMENSIONS

25 MW	105' 105' x 90'
50 MW	135' 120' x 100'

Figure A-6

TYPICAL CLEARANCE REQUIREMENTS - VERTICAL HEAT EXCHANGERS MINIMUM S.W. PIPING LENGTH

4.2.2 Piping Sizes

	25 MWe (net) <u>dia feet</u>	50 MWe (net) <u>dia feet</u>
Seawater Pipe	As req'd See 4.3	As req'd See 4.3
Ammonia Vapor	10	14
Ammonia Liquid	2	3

4.2.3 Maintenance Guidelines

The following guidelines shall be used in laying out the power system.

- No tube or bundle removal is contemplated.
- Tube plugging will be done, but no impact on space and weight requirements is foreseen.
- Turbine and pump maintenance will be required periodically and a lay down area(s) should be provided. As a minimum such an area should be at least the same area as one turbo-generator.
- A gantry crane of 100 short tons capacity should be provided to service the turbo-generator and the pumps.
- No external heat exchanger maintenance is envisioned.

4.2.4 Seawater Flow Requirements

At a design point of 40°F temperature difference the total flow requirements are:

	25 MWe (net) <u>cfs</u>	50 MWe (net) <u>cfs</u>
Evaporator	2,500	5,000
Condenser	3,000	6,000

One pump is required per heat exchanger.

The power as a function of temperature difference is well described by:

$$\frac{\text{power}}{\text{power}^*} = \left(\frac{T}{T^*} \right)^{+2}$$

where * indicates design point condition of 40°F

4.2.5 Ammonia Auxiliary System Requirements

The major requirement of the auxiliary ammonia system is the storage tanks. For a 400 MWe (net) plant the following is required:

16 tanks 25' dia X 50' with a wet weight of 600 k-lbs/tank = 9,600 k-lbs.

The other ammonia system requirements have not been identified but can be assumed to be small.

4.2.6 Chlorination

The 400 MWe plant requires chlorine generators. Their size and weight is as follows:

For a chlorine generation rate of 120,000 ppd, there will be 120 units each: 17' x 3' x 6' x 4,000 lbs. or equal.

4.2.7 Motion Limitation

No motion limitations have been identified.

4.2.8 Startup Power Requirements

To startup the plant three 8,000 hp diesel-generators or their equivalent are required, located either on the Plant or on a service vessel.

4.2.9 Safety Considerations

Safety procedures should be observed with respect to the ammonia system, hypochlorite system and the hydrogen generator cooling plant.

The potential hazards of ammonia and hypochlorite are toxicity and explosion. The potential hazard of hydrogen is explosion.

4.3 Seawater System

The Seawater System shall consist of the following major components, all suitable for a net plant output of 400 MW:

- Cold Water Inlet Pipe
- Cold Water Discharge Pipe
- Cold Water Pump(s) and Interface Pipes
- Warm Water Inlet Pipe
- Warm Water Discharge Pipe
- Warm Water Pump(s) and Interface Pipes
- Inlet Filtration Assemblies

A minimum of one each of the above components shall be provided for each 25 or 50 MW module. The following sections define tentative characteristics for these components suitable as a baseline for early-phase Conceptual Design studies, based on data in Reference (5). These characteristics shall be refined during later phases of Conceptual Design. Figure A-7 illustrates the interfaces of these components within the Seawater System and with the Power System. All components may be external to the platform if they can still be properly inspected, monitored and maintained.

4.3.1 Cold Water Pipe

A single cold water pipe shall be provided suitable for providing cold water to all condensers via a system of plenums and pumps as defined below.

4.3.1.1 Length

The length of the CWP shall be selected on the basis of a desired temperature differential ΔT between cold and warm water inlets of 40°F. Section 4.2.4 quantifies the change in Power System efficiency as a function of variations from the 40°F design point. CWP length shall be optimized based on the trade-off between CWP weight and cost, plant efficiency, pumping efficiency and other factors, reflecting the temperature profile specified in Section 9 for the site. Heat gain by the cold water should be minimized, but no specific limits have been identified in Section 4.2.

4.3.1.2 Diameter

The CWP shall be circular in cross-section and of constant inside diameter. The diameter shall be selected on the basis of trade-offs of CWP drag, bending moments and cost versus hydraulics and pumping costs for the following range:

<u>Flow Rate GPM</u>	<u>Inside Diameter, FT.</u>	<u>Flow Velocity, Ft/Sec</u>
21.5 X 10 ⁶	110	5 (min. allowable)
21.5 X 10 ⁶	78	10
21.5 X 10 ⁶	64	15
21.5 X 10 ⁶	55	20

4.3.1.3 Material

Table A-2 defines the materials and allowable bending stresses for the 100 year storm which shall be considered for the CWP at this stage of design. All materials considered for the CWP must be suitable for continuous exposure to salt water for the life of the system at pressures corresponding to an operating depth of about 3000 feet, and with no maintenance after deployment.

TABLE A-2

TYPICAL PROPERTIES - CWP MATERIALS

<u>MATERIAL</u>	<u>Ultimate Strength KSI (Min)</u>	<u>Yield Strength KSI (Min)</u>	<u>Modulus of Elas- ticity, KSIx10⁶</u>	<u>Density Lbs./Cu. Foot</u>	<u>Maximum Stress KSI</u>
Mild Steel	58	34	30	490	27
HTS	68	45	30	490	33
HY 80	110	80	30	490	55
Aluminum	40	28	10	160	19
GRP	65	--	2.9	112	19
Concrete	6	--	3.4	165	2

Material Specifications - TABLE A-2

Mild Steel	=	American Bureau of Shipping (ABS) Grade A
High Tensile Steel	=	ABS Grade AH32
High Yield Steel	=	MIL-S-16216
Aluminum	=	5086-H32 Alloy
Glass Reinforced Plastic	=	Woven roving/unidirectional composite

4.3.1.4 CWP Fixity

Both fixed and hinged or compliant connections of the CWP to the hull are to be considered. In addition intermediate hinges or other forms of pipe flexibility are to be considered. The design of such flexible connections shall reflect the anticipated 40 year cyclic loading anticipated for the combination of hull, CWP and site characteristics, and shall not fail due to fatigue.

4.3.1.5 Maintainability

The design of the CWP shall reflect no maintenance after deployment except for the possible removal of biofouling and other marine growth if weight buildup, drag or hydraulic losses become excessive. The Ocean System design should reflect consideration of such fouling, particularly in terms of increased drag and displacement.

4.3.2 Cold Water Discharge Pipe

One cold water discharge pipe shall be provided for each power module, leading from the condenser discharge side. If the use of one pipe to serve multiple modules or a single centralized discharge appears to offer advantages for a specific hull configuration, such alternatives may be considered.

4.3.2.1 Length

The length of the cold water discharge shall be suitable to direct the discharge to a location and at a depth which will insure no reingestion into the warm water system. As a minimum, the bottom of the discharge shall be at the mixing layer, defined as the depth at which the surface temperature has dropped 1°C below the surface temperature. The discharges should be directed downward and should be located in a relatively symmetric pattern around the platform's center of flotation to avoid moments on the position control system. The cold and warm water discharges shall be mixed.

4.3.2.2 Shape

The cold water discharges shall be circular with flared exits to minimize discharge losses.

4.3.2.3 Diameter

The nominal inside diameter of the cold water discharge is 26 feet for a 25 MW condenser and 37 feet for a 50 MW condenser. The final diameter is to be determined on the basis of hydraulic analysis and shall accommodate the flow rate through the condenser specified in Section 4.2.4.

4.3.2.4 Materials

Materials for the cold water discharge shall be selected to suit the hull structure into which they are integrated and the materials of the condensers to which they are attached.

4.3.2.5 Design Requirements

If a metal CWP is used, the CWP structure shall not yield or buckle under the worst combination of loading to be experienced during 95 percent of the system life. The CWP shall not fail under the effects of the critical 100 year event. The CWP/hull connection shall have a safety factor on the yield strength of 1.25 and 1.0 under the two conditions described above. If a non-yielding material is used, such as concrete, the corresponding safety factors or ultimate strength shall be determined as noted in Section 5.2.3.

4.3.3 Cold Water Pumps

A minimum of one cold water pump shall be provided for each power module to pump water from the cold water inlet plenum through the condenser at the rate specified in Section 4.2.4. Multiple pumps may be used if justified on the basis of risk, cost, efficiency, size, parasitic power and other factors entering into the trade-off. The pumps shall reflect state-of-the-art technology in large, low head pumps.

4.3.3.1 Pump Type

Pump type shall be determined on the basis of trade-off studies. However, past studies suggest that the pumps will be axial flow with high specific speeds and low RPM.

4.3.3.2 Pump Orientation and Location

The pumps may be either horizontal or vertical. The baseline location is adjacent to the condenser inlet, though alternative locations may be considered.

4.3.3.3 Pump Drive

The pumps shall be driven by electric motors, either direct drive or using higher speed motors and step down transmissions. The selection of drive type will depend upon the selection of motors and shall be selected to minimize parasitic losses as well as starting current and speed variability considerations.

4.3.3.4 Pump Head

Pump head shall be sufficient to overcome pressure drops in the system and to provide the flow rate specified for the condenser. Heads in the range of 10 - 15 feet are expected for the cold water pumps, though the limits on head will be set by considerations of blade strength and possibly cavitation.

4.3.3.5 Pump Efficiency

The pumps shall have maximum efficiency for the specified steady flow conditions.

4.3.3.6 Inlet Configuration

The pump inlet configuration shall reflect considerations of improved pumping efficiency versus the desire to maintain a compact, minimum-volume seawater system.

Diffusers, if used in conjunction with the normal pump inlets, shall be optimized in size by trading off the gain in pumping efficiency versus the cost of the added volume in the hull.

4.3.3.7 Materials

Pump materials shall resist corrosion and erosion, and shall be compatible with the structure in which they are installed and the heat exchangers.

4.3.3.8 Maintenance

All portions of the pump drive and transmission shall be accessible during normal operations. Provision for removal of all pump and drive rotating parts shall be incorporated..

4.3.3.9 Pump Design

Other aspects of the cold water pump design shall reflect current technology for design of similar pumps, modified to reflect the anticipated life and corrosive operating environment.

4.3.4 Warm Water Inlets

Warm water inlets shall be provided for each evaporator, drawing water from a point to maximize inlet temperature yet sufficiently below the operating waterline to eliminate the possibility of emersion in the most critical seas in which operation is required. The inlets shall be provided with screens to prevent injection of debris as specified in Section 4.3.7, and shall be located and configured in a manner which minimizes the likelihood of reingestion of cold or warm water discharges..

4.3.4.1 Diameter

The nominal diameter of the warm water inlet is 27 feet for a 25 MW evaporator and 38 feet for a 50 MW evaporator. The final diameter is to be determined on the basis of hydraulic analysis, and shall accommodate the flow rate through the evaporator specified in Section 4.2.4.

4.3.4.2 Inlet Velocity

The inlet velocity at the intake screens shall be less than 1.5 feet per second to prevent trapping of fish against the screen. Velocities through the pipe shall be based upon requirements for the pump discussed in Section 4.3.6.

4.3.4.3 Materials

See Section 4.3.2.4

4.3.5 Warm Water Discharge Pipe

One warm water discharge pipe shall be provided for each power module, leading from the evaporator discharge side. If the use of one pipe to serve multiple modules as a single centralized discharge appears to offer advantages for a specific hull configuration, such alternatives may be considered.

4.3.5.1 Length

See Section 4.3.2.1

4.3.5.2 Diameter

The nominal inside diameter of the warm water discharge is 25 feet for a 25 MW evaporator and 36 feet for a 50 MW evaporator. The final diameter is to be determined on the basis of hydraulic analysis, and shall accommodate the flow rate through the evaporator specified in Section 4.2.4.

4.3.5.3 Materials

See Section 4.3.2.4.

4.3.6 Warm Water Pumps

A minimum of one warm water pump shall be provided for each power module to pump water from the warm water inlet pipe through the evaporator at the rate specified in Section 4.2.4. Other considerations relating to these pumps are identical to the cold water pumps, Section 4.3.3 except for the difference in flow rate. As a design goal, the warm and cold water pumps should have as many common components as practical.

4.3.7 Filtration Assembly

Filtration assemblies of the plate strainer or screen type shall be provided to eliminate or control the ingestion of marine life and debris as noted below.

4.3.7.1 Cold Water Pipe Inlet

A large mesh screen or grating shall be provided at the lower end of the CWP to prevent ingestion of large marine life. The size of this mesh shall reflect the anticipated marine life at the depth of the CWP inlet and the size distribution. If the fine filtration system is located downstream of the pumps, the mesh or grating size shall be small enough to prevent passage of fish which would foul or damage the pump impeller.

4.3.7.2 Warm Water Inlet

A large-mesh screen shall be provided at the warm water inlet to prevent ingestion of divers, debris and large marine life. See Sections 4.3.7.1 and 4.3.4.2.

4.3.7.3 Heat Exchanger Filtration Cleanout

The condensers and evaporators shall be protected from clogging by a filtration or cleanout system capable of filtering marine life and debris up to 1/2 inch smaller than the diameter of the heat exchanger tubes or by selectively backflushing tubes. The choice shall reflect the probable fish population and debris density. Provision shall be made for periodic removal of debris via travelling screens or similar devices on a schedule which minimizes pressure drops. All mechanical parts of the system shall be accessible for maintenance without shutting down the plant more often than required for the pumps.

4.4 Transmission System

The Transmission System shall be capable of receiving the electrical power generated by the Power System turbogenerators, converting and otherwise conditioning this power to a type and voltage suitable for transmission, and transmitting the power ashore via hardwire cable.

4.4.1 Input Power

The input power developed by the turbogenerators shall be 13.8 KV Alternating Current, rated at 65 MW (gross), 50 MW (net) per 50 MW module. This assumes a parasitic loss factor of 0.3, which shall be verified.

4.4.2 Output Power

The output voltage shall be as follows for the three sites included in Section 9:

Hawaii:	138 KV AC or 230 KV AC
New Orleans:	250 KV DC
Florida:	250 KV DC

4.4.3 Power Conditioning Equipment

4.4.3 Power Conditioning Equipment (Continued)

conditioning equipment. For the purposes of this table, it is assumed that separate generator leads, generator transformers and 138 KV buses are provided for each of 8 - 50 MW modules, but that a single centralized complex is provided for transmission transformers, transmission bus and AC/DC converters.

4.4.4. Riser Cable

A single bundle of riser cables (2 for DC, 3 for AC) shall be assumed, exiting from the platform and supported by a submerged buoy before going to the bottom. The cable bundle will not interface in any way with the CWP or seawater discharge pipes. The point of cable entry shall minimize motion inputs to the cable, particularly in torsion, and shall minimize the likelihood of the cable contacting either the seawater system pipes or mooring/positionkeeping system components. Motion limitations are specified in Section 3.4.2 based upon considerations of cable tension. No torsional limitations are specified at this time.

TABLE A-3

TRANSMISSION SYSTEM FOR 400 MWe (net)(8-50 MW Modules Assumed)

EQUIPMENT	NUMBER	HEIGHT	WIDTH	DEPTH	WEIGHT k-lbs	SPACE cu. ft x 1000
1. Generator Leads	8	—	—	—	66	15
2. Generator Transformer	8	21	18	16	1320	151
3. 138 KV Bus	8	—	—	—	255	127
4. Transmission Transformers	8	—	—	—	3000	283
5. Transmission Bus	1	—	—	—	144	114
6. AC/DC Converter (If Req'd)	1	—	—	—	275	175

NOTES APPLICABLE TO TABLE 3

1. The height, width and depth are given for a single piece of equipment and are given in feet.
2. The weight and space are the sum for all 8 modules.
3. The space requirements for the generator leads, generator transformers, and the 138 KV bus and breaker were calculated on a basis of 6 feet of head room plus 4 feet of clearance on all sides and no bare, live connections.
4. The space requirements for the transmission transformers, transmission bus, and the AC/DC converter were computed using the above method with the appropriate clearances.

5. HULL SYSTEM

The hull system shall support the payload elements defined in Section 4 and shall provide for crew living, support systems, stowage and other functions necessary for the fulfillment of mission requirements.

5.1 Configurations

The platform configurations to be considered for the OTEC Commercial Plant of this study include the following two (2) candidates (Reference (2)).

- Ship (barge)
- Semi-submersible

5.1.1 Size

The size of the Plant shall be the minimum required to support the payload components and platform personnel and support requirements. The enclosed hull volume shall be minimized by eliminating or combining maintenance areas and locating functions in superstructures where possible. The size of the hull shall also provide adequate reserve buoyancy to satisfy freeboard and stability requirements.

5.1.2 Proportions

The proportions of the hull shall be optimized for the prime deployment site defined in Section 9, to minimize the probability of resonances with peak energy wave spectra and to achieve a proper balance between form and friction drag to suit positionkeeping requirements. Draft shall be suitable for the required heads to Seawater System components and heat exchangers. Freeboard shall be suitable for the stability requirements defined elsewhere.

5.2 Structures

The platform structure shall be designed to withstand the the overall and local loads imposed during construction, deployment and operation at the specified operating site for the platform life specified in Section 2.3. Design loads

5.2 Structures (Continued)

and safety factors shall reflect the intent of American Bureau of Shipping and U.S. Coast Guard regulations applicable to offshore platforms. If concrete or other materials are used which do not exhibit a well-defined yield point or for which properties vary, special consideration shall be given to these areas when developing safety factors.

5.2.1 Materials

The primary structure of the OTEC platform shall be steel, reinforced concrete or a composite of these materials. For the purposes of this study, "steel" includes all commercial grades of mild and high tensile or notch tough steel defined in the applicable Rules of the American Bureau of Shipping. "Reinforced concrete" includes combinations of cement, sand, aggregate, water, additives, and reinforcing bars currently used on large offshore structures.

5.2.2 Design Loads

In the absence of applicable ABS or USCG structural criteria, the design loads of this Section shall be used for guidance in conjunction with the safety factors of Section 5.2.3. In the event of any conflict between these requirements and those of ABS or USCG, the latter shall govern.

5.2.2.1 Overall hull design of the ship shall reflect a static balance on a wave equal in length to the hull and in height, equal to $1.1 \sqrt{L}$ in combination with secondary loads as defined below. For the semi-submersible, beam and oblique sea loading shall also be considered.

5.2.2.2 Shell Panels and supporting structure shall be designed for a hydrostatic head corresponding to a static head to the operating waterline plus $0.68 \sqrt{L}$ where L is the length of the platform, or 500 PSF, whichever is critical, in combination with hull girder bending stresses.

5.2.2.3 Decks shall be designed for a combination of hull girder bending plus secondary loading caused by deadweight plus a live load as follows:

- 200 PSF in living, working and control areas.
- 300 PSF or the weight of stowed equipment in the storage areas
- Weight of installed equipment as applicable
- 75 PSF on exposed superstructure decks
- 300 PSF on weather decks forming the top of the hull or cross-structure.

5.2.2.4 Watertight bulkheads shall be designed for a hydrostatic head to the subdivision decks. Tank bulkheads shall be designed to a head equal in height to the tank overflow.

5.2.2.5 Equipment foundations shall be designed for the weight (wet) of equipment installed, reflecting acceleration factors to account for ship motions.

5.2.2.6 Semi-submersible cross structure bottom shall be designed for a slamming load of 2000 PSF equivalent static pressure at ends tapering uniformly to 1000 PSF amidships.

5.2.3 Safety Factors

For mild steel structures, a safety factor of 2.0 on the yield strength is required for primary bending and all normal loads. A safety factor of 1.25 on the yield strength is required for flooding and slamming loads. The corresponding safety factors for panel and column buckling are 2.50 and 1.67 respectively. For

5.2.3 Safety Factors (Continued)

high strength steel, the safety factor on yield strength shall be as follows:

$$SF_{HSS} = SF_{MS} \times \frac{U_{MS} / Y_{MS}}{U_{HSS} / Y_{HSS}}$$

where Y, U = yield and ultimate strengths of mild and high strength steels as specified.

For reinforced concrete, the safety factor on ultimate strength shall be as follows:

$$SF_{RC} = SF_{MS} \text{ (yield)} \times 2.5$$

where SF_{RC} is the safety factor for reinforced concrete and the factor 2.5 includes an allowance for the ratio of yield to ultimate long term strength retention variability and long-term strength retention.

5.2.4 Fatigue

For structures subject to cyclic loads, such as the CWP/hull connection, relative fatigue characteristics shall be considered in conjunction with life cycle wave-induced stress profiles in defining allowable stresses for various materials.

5.3 Arrangements

The functional arrangement of the internal volume of the platform shall reflect requirements for:

- Personnel comfort and safety in accordance with USCG and other applicable requirements
- Accessibility for maintenance and equipment removal
- Flow of personnel traffic, particularly during emergency conditions
- Stores transfer
- Proximity of functionally related spaces
- Isolation of noise and vibration producing equipment from working and habitability areas

5.3.1 Mission Support

Section 4 defines specific arrangement requirements related to the support of the Power, Seawater and Transmission Systems.

5.3.2 Personnel Support

Section 7 defines specific arrangement requirements related to personnel support.

5.3.3 Platform Support

Section 6 and 7 define specific arrangement requirements related to Positionkeeping and Support Systems.

5.4 Motions

Three seakeeping qualities must be addressed in the evaluation and design of the platform: habitability, operability and survivability.

- Habitability concerns itself with mission performance or the ability of the platform personnel to make judgments and to perform physically demanding functions without motion-induced fatigue.
- Operability concerns itself with the proper functioning of all platform subsystems under the varying environmental conditions in which the platform is expected to function. This includes keeping instruments operating, operating the Power System, ensuring safety of deck equipment, etc.
- Survivability is the capability of the platform and its most essential subsystems to continue functioning until the danger is over or until corrective measures can be taken. Habitability is no longer a factor of primary concern, and operability is important only with respect to the most essential subsystem. Survivability criteria apply to the motions to be seen during the most critical 5 per cent of the system life, up to the limits of the 100 year critical event.

5.4.1 Motion Limits for Equipment Operability

At this time, no definitive motion limits have been identified for operability or survivability of the Power System or Seawater System. However, good design practice for rotating machinery suggests that accelerations normal to the axis of rotation be limited to 0.5 "g" while accelerations parallel to the axis of rotation be limited to 0.25 "g" unless special provisions are incorporated in the design of bearings and shafting.

5.4.2 Motion Limits for Riser Cable

The locus of limiting motions (including both hull response to waves and positionkeeping watchcircle) shall not exceed the limits defined in Figure A-8 (Reference (7)) based on cable mechanical strength limitations during 95 per cent of the life of the system. Provision shall be made to temporarily detach the riser cable if motions exceed these limits.

5.4.3 Motion Limits for Personnel Comfort

In order to ensure personnel comfort and performance, platform accelerations in way of living or working areas shall not exceed the tolerable motion spectrum of Figure A-9 (Reference (8)) when deployed in the environment defined in Section 9. These limiting motions shall not be exceeded over 95 per cent of the life of the system.

5.4.4 Motion Limits for Survivability

The platform shall be designed in such a manner that it can continue performing its functions until the danger is over or until corrective measures can be taken. Survivability of the platform shall be assured under the effects of the most critical 100 year event defined in Section 9. Under these conditions, the platform shall have sufficient righting energy to avoid overturning due to the action of the winds and waves. The hull structure shall be designed so that catastrophic failure of the platform and CWP attachment is prevented as required by Section 4.3.2.5.

Figure A-8

TRANSMISSION CABLE MOTIONS ENVELOPE

Motions Profile - Vertical Plane

Position	Max Heave
1.00 0	$\pm 0.01 0$
1.04 0	$\pm 0.10 0$
1.10 0	$\pm 0.15 0$
1.30 0	$\pm 0.12 0$
1.50 0	$\pm 0.06 0$
1.60 0	0

Motions Profile - Horizontal Plane

- Notes:
1. Drawings are not to scale.
 2. Permissible yaw = $\pm 5^\circ$
 3. Assume $D = 3500$ ft

Figure A-9
 PHYSIOLOGICAL RESPONSE TO
 PERIODIC VERTICAL OSCILLATIONS

6. POSITION CONTROL SYSTEM

A position control system consisting of anchors, dynamic positioners or a combination of these shall be provided which is capable of limiting the movement of the platform as defined below. Separate requirements for static and dynamic position control systems are provided in Sections 6.3 and 6.4 respectively.

6.1 Operational Mode Requirements

The Position Control System shall limit platform lateral motions to those which, in combination with wave-induced motions do not exceed the limits established for cable mechanical strength in Section 5.4.2, during 95 per cent of the life of the system.

6.2 Survival Mode Requirements

The excursions of the platform during the most critical 5 percent of the life of the system up to the limits of the 100 year critical event shall not exceed the following:

- That required to prevent grounding of the CWP
- That required to prevent collision with adjacent OTEC platforms in an energy park, or other fixed obstructions

6.3 Static Positioning System

A mooring or static positioning system includes the necessary equipment and controls to permanently anchor the platform to the bottom. The system shall consist of single or multiple anchors, mooring lines, winches and controls.

6.3.1 Anchor

6.3.1.1 Type

Anchors shall consist of one or more of the following types,

6.3.1.1 Type (Continued)

as required to suit the specific bottom composition, water depth and mooring line scope:

- Deadweight anchors
- Embedded plates
- Self-setting fluke-type anchors
- Piles

6.3.1.2 Life

Anchors shall be suitable for a life of 40 years or the life of the mooring line, whichever is less. If suitable means of returning and reusing the anchors are available, the 40 year life requirement applies.

6.3.1.3 Configuration

A multi-point moor shall be used to avoid interference with the CWP, with a minimum of four anchors. The location and spacing of the anchors shall be based on relative hull lateral and longitudinal drag and prevailing wind, seas and currents.

6.3.1.4 Holding Power

The anchors shall not move when subjected to a pull equal to the breaking strength of the mooring line. For this condition the cable angle above horizontal shall be the natural catenary resulting from the above line pull.

6.3.2 Lines

6.3.2.1 Type

Mooring lines may be wire rope, synthetic rope, hollow links, chain or a combination of these. State-of-the-art materials and diameters shall be used if practical.

6.3.2.2 Life

Mooring lines shall be suitable for a minimum life of 5 years. Replacement shall be accomplished with no impact on plant operations.

6.3.2.3 Strength

The line system and associated fittings shall have a safety factor of 2.0 on the ultimate tensile strength appropriate to submerge for 5 years when the mooring system is loaded with the worst loads corresponding to the operational condition. The corresponding safety factor for the survival mode shall be 1.5 on the ultimate strength. If one line fails under this condition, the remaining line(s) shall be capable of holding without failure, unless drifting for the duration of the storm will not exceed the survival conditions of Section 6.2.

6.3.2.4 Protection

The mooring lines shall be adequately protected against abrasion and impact from the platform as well as workboats.

6.3.3 Winches and Controls

A system of constant tension winches and appropriate controls shall be provided for each line, capable of holding the line without slipping or yielding up to its breaking strength. State-of-the-art equipment, including fairleads, etc. shall be used if standard mooring lines are used.

6.4 Dynamic Positioning System

A dynamic positioning system consisting of multiple directional thrusters may be used as an alternative to, or in combination with, the static system described in Section 6.3. The system may consist of rotating shrouded propellers, fixed propellers (tunnel type thrusters), or waterjets. Such systems shall not disturb the flow of water into the Warm Water Inlets.

6.4.1 Thrust Requirements

The system shall provide sufficient thrust to satisfy the operational and survival conditions specified in Section 6.2 with one thruster inoperative. For the survival mode, it can be assumed that the platform will be aligned to minimize drag. However, for the operational condition, the 30° heading variation limits of Figure A-8 apply. Thrust calculations shall reflect a 10 percent power margin and accumulated marine growth as appropriate to the hull maintenance concept.

6.4.2 Power Source

The dynamic positioning system may draw power from the OTEC Power System as long as the total parasitic load from the Ocean System does not exceed 120 MW.

6.4.3 Use of Power System Discharges

It is not acceptable to vector the discharges from the Seawater System for either normal or survival operations due to the additional loading imposed on the pumps in achieving high enough velocities for thrusting purposes, and the possibility of Power System shutdown during extreme weather conditions or because of mechanical failure.

6.4.4 Maintainability

All prime mover components of the Dynamic Position Control System shall be accessible for inspection and maintenance. External components shall be accessible for inspection by divers, and shall be modular to permit replacement as required during the life of the system.

6.4.5 Control System

A control system shall be provided which automatically tracks the position of the platform relative to the riser cable buoy and adjusts thrust as required to maintain the platform within the envelope of acceptable motions established by Figure A-8. The system shall normally provide a 10 percent safety factor within this envelope, and shall sound appropriate alarms when this safety factor has been exceeded.

Manual backup shall be provided for all critical automatic operations, including startup, thrust control and vector control. Such controls shall be provided both locally and at the control station.

7. SUPPORT SYSTEMS

Platform support systems shall be provided as required for mechanical/electrical requirements, environmental control, personnel support, life-saving, platform support, material handling and navigation/ communication. All such systems shall meet the requirements of the applicable regulatory agencies, including the American Bureau of Shipping and U.S. Coast Guard. All equipment shall be of commercial marine type.

The requirements as set forth in this Section are based upon the assumption that the platform Support Systems are essentially self-sufficient, requiring only resupply of consumables which cannot be generated onboard. As indicated in Section 9, the platform is to be deployed in an Energy Park consisting of eight-400 MW Commercial Plants, which opens up the option of using shoreside facilities and platform/shore transfer for many Support System functions such as

processing sewage and other liquid or solid pollutants, producing make-up compressed gases and fresh water, etc. These options shall be traded off against the cost and benefit of self-contained capability in the selection of Support Systems.

7.1 Mechanical/Electrical System

7.1.1 Auxiliary Electric System

The platform shall be provided with an auxiliary electrical system which includes three principal capabilities:

1. Power for normal hotel, platform auxiliary and Power System auxiliary loads.
2. Power for Power System start-up (See 4.2.8) unless provided by an outside source (See 7.1.1.1)
3. Emergency power to vital systems per USCG requirements

7.1.1.1 Start-Up-Generators

Due to the intermittent nature of the start-up operation, it is acceptable to utilize the start-up generators specified in 4.2.8 for powering the Position Control System and those portions of the hotel/ auxiliary load that can be cut off during the start-up operation. In this regard start-up should be feasible without losing vital functions such as lighting, environmental control, etc. Elimination of the start-up generators in favor of installing such capability on a service boat serving the Energy Park shall be considered.

7.1.1.2 Auxiliary Electrical System

The auxiliary electrical system shall be capable of supporting the hotel/auxiliary load using power from the Power System, start-up generators

7.1.1.2 Auxiliary Electrical System (Continued)

(if installed), dedicated Auxiliary Service Generators or a combination of these. The system shall be sized for 30% load growth except in the Position Control System. Auxiliary Service Generators, if used, shall be diesel or gas turbine driven, 3 phase 60 Hz AC, with appropriate switchgear and distribution system.

The Auxiliary Electrical System shall provide power to those elements of the Power System requiring electrical power for operation, including ammonia pumps, vacuum pumps, and chlorine generators.

7.1.1.3 Emergency Generator

A minimum of one diesel powered generator shall be provided for vital services in the event of Auxiliary Electrical System failure.

7.1.2 Fluid and Gas Systems

Provision shall be made for the distribution, storage and replenishment or generation of all necessary fluids to support Plant operations. This shall include, but not be limited to, compressed air, nitrogen, ammonia, salt water, chlorine, fresh/distilled water, diesel oil, lubricating oil, hydraulic oil, firefighting and sewage. Such systems shall reflect current practice in the design and operation of offshore platforms.

7.1.3 Compressed Gas

7.1.3.1 Compressed Air

The compressed air system shall supply diesel or turbine start-up platform service and control air.

7.1.3.2 Nitrogen

A nitrogen system shall be provided for inerting all ammonia piping. The sub-system shall be sized to provide a complete purging of an average of one module per month.

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7.1.4 Bilge and Ballast

7.1.4.1 Bilge System

A bilge system shall be provided to drain all spaces below the waterline which are not tanks or voids. Bilge water shall be properly filtered or otherwise treated to remove pollutants before being discharged overboard.

7.1.4.2 Ballast System

A ballast system shall be provided to permit controlled flooding and dewatering of specified tanks for the purposes of maintaining proper draft, trim and stability. The stowage of fuel oil or other liquids in ballast tanks is not permitted.

7.1.5 Fuel Oil Transfer and Stowage

A fuel oil transfer and stowage system shall be provided to supply fuel to Auxiliary Electrical Service and start-up generators, if installed, auxiliary boilers and other fuel-fired equipment. Storage for 60 days' supply shall be provided. Facilities shall be provided for the transfer of fuel oil from resupply vessels at a pressure and pumping rate appropriate to state-of-the-art in offshore fuel transfer.

7.1.6 Fire Detection and Extinguishing

Fire extinguishing systems shall consist of firemain, portable CO₂, AFFF and HALON 1301 or CO₂ as defined below, in accordance with U.S. Coast Guard requirements. Fire detection capability shall include the ability to detect smoke and infrared (IR) radiation in all unmanned spaces, and to sound appropriate alarms.

7.1.6.1 Firemain

A horizontal loop-type firemain shall be provided to supply seawater to fire stations located throughout the platform such that water can be directed to any area within or on the platform at a minimum pressure of 100 PSI. A minimum of 4 electrically driven firepumps shall be provided, located at the four

7.1.6.1 Firemain (Continued)

quarters of the platform, with cross-connections such that any pump can feed any fire station.

7.1.6.2 Portable CO₂

Portable CO₂ fire extinguishers shall be provided throughout the platform in accordance with applicable U.S. Coast Guard requirements.

7.1.6.3 AFFF

A system for manual spraying with AFFF or other foam-type smothering agents approved by U. S. Coast Guard shall be provided in way of the helicopter landing area.

7.1.6.4 HALON 1301 or CO₂

A HALON 1301 or CO₂ fixed flooding system shall be provided for all machinery spaces, platform control spaces and other spaces containing high-value equipment which would be damaged by water. The system shall be manually activated, with activation alarms both locally and in the Central Control Station.

7.1.7 Lubrication and Hydraulic

A lubrication system including pumps, filters, transfer piping, fittings and storage tanks for 60 days' supply of oil shall be provided to service turbo-generators, pumps, thrusters and other systems without attached lubricating systems. The system shall be suitable for supplying clean lube oil to equipment with attached auxiliaries and of transferring dirty oil to storage tanks for processing. Hydraulic system(s) shall be provided to supply properly filtered hydraulic fluid to those equipments requiring same, at the specified pressure.

7.1.8 Fresh Water

A fresh water system shall be provided for diesel engine cooling, generator cooling, washdown, auxiliary boiler feed and domestic use, including drinking, cooking, washing and showers.

7.1.8 Fresh Water (Continued)

Hot fresh water shall be supplied to the galley, laundry, sanitary facilities and other services using either waste heat, oil-fired or electric boilers.

Domestic water systems shall comply with applicable U. S. Public Health Service (USPHS) regulations.

Fresh water shall be provided by a minimum of two distilling plants, each capable of satisfying normal daily demands, including 60 gallons per man per day and cooling system makeup. Alternatively, water may be supplied by tank vessels.

Potable water tanks shall be provided with a capacity equivalent to 120 gallons per accommodation if distillers are installed. If external resupply is used, the tanks shall be sized to suit the resupply cycle.

7.1.9 Sanitary

A sanitary subsystem shall be provided serving water closets and selected flushing/washdown systems. This system shall comply with applicable USPHS regulations.

7.1.10 Pollution Control

Pollution control subsystems shall be provided to eliminate the discharge of liquid or solid pollutants into the environment. Such systems shall include collecting tanks, filters, incinerators, chemical treatment and other systems as required to effectively treat or transfer oily bilge water, sanitary system discharge, galley wastes, chemical waste, trash and other polluting substances. These systems shall prevent discharge of pollutants in accordance with applicable U.S. Coast Guard and Environmental Protection Agency regulations. Where such requirements are not met by onboard processing, provision shall be made for transfer to shoreside facilities.

7.1.11 Miscellaneous Fluid Systems

Additional fluid systems shall be provided as required to suit operational conditions.

7.1.12 Aircraft Fuel

Provision shall be made for emergency refueling of helicopters, including a storage tank, hoses, pumps, controls and filtration equipment.

7.1.13 Refrigeration

A refrigeration system shall be provided to support the air conditioning and food storage systems.

7.2 Environmental Control Sub System

Heating, ventilation and air conditioning (HVAC) systems shall be provided as specified below for all platform spaces based upon the following environmental extremes (for site specified in Section 9):

Temperature: 60°F to 100°F

Humidity : 80% to 95%

7.2.1 Heating System

Portable electric heaters shall be provided for living, working and control spaces to insure a minimum temperature of 65°F.

7.2.2 Ventilation

All non-air conditioned spaces shall be ventilated in accordance with U.S. Coast Guard 46CFR Subchapter 0 Section 151.50-32(d). Compartments containing ammonia tanks, evaporation, pumps, piping, and turbines shall contain high-volume exhaust fans with natural supplies to exhaust ammonia fumes in the event of leakage. These fans shall have automatic shutdown capability in the event of fire.

7.2.3 Air Conditioning

All living, recreation, messing, working, medical and control spaces shall be air conditioned in accordance with SNAME T & R Bulletin No. 4-7. Working spaces are those in which personnel are permanently stationed and exclude operational spaces served by a roving watch.

7.3 Personnel Support

The Personnel Support subsystem shall provide for the living, messing, recreation and welfare of all embarked personnel. Standards shall generally conform to current offshore practices.

7.3.1 Habitability

Maritime crew members shall be provided with private or semi-private accommodations in accordance with current offshore practices. Senior supervisory plant operating personnel shall have private accommodations while intermediate supervisory and non-supervisory personnel shall have semi-private staterooms, and 4-man bunkrooms respectively. Each single or double stateroom shall have a sanitary facility, while bunkrooms shall share a centralized sanitary facility. A minimum of 100 square feet per man shall be provided (average).

Private cabins shall be provided for transients as specified in Section 8.10.

Messing facilities shall be provided to accommodate a minimum of one half of the total accommodations per sitting.

A separate recreation facility shall be provided, divided into a "quiet" and "noisy" area. This facility may be used for crew training.

7.3.2 Medical

A dispensary shall be provided suitable for treating illness and minor injuries. An isolation ward shall be provided in accordance with U.S. Coast Guard regulations. Provision shall be made for the rapid transfer of seriously ill or injured personnel to shore based hospitals via helicopter. Dental facilities are not required.

Emergency medical equipment shall be provided in all living, working and control spaces, located in damage control lockers as required by 7.4.2.

7.3.3 Offices

A centralized office complex shall be provided for the normal administration of platform and payload operations. Combined training and conference facilities shall also be provided.

7.3.3 Offices (Continued)

A Central Control Station (CCS) shall be provided for the control of all primary Plant operating functions, including Power System and Transmission System, Seawater System, Position Control System, major auxiliary systems and damage control. This Station shall include consoles for the remote operation and monitoring of all major Platform equipment, and shall be adjacent to the communication spaces.

7.3.4 Personnel Stowage

Provision shall be made for the stowage of galley and stewards stores, baggage, medical supplies and other portable and consumable gear associated with personnel support. Galley stores and other consumables shall be based upon a 30 day resupply for chill, frozen and dry stores.

7.3.5 Commissary, Laundry

A centralized galley complex shall serve all messing areas, and shall be in close proximity to food stowage areas to facilitate transfer of supplies. The galley shall be designed to serve up to one-half the accommodations at one sitting.

A laundry shall be provided capable of handling all soiled clothes and linen generated by embarked personnel, unless shoreside laundering is utilized.

7.4 Lifesaving

7.4.1 Boats and Rafts

Boats, rafts and other lifesaving appliances shall be provided for all personnel in accordance with U. S. Coast Guard requirements.

7.4.2 Damage Control

Systems shall be provided to detect water leakage, smoke, ammonia vapor and other potential hazards and to sound alarms both locally and in the

7.4.2 Damage Control (Continued)

Central Control Station. Portable damage control equipment shall be located in lockers throughout the platform to combat such hazards, including oxygen breathing apparatus in all spaces containing ammonia transfer or storage.

7.5 Platform Support

7.5.1 Shops

A central workshop shall be provided to permit normal maintenance and repair to both platform and payload electrical and mechanical equipment. Provision shall be made for the transfer of equipment to the shop in accordance with Section 7.6. A separate electronics shop shall be provided to service navigation, communication and test equipment.

7.5.2 Test Facilities and Laboratories

A permanent laboratory shall be provided suitable for conducting all tests, analyses, data processing and performance monitoring of OTEC Ocean System and environmental parameters as specified by DOE. Provision shall also be made for the temporary topside stowage of up to four 8 x 8 x 20 vans containing special test, monitoring equipment and supplemental accommodations for technical personnel.

7.5.3 Spare-Parts Stowage

Stowage shall be provided for spare parts and miscellaneous equipment associated with the Seawater, Position Control and Support Systems, based on a 30 day resupply cycle.

7.6 Material Handling

7.6.1 Air to Sea

Aircraft landing facilities shall be provided for day/night operation of helicopters of up to 50,000 pounds gross takeoff weight. These facilities shall

7.6.1 Air to Sea (Continued)

include a landing pad with suitable visual landing aids, navigation transponders and tiedown facilities. A helicopter control station with 360 degree visibility and voice communications to both the helicopter and firefighting crews shall be provided. Aircraft hangaring, maintenance and repair capabilities are not required, though the platform shall be capable of emergency refueling aircraft and of providing firefighting and emergency services in way of the landing area. Provision shall be made for the transfer of air cargo from the landing zone to stowage areas.

7.6.2 Sea to Sea

Facilities shall be provided for the day/night mooring of offshore supply boats and the transfer of personnel and cargo from these boats in conditions up to Sea State 3. Boat maintenance, repair and refueling capabilities are not required. Cranes capable of lifting up to 50 short tons at an outreach of 50 feet shall service the boat mooring areas.

7.6.3 Intra Platform

Facilities shall be provided for the safe transfer of supplies, spare parts and equipment throughout the platform via a system of power hoists and monorails, conveyors, and other appliances. Overhead cranes shall be provided in way of turbogenerator sets, pumps and other rotating equipment to permit removal or laydown of major components for servicing.

7.7 Navigation and Communication

7.7.1 Radio

A suite of two way voice communications equipment shall be provided which is in accordance with current practice for large offshore platforms, and shall provide the ability to communicate with other Plants, shore facilities, helicopters, supply boats and nearby shipping traffic.

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7.7.2. Radar

A radar system with a range of up to 20 nautical miles shall be provided capable of detecting and tracking both low air and surface targets.

7.7.3 Interior Communications

Telephone and announcing systems shall be provided to permit communications between all platform compartments. Television monitoring shall be provided for the helicopter pad, boat landing position, power plant machinery rooms and other key operations, with monitors in the Central Control Station. General, fire, flooding and NH_3 leakage alarms shall be provided.

7.7.4 Position Sensing

The capability shall be provided to sense platform position with ± 50 feet relative to the riser cable buoy.

7.7.5 Lights

Navigation lights shall be provided in accordance with international standards. Additional high-intensity lighting shall be provided as an aid to nearby shipping.

Helicopter night flight operating lights shall be in accordance with the latest edition of "Visual Landing Aids General Service Bulletin No. 9-2"

7.7.6 Weather Monitoring

Facilities shall be provided to monitor weather conditions, both via communication with the U.S. Weather Service and by on-board observation of wind and sea conditions.

7.7.7 Exploration Aids

Facilities shall be provided for monitoring sea conditions (wave height and length, wind, etc.), ocean thermal profiles, current strength and other factors vital to Plant operation.

8. SYSTEMS ENGINEERING REQUIREMENTS

8.1 Construction

The Ocean System shall be fabricated at existing or modified U.S. facilities or in a new facility located on U.S. territory. The hull and major systems may be constructed as a unit or as a series of modules to be joined afloat, depending on the size and configuration of the platform, and economic considerations. Construction of eight (8) identical platforms is envisioned for a 3200 MW Energy Park.

8.2 Deployment

The Plant shall be deployed to the operating site by tugs, dynamic positioners or a combination of these. Additional self-propulsion capability is not required.

8.3 Maintenance

The maintenance concept for the Ocean System parallels that for the payload, Section 4.2.3, and is based upon the assumption that the Ocean System will remain on site throughout its useful life and will not return to drydock for maintenance and repair except in the event of major damage. Based upon this, the maintenance concept for the Hull, Position Control and Support Systems shall include the following:

8.3 Maintenance (Continued)

1. Use of materials which are not degraded by the marine environment
2. Removal of marine growth from underwater surfaces by divers
3. Repair and maintenance of equipment in place or by replacement
4. Rotation of common equipment to shoreside maintenance facilities for periodic overhaul

8.4 Operation

The OTEC Commercial Plant shall be operated by rotating crews similar to the concepts now in use with offshore platforms. The Plant shall function 24 hours a day, with crews rotating in 12 hour shifts. Maintenance and the operation of functions such as the laundry, administration, shops, etc., shall be during a single shift, with reduced crews operating the Power System, Seawater System and essential platform functions during the other shift.

8.5 Safety

The design, construction and operation of the Plant shall reflect considerations of safety throughout. All applicable safety codes and standards shall be implemented, including OSHA, Coast Guard, and National Fire Protection Association. Special attention shall be directed toward the potential safety hazards associated with ammonia vapor.

8.6 Stability

The subdivision and other stability features of the platform shall guarantee survival after the following events, where survival means retention of adequate reserve buoyancy to prevent sinking, and adequate stability to prevent capsizing in the worst 100 year event specified in Section 9.

1. Flooding of any two adjacent compartments
2. Being struck by a ship of displacement not greater than the Plant, with sufficient force to penetrate 20 percent of the beam.
3. Operating with or without the CWP in the worst 100-year event.

8.7 Logistics

The OTEC Commercial Plant shall use off-the-shelf components and identical components from the same manufacturer to the maximum extent practical. Stockpiles of platform-peculiar components shall be maintained to the extent necessary to insure availability of critical components throughout the life of the Plant. Stockpiles of small items shall be maintained aboard the platform while those of larger items shall be maintained in a shoreside facility.

8.8 Noise and Vibration

Noise and vibration producing equipment shall be resiliently mounted or isolated to minimize degradation of working and living conditions in nearby manned compartments. Special attention shall be directed toward noise reduction in living, recreation, and control spaces.

8.9 Environmental Protection

Pollution control systems shall be provided to treat or collect pollutants such that overboard discharge of solid wastes, oily ballast, sewage wastes and chemicals is eliminated as required in 7.1.10. The effluent of warm and cold water shall be mixed and discharged below the mixing layer as required in 4.3.2. The spacing and configuration of Plants in an Energy Park shall minimize long term thermal or biological impacts.

8.10 Manning

The operating personnel for the Ocean System shall be licensed or unlicensed civilian marine operating personnel with qualifications similar to those of current offshore platforms. The operating personnel for the Power and Transmission Systems shall have parallel qualifications to personnel now operating shoreside power plants of similar size. All personnel shall be rotated on assignment in accordance with current offshore platform practices generally on a 2-week schedule. Work schedules shall be in accordance with Section 8.4. The platform shall have a 10 percent reserve in accommodations to house transients including scientists, vendor representatives, inspectors, flight crews, shorebased maintenance personnel and other visitors.

8.11 Licenses and Regulations

The OTEC Commercial Plant shall meet all regulations and satisfy all licensing requirements currently applicable to offshore platforms and power plants of similar size and capacity. Where the scope of such regulations does not address the OTEC Ocean Systems, their intent shall be met pending modification to the regulations. Applicable regulations and their areas of responsibility include but are not limited to the following:

- American Bureau of Shipping (ABS)
- United States Coast Guard (USCG)
- United States Public Health Service (USPHS)
- Federal Communications Commission (FCC)
- ASHRAE Standard 26-63 (ANSI B59.1)
- Federal Aviation Authority (FAA), "Helicopter Design Guide".
- Standard Specification for Merchant Ship Construction, U.S. Department of Commerce, Maritime Admin., Spec No. PB-257261, 1976
- Hydraulic Institute Standards, 23 Edition 1975
- Occupational Safety and Health Administration (OSHA)
- Department of Energy Manual Chapters.

9. ENVIRONMENT

9.1 Location of Sites

Five locations have been identified as potential sites for an OTEC Plant: Keahole Point, Hawaii; Punta Tuna, Puerto Rico; New Orleans, Louisiana; West Coast of Florida; and an area in the South Atlantic off the coast of Brazil. Figure A-10 shows the location of these sites. Only the Hawaii, New Orleans and Florida sites are of concern in the studies being conducted by Gibbs & Cox, Inc.

9.2 Principal Site

The Hawaii site shall be used as the baseline for OTEC Commercial Plant optimization studies. Sensitivity studies shall identify the potential impact of optimizing for either New Orleans or Florida.

9.3 Site Characteristics

Table A-4 and Figure A-11 summarize the environmental characteristics of the above sites, based upon Reference 9.

TABLE A-4
SUMMARY OF SITE ENVIRONMENTAL CHARACTERISTICS

<u>SITE</u>	HAWAII	PUERTO	NEW ORLEANS	W. COAST FLORIDA	BRAZIL (Question- able Data)
Water Depth, ft.	3150	4000	4650	4592	(18,000)
Depth for 36°F T:					
Max, ft.	3280	2790	4650(*)	4592(**)	2020
Min. ft.	1560	2050	1560	1476	950
Current Velocities:					
Extreme, Kts.	2.18	2.76	2.49	5.0	3.20
Normal, Kts.	1.13	1.21	1.17	2.5	0.50
<u>100 Yr Return Period:</u>					
Max. Wind, Kts.	65.7	92.8	100.3	113.8	61.0
Gusts, Kts.	95.2	134.6	145.4	165.0	—
Period Max. Energy, Sec.	12.71	13.8	15.91	13.27	-
Sign. Wave Ht. Ft.	35.9	44.2	58.1	45.8	29.0
<u>AVG. MONTHLY EXCEEDANCES:</u>					
20 kt. wind	1.09	3.37	26.42	12.86	6.52
32 kt. wind	0.01	0.17	2.20	0.97	0.23
44 kt. wind	0.01	—	0.26	0.10	-
12 ft. sig. wave ht.	1.71	0.15	2.02	0.84	0.61
16 ft. sig. wave ht.	0.51	0.05	0.46	0.13	0.11
19 ft. sig. wave ht.	0.31	0.02	0.24	0.03	0.03

(*) 36°F ΔT not achieved during January, February, March, April

(**) 36°F ΔT not achieved during January February, March

Figure A-10 GENERAL SITE LOCATION MAP

X POTENTIAL SITE LOCATIONS

COMPARISON OF DESIGN WAVE SPECTRA

FOR FIVE ERDA - OTEC SITES

PRVH Jo. 1 August 1977

NOTE:

$$W \text{ (RAD/SEC)} = 2\pi f \text{ (HZ)}$$

$$I_W = 5.12 T_W^2 = \frac{5.12}{f^2}$$

Figure A-11

18351-5(M-9230)

18351-5 (W-9230)

REFERENCES

1. Gibbs & Cox, Inc. Report 18251-2 (W-8400) OTEC Platform Configuration and Integration - Task I, IIA and IIB Final Report dated October 1977
2. Gibbs & Cox, Inc. Record of Telephone Conversation 18351-5 (W-9142) dated January 9, 1978
3. ERDA RFP No. EG-77-R-01-4011
4. Gibbs & Cox, Inc. Report 18351-3 (W-8500) Task III Technology Review Final Report dated October 1977
5. DOE letter from J. Horwitz to D. Price of NOAA, January 10, 1978
6. Simplex Co. Development Engineering Report No. 20 dated November 20, 1977
7. Simplex Wire & Cable Co. Report 18 "OTEC Preliminary Analysis of Allowable Movement of Plant as it Affects Power Cables" dated October 11, 1977
8. Society of Naval Architects and Marine Engineers - Technical and Research Bulletin 1-32 "On the Environmental Operability of Seagoing System", dated January 1976
9. OTEC Demonstration Plant Environmental Package dated July 24, 1977

DETAIL 1
AXIAL STIFFENERS
1/2" = 1.0'

SECTION C
1" = 1.0'

SECTION B
1" = 1.0'

SECTION C

DETAIL 1

GIBBS & COX, INC. NEW YORK	
COLD WATER PIPE WELDING DETAILS	
SCALE: AS SHOWN	DATE: JAN. 1970
DRAWN BY: S. WATSON	APPROVED: S. SCOTT
CHECKED: _____	APPROVED: _____
DR NO 18391-8001-6 SH. 2 OF 2 REV

GIBBS & COX, INC. NEW YORK	
COLD WATER PIPE DETAILS	
DATE: 10/1/57	DATE: 10/1/57
DESIGNED BY: J. W. H. H. H.	APPROVED BY: R. S. H.
CHECKED BY: J. W. H. H.	APPROVED BY: R. S. H.
DR. NO. 10351-8001-6 QUT. 1.012 REV

INTERMEDIATE RING STIFFENERS
TO BE $18 \times 77^* T$ UNLESS
OTHERWISE NOTED.

RING FRAMES
 $50 \times 36 \times 0.68^* / 1.5^* T$

RING FRAMES
 $50 \times 36 \times 0.68^* / 1.5^* T$

RING FRAMES
 $50 \times 36 \times 0.68^* / 1.5^* T$

AXIAL STIFFENERS
 $18 \times 7 \frac{1}{2} \times 60^* 1^* T$

AXIAL STIFFENERS
 $18 \times 11 \frac{1}{2} \times 96^* 1^* T$

AXIAL STIFFENERS
 $18 \times 12 \times 75^* 1^* T$

INTERMEDIATE DECK STIFFENER $18 \times 8 \times 50^* 3^* T$

DEEP GIRDER $30 \times 18 \times 174^* 1^* T$

Technical drawing showing two circular stiffener layouts, labeled DECK-E and DECK-A.

DECK-E:

- Dimensions: $68 \times 42 \times 1.00 / 1.38$, $72 \times 40 \times 1.00 / 1.25$, $68 \times 42 \times 1.00 / 1.38$, $24 \times 9 \times 94 \text{ I-T}$, $56 \times 40 \times 0.76 / 1.25$, $68 \times 42 \times 1.00 / 1.38$, $24 \times 9 \times 94 \text{ I-T}$, $68 \times 42 \times 1.00 / 1.38$, $24 \times 9 \times 94 \text{ I-T}$, $68 \times 42 \times 1.00 / 1.38$.
- Stanchion BLW 2 W4x550 SEE DET 1-B
- INTMD STIFFENERS $9 \times 7 \frac{1}{2} \times 25 \text{ T}$
- 125 PL

DECK-A:

- Dimensions: $16 \times 7 \times 36 \text{ I-T}$, $9 \times 7 \frac{1}{2} \times 25 \text{ T}$, $24 \times 9 \times 94 \text{ I-T}$, $68 \times 42 \times 1.00 / 1.38$, $24 \times 9 \times 94 \text{ I-T}$, $68 \times 42 \times 1.00 / 1.38$, $24 \times 9 \times 94 \text{ I-T}$, $68 \times 42 \times 1.00 / 1.38$, $24 \times 9 \times 94 \text{ I-T}$, $68 \times 42 \times 1.00 / 1.38$.
- Stanchion BLW 2 W4x730 SEE DET 1-A
- INTMD STIFFENERS $3 \times 1 \frac{1}{2} \times 22 \text{ T}$
- 125 PL

DECK-A (continued):

- Dimensions: $16 \times 7 \times 36 \text{ I-T}$, $9 \times 7 \frac{1}{2} \times 25 \text{ T}$, $24 \times 9 \times 94 \text{ I-T}$, $68 \times 42 \times 1.00 / 1.38$, $24 \times 9 \times 94 \text{ I-T}$, $68 \times 42 \times 1.00 / 1.38$, $24 \times 9 \times 94 \text{ I-T}$, $68 \times 42 \times 1.00 / 1.38$, $24 \times 9 \times 94 \text{ I-T}$, $68 \times 42 \times 1.00 / 1.38$.
- Stanchion BLW W4x455
- INTMD STIFFENERS $3 \times 1 \frac{1}{2} \times 22 \text{ T}$
- 125 PL

GIBBS & COX, INC.			
NEW YORK			
400 NEW YORK COMMERCIAL PLAZA SEMI-SUBMERGIBLE STRUCTURAL ARRANGEMENTS			
SCALE	AS SHOWN	DATE	4/13/78
DRAWN BY	M. A. DEVOST	APPROVED	A. SHORT
CHECKED		APPROVED	
DR. NO. 1051-B001-5		SHEET 1 OF 2	REV

GIBBS & COX, INC.	
NEW YORK	
400 MW OTEC COMMERCIAL PLANT	
SHIP	
MIDSHIP SECTION	
SCALE $\frac{1}{16}'' = 1'-0''$	DATE 4/19/78
DRAWN BY A. SYMMES	APPROVED R. SCOTT
CHECKED	APPROVED
DR NO. 18351- 8001 - 4	REV

GIBBS & COX, INC.	
NEW YORK	
400 MW OTEC COMMERCIAL PLANTS	
SHIP	
STRUCTURAL ARRANGEMENTS	
SCALE: AS NOTED	DATE: APRIL 19, 1975
DRAWN BY: D.S.	APPROVED: S. SCOTT
CHECKED: _____	APPROVED: _____
DR. NO. 18351-8001-3	SHEET 2 OF 2
	REV

GIBBS & COX, INC. NEW YORK	
400 MW OTEC COMMERCIAL PLANT SHIP STRUCTURAL ARRANGEMENTS	
SCALE	DATE 4/15/79
DRAWN BY AG	APPROVED E. SCOTT
CHECKED	APPROVED
DR NO. 18351-8001-3 SHEET 2 OF 2 REV

NOTES:
A - AMMONIA TANKS
H - HARDPACH
E - EVAPORATOR

GIBBS & COX, INC.
NEW YORK
400 MW OTEC COMMERCIAL PLANT
SEMI-SUBMERSIBLE
GENERAL ARRANGEMENTS
SCALE: AS SHOWN DATE: 14 APRIL 78
DRAWN BY: R. WHITWELL APPROVED: R. SCOTT
CHECKED: APPROVED:
DR NO. 18351-B001-2 SHT 1 OF 2 REV

NOTE:

- A = AMMONIA TANK
- C = CONDENSER
- D = DEMISTER
- E = EVAPORATOR
- G = GENERATOR
- M = MOTOR
- P = PUMP
- S = SCREEN
- T = TURBINE

GIBBS & COX, INC.	
NEW YORK	
400 MW OTEC COMMERCIAL PLANT SHIP	
GENERAL ARRANGEMENTS	
SCALE 1/32" = 1'-0"	DATE 4/19/78
DRAWN BY M.A. DEVOST	APPROVED RS
CHECKED	APPROVED
DR NO. 18351-8001-1	SHT 3 OF 3 REV

MAIN DECK
85' ABOVE BASELINE

AP 600 550 500 450 400 350 300 250 200 150 100 50 FP

INNER BOTTOM 10' ABOVE BASELINE

AP 600 550 500 450 400 350 300 250 200 150 100 50 FP

SECOND DECK
40' ABV BL

AP 600 550 500 450 400 350 300 250 200 150 100 50 FP

NOTE:

- A = AMMONIA TANK
- CO = COMPRESSOR
- D = DEMISTER
- F = FEED PUMP
- FO = FUEL OIL
- G = GENERATOR
- LO = LUBE OIL
- M = MOTOR
- N = NITROGEN TANK
- PW = POTABLE WATER
- SSDG = SHIP SERVICE DIESEL GENERATOR
- SWB = SALT WATER BALLAST
- T = TURBINE
- V = VACUUM PUMP

GIBBS & COX, INC.	
NEW YORK	
400 MW OTEC COMMERCIAL PLANT	
SHIP	
GENERAL ARRANGEMENTS	
SCALE: 1/32" = 1'-0"	DATE: 4/19/78
DRAWN BY: M.A. DEVOS	APPROVED: AS
CHECKED:	APPROVED:
DR NO. 18351-800-1	SHT 2 OF 3 REV

18351-10 (W-10,010)

APPENDIX D

MACHINERY EQUIPMENT LISTS
SHIP AND SEMI-SUBMERSIBLE

BY: Ckd: ADP:	WDS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SEA/CAT SIC	1.3	2	Position Control Winches	Motor 500 HP							
		14	Anchor								
		14	Cables & Fittings Fairleads, Benders								
		OREC PLANNED LOG W/ SEC LIST OF MACHINERY GIBBS & COX, INC.									
		SHEET 0-1									

37: C&D: AP:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
37: C&D: AP:	1.4.1	1	Foam Proportioner (Fixed)		FP-1000	1000 gpm	Halo Fire Fighting		TBD	3955
		30	Portable CO ₂ Extinguishers			15 lb. size	Accommodations, spaces with electrical EQPT and circuitry		30"W x 38"H	38
		6	Portable CO ₂ Extinguishers			5 lb. size	Control rooms		6"W x 15"H	15
		3	Portable Dry Chemical Extinguishers			10 lb. size	Galley, scullery		3"W x 21"H	21
		4	Portable Dry Chemical Extinguishers			5 lb. size	Passageways		4"W x 9"H	9
		108	CO ₂ Cylinders			100 lb. Cylinders	For Motor and/or Generator Rooms and/or SSOI Rooms (Automatic Centralized System)		11" ODx62"H	300

ORIG. PLANNED
100 MW SET
LIST OF MACHINERY
GIBBS & COX, INC.

SHEET D-2

BY: CDD: AD:	WDS No.	NO. PER SHIP	UNIT	SERVICE ON DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
374 SIC GIBBS & COX, INC.	1.4.2 .1	4	End Outbd Mtr Rm Vent. Fans	Electric Motor 3 HP	Centrif.	4200 CFM Size 50 CF	Exhaust Only Natural Supply		2.6x3.9x3.2	335	
		4	End Inbd Mtr Rm Vent. Fans	Electric Motor 2 HP	Centrif.	3450 CFM Size 40 CF	Exhaust Only Natural Supply		2.6x3.0x3.2	300	
		4	Center Outbd Mtr Rm Vent. Fans	Electric Motor 4 HP	Vaneaxial	7300 CFM Size 80 AF	Exhaust Only Natural Supply		Fig.-2.50 Lgth-2.5	620	
		4	Center Inbd Mtr Vent. Fans	Electric Motor 4 HP	Vaneaxial	6700 CFM Size 80 AF	Exhaust Only Natural Supply		Fig.-2.50 Lgth-2.5	620	
		8	Demister Rm Vent. Fans	Electric Motor 35 HP	Vaneaxial	41,500 CFM Size 550 AF	Exhaust Only Natural Supply			1720	
		8	Pwr. Cond. Eqt. Rm. Vent. Fans	Electric Motor 5 HP	Centrif.	8700 CFM Size 100 CF	Exhaust Only Natural Supply		3.7x4.7x4.8	1050	
		8	Pwr. Cond. Eqt. Rm. Vent. Fans	Electric Motor 7.5HP	Vaneaxial	12,900 CFM Size 150 AF	Exhaust Only Natural Supply		Fig.-2.90 Lgth-2.8	800	
		8	T/O Room Vent. Fans	Electric Motor 35 HP	Vaneaxial	41,500 CFM Size 550 AF	Exhaust Only Natural Supply			1720	
		8	Warm Wtr Pump Rm. (1st Lev.) Vent. Fans	Electric Motor 5 HP	Vaneaxial	10,000 CFM Size 100 AF	(4) Supply (4) Exhaust Each Fan Serves 2 Rm.		Fig.-2.70 Lgth-2.7	650	

ORIG PLANNED
400 HP SET
LIST OF MACHINERY

SHEET 0-3

SY: CD: AP:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
37: CD: AP: SIC OREC PLANT 400 MW SET LIST OF MACHINERY GRASS & COX, INC. SHEET 0-4	1.4.2.1	0	Cold Wtr Pump (m. (1st Lvl.) Vent. Fans	Electric Motor 7 1/2 HP	Vaneaxial	11,600 CFM Size 150 AF	(4) Supply (4) Exhaust Each Fan Serves 2 Rms.		Fig.-2.9D Lgth-2.8	800	
		4	Evap. & Cond. Rms. (Lower Level) Vent. Fans	Electric Motor 4 HP	Centrif.	6920 CFM Size 80 CF	(2) Supply (2) Exhaust Each Fan Serves 4 Rms.		3.6x4.5x4.4	700	
	1.4.2.2	0	Deck House Ventilation Fans	Electric Motor 1.5 HP	Centrif. 2 Speed	1075 CFM Size 30 CF	4 Supply 4 Exhaust		2.2x3.3x2.7	285	
	1.4.3	2	A/C Plants	Electric Motor 50 HP	Recipr.	40 Tons	Compressor & Motor, Condenser, Chiller		8x2.5x5	5820	
		2	AG SW Circ Pump	Motor 5 HP	Centrif.	160 gpm @ 35 psig			4x2x3	470	
		2	AG Chilled Water Circ Pump	Motor 10 HP	Centrif.	160 gpm @ 75 psig			4x2x3	470	
		2	CW Compression Tank	CW Sys		5 gal.				100	
		4	A/C Recirc. Air Handling Units	Electric Motor 5 HP	Centrif.	7500 CFM				1200	
		0	A/C Recirc. Sys. Replenishment Fans	Electric Motor 1 HP	Centrif.	1400 CFM Size 20 CF	4 Supply 4 Exhaust		2.2x3.1x2.7	250	

3Y:
C&C:
AP:

BY: Cdd: AP:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
BY/CDD STC	1.4.	4	Emergency Drain- age & Ballast Pump	Motor 75 HP	Centrif.	1500 gpm @ 50 psig			5x2x2.5	2096
		4	Drainage & Ballast Priming Unit	Electric	NASH	30 CFM 15" Hg			40"x30"	600
<p>OTEC PLANT 400 W. 5TH LIST OF MACHINERY GIBBS & COX, INC.</p>										
<p>Sheet 0-6</p>										

BY:	Q&D:	WDS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SEN/CAN	SIC	1.4.8 .1	4	Fire Pump	Motor 25 HP	Centrif.	200 gpm @ 125 psig			5x2x2.5	675	
OREG PATROL 400 LB SET LIST OF VACCINANT GIBBS & COX, INC.		SHEET 0-7										

SY: Cdt: AP:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SY: SEA/CAT Cdt: SIC AP: CARGO STOWAGE LIST OF MACHINERY GIBBS & COX, INC. Sheet D-8	1.4.9	2	Distilling Plant	Electric 20.5 KW	S-200 SPE-EI(3) Aqua Chem	4800 GPD (3125 Req'd)	Based on 60 GPD/man 50 Men + 125 GPD for Halo Washdown		8x5x6	4200	
		2	Distiller Feed Pump	Motor 1/4 HP		5 gpm @ 50 psig			15"x6.5"x11"	76	
	1.4.9	2	Potable Water Pumps	Motor 2 HP	Centrif.	20 gpm @ 60 psig			30" x 14" x 11"	110	
		1	Potable Water Priming Unit	Motor 1/4 HP		5 cfm 15" Hg	May not be required		20"x18"	TBD	
		1	Hot Potable Water Circulation Pump	Motor 1/4 HP		5 gpm @ 15 psig			30" x 14" x 10"	89	
		2	Distilled Water XFH Pump	Motor 1/2 HP		10 gpm @ 40 psig			15"x6.5"x10"	76	
		1	Distilled Water Collecting Tank			150 gal.			TBD	TBD	
		1	Recirculating Bromine Feeder Unit	Electric		7000 Gal/60 minute contact time	5 HP Motors + 1/2 Watts for Feeder		Unit 1.5x1.5x2.5 Pump 2x1x1	180	

BY:	WDS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
C&D: AP: SIC	1,4,9,1	1	Proportioning Bromide Feeder Unit			4000 gal/day			1.5x1 (Brominator) 1x1 (Cartridge) 1x1 (Feeder)	20	
OTEC PLATFORM 400 HP SET LIST OF MACHINERY GIBBS & COX, INC.		2	Potable Water Tank			3200 Gal.			10x5.5x6	TBD	
		1	Hot Potable Water Accumulation Tank	Electric Heater		200 gal. and 35,000 BTU/hr			TBD	TBD	
SEELET 0-9											

BY:	CD:	AD:	WDR No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
SEA/CW	SEC		1.4.10	1	FUEL SYSTEM							
			1	1	FO Storage Tank	FO System	Built-in Structure	250,000 Gal.	Sized for 60 days operation of 1 SSIM @2000KW			
				2	FO XFR/Stripping Pump	Motor 5 HP	Rotary	50/25 gpm @ 25 psig			1 x 11 23"x12"	372
				2	XFR Filter/Separator			50 gpm			42"x20"x53"	550
			1.4.10	2	Halo Fuel Service Tank	Halo Fuel System		900 Gal.				
				1	Halo Fuel Service Pump	Motor 5 HP	Rotary	50 gpm @ 50 psig			23"x1 x 12"x11"	372
				1	Halo Fuel Filter/Separator			50 gpm			42"x20"x53"	550
				1	Small Boat/Inboard Service Pump	Motor 2 HP	Rotary	25 gpm @ 50 psig			20"x11"x11"	268

DECK PLANTING
400 YW SENS
LIST OF MACHINERY
GIBBS & COX, INC.

SHEET 0-10-

BY: Ckd: AP:		WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA-TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
ENL/CAY SEC		1.4.11	2	L.P. Air Compr.	3 CHDR	Reciprocating	100 SCFM @ 125 psig	3 HP		33"x19"x18"	350	
			2	H.P. Air Compr.		Reciprocating	15 CFM @ 600 psig	5 HP		44"x22"x25"	500	
			2	Air Receiver (L.P.)			20 ft. ³					
			2	Air Float (H.P.)			20 ft. ³	6 SSDG starts				
OREGON PLANTERS 400 W. 5TH LIST OF MACHINERY GIBBS & COX, INC.												
SHEET 0-11												

BY:	C&D:	WDS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
SEA/CAP	SIC	1. 4. 12 .1	2	Oilly Waste Holding Tanks			TBD				
			16	Oilge Stripping Pumps	Motor 7.5 HP	Rotary Sliding Vane	100 gpm @ 60 psig			4 x4 x2	610
			2	Oil Water Separator		SAREX ECC-60	60 gpm	Includes Oil Water Separator Tank, Duplex Strainer, Control Panel Oil Pump, Air Pump, and Water Pump.		11'9" X 19.5" X 5'5"	770
			2	Waste Oil Tanks			TBD				
			2	Oilly Waste Transfer Pump	Motor 10 HP	Rotary Sliding Vane	100 gpm @ 100 psig				
			2	Contaminated Fuel Oil Settling Tank (COST)			TBD				

BY: CDD: AP:	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
324/CW SEC OFFICE PLANNED 400 1st ST LIST OF VACUUMITY GIBBS & CO., INC. SHEET 0-13	1.4.12.2	1	Sewage Treatment Plant	Red Fox	MSD Type II	60 gal./man-day	Includes tank, handles soil, waste & gray water	15x6x7.5	7705	
		2	Sewage Transfer Pump	Peabody Barnes JTCU	Horizontal Centrifugal Non-Clog	50 gpm @ 50 psig 5 HP		29"x14"x27"	325	
	1.4.12.3	2	Garbage Grinders	Motor	TBD					
		1	Trash Compactor	Motor 3 HP						
		1	Trash, Garbage and Sewage Incinerator		TBD	(Possibly not Required)				

SY: CDD: AP:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
224/CAT SIC OEG PLATFORM 400 MW SET LIST OF MACHINERY GIBBS & COI, INC. SHEET 0-14	1.4. 40 .1	2	Ship's Service/ Emergency Generator set	Diesel Engine	AC, 3-Phase 60Hz 480 Volt	2000KW @ 900 rpm	EMD 16-645E2 w/Accessories, Jacket Water Pump, Seawater Pump, F.W. Expansion Tank, Lube Oil Pump, Lube Oil Cooler, J.W. Cooler, Sump Tank, Fuel Pump, Fuel Filter, Fuel Strainer, Lube Oil Filter, J.W. Cooler, Mufflers		20'x7'x10'	103,480 Including Accessories (Dry) 108,225 Including Accessories (Wet)
	1.4. 40 .2	1	Ship's Service Switch Board	Ship's Service, Emergency Power			Generator & Modular Supply Section Distribution Section		9 x 4 x 7 15 x 3 x 7	7,000 6,000
	1.4. 40 .3	1	Distribution System Ship's Service Transformer	Ship's Service	Dry, A/A	300 KVA, 480V/120V, 3 PH			4 x 3 x 4.5	2,000
	1.4 40 .5	1	Emergency Transformer		Dry, A/A	150 KVA, 480V/120V, 3 PH			4 x 3 x 2	1,000
		2	Lube Oil Storage Tank	SSDG	Free Standing	1625 gal	1 tank per SSDG sized for 1 pump change and 60 days ID consumption.		12x3x6	4,875
		4	Fuel Oil Service Tanks	SSDG	Free Standing	2000 gal	2 tanks per SSDG each sized for 12 hrs. operation @ 2,000 KW.		10'x4'x7'	6,000
		2	Lube Oil Hand Pumps	SSDG	Rotary	15 gpm @ 15 psig			LXI 12"x16"	34
		2	SSDG SW Booster Pumps	Motor 30 HP	Centrifugal	845 gpm @ 35 psig				

BY:	CD:	AD:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
SEA/CAN	STC		1.7	1	Cold Water Pumps	Cold Water System	Axial Propeller	2.7x10 ⁶ gpm @ 12.4ft (5.5 psig) and 41 rpm	Efficiency: 90% Axial Thrust: 290,000 lbs Material: Suction Bell - Carbon Steel Impeller Case - Carbon Steel with 316 liner Impeller - 316L Diffuser - NI-Resistat		25.5 ft Impeller Diameter 28 ft long	830,000 (less shaft)
				8	Cold Water Pump Drive Shaft	Cold Water Pump	Solid				40' 25" O.D.	74,000
				8	Cold Water Pump Shaft Stuffing Box		Water Lubricated & Cooled	25"				2,000
				8	Cold Water Pump Motor	Cold Water Pump	AC	11,000 HP 41 rpm	3-Phase, 60 cycle 13,800 volt, Synchronous, TEWAG w/thrust bearing & lubrication & cooling system		23.4x20.8 Diameter	295,000
				16	Cold Water Pump Motor Cooling Pumps	Motor 10 HP	Centrifugal	275 gpm @ 35 psig	2 Cooling Water Pumps per Cold Water Pump Motor (1 standby)		4x2x2.5	525

GENE H. JENSEN
400 W. 5TH ST
LIST OF MACHINERY

GIBBS & COX, INC.

SHEET 0-15

BY: Ckd: AP:	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
2nd/CW	1.7 .2	Warm Water Pumps	Warm Water System	Axial Propeller	2.25x10 ⁶ gpm @ 10.9 ft (4.9 psig) and 41 rpm	Efficiency: 90% Axial Thrust: 230,000 lbs Material: Suction Bell - Carbon Steel Impeller Case - Carbon Steel with 316 Liner Impeller - 316 L Diffuser - NI-resist		24.0 ft Impeller Diameter 26.4 ft long	700,000 lbs (less shaft)
CIRC PLANTORY 400 MW SET LIST OF MACHINERY GIBBS & COX, INC.	0	Warm Water Pump Drive Shaft	Warm Water Pump	Solid				40' x 23" O.D.	60,000 lbs
	0	Warm Water Pump Shaft Stuffing Box		Water Lubricated & Cooled	23"				1,650
	0	Warm Water Pump Motor	Warm Water Pump	AC	0,000 HP 41 rpm	3-Phase, 60 cycle 13,800 volt, Synchronous, TEWAC w/thrust bearing & lubrication & cooling System		20.9x19.4 Diameter	239,000
	16	Warm Water Pump Motor Cooling Pumps	Motor 7.5 HP	Centrifugal	200 gpm @ 35 psig	2 Cooling Water Pumps per Warm Water Pump Motor (1 Standby)		4x2x2.5	525

SP. No.	CD. No.	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
1.2	11	Evaporator	NH3 Evaporation	Vertical External	50MM net @ 40° Δ T	Length is tube bundle length only		50x55 O.D.	2,400,000

GTE PLANT
 400 W. 100 S.
 LIST OF VAPORIZERS
 GIBBS & COX, INC.
 SHEET 0-17

3P: Ccd: AP:	UNIT	SERVICER OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
33U/CAR SIC	Condenser	NH3 Condensation	Vertical External	50MM (Net) @ 40° Δ T	Length is tube bundle length only		50x55 O.D.	2,400,000	

OTEC SYSTEM
 LOG IN SET
 LIST OF MACHINERY
 GIBBS & COX, INC.
 SHEET 0-18

SHIP No.	UNIT	SERVICER OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L. x W x H (ft)	WEIGHT (lbs)
24	Ammonia Feed Pumps	Elec. Motor 1000 HP			1 for each evaporator 1 standby		13.5x7 O.D.	27,000
8	Ammonia Compressor	Elec. Motor					6x18x4	20,000
8	Vacuum Pump	Elec. Motor					5x6x7	8,000
8	Distiller						30x30	900,000
24	Ammonia Reflux Pumps	Motor 40 HP			1 for each evaporator 1 standby			

SHIP/CAT /

STC

CREG PLANT

400 HP

LIST OF MACHINERY

GREENS & CO., INC.

SHEET 0-19.

BY: Ckd: AP:	WDS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
<div>321/CAR</div> <div>SIC</div> <div>OTEC PLATFORM 400 YD SIZED LIST OF MACHINERY</div> <div>GIBBS & COX, INC.</div> <div>SHEET 0-20</div>	3.5	16	Ammonia Tanks & Ammonia Fluid	N/A			Ammonia Make-Up		50x25 O.D.	600,000

37: C'd: AP:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SEA/CAT SEC	3.6	16	Nitrogen Generator Nitrogen Storage Tanks	N2 Purge System	Steel	900 ft ³ 16 lb N ₂ 1800 gal			20 x 8 x 0.0	16,500 25,000 w/N ₂	
CHOC IT, LORRAINE 400 W. 5TH LIST OF MACHINERY GIBBS & COX, INC.											
SECT 0-21											

BY: Cdr: AP:	WBS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
351/CWV SIC	1.7 .1	0	Turbine	Ammonia Vapor		50 MW (net)			25x25 O.D.	150,000	
	1.7 .2	0	Generator			50 MW (net)	3-Phase, 60 cycle 13,800 volts Totally enclosed, hydrogen/water cooled		30x18 O.D.	240,000	
		0	Generator Exhaust			TBD			TBD	TBD	

OTIC PLATFORM
400 MW SET
LIST OF MACHINERY

GIBBS & COX, INC.

SHEET 0-22

BY:	C&D:	AP:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L. x W. x H. (ft)	WEIGHT (lbs)
GEN/CAY	SIC		3.0	2	Power System Auxiliary Support Transformers	Power System Auxiliaries and Ships Service	Step-Down 3 Phase OA/FA (Oil Self-Cooled) May be changed to water/oil cooled.	7,500 KVA 13.8 KV/480 V	Additional capacity provided for these transformers so that two modules (1 on line, 1 on standby) can support ships service 480 V electrical load.		9 x 8.7 x 13.6	42,400
				6	Power System Auxiliary Support Transformers	Power System Auxiliaries	Step Down 3 Phase OA/FA (Oil Self-Cooled) May be changed to water/oil cooled.	5,000 KVA 13.8 KV/480 V			8 x 7.8 x 13	33,400
				4	Power System Auxiliary Support Transformer Cooling Water Pumps	Motor 2 HP	Horizontal Centrifugal	50 gpm @ 35 psig	2 for each 7,500 KVA Transformer (1 Standby) (If required for water cooling).			
				12	Power System Auxiliary Support Transformer Cooling Water Pumps	Motor 1.5 HP	Horizontal Centrifugal	35 gpm @ 35 psig	2 for each 5,000 KVA Transformer (1 Standby) (If required for water cooling).			

GEN. PLANT
400 MW SET
LIST OF MAJORITY

GIBBS & COX, INC.

SHEET 0-23

BY:	CD:	AP:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
25V/CW	STC		3.10	16	Generator Cooling Pumps	Electric Motor SHP		800 gpm @ 35 psig	Generator oil Cooling 2 per generator (1 standby)		4'x2'x3'	640	
				1	Turbine - Generator Set Lube Oil Modules	TBD		TBD	Contains Lube Oil Sump Tank, Lube Oil Coolers, & Lube Oil Pumps for Turbine Generator Set		TBD	TBD	
				TBD	Turbine- Generator Set Lube Oil Storage Tanks	Need oil purifiers & settlers & heaters		TBD					
				16	Turbine-Generator Set Lube Oil Cooler Seawater Pumps	Motor 30 HP	Horizontal Centrifugal	800 gpm @ 35 psig (est.)	Generator oil Cooling 2 per generator (1 standby)		4'x2'x3'	640	

CREW STATIONARY
400 KM SET
LIST OF MACHINERY
GIBBS & COX, INC.

SHEET 0-24

BY: Cdd: AP:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
324/CAW SIC CEC SYSTEMS 400 1st ST LIST OF MACHINERY GIBBS & COX, INC. SHEET 0-25	3.11	24	Chlorine Generators	Electrical 440KW		3360 lb/day	3 units for each condenser, provide .25 ppm chlorine concentration for 6000 cfm of cold seawater (if required)		24x2x12	3850	
		16	Chlorine Generator Seawater Circulation Pumps	Electric Motor 30 HP	Centrifugal	750 gpm @ 50 psig	2 for each bank of 3 condenser chlorine generators (1 standby)		5x2x2.5	850	
		16	Chlorine Generators	Electrical 350KW		3360 lb/day	2 units for each evaporator, provide .25 ppm chlorine concentration for 5000 cfm of warm seawater		24x2x12	3850	
		16	Chlorine Generator Sea-water Circulation Pumps	Electric Motor 20 HP	Centrifugal	500 gpm @ 50 psig	2 for each bank of 2 evaporator chlorine generators (1 standby)		5x2x2.5	670	
		16	AMENAP H/X Cleaning Systems				1 unit for each heat exchanger (evaporator and condenser), if required		TBD	TBD	
		TBD	Cathodic Protection System								

BY:	CD:	AD:	WBS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
354/CW	SIC		4.3		Power Conditioning Equipment							
				TBD	First Stage Power Conditioning Transformers		Step-Up	138 KV/138 KV Aggregate Capacity 400 MW	Water Cooled, Assumed Full Load Efficiency = 99%		TBD	TBD
				TBD	Second Stage Power Conditioning Transformers		Step-Up	138 KV/230 KV Aggregate Capacity 400 MW	Water Cooled, Assumed Full Load Efficiency = 99%		TBD	TBD
				16	First Stage Power Conditioning Transformer Cooling Water Pumps	Motor 15 HP	Horizontal Centrifugal	400 gpm @ 35 psig	2 per 50 MW Module (1 Standby)		4' x 2' x 3'	640
				16	Second Stage Power Conditioning Transformer Cooling Water Pumps	Motor 20 HP	Horizontal Centrifugal	400 gpm @ 55 psig	2 per 50 MW Module (1 Standby)		4' x 2' x 3'	720

354/CW
SICOTEC PLANT
400 MW SET
LIST OF MATERIAL
GIBBS & COX, INC.

SHEET 0-26

BY:	CDL:	WIND No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SEA/CUY	SEC	1.3	4	Position Control Winches	Motor 500 HP							
			14	Anchora								
			14	Cables & Fittings								
				Fairleads, Benders								

GENC PLANT
 400 W 5TH
 LIST OF MACHINERY
 GISH & COX, INC.
 SHEET 0-27

BY:	CD:	WDR No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L. x W. x H. (ft)	WEIGHT (lbs)
SEC	SEC	1.4.1	1	Foam Proportioner (Fixed)		FP-1000	1000 gpm	Main Fire Fighting		7'0"	3955
			30	Portable CO ₂ Extinguishers			15 lb. size	Accommodations, spaces with electrical EQPT and circuitry		30"W x 30"H	30
			6	Portable CO ₂ Extinguishers			5 lb. size	Control rooms		6"W x 15"H	15
			3	Portable Dry Chemical Extinguishers			10 lb. size	Galley, scullery		3"W x 21"H	21
			10	Portable Dry Chemical Extinguishers			5 lb. size	Passageways		4"W x 9"H	9
			300	CO ₂ Cylinders			100 lb. Cylinders	For Motor and/or Generator Rooms and/or SSDB Rooms (Automatic Centralized System)		11"W x 62"H	300

BY:	CDL:	AP:	WBS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
SEA/CAR	SEC		1.4.1									
OFFICER PLACED LOG W/ SELF-SUB LIST OF VACANCIES GIBBS & COY INC			SHEET 0-29									

BY:	CD:	AP:	WBS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
SEA/CAM	SIC		1.4.2.1	1	FWW Comb. Eqt. IM Vent Fans	Motor 71 HP	Vaneaxial	13500 CFM Size 150 AF	4 Supply 4 Exhaust 2 Fans per IM		Fig. 2.9'D lgth. 2.8'	800
				1	Aux. Machy IM Vent Fans	Motor 3 HP	Centrif.	5000 CFM Size 60 CF	4 Supply 4 Exhaust 2 Fans per IM		3.4x4.2x4.1	500
				1	Chlorinator IM Vent Fans	Motor 4 HP	Vaneaxial	7500 CFM Size 80 AF	4 Supply 4 Exhaust 2 Fans per IM		Fig. 2.5'D lgth. 2.5'D	620
				1	Miscellaneous Spar Vent Fans	Motor 14 HP	Centrif.	2500 CFM Size 30 CF	4 Supply 4 Exhaust 2 Fans per Spar		2.2x3.3x2.7	285
				1	Motor/Pump IM Vent Fans	Motor 71 HP	Vaneaxial	12000 CFM Size 150 AF	4 Supply 4 Exhaust 2 Fans per IM		Fig. 2.9'D lgth. 2.8'	800
				16	C/O & Demister IM Vent Fans	Motor 50 HP	Vaneaxial	60000 CFM Size 700 AF	4 Supply 4 Exhaust 4 Fans per IM			2380

CREC ELATED
400 MMSAT-SUB
LIST OF MACHINERY

SHEET D-30

[illegible]

SEC. 1	SEC. 2	SEC. 3	WOB No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SEC. 4	SEC. 5	SEC. 6	1.4.3	2	A/O Plants	Electric Motor 50 HP	Recipr.	40 Tons	Compressor & Motor, Condenser, Chiller		8x2.5x5	5820	
				2	AG SW Circ Pump	Motor 5 HP	Centrif.	160 gpm @ 35 psig			4x2x3	470	
				2	AO Chilled Water Circ Pump	Motor 10 HP	Centrif.	160 gpm @ 85 psig			4x2x3	470	
				2	CW Compression Tank	CW Sys		10 gal.				65	
				4	A/O Recirc. Air Handling Unit	Electric Motor 5 HP	Centrif.	7500 CFM	20 Ton Cooling Coil Hq heat			1200	
				4	Self Contained Air Conditioner for local Control Station	HP		1 1/2 Ton CFM	SW Cooled Condenser 1 Unit per Station		2x2x3		
				8	A/O Recirc. Sys. Replenishment Fans	Electric Motor 1 HP	Centrif.	1400 CFM Size 20 CF	4 Supply 4 Exhaust 2 Fans per Room		2.2x3.1x2.7	250	

SEC. 7

CHECK STAMPED
FOR WOB SUB
LIST OF VACANCIES

SERIAL 0-32

BY:	CD:	AP:	WDS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
SEA/CW	SIC		1.4.4	2	Ship Stores Refrigeration Plant	Motor 5 HP	Reciprocating	1 Ton			5 x 2.5 x 6	1,400 Dry 1,500 Wet
OTHER PLANTORY 400 HP SEA-SUB LIST OF MACHINERY GRES & CO, INC.			SHEET 0-33									

BY:	CD:	AP:	WDA No.	NO. PER SHIP	UNIT	SERVICE ON DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
330/CAR	STC		1.4.7	8	Emergency Drainage Pump	Motor 75 HP	Centrif.	350 gpm @ 80 psig			5x2x2.5	2096
				4	Drainage Pump Priming Unit	Electric	NASH	9 CFM 15" Hg				

OTHER FACTORY
LOG W/ SERIAL
LIST OF VACUUMS

SEE: 0-34

GIBBS & CO., INC.

37: Ccd: 42:	WBS No.	NO. PER SHEET	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
224/CWY STC	1.4.0 .1	4	Firs Pumpu	Motor 25 HP	Contrif.	200 gpm @ 125 psig			5x2x2.5	675

ORIG PLACED BY
400 W/ SER-503
LIST OF MACHINERY
GIBBS & COX, INC

SHEET
0-35

BY:	CD:	AD:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
SEA/CAT	ETC		1.4.9.1	2	Distilling Plant	Electric 20.5 KW	S-200 SPE-ET(9) Aqua Chem	4000 GPD (3125 Req'd)	Based on 60 GPD/man 50 Men + 125 GPD for Halo Washdown		8x5x6	4200
				2	Distiller Feed Pump	Motor 1/4 HP		5 gpm @ 70 psig			15"x6.5"x11"	76
			1.4.9.2	2	Potable Water Pump	Motor 2 HP	Centrif.	20 gpm @ 30 psig			30" x 14" x 11"	110
				1	Potable Water Priming Unit	Motor 1/4 HP		5 gpm 15" Hg	May not be required		20"x18"	TBD
				2	Hot Potable Water Circulation Pump	Motor 1/4 HP		5 gpm @ 15 psig			30" x 14" x 10"	89
				2	Distilled Water XTR Pump	Motor 1/2 HP		10 gpm @ 30 psig			15"x6.9"x10"	76
				1	Distilled Water Collecting Tank			150 gal.			TBD	TBD
				1	Recirculating Bromine Feeder Unit	Electric		7000 Gal/60 minute contact time	5 HP Motors + 172 Watts for Feeder		Unit 1.5x1.5x2.5 Pump 2x1x1	180

OTEC PLANT
400 W. STATE ST.
LIST OF MACHINERY
GIBBS & COX, INC.

SHEET
D-36

BY:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
AP: SEC	1,4,9,1	1	Proportioning Bromide Feeder Unit			4000 gal/day			1,5x1 (Brominator) 1x1 (Cartridge) 1x1 (Feeder)	30	
		2	Potable Water Tank			3200 Gal.			10x5.5x6	TBD	
		1	Hot Potable Water Accumulation Tank	Electric Heater		200 gal. and 35,000 BTU/Hr			TBD	TBD	

BY: SEC/CAT

SEC PLANT
400 W. 34th St
LIST OF WAREHOUSE
GIBBS & COX, INC.

SHEET 0-37

SP:	WHA No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
Ccd: SEC	1,4,10	1	FUEL SYSTEMS							
			FO Storage Tank	FO System	Built-in Structure	250,000 Gal.	Sized for 60 days operation of 1 3314 22000KW			
			FO XFR/Stripping Pump	Motor 5 HP	Rotary	50/25 gpm @ 25 psig			1 x H 23"x12"	372
			XFR Filter/Separator			50 gpm			42"x28"x53"	550
			Halo Fuel Service Tank	Halo Fuel System		900 Gal.				
			Halo Fuel Service Pump	Motor 5 HP	Rotary	50 gpm @ 50 psig			23"L x 12"H	372
			Halo Fuel Filter/Separator	Motor 2 HP	Rotary	50 gpm 25 gpm @ 50 psig			42"x28" 53" 20"(1.)x11"H	550 268
Ccd: SEC	1,4,10	2	Small Boat/Inflator Service Pump							

BY:	SHIP No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
BY: TEL/CW	1.4.11	2	L.P. Air Compr.	3 CHDR	Reciprocating	100 SCFM @ 125 psig	3 HP		33"x19"x18"	350	
Cd: SEC		2	H.P. Air Compr.		Reciprocating	15 CFM @ 600 psig	5 HP		44"x22"x25"	500	
AD:		2	Air Receiver (L.P.)			20 ft. ³					
		2	Air Flank (H.P.)			20 ft. ³	6 SSDQ startu				

GIBBS & COX, INC.
 400 W. 3RD ST
 LIST OF MACHINERY

Sheet 0-39

BY: Cdr: AR:	WPH No.	NO. PER SHIP	UNIT	SERVICE ON SHIPS	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SEA/CST SU	14. 12 .1	4	Oil Waste Holding Tanks			TBD					
		0	Sludge Stripping Pump	Motor 7.5 HP	Rotary Sliding Vane	50 gpm @ 60 psig			4 x4 x2	610	
		0	Oil Water Separ- ator			20 gpm	Inalynon Oil Water Separator Tank, Duplex Strainer, Control Panel, Oil Pump, Air Pump, and Water Pump.		2x20x5.5	770	
		4	Waste Oil Tanks			1500 Gal.				4500	
		0	Oil Waste Transfer Pump	Motor 10 HP	Rotary Sliding Vane	100 gpm @ 100 psig				610	
		2	Contaminated Fuel Oil Settling Tank (603T)			TBD					

REC PLACED
400 WY SET-SUB
LIST OF MACHINERY

SHEET 0-40

BY:	CD:	AD:	WON No.	NO. PER SHIP	UNIT	SERVICE ON DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SEE/CD	SEE		1.4. 12 .2	1	Sewage Treatment Plant	Red Fox	MSP Type II	60 gal./man-day	Inclusion tank, handles soll, waste & gray water		15x6x7.5	7705	
				2	Sewage Transfer Pump	Pashody Barnes TREN	Horizontal Centrifugal Non-Clog	50 gpm @ 30 psig 5 HP			29"x14"x27"	325	
				4	Waste Water Holding Tank			100 Gal.					
				4	Waste Water Effluent Pump	Motor-5 HP	Centrifugal	15 gpm @ 80 psig					
			1.4. 12 .3	2	Garbage Grinders	Motor		TBD					
				1	Trash Compactor	Motor 3 HP							
				1	Trash and Garbage & Sewage Incinerator			TBD	(Possibly not Required)				

SEE/CD
400 W. 5th St
LIST OF AGENCIES
CHAS & Co

SEE/CD
0-41

SY: Ctd: AP:	NO. PER SHIP	UNIT	SERVICE ON DRIVE	TYPE	CAPACITY ON SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
320/0457 SIC	1.7 .1	8	Cold Water Pumps	Cold Water System	Axial Propeller	2.7x10 ⁶ gpm @ 12.4 ft (5.5 psig) and 41 rpm	Efficiency: 90% Axial Thrust: 290,000 lbs Material: Suction Bell - Carbon Steel Impeller Case - Carbon Steel with 316 liner Impeller - 316L Diffuser - HI-Heatat	25.5 ft Impeller Diameter 28 ft long	430,000 (less shaft)	
OTIC STARTER 400 W/ SOL-SUB LIST OF MACHINERY GIBBS & COX, INC.		8	Cold Water Pump Drive Shaft	Cold Water Pump	Solid			40" 25" O.D.	74,000	
		8	Cold Water Pump Shaft Stuffing Box		Water Lubricated & Cooled	25"			2,000	
		8	Cold Water Pump Motor	Cold Water Pump	AC	11,000 HP 41 rpm	3-Phase, 60 cycle 13,000 volt, Synchronous, TEWAG w/thrust bearing & lubrication & cooling system	23.4x20.8 Diameter	295,000	
SECT D-43		16	Cold Water Pump Motor Cooling Pumps	Motor 10 HP	Centrifugal	275 gpm @ 35 psig	2 Cooling Water Pumps per Cold Water Pump Motor (1 standby)	4x2x2.5	525	

BY: Ckd: JD:	END/CAT SIC	QEG PLANNED ACQ. BY SEM-SUB LIST OF MACHINERY GIBBS & COX, INC.	SECT 0-44	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
				1.7. .2	0	Warm Water Pumps	Warm Water System	Axial Propeller	2.25x10 ⁶ gpm @ 10.9 ft (4.9 psig) and 41 rpm	Efficiency: 90% Axial Thrust: 230,000 lbs Material: Suction Bell - Carbon Steel Impeller Case - Carbon Steel with 316 lining Impeller - 316 L Diffuser - Ni-Haast		24.0 ft Impeller Diameter 26.4 ft long	700,000 lbs (less shaft)
					0	Warm Water Pump Drive Shaft	Warm Water Pump	Solid				40" x 23" O.D.	60,000 lbs
					0	Warm Water Pump Shaft Stuffing Box		Water Lubricated & Cooled	23"				1,650
					0	Warm Water Pump Motor	Warm Water Pump	AC	0,000 HP 41 rpm	3-Phase, 60 cycle 13,800 volt, Synchronous, TEWAG w/thrust bearing & lubrication & cooling System		20.9x19.4 Diameter	239,000
					16	Warm Water Pump Motor Cooling Pumps	Motor 7.5 HP	Centrifuga	200 gpm @ 35 psig	2 Cooling Water Pumps per Warm Water Pump Motor (1 Standby)		4x2x2.5	525

BY:	CD:	WDH No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)
EN/CAT	SEC	3.2	11	Evaporator	HIJ Evaporation	Vertical External	50MM net B 400 ΔT	length in tube bundle length only		50x55 O.D.	2,400,000

END PLACEMENT
400 MM SEC-508
LIST OF VACUUMITY

SECRET 0-45

UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L. x W. x H. (ft)	WEIGHT (lbs)
Condenser	H-13 Condensate Bo.	Vertical External	50MM (Hot) @ 40° ΔT	Length in tube bundle length only		50x55 O.D.	2,400,000

QRC 7-10-64
 400 W. 500-308
 LIST OF MACHINERY
 GIBBS & CO., INC.
 0-46

BY:	CD:	AD:	WHS No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
220/CSY	SEC		3.5	16	Ammonia Tanks & Ammonia Fluid	N/A			Ammonia Make-Up		50x25 O.D.	600,000	
QREC STATIONED 400 WY 32nd St LIST OF VACCINEES GIBBS & COX, INC			SECT 0-48										

BY:	CD:	AP:	WHH No.	NO. PER UNIT	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
EM/CAT	SEC		1.6	16	Nitrogen Generator Nitrogen Storage Tanks	H ₂ Purge System	Steel	900 ft ³ 4,500 lb H ₂ ø 1000 poly			20 x 10 O.D.	16,500 25,000 w/H ₂	
GENC PLANT 400 W 500-500 LIST OF MAINTENANCE CHARGES & COSTS			SEE: 0-49										

SHIP No.	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
37: 354/CST C&D: SIC	3.7 .1	1	Turbine	Ammonia Vapor	50 MW (net)			25x25 O.D.	150,000	
	3.7 .2	1	Generator		50 MW (net)	3-Phase, 60 cycle 13,800 volts Totally enclosed, hydrogen/water cooled		30x18 O.D.	440,000	
		1	Generator Exhaust		TBD			TBD	TBD	

ORIG. FACTORY
400 HP SER-SUB
LIST OF MACHINERY

GIBBS & COX, INC.

SHEET 0-50

BY: Cdd: AP:	WHS No.	NO. PER SHIP	UNIT	SERVICE ON DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SEC	3.0	2	Power System Auxil- iary Support Trans- formers	Power System Auxiliaries and Ships Service	Step-Down 3 Phase OA/FA (Oil Self-Cooled) May be changed to water/oil cooled.	7,500 KVA 13.8 KV/480 V	Additional capacity provided for these transformers so that two modules (1 on line, 1 on standby) can support ships service 480 V electrical load.		9 x 8.7 x 13.6	42,400	
		6	Power System Auxil- iary Support Trans- formers	Power System Auxiliaries	Step Down 3 Phase OA/FA (Oil Self-Cooled) May be changed to water/oil cooled.	5,000 KVA 13.8 KV/480 V			8 x 7.8 x 13	32,400	
		4	Power System Auxil- iary Support Trans- former Cooling Water Pumps	Motor 2 HP	Horizontal Centrifugal	50 gpm @ 35 psig	2 for each 7,500 KVA Transformer (1 Standby) (If required for water cooling).				
		12	Power System Auxil- iary Support Trans- former Cooling Water Pumps	Motor 1.5 HP	Horizontal Centrifugal	35 gpm @ 35 psig	2 for each 5,000 KVA Transformer (1 Standby) (If required for water cooling).				

GENE PLANNING
400 WA SALT-508
LIST OF MACHINERY
GIBBS & COX, INC.

SECRET
0-51

BY:	NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCATION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
AP: SEC	2,10	16	Generator Cooling Pumps	Electric Motor 30 HP	800 gpm @ 35 psig	Generator Oil Cooling 2 per generator (1 standby)		4'x2'x3'	640	
		8	Turbine - Generator Set Lube Oil Modules	TBD	TBD	Contains Lube Oil Sump Tank, Lube Oil Coolers, & Lube Oil Pumps for Turbine Generator Set		TBD	TBD	
		TBD	Turbine-Generator Set Lube Oil Storage Tanks	Heat oil purifiers & settlers & heaters	TBD					
		16	Turbine-Generator Set Lube Oil Cooler Seawater Pumps	Motor 30 HP	Horizontal Centrifugal 800 gpm @ 35 psig (est.)	Generator Oil Cooling 2 per generator (1 standby)		4'x2'x3'	640	

SEE LISTED
400 HP SET SUB
LIST OF MACHINERY

SEE 0-52

37: Ccd: AP:	38: WBS No.	39: NO. PER SHIP	UNIT	SERVICE OR DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SEC ORC PLANT 400 LB SEA-SUB LIST OF MACHINERY GIBBS & COX, INC. SHEET 0-53	3.11	24	Chlorine Generators	Electrical 440KW		3360 lb/day	3 units for each condenser, provide .25 ppm chlorine concentration for 6000 cfm of cold seawater (if required)		24x2x12	3050	
		16	Chlorine Generator Seawater Circulation Pumps	Electric Motor 30 HP	Centrifugal	750 gpm @ 50 psig	2 for each bank of 3 condenser chlorine generators (1 standby)		5x2x2.5	850	
		16	Chlorine Generators	Electrical 350KW		3360 lb/day	2 units for each evaporator, provide .25 ppm chlorine concentration for 5000 cfm of warm seawater		24x2x12	3050	
		16	Chlorine Generator Sea- water Circulation Pumps	Electric Motor 20 HP	Centrifugal	500 gpm @ 50 psig	2 for each bank of 2 evaporator chlorine generators (1 standby)		5x2x2.5	670	
		16	AMEITAP H/X Cleaning Systems				1 unit for each heat exchanger (evaporator and condenser), if required		TBD	TBD	
		TBD	Cathodic Protection System								

BY:	CD:	AD:	WDS No.	NO. PER SHIP	UNIT	SERVICE ON DRIVE	TYPE	CAPACITY OR SIZE	REMARKS	LOCA- TION	DIMENSIONS L x W x H (ft)	WEIGHT (lbs)	
SEA/CAN	SIC		4.3		Power Conditioning	Equipment							
				TDD	First Stage Power Conditioning Trans- formers		Step-Up	13.8 KV/138 KV Aggre- gate Capacity 400 MW	Water Cooled, Assumed Full Load Efficiency = 99%		TDD	TDD	
				TDD	Second Stage Power Conditioning Trans- formers.		Step-Up	138 KV/230 KV Aggre- gate Capacity 400 MW	Water Cooled, Assumed Full Load Efficiency = 99%		TDD	TDD	
				16	First Stage Power Conditioning Trans- former Cooling Water Pumps.	Motor 15 HP	Horizontal Centrifugal	400 gpm @ 35 psig	2 per 50 MW Module (1 Standby)		4' x 2' x 3'	640	
				16	Second Stage Power Conditioning Trans- former Cooling Water Pumps	Motor 20 HP	Horizontal Centrifugal	400 gpm @ 50 psig	2 per 50 MW Module (1 Standby)		4' x 2' x 3'	720	

GEN PLANT
400 MW SUB-SYS
LIST OF MAINTENANCE
GIBBS & COX, INC.

SHEET
D-54

APPENDIX E

OTEC PLANT WEIGHT ESTIMATES

SHIP AND SEMI-SUBMERSIBLES

18351-10(W-10,010)
GIBBS & COX INC

2341 JEFFERSON DAVIS HIGHWAY
 ARLINGTON, VIRGINIA 22202

WEIGHT ESTIMATE FORM
 OTEC COMMERCIAL PLANT

SHIP

OTEC WEIGHT ESTIMATE BREAKDOWN

WES	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOMT. FT-TONS
1.0	PLATFORM SYSTEM			
1.2	HULL AND STRUCTURE (MARAD GROUPS 0-0			
	THRU 9-2)			
	Bottom Shell and Framing, including			
	Floors, Girders	5793.4	3.25	18829
	Side Shell and Framing, including Webs	4609	26.95	170303
	Inner Bottom and Framing	2301.6	9.81	22579
	Main Deck	6384.8	84.41	555823
	Second Deck	2537.6	40.02	101555
	Longitudinal Bulkheads (Main)	7937.7	39.93	316952
	Transverse Bulkheads (Main)	3475.4	54.16	188228
	Peak Framing and Breasthooks	580.6	34.6	20089
	Misc. Structural Bulkheads			
	Flats, Platforms	978.2	69.63	68112
	Trunks			
	CWP Plenum	261.7	-25.16	-6584
	Pillars, Girders	1767.8	40.51	71614
	Heat Exchanger Foundations			
	Pump Foundations (including waters)	310	42.71	13240
	Turbo/Generator Foundations	183.6	42.71	7842
	Demister Foundations	120	42.71	5125
	Miscellaneous Foundations			
	Superstructures	171.3	72.8	15897
	Welding, Mill Tolerance	562	44.8	25178
		374	44.8	16755
	Free Flooding Liquids (other than in	24927.9	23.36	582316
	Seawater System)			
	Sub-Total Group 1.2	63476.6	34.56	2912850

18351 10 (W-10,010)
GIBBS & COX INC

2241 JEFFERSON DAVIS HIGHWAY
 ARLINGTON, VIRGINIA 22202

WEIGHT ESTIMATE FORM
 OTEC COMMERCIAL PLANT

SHIP

WES	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOM. FT-TONS
1.3	POSITION CONTROL SYSTEM			
	Winches and Controls	2.5		
	Anchors			
	Cables and Fittings			
	Fairleads, Fenders	10.5		
	Sub-Total Group 1.3	130	85	11050
1.4	PLATFORM SYSTEMS (MARAD GROUPS 17-19)			
	Fire Detection, Extinguishing (excluding Fire Mains)	50 41	69.1	3455
	Heating Ventilation and Air Conditioning	119.7	62.3	3455
	Refrigeration	1.8	71.3	128.
	Plumbing Fixtures, Drains, Scuppers	6.3	78.6	
	Bilge, Ballast	52 40	1.2	62.
	Fire Mains, Sprinkling	12.8 10	36.4	466
	Sanitary, Fresh Water (including Distilling Plants)	8.9	30.3	270
	Fuel Oil Transfer	19.3 12	16.7	322
	Vents, Sounding Tubes, Overflows	106.4	40	4256
	Compressed Air	8.0	45	365
	Deck Machinery (cranes, hoists, bitts, chocks)	439 73	133.7 85	58694 1105
	Radio Communication	5	100	500
	Radar	2	100	200
	Interior Communications	10	90	900
	Monitoring and Control	4	85	340
	Data Processing, Telemetry	2	100	200
	Helicopter Control	1	100	100
	Ammonia Detection System	1	45	45

18351-10(W-10,010)
GIBBS & COX INC

2341 JEFFERSON DAVIS HIGHWAY
 ARLINGTON, VIRGINIA 22202

WEIGHT ESTIMATE FORM
 OTEC COMMERCIAL PLANT

SHIP

WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOMT. FT-TONS
1.4	(Continued)			
	Ship Service Generators	97	60	5520
	Emergency Generator and Batteries	30	60	1800
	Switchboards	6	60	360
	Distribution	16	80	1280
	Lighting	5	85	425
	Elevators, Hoists	24	50	1200
	Aircraft Fittings	1	85	85
	Operating Fluids	110	20	2200
	Sub-Total Group 1.4	1150	80.31	72849
1.5	OUTFIT AND FURNISHINGS			
	Masts, Kingposts	25		
	Castings, Forgings	30		
	Rails, Stanchions	10		
	Ladders	100		
	Misc. Fittings	50		
	Doors, Closures	25		
	Insulation, Sheathing	75		
	Deck Covering	50		
	Joiner Work (non-structural bulkheads)	100		
	Furniture	20		
	Boats, Boat Handling	25		
	Paint	693		
	Permanent Ballast	47361.7	22.5	1065638
	Commissary Equipment	15		
	Damage Control Equipment	25		
	Utility Space Equipment (laundry, medical, offices, laboratories, shops)	25		

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GIBBS & COX INC

2341 JEFFERSON DAVIS HIGHWAY
 ARLINGTON, VIRGINIA 22202

WEIGHT ESTIMATE FORM
 OTEC COMMERCIAL PLANT

SHIP

WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOMT. FT-TONS
1.5	(Continued).			
	Stowages	30		
	Sub-Total Group 1.5	1298	95	123310
1.7	SEAWATER SYSTEMS (EXCLUSIVE OF CWP)			
	CW Pumps, Motors, Transmissions	4290	45	193050
	WW Pumps, Motors, Transmissions	3574	45	160830
	CW Piping including Diffusers	488.9	21.8	10658
	WW Piping including Diffusers	511.2	22.14	11318
	Valves, Fittings			
	Screens, Filters (except those in CWP)	183.7	-36.32	-6672
	Discharge Pipes	3332.8	-114.5	-381006
	Seawater in Pumps and Piping between Pumps, H/X	61446	20	1228920
	Sub-Total Group 1.7	73826.6	16.48	1216948
1.8	BIOFOULING AND CORROSION CONTROL			
	Hull Cathodic Protection System	10		
	Sub-Total Group 1.8	10	22.5	225
	ADD TO 1.4	172	25	4300
	AVG. SW.	17	20	340
	POLLUTION CONTROL	189	24.55	4640
	SUB-TOTAL MINUS BALLAST	140086.2	31.14	4362972
	TOTAL GROUP 1.0	187447.9	28.96	5428510

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GIBBS & COX INC2341 JEFFERSON DAVIS HIGHWAY
ARLINGTON, VIRGINIA 22202WEIGHT ESTIMATE FORM
OTEC COMMERCIAL PLANT

SHIP

WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOMT. FT-TONS
2.0	CWP SYSTEM			
2.2	CWP STRUCTURE			
	Plating, Stiffeners, Ring Frames	21 905	0.0	0.0
	Connections (if used) including	1 747	0.0	0.0
	Intermediate Hinges			
	Sub-Total Group 2.2	23 452	0.0	0.0
2.3	CWP SCREENS	348.3	0.0	0.0
2.4	CWP-HULL TRANSITION			
	Mechanical Devices	5	0.0	0.0
	Seals	20	0.0	0.0
	Special Fittings			
	Sub-Total Group 2.4	25	0.0	0.0
2.5	CWP PUMP (INCLUDE IN 1.7, SEAWATER SYSTEMS)			
2.6	CWP BIOFOULING, CORROSION CONTROL			
	CWP Cathodic Protection System			
	Sub-Total Group 2.6			
2.7	CWP MOORINGS, FLOATATION			
	Floatation Material			
	Buoyancy Chambers			
	Mechanical Equipment			
	Sub-Total Group 2.7	1190	0.0	0.0
	TOTAL GROUP 2.0	25 015.3	0.0	0.0

GIBBS & COX INC2341 JEFFERSON DAVIS HIGHWAY
ARLINGTON, VIRGINIA 22202WEIGHT ESTIMATE FORM
OTEC COMMERCIAL PLANT

SHIP

WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOMT. FT-TONS
3.0	POWER SYSTEM			
3.2	WARM WATER SYSTEM			
	Evaporators	7056	-25	-176400
	Salt Water in Evaporator	23600	-25	-590000
	Sub-Total Group 3.2	30656	-25	-766400
3.3	COLD WATER SYSTEM			
	Condensers	7056	-25	-176400
	Salt Water in Condenser	23600	-25	-590000
	Sub-Total Group 3.3	30656	-25	-766400
3.4	WORKING FLUID SYSTEM			
	Ammonia Feed Pumps	290.4		
	Ammonia Compressors	100		
	Ammonia Transfer System (Vapor & Liquid)	20		
	Ammonia in System (excluding Tanks)	30		
	Demisters	3216		
	Sub-Total Group 3.4	3656.4	50	182825
3.5	WORKING FLUID STORAGE SYSTEM			
	Ammonia Tanks and Fittings	576		
	Ammonia (Liquid) in Tanks	3712		
	Sub-Total Group 3.5	4288	36	154368
3.6	PURGE SYSTEM			
	Nitrogen Generator			
	Piping, Fittings			
	Storage Tanks			
	Sub-Total Group 3.6	200	50	10000

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ARLINGTON, VIRGINIA 22202WEIGHT ESTIMATE FORM
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SHIP

WES	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOMT. FT-TONS
3.7	GENERATION SYSTEM			
	Turbo-generators	2104		
	Exciters (if req'd)	45		
	Sub-Total Group 3.7	2149	55	118195
3.8	ELECTRICAL SYSTEMS	32	50	1160
3.9	INSTRUMENT AND CONTROL SYSTEM			
	Control Console			
	Cabling, Sensors			
	Sub-Total Group 3.3	16	50	800
3.10	AUXILIARY SYSTEMS			
	Turbo-Generator Lubrication	87.9		
	Turbo-Generator Cooling	58.6		
	Other			
	Sub-Total Group 3.10	146.5	40	5860
3.11	BIOFOULING AND CORROSION CONTROL			
	AMERTAP or other Tube Cleaning System			
	Cathodic Protection System			
	Chlorination System	128	30	3840
	Sub-Total Group 3.11	128	30	3840
3.12	START-UP SYSTEM			
	Start-up Bus			
	External Power Connection (if used)			
	Start-up Generators (if used)			
	Generator Auxiliaries, Cabling (if used)			
	Sub-Total Group 3.12			
	TOTAL GROUP 3.0	71927.9	-14.67	-1055182

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WEIGHT ESTIMATE FORM
OTEC COMMERCIAL PLANT

SHIP?

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WEIGHT ESTIMATE FORM
 OTEC COMMERCIAL PLANT

SHIP

VES	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VOG ABOVE BASE	VERT MOMT. FT-TONS
	SUMMARY			
	LIGHT SHIP:			
	Group 1 Platform System	187447.9	28.96	5428510
	2. CWP System	25015.3	0.0	0.0
	3 Power System	71917.9	-14.47	-1055182
	4 Energy Transfer System	2166.2	80.59	174566
	Sub-Total	286557.3	15.87	4547874
	Margin (10%) MINUS BALLAST	23919.56	42.6	1016581
	TOTAL LIGHT SHIP	310476.86	17.92	5564475
	LOAD ITEMS:			
	Crew and Effects	10	90	900
	Fresh Water	25	5	125
	Stores	10	90	900
	Fuel Oil	790	40	31600
	Aircraft Fuel	3	90	270
	Lube Oil	55	5	275
	Stores (Dry, Refrigerated)	10	90	900
	Equipment Vans	40	90	3600
	Spare parts - Platform	10	90	900
	Spare parts - Power, Transmission Systems	20	90	1800
	TOTAL LOADS	973	42.4	4117
	FULL LOAD CONDITION	311449.86	17.88	5568607

GIBBS & COX INC2241 JEFFERSON DAVIS HIGHWAY
ARLINGTON, VIRGINIA 22202WEIGHT ESTIMATE FORM
OTEC COMMERCIAL PLANT

SEMI-SUBMERSIBLE

OTEC WEIGHT ESTIMATE BREAKDOWN

WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOMT FT-TONS
1.0	PLATFORM SYSTEM			
1.2	HULL AND STRUCTURE (MARAD GROUPS 0-0			
	THRU 9-2)			
	Column - Lower Head Plating and Framing	1190.4	-11.1	-13213
	LEGS - Plating and Framing - Motor Room	2720.4	29.1	79164
	- Plating and Framing - Generator	2601.6	116.7	303607
	PLATING AND FRAMING DEMISTER	1460.4	75.5	110260
	- Plating and Framing - Upper	1548.4	118.3	260396
	Transition			
	- Plating and Framing - Upper COLUMN	670	232.5	155775
	STANCHIONS	812.4	127.6	103662
	- Decks and Platforms	4977	140.88	701160
	- Structural Bulkheads	576.6	73.6	13608
	Lower Cross Structure - Plating and			
	Framing	9202.6	43.75	402614
	- Top Plenum	1287.4	64.4	82909
	- Transition Plenum	524.4	-36.4	-19088
	Upper Cross Structure - Decks, Flats	3256.6	289.2	941908
	- Sides	189.2	289	54679
	TRUSSES	4351.3	289	1257526
	Main Braces STRUTS	2096.4	180	377352
	Trunks			
	Heat Exchanger Foundations	472	30	14160
	-to-Heat Exchanger Pipe and	601.4	72.06	43337
	H/X TO PUMP PIPE	1368	-23.74	-32476
	W.W. SCREEN PIPE TO H/X	706.2	81	57202
	Turbo-generator Foundation	287	67.6	19401
	Demister Foundations	112.8	-2.4	-271
	Miscellaneous Foundations -PUMP MOTORS	100.5	-2.4	-386

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OTEC COMMERCIAL PLANT

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WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOMT. FT-TONS
1.2	(Continued) <i>FREE FLOODING</i>	4534.4	45	204048
	Deckhouses	2.7	334	902
	Welding, Mill Tolerance	618	120.4	74407
		412	120.4	49605
	Sub-Total Group 1.2	46740.1	112.16	5242147
1.3	POSITION CONTROL SYSTEM			
	Winches and Controls	25		
	Anchors			
	Cables and Fittings			
	Fairleads, Fenders	105		
	Sub-Total Group 1.3	130	313	40640
1.4	PLATFORM SYSTEMS (MARAD GROUPS 17-19)			
	Fire Detection, Extinguishing (excluding Fire Mains)	67.	25	1075
	Heating Ventilation	141	186	26226
	Refrigeration, AC	28 1	261 313	7398 313
	Plumbing Fixtures, Drains, Scuppers	4	291	1164
	Bilge, Ballast	29	100	2900
	Fire Mains, Sprinkling	112	297	3326
	Sanitary, Fresh Water (including Distilling Plants)	9	240	2160
		25	147	3675
	Fuel Oil Transfer	12	226	2712
	Vents, Sounding Tubes, Overflows	12	198	2376
	Compressed Air	8	300	2400
	Deck Machinery (cranes, hoists)	439	380	166820
	BITS, chocks	9	332	2988
	Radio Communication	5	323	1615
	Radar	2	323	646
	Interior Communications	10	310	3100

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WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT. MOMT. FT.-TONS
1.4	(Continued): <i>AUX. S.W.</i>	184	128	23552
	Monitoring and Control	4	323	1292
	Data Processing, Telemetry	2	323	646
	Helicopter Control	1	332	337
	Ammonia Detection System	1	128	128
	Ship Service Generators	92	323	29716
	Emergency Generator and Batteries	30	320	9600
	Switchboards	6	323	1938
	Distribution	16	220	3520
	Lighting	5	323	1615
	Elevators, Hoists	151	147	22147
	Aircraft Fittings	1	332	332
	Operating Fluids	110	147	16170
	Sub-Total Group 1.4	1415.2	241.97	342442
1.5	OUTFIT AND FURNISHINGS			
	Masts, Kingposts	25		
	Castings, Forgings	30		
	Rails, Stanchions	10		
	Ladders	100		
	Misc. Fittings	50		
	Doors, Closures	25		
	Insulation, Sheathing	75		
	Deck Covering	50		
	Joiner Work (non-structural bulkheads)	100		
	Furniture	20		
	Boats, Boat Handling	25		
	Paint	823.5		
	Permanent Ballast	81052.6	45	3647367

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WES	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VOG ABOVE BASE	VERT MOMT. FT-TONS
1.5	(Continued):			
	Commissary Equipment	1.5		
	Damage Control Equipment	2.5		
	Utility Space Equipment (laundry, medical, offices, laboratories, shops)	2.5		
	Stowages			
	Sub-Total Group 1.5	30		
		1428.5	318	45463
1.7	SEAWATER SYSTEMS (EXCLUSIVE OF CWP)			
	CW Pumps, Motors, Transmissions	4304.4		
	WW Pumps, Motors, Transmissions	3582.4		
	CW Piping including Diffusers			
	WW Piping including Diffusers			
	Valves, Fittings			
	Screens, Filters (except those in CWP)	183.7		
	Discharge Pipes			
	Seewater in Pumps and Piping between - Pumps, H/X	178760		
	Sub-Total Group 1.7	186931.5	23	4297125
1.8	BIOFOULING AND CORROSION CONTROL			
	Hull Cathodic Protection System	10	105	1050
	Sub-Total Group 1.8	10	105	1050
	SUB-TOTAL MINUS BALLAST	236555.3	43.87	1037791.7
	TOTAL GROUP 1.0	317607.9	44.16	14025284

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WEIGHT ESTIMATE FORM
 OTEC COMMERCIAL PLANT

SEMI-SUBMERSIBLE

WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VOG ABOVE BASE	VERT. MOMT. FT-TONS
2.0	CWP SYSTEM			
2.2	CWP STRUCTURE			
	Plating, Stiffeners, Ring Frames	21705	0.0	0.0
	Connections (if used) including	1747	0.0	0.0
	Intermediate Hinges	XXXX	XXXX	XXXX
	Sub-Total Group 2.2	23452	0.0	0.0
2.3	CWP SCREENS	348.3	0.0	0.0
2.4	CWP-HULL TRANSITION			
	Mechanical Devices	XXXX	XXXX	XXXX
	Seals	5	0.0	0.0
	Special Fittings	20	0.0	0.0
	Sub-Total Group 2.4	25	0.0	0.0
2.5	CWP PUMP (INCLUDE IN 1.7, SEAWATER SYSTEMS)			
2.6	CWP BIOFOULING, CORROSION CONTROL			
	CWP Cathodic Protection System			
	Sub-Total Group 2.6			
2.7	CWP MOORINGS, FLOATATION			
	Floatation Material			
	Buoyancy Chambers			
	Mechanical Equipment			
	Sub-Total Group 2.7			
	WELDING + CONTINGENCIES	1190	0.0	0.0
	TOTAL GROUP 2.0	25015.3	0.0	0.0

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WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOMT. FT-TONS
3.0	POWER SYSTEM			
3.2	WARM WATER SYSTEM			
	Evaporators	7056		
	Salt Water in Evaporator	23600		
	Sub-Total Group 3.2	30656	30	919680
3.3	COLD WATER SYSTEM			
	Condensers	7056		
	Salt Water in Condenser	23600		
	Sub-Total Group 3.3	30656	30	919680
3.4	WORKING FLUID SYSTEM			
	Ammonia Feed Pumps	290.4		
	Ammonia Compressors	100		
	Ammonia Transfer System (Vapor & Liquid)	20		
	Ammonia in System (excluding Tanks)	30		
	Demisters	3216		
	Sub-Total Group 3.4	3656.4	75	274230
3.5	WORKING FLUID STORAGE SYSTEM			
	Ammonia Tanks and Fittings	576		
	Ammonia (Liquid) in Tanks	3712		
	Sub-Total Group 3.5	4288	120	514560
3.6	PURGE SYSTEM			
	Nitrogen Generator			
	Piping, Fittings			
	Storage Tanks			
	Sub-Total Group 3.6	200	120	24000

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WEIGHT ESTIMATE FORM
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SEMI-SUBMERSTIBLE

WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT. MOMT. FT.-TONS
3.7	GENERATION SYSTEM			
	Turbo-generators	2104		
	Exciters (if req'd)	45		
	Sub-Total Group 3.7	2149	110	236390
3.8	ELECTRICAL SYSTEMS	32	292	9344
3.9	INSTRUMENT AND CONTROL SYSTEM			
	Control Console			
	Cabling, Sensors			
	Sub-Total Group 3.8	76	217	1472
3.10	AUXILIARY SYSTEMS			
	Turbo-Generator Lubrication			
	Turbo-Generator Cooling			
	Other			
	Sub-Total Group 3.10	146.5	240	35160
3.11	BIOFOULING AND CORROSION CONTROL			
	AMERTAP or other Tube Cleaning System			
	Cathodic Protection System			
	Chlorination System	128	30	3840
	Sub-Total Group 3.11	128	30	3840
3.12	START-UP SYSTEM			
	Start-up Bus			
	External Power Connection (if used)			
	Start-up Generators (if used)			
	Generator Auxiliaries, Cabling (if used)			
	Sub-Total Group 3.12			
	TOTAL GROUP 3.0	7197.7	40.88	7940356

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WEIGHT ESTIMATE FORM
OTEC COMMERCIAL PLANT

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Project No.: 13351

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 ARLINGTON, VIRGINIA 22202

WEIGHT ESTIMATE FORM
 OTEC COMMERCIAL PLANT

SEMI-SUBMERSIBLE

WBS	DESCRIPTION	WEIGHT L. TONS	VERTICAL CENTER	
			VCG ABOVE BASE	VERT MOMT FT-TONS
	SUMMARY			
	LIGHT SHIP:			
	Group 1 Platform System	317607.9	44.16	14035284
	2 CWP System	25015.3	0.0	0.0
	3 Power System	71927.9	40.88	2940356
	4 Energy Transfer System	2166.2	287.92	623682
	Sub-Total	416717.3	42.21	17589322
	Margin (10%) MINUS BALLAST	33566.47	42.21	1416841
	TOTAL LIGHT SHIP	450283.77	42.21	19006163
	LOAD ITEMS:			
	Crew and Effects	10	318	3180
	Fresh Water	25	164	4100
	Stores	10	318	3180
	Fuel Oil	790	164	129560
	Aircraft Fuel	3	318	954
	Lube Oil	55	164	9070
	Stores (Dry, Refrigerated)	10	318	3180
	Equipment Vans	40	318	12720
	Spare parts - Platform	10	318	8180
	Spare parts - Power, Transmission Systems	20	318	6360
	TOTAL LOADS	973	180.3	175434
	FULL LOAD CONDITION	451256.77	42.51	19181597

APPENDIX F

COST SUMMARIES

SHIP AND SEMI-SUBMERSIABLE

OTEC COMMERCIAL PLANT
CONCEPTUAL DESIGN

COST ESTIMATING WORKSHEETS
400 MW SHIP

PREPARED FOR
DEPARTMENT OF ENERGY
CONTRACT No. EG-77-C-01-4064

GIBBS & COX, INC.
WASHINGTON, D. C.
MARCH 31, 1978

R. J. Scott

R. J. SCOTT
PROJECT MANAGER

SECTION 1
COST ESTIMATING SHEETS
SHIP

OTEC COST ESTIMATING SHEET
Platform: SHIP

GIBBS & COX, INC.
Date:

18351-10 (W-10,010)

[illegible]

* ESTIMATE CODE: Insert "P" for Parametric or "D" for Bottom-up

NOTES: (1) All Costs $\$ \times 10^6$, FY 78
(2) Same Costs Handled on 120 m/10

(3) Roofing Included With Labor Cost
(4) Platform Costs Based on First of 4 Identical Plants
(5) (H) - Recurring Costs, in 5/8c

OTEC COST ESTIMATING SHEET
Platform: SHIP

GIBBS & COX, INC.

Date:

18351-10(W-10,010)

[illegible]

* ESTIMATE CODE; Insert "P" for Parametric or "D" for Bottom-up

NOTES: (1) All Costs @ 10⁶, 85 78 .
(2) Same Costs Based on 120 M/4

(3) Tooling Included With Labor Cost
(4) Platform Costs Based on First of 8 Identical Plants
(5) (H) - Recurring Costs, in 3/4's

Sheet 4 of 12

OTEC COST ESTIMATING SHEET
Platform: SHIP

GIBBS & COX, INC.

Date:

18351-10 (W-10,010)

MDS		ESTIMATE CODE*	PRELIM. DESIGN	CONTRACT DESIGN	DETAIL DESIGN	FABRICATION/CONSTRUCTION			DEPLOYMENT/INSTALLATION			TEST & OPERATION		TOTAL COST
NO.	TITLE					TOOLING	LABOR	MATERIAL & OTHER	TOOLING	LABOR	MATERIAL & OTHER	LABOR	MATERIAL & OTHER	
3.0	POWER SYSTEMS													
3.1	POWER SYSTEM DESIGN, ANALY & INTEGRATION	P	0.2	0.4	2.0	—	—	—	—	—	—	—	—	2.6
3.2	WARM WATER SYSTEM	B	X	X	X	—	1.0	—	—	—	—	—	—	1.0
3.2.1	EVAPORATOR SUBSYSTEM	B				—	0.4	—	—	—	—	—	—	0.4
3.3	COLD WATER SYSTEM	B				—	1.0	—	—	—	—	—	—	1.0
3.3.1	CONDENSER SUBSYSTEM	B				—	0.4	—	—	—	—	—	—	0.4
3.4	WORKING FLUID SYSTEM	B				—	1.5	—	—	—	—	—	—	1.5
3.5	WORKING FLUID STORAGE SYSTEM	B				—	0.9	—	—	—	—	—	—	0.9
3.6	PURGE SYSTEM	P				—	0.5	—	—	—	—	—	—	0.5
3.7	GENERATION SYSTEM	P				—	1.0	—	—	—	—	—	—	1.0
3.8	ELECTRICAL SYSTEMS	P				—	0.3	—	—	—	—	—	—	0.3
3.9	INSTRUMENT & CONTROL SYST.	P				—	1.0	—	—	—	—	—	—	1.0
3.10	AUXILIARY SYSTEMS	B				—	0.5	—	—	—	—	—	—	0.5
3.11	HYDROFORMING & COMPOSITION CONT. SYSTEMS	P				—	1.5	—	—	—	—	—	—	1.5
3.12	START-UP SYSTEM	P	—	—	—	—	0.1	—	—	—	—	—	—	0.1
TOTAL			0.2*	0.4*	2.0*	—	9.7	—	—	—	—	(INCL IN 6.0)	—	12.3

* ESTIMATE CODE: Insert "P" for Parametric or "B" for Bottom-up

NOTES: (1) All Costs \$ = 10⁶, EX 10
(2) Labor Costs Based on \$20 H/H(3) Tooling Included With Labor Cost
(4) Platform Costs Based on Plant of 6 Identical Plants
(5) (4) - Recurring Costs, in \$/yr

OIEC COST ESTIMATING SHEET
Platform: SHIP

GIBBS & COX, INC.
Date: _____

[illegible]

* ESTIMATE CODE: Insert "P" for Parametric or "D" for Bottom-up

NOTES: (1) All Costs $\times 10^6$, FY 70
(2) Labor Costs Based on \$20 H/M

(3) Tooling Included With Labor Cost
(4) Platform Costs Based on First of 4 Identical Plants
(5) (6) - Recurring Costs, in \$/Yr

[illegible]

^A ESTIMATE CODE: Insert "P" for Parametric or "D" for Bottom-up

NOTED: (1) All Costs @ \$10⁶, RV 70
(2) Labor Costs Based on \$10 M/H

(1) Tooling Included With Labor Cost
(2) Platform Costs Based on First of 8 Identical Plants
(3) (A) - Recurring Costs, in \$/yr

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Sheet 2 of 121

DEC COST ESTIMATING SHEET
Platform: SHIP

GIBBS & COX, INC.
Date: _____

[illegible]

* ESTIMATE CODE: Insert "P" for Parametric or "B" for Bottom-up

NOTES: (1) All Costs \$ x 10⁶, \$178
(2) Labor Costs Based On \$20 M/M

(3) Tooling Included With Labor Cost
(4) Platform Costs Based on First of 4 Identical Plants
(5) (b) - Recurring Costs, in 5/75

OTEC COST ESTIMATING SHEET
Platform: SHIP

GIBBS & COX, INC.
Date:

[illegible]

* ESTIMATE CODE: Insert "P" for Parametric or "B" for Bottom-up

NOTES: (1) All Costs \$ in 10⁶, FY 78
(2) Labor Costs Based on \$20 M/H

(3) Tooling Included with Labor Cost
(4) Platform Costs Based on First of 4 Identical Plants
(5) (N) = Recurring Costs, in \$/Yr

DTIC COST ESTIMATING SHEET
Platform: SHIP

GIBBS & COX, INC.
Date: _____

[illegible]

* ESTIMATE CODE: Insert "P" for Parametric or "U" for Bottom-up

NOTES: (1) All Costs @ $\times 10^6$, FY 78
(2) Labor Costs Based On 120 H/M

(3) Fueling Included With Labor Cost
(4) Platform Costs based on Price of 8 Identical Plants
(5) 4th - Busscoring Costs, in \$/yr

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OTEC COST ESTIMATING SHEET
Platform: SHIP

GIBBS & COX, INC.

Date:

18351-10 (W-10,010)

[illegible]

* ESTIMATE CODE; Insert "P" for Parametric or "U" for Bottom-up

NOTES: (1) All Costs @ \$ 10⁶. FY 70
(2) Labor Costs Based on \$20 H/H

(3) Testing Included With Labor Cost
(4) Platform Costs Based on First of 8 Identical Plants
(5) (u) - Recurring Costs, in \$/Yr

18351-10 (W-10,010)

SECTION 2

COST ESTIMATE

BACK-UP DATA -

SHIP

GIBBS & COX, INC.

OTEC COST ESTIMATE BREAKDOWN

SHIP

WBS	DESCRIPTION	WEIGHT L. TONS	LABOR		MATERIAL	
			FACTOR \$/TON	COST \$ MILLION	FACTOR \$/TON	COST \$ MILLION
1.0	PLATFORM SYSTEM					
1.2	HULL AND STRUCTURE (MARAD GROUPS 0-0 THRU 9-2)					
	Bottom Shell and Framing, including Floors, Girders	5160	3000	15.5	500	2.6
	Side Shell and Framing, including Webs	4609	3000	13.8	500	2.3
	Inner Bottom and Framing	2302	3000	6.9	500	1.2
	Main Deck	6585	2400	15.8	500	3.3
	Second Deck	2538	2400	6.1	500	1.3
	Longitudinal Bulkheads (Main)	7974	3000	23.9	500	4.0
	Transverse Bulkheads (Main)	3475	3000	10.4	500	1.7
	Peak Framing and Breasthooks	581	5000	2.9	500	.3
	Misc. Structural Bulkheads		5000		500	
	Flats. Platforms	978	5000	4.9	500	.5
	Trunks		5000		500	
	CWP Plenum	262	3000	.8	500	.1
	Pillars. Girders	1768	2400	4.2	500	.9
	Heat Exchanger Foundations	634	11,000	7.0	500	.3
	Pump Foundations (including waters)	310	11,000	3.4	500	.2
	Turbo/Generator Foundations	184	11,000	2.0	500	.1
	Demister Foundations	120	11,000	1.3	500	.1
	Superstructures	171	3000	.5	500	.1
	Welding	562	-	-	2500	1.4
	Mill Tolerance	374	-	-	500	.2
	Free Flooding Liquids (other than in Seawater System)					
	Sub-Total Group 1.2			119.0		20.3
	Margin 10%			130.9		22.3

COST ESTIMATING SHEET
OTEC COMMERCIAL PLANT

SHIP

[illegible]

Date _____

Sheet 63

GIBBS & COX, INC.

OTEC COST ESTIMATE BREAKDOWN

SHIP

WBS	DESCRIPTION	WEIGHT L. TONS	LABOR		MATERIAL	
			FACTOR \$/TON	COST \$ MILLION	FACTOR \$/TON	COST \$ MILLION
1.4	(Continued)					
	Deck Machinery (cranes, hoists, bitts, chocks) *	439	—	.08	—	1.7
	Ship Service/Emergency Generators	13	3,600	.05	3,500	.05
	Switchboards	92	3,000	.28	25,000	2.3
	Distribution	6	31,200	.19	11,200	.07
	Lighting	16	24,400	.39	45,500	.73
	Ship's Service Support System	5	49,200	.25	3,200	.04
	Radio Communication	30	30,000	.9	5,000	.15
	Radar	5	30,800	.2	32,000	.2
	Interior Communications	2	50,000	.1	50,000	.1
	Monitoring and Control	10	30,800	.3	32,000	.3
	Data Processing, Telemetry	4	—	.3	—	.7
	Helicopter Control	2	—	.6	—	.9
	Ammonia Detection System	1	—	.1	—	.2
	Elevators, Hoists	1	—	—	—	—
	Aircraft Fittings	24	10,900	.3	9,200	.2
	Operating Fluids	1	—	—	—	—
		110	—	—	—	—
	Sub-Total Group 1.4			15.0		15.0
	MARGIN 10%			16.5		16.5
1.5	OUTFIT AND FURNISHINGS					
	Masts, Kingposts	25	16,000	.4	3,500	.9
	Castings, Forgings	30	4000	.1	1100	.03
	Rails, Stanchions	10	5000	.05	3100	.03
	Ladders	100	14,100	1.4	2500	.3
	Misc. Fittings	50	10,000	.5	3000	.2
	Doors, Closures	25	17,000	.4	5000	.1

* Gantry crane cost of \$1.3M includes material & labor cost plus \$.5M for 2 whirley cranes, purchase cost only. \$.08M labor is for installation of two whirley cranes

Project No. 18351

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Date _____

By _____

Sheet

of

GIBBS & COX, INC.

COST ESTIMATING SHEET
OTEC COMMERCIAL PLANT

OTEC COST ESTIMATE BREAKDOWN

SHIP

WBS	DESCRIPTION	WEIGHT L. TONS	LABOR		MATERIAL	
			FACTOR \$/TON	COST \$ MILLION	FACTOR \$/TON	COST \$ MILLION
1.5	(Continued)					
	Insulation, Sheathing	75	14,000	1.1	3000	.2
	Deck Covering	50	3600	.2	1700	.1
	Joiner Work (non-structural bulkheads)	100	17,000	1.7	5000	.5
	Furniture	20	7000	.1	5500	.1
	Boats, Boat Handling	25	7000	.2	4600	.1
	Paint	500	18,000	9.0	5000	2.5
	Permanent Ballast (Pig Iron, Cover Can)		2000		250	
	Commissary Equipment	15	17,000	.3	12,300	.2
	Damage Control Equipment	25	8000	.2	11,700	.3
	Utility Space Equipment (laundry, medical, offices, laboratories, shops)	25	8000	.2	15,000	.4
	Stowages	30	14,600	.4	5000	.2
	Sub-Total Group 1.5			16.25		6.16
	Margin 10%			17.9		6.8
1.7	SEAWATER SYSTEMS (EXCLUSIVE OF CWP)					
	CW Pumps, Motors, Transmissions	4290	—	6.5	—	65.4
	WW Pumps, Motors, Transmissions	3574	—	5.6	—	56.0
	CW Piping including Diffusers	499	6000	2.9	500	.2
	WW Piping including Diffusers	511	6000	3.1	500	.3
	Valves, Fittings	—	—	—	—	—
	Screeners, Filters (except those in CWP)	184	8000	1.5	24,500	4.5
	Discharge Pipes	—	—	—	—	—
	Seawater in Pumps and Piping between Pumps. E/X	—	—	—	—	—
	Sub-Total Group 1.7 / MARGIN 10%			19.6 21.6		126.4 13

GIBBS & COX, INC.

SHIP

[illegible]

18351-10 (W-10,010)

COST ESTIMATING SHEET
OTEC COMMERCIAL PLANT

GIBBS & COX, INC.

OTEC COST ESTIMATE BREAKDOWN

SHIP

WBS	DESCRIPTION	WEIGHT L. TONS	LABOR		MATERIAL	
			FACTOR \$/TON	COST \$ MILLION	FACTOR \$/TON	COST \$ MILLION
2.0	CWP SYSTEM					
2.2	CWP STRUCTURE					
	Plating, Stiffeners, Ring Frames	21705	700	6.5	1900	41.2
	Connections (if used)	1747	400	.7	2900	5.0
	WELDING & CONTINGENCIES	1190	500	.6		
	Sub-Total Group 2.2	24642		7.8		46.2
2.3	CWP SCREENS	348	14045	4.9	1700	2.7
2.4	CWP-HULL TRANSITION					
	Mechanical Devices	5		5.0		
	Seals	20		.7		
	Special Fittings	11		.7		.3
	Sub-Total Group 2.4	36		6.4		.3
2.5	CWP PUMP (INCLUDE IN 1.7. SEAWATER SYSTEMS)					
2.6	CWP BIOFOULING. CORROSION CONTROL					
	CWP Protective Coatings		(2)	.5	(2)	1.3
	(CWP Cathodic Protection included in 1.8)					
	Sub-Total Group 2.6			.5		1.3
2.7	CWP MOORINGS. FLOATATION					
	Floatation Material					
	Buoyancy Chambers					
	Mechanical Equipment					
	Sub-Total Group 2.7					
	MARGIN (10%)			2.0		2.0
	TOTAL GROUP 2.0			21.6		5

(1) Copper-Nickel Screens 5700 @ \$84210/LT
 Support Structure 2910 @ \$500/LT
 (2) Painting Cost Factors Mat'l - \$0.50/H²
 Labor - \$1.30/H²

Project No. 18351

Date 3/30

By JL

5.0 INTEGRATION/ENGINEERING COST ESTIMATE (\$M)
(Applicable to First Unit Only)

WBS	DESCRIPTION	SHIP			SEMI-SUBMERSIBLE		
		Prelim. Design	Contract Design	Detail Design	Prelim. Design	Contract Design	Detail Design
1.1	Platform	.25 ⁴⁾	.80	4.00	.30	1.00	5.00
2.1	CWP	.15	.40	4.00	.15	.40	4.00
3.1	Power System ⁽¹⁾	.20	.35	2.00	.20	.35	2.00
4.1	Energy Transfer ⁽²⁾	.05	.15	.80	.05	.15	.80
5.1	Syst. Design, Anal.	.15	.65 ⁽⁶⁾	3.00 ⁽⁷⁾	.15	.75	3.50
5.2	Syst. Integration ⁽³⁾	.20 ⁵⁾	.25	2.50 ⁽⁸⁾	.25	.35	3.00
	<u>TOTAL</u>	1.0	2.60	16.30 ⁽⁹⁾	1.1	3.00	18.30

NOTES:

- 1) Excludes hardware design of heat exchangers, turbogenerators, other Power System components. Includes installation design only.
- 2) Excludes hardware design of Transfer System components. Includes installation design only, including cable interface.
- 3) Includes design management, supervision.
- 4) Includes model tests.
- 5) Includes all planning and systems engineering studies not included in WBS 11.0, such as safety, ILS, value engineering, producibility, RMA, etc.
- 6) Includes specifications.
- 7) Includes purchase specifications, vendor liaison.
- 8) Includes design control (interference check).
- 9) Reflects level of documentation and controls required for Commercial contracts plus additional safety-related efforts.

6.0 SYSTEM TEST AND EVALUATION COST ESTIMATE (\$M)
 (Applicable to First Unit Except as Noted)

WBS	TEST PHASE	PREL. DESIGN	CONTR. DESIGN	DETAIL DESIGN	FABRIC/ CONSTR.		DEPLOY/ INSTALL		TEST/ OPER.	
					LABOR	MAT'L.	LABOR	MAT'L.	LABOR	MAT'L.
6.1	Test Planning	.15	.30	.35	-	-	-	-	-	-
6.2	Special Test Facility	None Identified At This Time								
6.3	Independent T&E									
6.3.1	In-Plant Tests	-	-	.08 ⁽¹⁾	.12 ⁽²⁾	-	-	-	-	-
6.3.2	Dockside Tests	-	-	.08 ⁽³⁾	.40 ⁽³⁾	.10	-	-	-	-
6.3.3	Builder's Trials	-	-	-	.40 ⁽⁴⁾	.30 ⁽⁴⁾	-	-	-	-
6.3.4	Acceptance Trials	-	-	-	-	-	.52 ⁽⁵⁾	.39 ⁽⁵⁾	-	-
6.3.5	OTEC Syst. Tests	-	-	-	-	-	-	-	1.50 ⁽⁶⁾	1.90 ⁽⁶⁾
TOTAL - 1ST UNIT		.15	.30	.51	.92	.40	.52	.39	1.50	1.90
TOTAL - UNIT 2 - 6		0	0	0	.40	.20	.25	.20	0.50	0.60

NOTES:

- 1) Assumes 2 man-years of Systems Integration Contractor (SIC) effort.
- 2) Assumes 3 man-years of shipbuilder effort (Vendor effort included in cost of equipment).
- 3) Assumes 2 man-years of SIC effort, 10 man-years shipbuilder effort.
- 4) Assume 3 week trial involving 60 shipbuilder personnel, 10 SIC/DOE personnel, \$10K/day platform operations, \$50K towing and 2 man-year data reduction. Allow \$40K for test instrumentation.
- 5) Assume similar breakdown as Builder's Trials, but increase 30% for additional travel and test instrumentation.
- 6) Assume 3 month test prior to tie-in to shore grid involving 50 SIC personnel, 10 DOE personnel, \$10K/day platform operations, \$5K/day logistics support (\$30K/day total). Allow \$500K for instrumentation, data processing. Include 10% on labor for travel.
- 7) Vendor test costs and cost of vendor personnel attending above tests and trials are assumed to be included in equipment costs.

7.0 OPERATIONAL SUPPORT COST ESTIMATE7.1 SPARE PARTS7.1.1 INITIAL SPARES

Assume an initial stock inventory of \$1M on each platform plus the following stored ashore:

1	Spare CW pump motor rotor @ \$1M	
1	Spare WW pump motor rotor @ \$1M	
1	Spare Turbo-Generator Rotating Element	} Not Included
Pending
Cost Data
From DOE
2	Spare Reflux Pumps	
2	Spare Ammonia Feed Pumps	
4	Spare Chlorinator Units	
1	Spare Mooring Winch, Chain, Wire @ \$1M	
•	Platform System Spares (Fans, Pumps, Motors, AC Units, etc. - assume \$10M.	

TOTAL FOR PARK = \$21 M

TOTAL PER PLATFORM = \$14.0M against 1st Platform

= \$1.0 M against Other Platform

7.1.2 FOLLOW-ON SPARES

Assume that the initial spares loadout onboard each platform will last one year (\$1M/year) and that the components stored shoreside will be utilized at the rate of \$2M/year = \$3M/year total per platform.

7.2 EXPENDABLE MATERIALS (PLATFORM) PER YEAR

Fuel Oil	=	\$0.6 M
Lube Oil	=	\$0.1 M
Aircraft Fuel	=	\$0.1 M
Food, Dry Stores	=	\$0.2 M @ \$10/day/man
Miscellaneous	=	<u>\$1.0 M</u> (Paint, etc.)
Sub-Total	=	\$2.0 M/year

Logistics Support Exendables = \$0.8 M total for boat and truck fuel, spare parts, supplies, etc., which is negligible when amortized over 8 platforms.

7.0 OPERATIONAL SUPPORT COST ESTIMATE (Continued):

7.2 EXPENDABLE MATERIALS (PLATFORM) PER YEAR (Continued):

Ammonia resupply is not included. Although this is recognized as a potentially significant item, no data has been supplied by DOE on required makeup or resupply rates.

7.3 PECULIAR SUPPORT EQUIPMENT

Assume these items are included in the total weight and cost of shop equipment reflected in Outfit and Furnishings, WBS 1.5.

7.4 COMMON SUPPORT EQUIPMENT

See 7.3

7.5 PERSONNEL

7.5.1 Platform Personnel

Total embarked personnel = 44, required for 2 - 12 hour shifts. Assuming 14 days on, 14 days off, a minimum of 88 people must be dedicated to each platform. With an allowance for leave, sickness, etc., a total of 96 people are required for one platform. Using an average annual cost per person of \$35 K (salary, fringe benefits, etc.) the annual cost of platform personnel is \$3.2 M per platform.

7.5.2 Shoreside Personnel

Total shoreside personnel for total logistics support includes 100 people, working a nominal 8 hour day.

- Administrative, communications = 19
- Maintenance and repair = 14 (maintenance teams to service platforms)
- Building, vehicle maintenance = 6
- Warehouse, materials handling = 19
- Boat crews = 32
- Diving Team = 10

At an average rate of \$32 K/year, total = \$3.2M.

These costs would undoubtedly vary somewhat with the number of platforms served, but for this estimate a constant cost of \$3.2 M will be assumed, equivalent to \$0.4 M per year per platform.

7.6 TECHNICAL MANUALS

Assume a budget of \$0.5 M, chargeable to the first platform.

8.0 DEPLOYMENT SYSTEMS AND SERVICES COST ESTIMATE8.1 PLATFORM DEPLOYMENT8.1.1 Ship

Assume the following procedures for joining the two halves of the hull at sea:

<u>TASK</u>	<u>LABOR @ \$25/MH</u>	<u>MATERIAL</u>
Maneuver, Join Halves	80 K	50 K
Construct, Install Caissons	150 K	800 K
Welding, Preparation	800 K	50 K
Remove Caissons	40 K	-
Install Deckhouse, Final Outfit	700 K	90 K
Overtime, Subsistence Allowance	= 1,770 K 500	990 K Say 1.0 M
	2,270 K	

8.1.2 Semi-Submersible

Assume the following procedures for joining the pairs of columns and adding the upper cross-structure at sea:

<u>TASK</u>	<u>LABOR @ \$25/MH</u>	<u>MATERIAL</u>
Maneuver, Join Modules	80 K	50 K
Construct, Install Caissons	320 K	1,000 K
Welding, Preparation	400 K	30 K
Remove Caissons	80 K	-
Install Cross Structure	500 K	200 K
Outfit	600 K	100 K
Overtime, Subsistence Allowance	= 1,980 K 600 K	1,380 K Say 1.4 M
	2,580 K	

8.2 CWP ASSEMBLY (SHIP AND SEMI-SUBMERSIBLE)

The CWP will be shipped from the shipyard in sections aboard the platform and assembled on site using a special deployment barge (see WBS 9.1). The costs associated with this operation are based upon assembling one 50 foot high section of CWP per day with a 90-man crew resulting in total MH of 130,000 based on 2 - 12 hour shifts or equal. Assuming \$40 per hour to cover overtime, travel and subsistence, the total labor cost is \$5.2 M. Corresponding material costs are estimated at about \$1.0 M.

8.3 CWP DEPLOYMENT (SHIP AND SEMI-SUBMERSIBLE)

It is estimated that a crew of 30 men working for 7 days on 2 - 12 hour shifts can prepare the CWP for deployment at \$40/hour = \$100 K. Material is as follows:

Crane Barge = 12 days (including transit) @ 25K/day	= \$300 K
Tugs (4) = 12 days @ 4K/day	= \$200 K
Rigging and Miscellaneous	= \$100 K
TOTAL MATERIAL	= \$600 K

8.4 MOORING SYSTEM DEPLOYMENTInstallation ItemsEquipment

Barge Mounted Windlass	500,000
Traction Winch	500,000
Modifications to Barge	100,000
Pendant Buoys 14 - @ \$20,000.	280,000
Pendants 9,920 fathoms - 2" dia. wire @ \$12/ft.	714,240
	<u>\$2,094,240</u>

Rental Items

Barge - 400' x 100' x 25'	\$ 2,000/day
Tugs - 3 @ \$4,000/day	\$ 12,000/day
Survey Boat @ \$4,000/day	\$ 4,000/day
Crane @ \$500/day	<u>\$ 500/day</u>
	<u>\$ 18,500/day</u>

Distance Honolulu to Keahole Point estimated to be 250 N. miles

Estimate tug/barge speed	= 3 kn
Time for Round Trip + Loading	= $\frac{500}{3} + 48$ hrs. = 215 hrs. = 9 days
Avg. length of chain/mooring	= 810 fathoms
Avg. length of rope/mooring	= 1970 fathoms

Wt. of above + pendant + buoy + anchors (100,000#) =

$810 \times 6 \times 144 + 1970 \times 6 \times 29.5 + 710 \times 6 \times 7.40 + 100,000 + 30,000$
 = 1,210,054# = 540 LT

Due to space considerations, assume only 2 moorings can be carried one at one time. Assume 2 days installation time per mooring.

8.4 MOORING SYSTEM DEPLOYMENT (Continued):

Installation Time = 14×2 = 28 days

Transit Time = $\frac{14}{2} \times 9$ = 63 days

5% Down Time = $\frac{91}{5}$ = 18 days

Rental Costs $96 \times 18,500$ = \$1,776,000.

Total Installation Costs = \$3,870,240.

Total Cost - 14 Anchor Array = \$17,207,840.
+ Margin on Installed Items

9.0 OTEC FACILITIES COST ESTIMATE9.1 SHIPYARD FACILITIES9.1.1 Platform Deployment AidsFor Ship:

The ship is to be temporarily buoyed by a pontoon to permit float-out and rotation of the two hull halves. For estimating purposes assume a gross pontoon volume of $20 \times 30 \times 400$ feet = 400,000 cubic feet. At a structural density of 6 lbs./cubic foot and \$1.30 per pound, the pontoon cost = \$3.10 M (bare hull). Use \$3.5 M to include attachments, ballast piping, fittings, etc., for each hull section (\$7.0 M total) chargeable to first hull.

For Semi-Submersible:

Each of the four columns is to be buoyed by pontoons at each end for float-out, in a horizontal configuration. A total of 8 pontoons are required, each of approximately 250,000 cubic foot volume, each costing \$2.0 M. Total cost for hull support = \$8.0 M. In addition, a $250 \times 80 \times 30$ foot barge is required to float in the top cross-structure during final assembly. This barge and the cross-structure support assembly costs approximately \$4.4 M. Total cost of floatation = \$13.5 M chargeable to first hull.

9.1.2 CWP Deployment Aids

For Ship and Semi-Submersible:

A special submersible barge approximately 180 x 150 x 50 feet is required to support the CWP during assembly and deployment. This barge is expected to cost approximately \$10.8.M including equipment, and outfit, and is reusable.

NOTE: For the purposes of this estimate, the cost of these floatation devices has been included with Facilities since they are non-recurring costs useable for all platforms. If these items were to be included with Deployment, Platform, or CWP WBS elements, they would be mixed with recurring costs and might be lost. Therefore, Facilities appears to be a better element for such items.

9.0 OTEC FACILITIES COST ESTIMATE (Continued)9.2-9.5 SHORESIDE FACILITIES

	Item	Description	Cost, \$M
9.2	<u>Boats and Service Craft</u>	200 foot Offshore Supply Boat	5.3
	Start-Up Generator Barge	3-8000 KW Generators plus fuel	5.3
	Fluids/Supply Barges (2)	200 foot flat deck barges	2.0
	Service Tug	125 foot/4000 HP	3.6
	Surveillance Craft	65 foot/35 Knot	0.8
	Crew Boats	100 foot/100 person	2.1
	Submersible Support	2000 M Sub with Support Boats	5.2
	Barges (3)	General Duty	5.0
	SUB-TOTAL		29.3
9.3	<u>Ground Transportation</u>		
	Cranes	1-60 Ton, 1-5 ton capacity	.30
	Fork Lift	50 ton capacity	.28
	Fork Lift	5 ton	.05
	Miscellaneous	cars, pick-up truck, bus	.17
	SUB-TOTAL		0.8
9.4	<u>Buildings, Piers, Etc.</u>		
	Warehouse (2)	200 x 75 foot, 24 foot high	0.4
	Office/Shop Building	120 x 40 foot, 1 story	0.2
	Garage, Misc. outbuildings	40 x 30 foot garage, 2 or 3 sheds	0.1
	Roads, parking		3.0
	Pier	30 x 250, concrete @ \$100/SF	1.0
	Fuel storage	Fuel supplied by truck or tractor	0.2
	Building equipment	Office equipment, etc.	0.5
	Supplies	Initial inventory	0.1
	Communications, Data Proc.		0.3
	Incinerator		0.1
	SUB-TOTAL		5.9
9.5	<u>Other Facilities</u>	10% of above	3.6
	TOTAL		39.6

OTEC COMMERCIAL PLANT
CONCEPTUAL DESIGN

COST ESTIMATING WORKSHEETS
400 MW SEMI-SUBMERSIBLE

PREPARED FOR
DEPARTMENT OF ENERGY
CONTRACT NO. EG-77-C-01-4064

GIBBS & COX, INC.
WASHINGTON, D. C.
MARCH 31, 1978

R. J. SCOTT
PROJECT MANAGER

18351-10 (W-10,010)

SECTION 1

COST ESTIMATING SHEETS

SEMI-SUBMERSIBLE

OTEC COST ESTIMATING SHEET
Platform: SEMI-SUBMERSIBLE

GIBBS & COX, INC.
Date:

18351-10 (W-10,010)

[illegible]

* ESTIMATE CODE: Insert "P" for Parametric or "B" for Bottom-up

NOTES: (1) All Costs $\times 10^6$, FY 73
(2) Labor Costs limited on \$20 M/M

(3) Tooling Included With Labor Cost
(4) Platform Costs Based on First of 4 Identical Plants
(5) (H) - Recurring Costs, in 3/4r

OTEC COST ESTIMATING SHEET
Platform: SENT-SUMMERSTABLE

GIBBS & COX, INC.
Date:

[illegible]

* ESTIMATE CODE: Insert "P" for Parametric or "B" for Bottom-up

NOTES: (1) All Costs @ 14%, FY 78
(2) Labor Costs Based on \$20 H/11

13) Tooling Included With Labor Cost
14) Platform Costs Based on First of 4 Identical Plants
15) (M) = Recurring Costs, in \$/Yr

18351-10 (W-10,010)

ATEC COST ESTIMATING SHEET
Platform: SEMI-SUBMERSTABLE

GIBBS & COX, INC.
Date:

18321-10 (W-10-010)

[illegible]

* ESTIMATE CODE; Insert "P" for Parametric or "B" for Bottom-up

NOTES: (1) All Costs $\leq 10^6$, R₁ 7M
(2) Labor Costs based on \$20/H/M

(3) Tinting Included With Labor Cost
(4) Platform Costs Based on First of 4 Identical Plants
(5) (a) - Bussing Cases, in 3/8"

18351-10(W-10,010)

SECTION 2

COST ESTIMATE

BACK-UP DATA

SEMI-SUBMERSIBLE

GIBBS & COX, INC.

OTEC COST ESTIMATE BREAKDOWN

SEMI-SUBMERSIBLE

WBS	DESCRIPTION	WEIGHT L. TONS	LABOR		MATERIAL	
			FACTOR \$/TON	COST \$ MILLION	FACTOR \$/TON	COST \$ MILLION
1.0	PLATFORM SYSTEM					
1.2	HULL AND STRUCTURE (MARAD GROUPS 0-0 THRU 9-2)					
	Column - Plating and Framing					
	- Lower Head	1190	3000	3.6	500	.6
	- Motor Room	2720	3000	8.2	500	1.4
	- Generator Room	2602	3000	7.8	500	1.3
	- Demister Room	1460	3000	4.4	500	.7
	- Upper Transition	1548	3000	4.6	500	.8
	- Upper Column	670	3000	2.0	500	.3
	- Stanchions	812	3000	2.4	500	.4
	- Decks and Platforms	4977	2400	11.9	500	2.5
	- Structural Bulkheads	577	3000	1.7	500	.3
	Lower Cross Structure - Plating and Framing	9203	2500	15.5	500	4.6
	- Top Plenum	1287	2800	3.6	500	.6
	- Transition Plenum	524	2800	1.5	500	.3
	Upper Cross Structure - Decks, Flats	3257	2400	7.8	500	1.6
	- Sides	189	2400	.5	500	.1
	- Trusses	4351	2800	12.2	500	2.2
	Main Braces (Struts)	2096	2800	5.9	500	1.0
	Trunks		5000		500	
	Heat Exchanger Foundations	472	4000	1.9	500	.2
	Plenum-to-Heat Exchanger Pipe	601	5000	3.0	500	.3
	Heat Exchanger-to-Pumps Pipe	1368	5000	6.8	500	.7
	Heat Exchanger-to-Screens, WW Pipe	706	5000	3.5	500	.4
	Turbo-Generator Foundation	287	4000	1.1	500	.1
	Demister Foundations	113	5000	.6	500	.1
	Miscellaneous Foundations - Pump Motors	161	11,000	1.8	500	.1

GIBBS & COX, INC.

SEMI SUBMERSIBLE

OTEC COST ESTIMATE BREAKDOWN

WBS	DESCRIPTION	WEIGHT L. TONS	LABOR		MATERIAL	
			FACTOR \$/TON	COST \$ MILLION	FACTOR \$/TON	COST \$ MILLION
1.2	(Continued)					
	Deckhouses	40	3000	.1	500	.02
	Welding	619	-	-	2500	1.5
	Mill Tolerance	412	-	-	500	.2
	Sub-Total Group 1.2 Margin 10%			122.7 135.0		22.4 24.6
1.3	POSITION CONTROL SYSTEM					
	Winches and Controls	25	4000	.1		0.13
	Anchors					1.4
	Cables and Fittings					11.2
	Fairleads, Fenders	105	4000	.4		1.1
	Sub-Total Group 1.3		.5 .6			13.7 14.7
1.4	PLATFORM SYSTEMS (MARAD GROUPS 17-19)					
	Fire Detection, Extinguishing (excluding Fire Mains)	43	25000	1.08	69000	2.58
	Ventilation	141	28000	3.9	7000	0.99
	Air Conditioning	28	12000	0.34	6250	0.18
	Refrigeration	1.0	12000	0.01	6250	0.01
	Plumbing Drains, Scuppers	4.0	62000	0.27	20750	0.08
	Vents, Sounding Tubes, Overflows	12	8000	0.1	6250	0.08
	Emergency Drainage and Ballast	29	17200	0.5	7700	0.22
	Fire Mains, Flushing, Sprinkling	14	13400	0.19	9400	0.12
	Fresh Water (including Distilling Plant, Potable Water)	9.0	2000	0.07		
	Fuel Oil (Helicopter, Boat, Fill & Transfer)	8.0	17200	0.14	11300	0.09
	Compressed Air	9.0	23000	0.02	24500	0.22
	Pollution Control	25	16950	0.42	13400	0.
	Auxiliary Seawater (Power System Support)	164	13400	2.5	8400	1.5

GIBBS & COX, INC.

OTEC COST ESTIMATE BREAKDOWN

SEMI SUBMERSIBLE

WBS	DESCRIPTION	WEIGHT LBS./TONS	LABOR		MATERIAL	
			FACTOR \$/TON	COST \$ MILLION	FACTOR \$/TON	COST \$ MILLION
1.4	(Continued)					
	Deck Machinery (Cranes, Hoists, Bitts, Chocks) *	439	—	0.08	—	1.7
	Ship Service/Emergency Generators	9	3600	0.03	3500	0.03
	Switchboards	92	3000	0.28	25000	2.3
	Distribution	6	31200	0.19	11200	0.07
	Lighting	16	24400	0.39	45500	0.73
	Ship's Service Support System	5	49200	0.25	8200	0.04
	Radio Communication	30	30000	0.9	5000	0.15
	Radar	5	30800	0.2	32000	0.2
	Interior Communication	2	50000	0.1	50000	0.1
	Monitoring and Control	10	30800	0.3	32000	0.3
	Data Processing, Telemetry	4	—	0.3	—	0.7
	Helicopter Control	2	—	0.6	—	0.9
	Ammonia Detection System	1	—	0.1	—	0.2
	Elevators, Hoists	1	—	—	—	—
	Aircraft Fittings	151	5450	0.8	9200	1.4
	Operations Fluids	1	—	—	—	—
	Sub-Total Group 1.4	110	—	14.1 15.5	—	15.34 16.9
1.5	OUTFIT AND FURNISHINGS					
	Masts, Kingposts	25	16,000	.4	3500	.9
	Castings, Forgings	30	4000	.1	1100	.03
	Rails, Stanchions	10	5000	.05	3100	.03
	Ladders	100	14,100	1.3	2500	.3
	Misc. Fittings	50	10,000	.5	3000	.2
	Doors, Closures	25	17,000	.4	5000	.1
	Insulation, Sheathing	75	14,000	1.0	3000	.2
	Deck Covering	50	3600	.2	1700	.1

(* Note - Material cost for bitts 7 chock use Kingposts and Masts data 1.5
Labor cost use Deck Covering data 1.5).

Project No. 18351

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Date

By

GIBBS & COX, INC.

COST ESTIMATING SHEET
OTEC COMMERCIAL PLANT

OTEC COST ESTIMATE BREAKDOWN

SEMI-SUBMERSIBLE

WBS	DESCRIPTION	WEIGHT L. TONS	LABOR		MATERIAL	
			FACTOR \$/TON	COST \$ MILLION	FACTOR \$/TON	COST \$ MILLION
1.5	(Continued)					
	Furniture	20	7000	.1	5500	.1
	Boats, Boat Handling	25	7000	.2	4600	.1
	Paint	500	18000	8.8	5000	0.4
	Permanent Ballast		2000	.5	250	.1
	Commissary Equipment	15	17000	.3	12,300	.2
	Damage Control Equipment	25	8000	.2	11,700	.3
	Utility Space Equipment (laundry, medical, offices, laboratories, shops)	25	8000	.2	15,000	.4
	Stowages	30	14,600	.4	5000	.2
	Joiner Work (non-structural bulkheads)	100	17,000	1.7	5000	=
	Sub-Total Group 1.5			16.3		6.7
				17.9		6.8
1.7	SEAWATER SYSTEMS (EXCLUSIVE OF CWP)					
	CW Pumps, Motors, Transmissions	4290	-	6.5	-	65.4
	WW Pumps, Motors, Transmissions	3574	-	5.6	-	56.0
	CW Piping including Diffusers		-	-	-	-
	WW Piping including Diffusers		-	-	-	-
	Valves, Fittings		-	-	-	-
	Screens, Filters (except those in CWP)	194	8000	1.5	24500	4.5
	Discharge Pipes		-	-	-	-
	Seawater in Pumps and Piping between Pumps, H/X		-	-	-	-
	Sub-Total Group 1.7			13.6		125.9
	MARGIN 10%			15.0		139.5

COST ESTIMATING SHEET
OTEC COMMERCIAL PLANT

OTEC COST ESTIMATE BREAKDOWN

SEMI-SUBMERSIBLE LE

Project No. 18351

Date _____

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18351-10 (W-10,010)

COST ESTIMATING SHEET
OTEC COMMERCIAL PLANT

GIBBS & COX, INC.

OTEC COST ESTIMATE BREAKDOWN

SEMI-SUBMERSIBLE

WBS	DESCRIPTION	WEIGHT L. TONS	LABOR		MATERIAL	
			FACTOR \$/TON	COST \$ MILLION	FACTOR \$/TON	COST \$ MILLION
2.0	CWP SYSTEM					
2.2	CWP STRUCTURE					
	Plating, Stiffeners, Ring Fasteners	21705	300	6.5	1900	41.2
	Connections (if used)	1747	400	.7	2900	5.0
	WELDING & CONTINGENCIES	1190	500	.6		
	Sub-Total Group 2.2	24642		7.8		46.2
2.3	CWP SCREENS	348	14045	4.9	7700	2.7
2.4	CWP-BULL TRANSITION					
	Mechanical Devices	5		5.0		
	Seals	20		.7		
	Special Fittings	11		.7		.3
	Sub-Total Group 2.4	26		6.4		.3
2.5	CWP PUMP (INCLUDE IN 1.7. SEAWATER SYSTEMS)					
2.6	CWP BIOFOULING, CORROSION CONTROL					
	Protective Covering			.5		1.3
	(CWP Cathodic Protection included in 1.8)					
	Sub-Total Group 2.6			.5		1.3

GIBBS & COX, INC.

SEMI-SUBMERSIBLE

OTEC COST ESTIMATE BREAKDOWN

Date _____

5.0 INTEGRATION/ENGINEERING COST ESTIMATE (\$M)
(Applicable to First Unit Only)

WBS	DESCRIPTION	SHIP			SEMI-SUBMERSIBLE		
		Prelim. Design	Contract Design	Detail Design	Prelim. Design	Contract Design	Detail Design
1.1	Platform	.25 ⁴⁾	.80	4.00	.30	1.00	5.00
2.1	CWP	.15	.40	4.00	.15	.40	4.00
3.1	Power System (1)	.20	.35	2.00	.20	.35	2.00
4.1	Energy Transfer ⁽²⁾	.05	.15	.80	.05	.15	.80
5.1	Syst. Design, Anal.	.15	.65 ⁽⁶⁾	3.00 ⁽⁷⁾	.15	.75	3.50
5.2	Syst. Integration ⁽³⁾	.20 ⁵⁾	.25	2.50 ⁽⁸⁾	.25	.35	3.00
	<u>TOTAL</u>	1.0	2.60	16.30 ⁽⁹⁾	1.1	3.00	18.30

NOTES:

- 1) Excludes hardware design of heat exchangers, turbogenerators, other Power System components. Includes installation design only.
- 2) Excludes hardware design of Transfer System components. Includes installation design only, including cable interface.
- 3) Includes design management, supervision.
- 4) Includes model tests.
- 5) Includes all planning and systems engineering studies not included in WBS 11.0, such as safety, ILS, value engineering, producibility, RMA, etc.
- 6) Includes specifications.
- 7) Includes purchase specifications, vendor liaison.
- 8) Includes design control (interference check).
- 9) Reflects level of documentation and controls required for Commercial contracts plus additional safety-related efforts.

6.0

SYSTEM TEST AND EVALUATION COST ESTIMATE (\$M)

(Applicable to First Unit Except as Noted)

WBS	TEST PHASE	PREL. DESIGN	CONTR. DESIGN	DETAIL DESIGN	FABRIC/ CONSTR.		DEPLOY/ INSTALL		TEST/ OPER.	
					LABOR	MAT'L.	LABOR	MAT'L.	LABOR	MAT'L.
6.1	Test Planning	.15	.30	.35	-	-	-	-	-	-
6.2	Special Test Facility	None Identified At This Time								
6.3	Independent T&E									
6.3.1	In-Plant Tests	-	-	.08 ⁽¹⁾	.12 ⁽²⁾	-	-	-	-	-
6.3.2	Dockside Tests	-	-	.08 ⁽³⁾	.40 ⁽³⁾	.10	-	-	-	-
6.3.3	Builder's Trials	-	-	-	.40 ⁽⁴⁾	.30 ⁽⁴⁾	-	-	-	-
6.3.4	Acceptance Trials	-	-	-	-	-	.52 ⁽⁵⁾	.39 ⁽⁵⁾	-	-
6.3.5	OTEC Syst. Tests	-	-	-	-	-	-	-	1.50 ⁽⁶⁾	1.90 ⁽⁶⁾
TOTAL - 1ST UNIT		.15	.30	.51	.92	.40	.52	.39	1.50	1.90
TOTAL - UNIT 2 - 8		0	0	0	.40	.20	.25	.20	0.50	0.60

NOTES:

- 1) Assumes 2 man-years of Systems Integration Contractor (SIC) effort.
- 2) Assumes 3 man-years of shipbuilder effort (Vendor effort included in cost of equipment).
- 3) Assumes 2 man-years of SIC effort, 10 man-years shipbuilder effort.
- 4) Assume 3 week trial involving 60 shipbuilder personnel, 10 SIC/DOE personnel, \$10K/day platform operations, \$50K towing and 2 man-year data reduction. Allow \$40K for test instrumentation.
- 5) Assume similar breakdown as Builder's Trials, but increase 30% for additional travel and test instrumentation.
- 6) Assume 3 month test prior to tie-in to shore grid involving 50 SIC personnel, 10 DOE personnel, \$10K/day platform operations, \$5K/day logistics support (\$30K/day total). Allow \$500K for instrumentation, data processing. Include 10% on labor for travel.
- 7) Vendor test costs and cost of vendor personnel attending above tests and trials are assumed to be included in equipment costs.

7.0 OPERATIONAL SUPPORT COST ESTIMATE7.1 SPARE PARTS7.1.1 INITIAL SPARES

Assume an initial stock inventory of \$1M on each platform plus the following stored ashore:

1	Spare CW pump motor rotor @ \$1M	
1	Spare WW pump motor rotor @ \$1M	
1	Spare Turbo-Generator Rotating Element	} Not Included
Pending
Cost Data
From DOE
2	Spare Reflux Pumps	
2	Spare Ammonia Feed Pumps	
4	Spare Chlorinator Units	
1	Spare Mooring Winch, Chain, Wire @ \$1M	
•	Platform System Spares (Fans, Pumps, Motors, AC Units, etc. - assume \$10M.	

TOTAL FOR PARK = \$21 M

TOTAL PER PLATFORM = \$14.0M against 1st Platform

= \$1.0 M against Other Platform

7.1.2 FOLLOW-ON SPARES

Assume that the initial spares loadout onboard each platform will last one year (\$1M/year) and that the components stored shoreside will be utilized at the rate of \$2M/year = \$3M/year total per platform.

7.2 EXPENDABLE MATERIALS (PLATFORM) PER YEAR

Fuel Oil	= \$0.6 M
Lube Oil	= \$0.1 M
Aircraft Fuel	= \$0.1 M
Food, Dry Stores	= \$0.2 M @ \$10/day/man
Miscellaneous	= <u>\$1.0 M</u> (Paint, etc.)
Sub-Total	= \$2.0 M/year

Logistics Support Exendables = \$0.8 M total for boat and truck fuel, spare parts, supplies, etc., which is negligible when amortized over 8 platforms.

7.0 OPERATIONAL SUPPORT COST ESTIMATE (Continued):7.2 EXPENDABLE MATERIALS (PLATFORM) PER YEAR (Continued):

Ammonia resupply is not included. Although this is recognized as a potentially significant item, no data has been supplied by DOE on required makeup or resupply rates.

7.3 PECULIAR SUPPORT EQUIPMENT

Assume these items are included in the total weight and cost of shop equipment reflected in Outfit and Furnishings, WBS 1.5.

7.4 COMMON SUPPORT EQUIPMENT

See 7.3

7.5 PERSONNEL7.5.1 Platform Personnel

Total embarked personnel = 44, required for 2 - 12 hour shifts. Assuming 14 days on, 14 days off, a minimum of 88 people must be dedicated to each platform. With an allowance for leave, sickness, etc., a total of 96 people are required for one platform. Using an average annual cost per person of \$35 K (salary, fringe benefits, etc.) the annual cost of platform personnel is \$3.2 M per platform.

7.5.2 Shoreside Personnel

Total shoreside personnel for total logistics support includes 100 people, working a nominal 8 hour day.

- Administrative, communications = 19
- Maintenance and repair = 14 (maintenance teams to service platforms)
- Building, vehicle maintenance = 6
- Warehouse, materials handling = 19
- Boat crews = 32
- Diving Team = 10

At an average rate of \$32 K/year, total = \$3.2M

These costs would undoubtedly vary somewhat with the number of platforms served, but for this estimate a constant cost of \$3.2 M will be assumed, equivalent to \$0.4 M per year per platform.

7.6 TECHNICAL MANUALS

Assume a budget of \$0.5 M, chargeable to the first platform.

8.0 DEPLOYMENT SYSTEMS AND SERVICES COST ESTIMATE8.1 PLATFORM DEPLOYMENT8.1.1 Ship

Assume the following procedures for joining the two halves of the hull at sea:

<u>TASK</u>	<u>LABOR @ \$25/MH</u>	<u>MATERIAL</u>
Maneuver, Join Halves	80 K	50 K
Construct, Install Caissons	150 K	800 K
Welding, Preparation	800 K	50 K
Remove Caissons	40 K	-
Install Deckhouse, Final Outfit	700 K	90 K
Overtime, Subsistence Allowance	= 1,770 K 500	990 K Say 1.0 M
	2,270 K	

8.1.2 Semi-Submersible

Assume the following procedures for joining the pairs of columns and adding the upper cross-structure at sea:

<u>TASK</u>	<u>LABOR @ \$25/MH</u>	<u>MATERIAL</u>
Maneuver, Join Modules	80 K	50 K
Construct, Install Caissons	320 K	1,000 K
Welding, Preparation	400 K	30 K
Remove Caissons	80 K	-
Install Cross Structure	500 K	200 K
Outfit	600 K	100 K
Overtime, Subsistence Allowance	= 1,980 K 600 K	1,380 K Say 1.4 M
	2,580 K	

8.2 CWP ASSEMBLY (SHIP AND SEMI-SUBMERSIBLE)

The CWP will be shipped from the shipyard in sections aboard the platform and assembled on site using a special deployment barge (see WES 9.1). The costs associated with this operation are based upon assembling one 50 foot high section of CWP per day with a 90-man crew resulting in total MH of 130,000 based on 2 - 12 hour shifts or equal. Assuming \$40 per hour to cover overtime, travel and subsistence, the total labor cost is \$5.2 M. Corresponding material costs are estimated at about \$1.0 M.

8.3 CWP DEPLOYMENT (SHIP AND SEMI-SUBMERSIBLE)

It is estimated that a crew of 30 men working for 7 days on 2 - 12 hour shifts can prepare the CWP for deployment at \$40/hour = \$100 K. Material is as follows:

Crane Barge = 12 days (including transit) @ 25K/day	= \$300 K
Tugs (4) = 12 days @ 4K/day	= \$200 K
Rigging and Miscellaneous	= \$100 K
TOTAL MATERIAL	= \$600 K

8.4 MOORING SYSTEM DEPLOYMENTInstallation ItemsEquipment

Barge Mounted Windlass	500,000
Traction Winch	500,000
Modifications to Barge	100,000
Pendant Buoys 14 - @ \$20,000.	280,000
Pendants 9,920 fathoms - 2" dia. wire @ \$12/ft.	<u>714,240</u>
	\$2,094,240

Rental Items

Barge - 400' x 100' x 25'	\$ 2,000/day
Tugs - 3 @ \$4,000/day	\$ 12,000/day
Survey Boat @ \$4,000/day	\$ 4,000/day
Crane @ \$500/day	<u>\$ 500/day</u>
	\$ 18,500/day

Distance Honolulu to Keahole Point estimated to be 250 N. miles

Estimate tug/barge speed:	= 3 kn
Time for Round Trip + Loading	= $\frac{500}{3} + 48$ hrs. = 215 hrs. = 9 days
Avg. length of chain/mooring	= 810 fathoms
Avg. length of rope/mooring	= 1970 fathoms

Wt. of above + pendant + buoy + anchors (100,000#) =

$810 \times 6 \times 144 + 1970 \times 6 \times 29.5 + 710 \times 6 \times 7.40 + 100,000 + 30,000$
 = 1,210,054# = 540 LT

Due to space considerations, assume only 2 moorings can be carried one at one time. Assume 2 days installation time per mooring.

8.4 MOORING SYSTEM DEPLOYMENT (Continued):

Installation Time = 14×2 = 28 days

Transit Time = $\frac{14}{2} \times 9$ = 63 days

5% Down Time = $\frac{91}{2}$
96 days

Rental Costs 96 x 18,500 = \$1,776,000.

Total Installation Costs = \$3,870,240.

Total Cost - 14 Anchor Array = \$17,207,840.
+ Margin on Installed Items

9.0 OTEC FACILITIES COST ESTIMATE9.1 SHIPYARD FACILITIES9.1.1 Platform Deployment AidsFor Ship:

The ship is to be temporarily buoyed by a pontoon to permit float-out and rotation of the two hull halves. For estimating purposes assume a gross pontoon volume of 20 x 50 x 400 feet = 400,000 cubic feet. At a structural density of 6 lbs./cubic foot and \$1.30 per pound, the pontoon cost = \$3.10 M (bare hull). Use \$3.5 M to include attachments, ballast piping, fittings, etc., for each hull section (\$7.0 M total) chargeable to first hull.

For Semi-Submersible:

Each of the four columns is to be buoyed by pontoons at each end for float-out in a horizontal configuration. A total of 8 pontoons are required, each of approximately 250,000 cubic foot volume, each costing \$2.0 M. Total cost for hull support = \$8.0 M. In addition, a 250 x 80 x 30 foot barge is required to float in the top cross-structure during final assembly. This barge and the cross-structure support assembly costs approximately \$4.4 M. Total cost of floatation = \$13.5 M chargeable to first hull.

9.1.2 CWP Deployment Aids

For Ship and Semi-Submersible:

A special submersible barge approximately 180 x 150 x 50 feet is required to support the CWP during assembly and deployment. This barge is expected to cost approximately \$10.3 M including equipment and outfit, and is reusable.

NOTE: For the purposes of this estimate, the cost of these floatation devices has been included with Facilities since they are non-recurring costs useable for all platforms. If these items were to be included with Deployment, Platform, or CWP WBS elements, they would be mixed with recurring costs and might be lost. Therefore, Facilities appears to be a better element for such items.

9.0 OTEC FACILITIES COST ESTIMATE (Continued)9.2-9.5 SHORESIDE FACILITIES

	Item	Description	Cost, \$M
9.2	<u>Boats and Service Craft</u>		
	Start-Up Generator Barge	200 foot Offshore Supply Boat	5.3
	Fluids/Supply Barges (2)	3-8000 KW Generator's plus fuel	5.3
	Service Tug	200 foot flat deck barges	2.0
	Surveillance Craft	125 foot/4000 HP	3.6
	Crew Boats	65 foot/35 Knot	0.8
	Submersible Support	100 foot/100 person	2.1
	Barges (3)	2000 M Sub with Support Boats	5.2
		General Duty	5.0
	SUB-TOTAL		29.3
9.3	<u>Ground Transportation</u>		
	Cranes	1-60 Ton, 1-5 ton capacity	.30
	Fork Lift	30 ton capacity	.28
	Fork Lift	5 ton	.05
	Miscellaneous	cars, pick-up truck, bus	.17
	SUB-TOTAL		0.8
9.4	<u>Buildings, Piers, Etc.</u>		
	Warehouse (2)	200 x 75 foot, 24 foot high	0.4
	Office/Shop Building	120 x 40 foot, 1 story	0.2
	Garage, Misc. outbuildings	40 x 30 foot garage, 2 or 3 sheds	0.1
	Roads, parking		3.0
	Pier	30 x 250, concrete @ \$100/SF	1.0
	Fuel storage	Fuel supplied by truck or tractor	0.2
	Building equipment	Office equipment, etc.	0.5
	Supplies	Initial inventory	0.1
	Communications, Data Proc.		0.3
	Incinerator		0.1
	SUB-TOTAL		5.9
9.5	<u>Other Facilities</u>	10% of above	3.6
	TOTAL		39.6