CONSTRUCTION FEASIBILITY
OF OTEC PLATFORMS

Final Report

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LIST OF REFERENCES

- 1) OTEC platform configuration and integration study - Final Report by Lockheed Missiles and Space Co. April 1978.
- 2) OTEC platform configuration and integration study - Final Report by Gibbs & Cox, Inc. June 1978.
- 3) OTEC platform configuration and integration study - Final Report by M. Rosenblatt & Son, Inc. July 1978.
- 4) Modular Applications platform feasibility study - By Gibbs & Cox August 1978.
- 5) Constructability of OTEC Concrete Commercial Plants (Platforms, Cold Water Pipes and Heat Exchangers) by Gilbert Commonwealth, April 18, 1978.
- 6) OTEC Preliminary Analysis of Commercialization Incentives. By The Mitre Corp., July 1978
- 7) Gibbs & Cox Transmittal Memorandum Dated November 10, 1978- Subject: 18641-3-OTEC Conceptual Design Spar Baseline M.A.P. Platforms, Revision.

Executive Summary

The primary conclusion of this study is that all configurations of OTEC plants studied can be constructed in the United States, using either steel or concrete materials. The larger configuration (Concepts 2, 3, 4 and 10) will require either modification to existing facilities or use of an undeveloped, deep water, sheltered areas for modular assembly or slip-form fabrication. Depending on the size of the proposed plant, required facility modification may be minimal, involving only dredging a deeper construction berth, or it may include developing a graving dock. For very deep draft (generally more than 80 feet) plants, a sheltered deep water location would be required. Two such sites have been identified; (1) Puget Sound in Washington and (2) offshore Hawaii (either Honolulu Harbor or Lahaina Roadstead).

The eleven plant configurations studied (shown in Figures 21, 23, 24, 26, 27, 29, 31, 33, 34, 36, 37, 39, and 40) are based on platform configuration and integration studies by Lockheed, Gibbs and Cox, and Rosenblatt (References 1, 2, and 3) and the Applied Physics Laboratory. Since these configurations are referenced throughout the report, they are presented on fold-out sheets (Figures 39 and 40) at the back of this report. Both ship and spar type configurations, for a range of plant sizes from 10 Megawatts (MWe) through 400 MWe, are included. In addition, each configuration is evaluated with regard to both steel and concrete construction.

To assist in the evaluation of concrete construction, Det Norske Veritas developed a series of construction schemes and evaluated each configuration's constructability in relation to an assumed typical construction facility.

Twenty shipyard/construction yard fabricators, all within the United States, were asked to evaluate the constructability of the eleven configurations with regard to any limitation of their existing facilities. The responses to the survey are contained in the appendix, while the results are summarized in Figure 39 and 40.

Note that the configurations in these figures are ranked according to an assessment of the ease of their construction. The ranking is identical for both steel and concrete because the overall dimensions of the plant configurations were the most critical factor for both construction materials.

The United States has not yet developed a floating concrete construction industry such as exists in Europe. Only three U.S. fabricators who are experienced in constructing buoyant concrete structures could be identified. The majority of the fabricators naturally expressed a preference for steel construction because of familiarity, past experience and facilities. Since the concrete construction technology is available, the large civil construction companies in the U.S. could adapt their experience to this technology, as has been done in Europe, if economics and market conditions warranted.

Only the largest platform configuration would require a deep water sheltered assembly site. Construction could be facilitated by placing orders for the required modules with several existing yards, sizing the modules to fit the existing fabrication and launch facilities. This would distribute the economic benefits and probably reduce the overall construction time, particularly if several similar plants were to be constructed in the same period of time. Close schedule coordination and exacting dimensional tolerances would be needed to benefit from this approach.

SECTION I

INTRODUCTION

This study represents the work in evaluating the feasibility of constructing numerous OTEC plant configurations within the United States accomplished by Deep Oil Technology, Inc. for the Division of Central Solar Technology of the U.S. Department of Energy. The plant configurations assessed are based on the preliminary designs developed by:

(1) Lockheed Missiles and Space Co. (2) Gibbs and Cox, Inc. (3) M. Rosenblatt and Son, Inc. and (4) the Applied Physics Laboratory of Johns Hopkins University.

Investigated were two basic hull types;

- o Ship shape, and
- o Spar

combined with three plant sizes;

- o 10/20 MWe
- o 100 MWe
- o 400 MWe

and two construction materials;

- o concrete
- o steel

Early in the study, a fourth parameter was considered important and included; namely, whether the heat exchangers were mounted within or external to the hull envelope.

The technical feasibility of constructing these platforms in existing shipyard facilities was evaluated first. Since the overall dimensions of the larger platforms exceeded the capabilities of existing facilities, the degree of required facility modification was examined. An economic comparison of the candidate platform configurations was considered premature and outside the given scope of work. However, the configurations were ranked according to a subjective evaluation of the ease of construction. This ranking could roughly be correlated with relative cost.

Using the reference platform configuration and integration studies as a data base, 39 ship and spar configurations were consolidated and listed. From this list, eleven configurations were selected for more detailed study. These eleven configurations are pictured in the fold-out Figures 39 and 40 of this report. Since the general dimensions and proportions were quite similar whether constructed of steel or concrete, each configuration shown was evaluated for both steel and concrete construction.

To aid and broaden the evaluation, twenty major shipbuilders/fabricators were asked to evaluate the constructability of these configurations in their facilities. These companies were selected based on their covering of a wide geographic area, their large size construction capabilities, and their familiarity with OTEC work. Their responses are contained in the appendix to this report.

An early study finding was that only small extensions of existing U.S. technology were required for steel fabrication. Therefore, work was initiated to investigate and develop methods for large platform concrete construction. Det Norske Veritas of Norway was contracted to work in this area, based on their previous experience and the expertise, developed in Europe, for concrete oil production platforms. Their study is included in Section VI.

In Brief;

Section II describes the methodology used in classifying vessel or platform types.

Sections III and IV identify the interrelationship between cold water pipe and power system components with platform construction.

Section V identifies and describes the possible construction sites.

Section VI presents techniques that could be used for construction of OTEC platforms of either steel or concrete.

Section VII contains a study summary and conclusions drawn.

Section VIII presents some recommendations for further study.

SECTION II

PLATFORM CLASSIFICATION

The OTEC platform configuration and integration studies (References 1, 2, and 3) provided most of the data base for this study. Included in these reports are six different hull types.

- o ship shape
- o spar
- o semi-submersible
- o tuned sphere
- o submersible
- o cylindrical surface barge

Only the first two hull types - ship shape and spar were to be evaluated. The contractors responsible for referenced studies 1,2, and 3 worked independently to develop many conceptual arrangements of ship-shape and spar type platforms. These were consolidated into a list of 37 different configurations. Reference 4 provided an additional five configurations. Thus, a total of 42 configurations, representing both steel and concrete, were tabulated. Since several configurations were identical for both steel and concrete, the final list included the 39 different concepts shown in Table I. These concepts are grouped under subheadings relative to their platform shape, construction material, and heat exchanger location.

In order to facilitate evaluation, the 39 concepts were further consolidated into the eleven configurations shown in Table II. These eleven represent the full range of platform sizes, hull shapes, and heat exchanger locations. Note that each configuration is assigned a concept number that correlates with Figures 39 and 40 and also with dimensioned Figures 1 through 11. Each of these concepts is evaluated separately with regard to its being constructed of either steel or concrete.

TABLE I

CONSOLIDATION OF OTEC SHIP & SPAR CONFIGURATIONSSHIP-STEEL, INTERNAL HEAT EXCHANGERSDATA SOURCE (Reference)

100 MW	L= 540'	B=216'	Lockheed (Vol 1 2-119 Ref.1)
200 MW	L=1000'	B=269'	Lockheed (Vol 1 2-119 Ref.1)
500 MW	L=1168'	B=269'	Lockheed (Vol 1 2-119 Ref.1)

SHIP-CONCRETE, INTERNAL HEAT EXCHANGERS

10/20/40 MW	L=377'	B=121'	G&C/APL Ref.4)
50 MW	L=262'	B=121'	Gibbs & Cox (Vol 2 A-1 Ref.2)
100 MW	L=561'	B=236'	Lockheed (Vol 0 14 Ref.1)
100 MW	L=525'	B=210'	Rosenblatt (Vol 1 59 Ref.3)
100 MW	L=390'	B=170'	G&C (Vol 3 8-6 Ref.2)
100 MW	L=298'	B=180'	G&C (Vol 1 2-9 Ref.2)
200 MW	L=469'	B=259'	G&C (" Ref.2)
200 MW	L=745'	B=272'	Rosenblatt (Vol 1 59 Ref.3)
350 MW	L=813'	B=341'	G&C (Vol 1 2-9 Ref.2)
400 MW	L=850'	B=407'	Rosenblatt (Vol 1 59 Ref.3)
500 MW	L=984'	B=361'	G&C (Vol 2 A5 Ref.2)

SPAR-CONCRETE, INTERNAL HEAT EXCHANGERS

10 MW	L=321'	B= 79'	G&C Ref.4)
50 MW	L=220'	B=151'	G&C (Vol 1 2-10 Ref.2)
100 MW	L=371'	B=230'	G&C (" Ref.2)
100 MW	L=377'	B=328'	Lockheed (Vol 1 2-213 Ref.1)
100 MW	L=688'	B=146'	Rosenblatt (Vol 1 59 Ref.3)
200 MW	L=753'	B=177'	Rosenblatt (Vol 1 59 Ref.3)
200 MW	L=328'	B=387'	Lockheed (Vol 1 2-213 Ref.1)
200 MW	L=308'	B=344'	G&C (Vol 1 2-10 Ref.2)
350 MW	L=440'	B=361'	G&C (" Ref.2)
400 MW	L=809'	B=214'	Rosenblatt (Vol 1 59 Ref.3)
500 MW	L=394'	B=512'	Lockheed (Vol 1 2-213 Ref.1)
500 MW	L=430'	B=440'	G&C (Vol 2 A 15 Ref.2)

TABLE I (contd')

SPAR-STEEL, INTERNAL HEAT EXCHANGERSDATA SOURCE (Reference)

10 MW	L=321'	B= 79'	G&C		Ref.4)
50 MW	L=220'	B=151'	G&C	(Vol 1 2-10	Ref.2)
100 MW	L=371'	B=230'	G&C	"	Ref.2)
100 MW	L=574'	B=	Rosenblatt	(Vol 1 A5	Ref.3)
200 MW	L=308'	B=344'	G&C	(Vol 1 2-10	Ref.2)
350 MW	L=440'	B=361'	G&C	(	" Ref.2)
500 MW	L=430'	B=440'	G&C	(	" Ref.2)

SHIP-CONCRETE, EXTERNAL HEAT EXCHANGERS

400 MW	L=689'	B=190'	Lockheed	(Vol 2 3-2	Ref.1)
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SPAR-CONCRETE, EXTERNAL HEAT EXCHANGERS

10 MW	L=282'	B= 70'	G&C		Ref.7)
40 MW	L=321'	B=121'	G&C		Ref.4)
100 MW	L=460'	B=132'	Lockheed	(Vol 1 233	Ref.1)
400 MW	L=413'	B=190'	Lockheed	(Vol 2 4-11	Ref.1)
(VERTICAL HEAT EXCHANGER)					
400 MW	L=456'	B=226'	Lockheed	(Vol 2 4-4	Ref.1)
(HORIZONTAL HEAT EXCHANGER)					

TABLE II

Typical OTEC Platforms Selected for Constructability Study (Concrete or Steel)

Configuration	Concept Number	Approx. Net Power	Height or Length OA.	Diameter or Breadth OA.	Reference	Remarks
SPAR -	1	10/20 MW	321' (98m)	79' (24m)	4	Two 100 MW configurations are listed as each has significant merit regarding constructability
INTERNAL HEAT EXCHANGERS	2	100 MW	377' (115m)	328' (100m)	1(Vol 1 2-213)	
	3	100 MW	688' (209m)	146' (45m)	3(Vol 1-59)	
	4	400 MW	430' (131m)	440' (134m)		
SPAR -						400 MW utilizes vertical heat exchangers
EXTERNAL HEAT EXCHANGERS	5	10/20 MW	282' (86m)	70' (21m)	7	
	6	100 MW	460' (140m)	132' (40m)	1(Vol 1 233)	
	7	400 MW	413' (126m)	190' (58m)	1(Vol 1 2.4-11)	
SHIP -	8	10/20 MW	377' (115m)	121' (37m)	4	Concept 8 is the JHU/APL Design
INTERNAL HEAT EXCHANGERS	9	100 MW	540' (165m)	216' (66m)	1(Vol 1 2-119)	
	10	400 MW	984' (300m)	361' (110m)	2(Vol 2-A5)	
SHIP -	-	40 MW	377' (115m)	121' (37m)	4	40 MW is the same configuration as Concept 8. Report not issued for 100 MW.
EXTERNAL HEAT EXCHANGERS	-	100 MW	-	-	-	
	11	400 MW	689' (210m)		1(Vol 2 3-2)

Figure 1. 10 MW Spar-Internal Heat Exchangers (Concept 1)

Figure 2. 100 MW Shallow Spar-Internal Heat Exchangers (Concept 2)

Figure 3. 100 MW Deep Spar-Internal Heat Exchangers (Concept 3)

Figure 4. 400 MW Spar-Internal Heat Exchangers (Concept 4)

Figure 5. 10 MW Spar External Heat Exchangers (Concept 5)

Figure 6. 100 MW Spar-External Heat Exchangers (Concept 6)

Figure 7. 400 MW Spar-External Heat Exchangers (Concept 7)

Figure 8. 10/20 MW Ship-Internal Heat Exchangers (Concept 8)

Figure 9. 100 MW Ship-Internal Heat Exchangers (Concept 9)

Figure 10. 400 MW Ship-Internal Heat Exchangers (Concept 10)

Figure 11. 400 MW Ship-External Heat Exchangers (Concept 11)

SECTION III

COLD WATER PIPE

This study does not address the feasibility of constructing the cold water pipe. For the purpose of this study, the following assumptions have been made:

- o The construction of the cold water pipe and its scheduling may be done independently and in parallel with the construction and scheduling of the platform.
- The attachment of the pipe presents only a localized impact on platform design and construction. It will not impact on the overall dimensions of the platform.
- The installation of the pipe will only impact the "deployment" phase of platform construction. Any special handling equipment will have only a localized effect.

These three assumptions allow the platform's constructability to be evaluated independently.

SECTION IV POWER PLANT COMPONENT

The weights and dimensions of the individual power plant components are important construction considerations. References 1, 2, and 3 provided data on the major components. The feasibility of constructing the various machinery components required for the OTEC power plant are not evaluated in this study.

Table III indicates the various sizes and weights for 25 MWe modules generated by the three contractors. Since there is a large variation, a typical maximum weight was established at 2000 tons for the 25 MWe heat exchangers.

For the "internal heat exchanger" configurations, 25 MWe modules, maximum lifts of 2000 tons would be required during construction.

For the "external heat exchanger" configurations, maximum lifts of approximately 350 tons would be required to install the cold and warm water pumps. The heat exchanger would be floated into place after launch.

TABLE III
TYPICAL WEIGHTS & DIMENSIONS OF MAJOR MACHINERY COMPONENTS
25 MW MODULES

<u>Component</u>	<u>Dimensions</u>	<u>Weight</u>	<u>Reference</u>
<u>Heat Exchangers</u>			
Horizontal	93' L X 35' DIA	2740 Tons (operating)	Gibbs & Cox (ES* 2-1)
"	80' L X 40' DIA	800 Tons (dry)	Rosenblatt (Vol 2 16)
"	102' L X 38' DIA	2274 Tons (dry)	Lockheed (Vol 1 2-15)
Vertical	73' L X 35' DIA	1170 Tons (operating)	Gibbs & Cox (ES 2-1)
"	85' L X 50' DIA	1300 Tons (dry)	Rosenblatt (Vol 2 16)
"	38' L X 38' DIA	945 Tons (dry)	Lockheed (Vol 1 2-15)
<u>Turbo Generator</u>			
	85' L X 12' DIA	190 Tons	Gibbs & Cox (ES 2-1)
	40' L X 25' DIA	200 Tons	Rosenblatt (Vol 2 16)
	92' L X DIA	226 Tons	Lockheed (Vol 1 2-15)
<u>Demisters</u>			
(5 x 5MM)	43' L X 14' DIA	40 Tons	Gibbs & Cox (ES 2-1)
	20' L X 20' DIA		Rosenblatt (Vol 2 16)
	43' L X 16' DIA	46 Tons	Lockheed (Vol 1 2-15)
<u>Water Pumps</u>			
		375 Tons	Gibbs & Cox (ES 2-3)
		336 Tons	Rosenblatt (Vol 2 9)
		560 Tons	Lockheed (Vol 2 3-4)

*Executive Summary

SECTION V

CONSTRUCTION SITES

The feasibility of constructing the eleven platform configurations was evaluated with respect to existing, developed shipyard or fabrication yard facilities that are currently active in marine vessel construction within the United States. Table IV lists the 20 companies contacted. These companies were selected on the basis of: (1) previous involvement with OTEC studies; (2) relatively large existing facilities (3) geographic distribution, and (4) demonstrated expertise in either steel or concrete construction.

It should be noted that the U.S. has not yet developed a large floating concrete structure construction industry such as exists in Europe. Thus, only three U.S. fabricators could be identified who are experienced in constructing buoyant concrete structures. They are Offshore Power Systems (Florida) Concrete Technology Corp. (Washington), and Hawaiian Dredging and Construction Co. (Hawaii). The majority of the contractors naturally expressed a preference for steel construction because of their familiarity and past experience with steel. Since the concrete construction technology is available, the large civil construction companies in the U.S. could adapt their experience to this technology as has been done in Europe, if economic and market conditions warranted. This would be required for concrete construction of the larger plants, particularly the deep draft spar configurations. The two potential deep water sheltered sites identified are located in Puget Sound, Washington and offshore Hawaii (either Honolulu Harbor, or Lahaina Roadstead). Offshore Florida has also been suggested; however, sufficiently deep water occurs at a considerable distance from shore in the open ocean where weather, currents, and offshore supply logistics could be expensive and involve high operational risks.

Table V summarizes the dimensions and capacities of the existing facilities of the 20 contractors surveyed. This table is intended to show a representative view of some of the larger facilities and is not intended as an all-inclusive listing.

TABLE IV
- SHIPYARDS & FABRICATORS CONTACTED
REGARDING FEASIBILITY OF CONSTRUCTION IN EXISTING & MODIFIED FACILITIES

Atlantic Coast:

General Dynamic Corp.	Quincy	Mass.
Seatrain Shipbuilding Corp.	Brooklyn	N.Y.
Dravo Corp.	Pittsburgh	PA.
Bethlehem Steel Shipbuilding Corp.	Baltimore	MD.
Sun Shipbuilding & Drydock	Chester	PA.
Newport News Shipbuilding	Newport News	VA.
Offshore Power Systems	Jacksonville	FL.

Gulf Coast:

Ingalls Shipbuilding Div.	Pascagoula	MS.
Alabama Drydock and Shipbuilding	Mobile	AL.
Avondale Shipyards	New Orleans	LA.
McDermott Fabricators	Morgan City	LA.
Marine Concrete Structures	New Orleans	LA.
Marathon LeTourneau Offshore	Houston	TX.
Brown and Root, Inc.	Houston	TX.

West Coast & Hawaii:

National Steel and Shipbuilding Corp	San Diego	CA.
Kaiser Steel Shipbuilding Corp	San Francisco	CA.
Kaiser Steel Proposed New Facility	Port Everet	WA.
Concrete Technology Cor. (ABAM ENGS.)	Tacoma	WA.
Hawaiian Dredging and Construction Corp.	Honolulu	HA.

Puerto Rico

Misener Marine Construction	San Juan	P.R.
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TABLE V

SUMMARY OF EXISTING FACILITIES AT POSSIBLE FABRICATORS

POSSIBLE FABRICATORS	MAIN BUILDING DOCKS				CHANNEL WATER DEPTH (FT.)	CRANE CAPACITY (S. TONS)
	TYPE	LENGTH(FT.)	WIDTH(FT.)	DEPTH(FT.)		
General Dynamic Corp.	Building	950	150 X 2	28	40/30	
Seatrain Shipbuilding Corp.	Graving	1092	143	41	42	
Dravo Corp.		not available				
Bethlehem Steel Shipbuilding Corp.	Building	1200	200	27		
Sun Shipbuilding & Drydock	Floating Dry	1100	195	40	40	800
Newport News Shipbuilding	Graving	1600	230		45/50	900
Offshore Power Systems	Building	501	415	21	48/30	900
Ingalls Shipbuilding Div.	Floating Dry	640	177	41	40/38	
Alabama Drydock & Shipbuilding		not available				
Avondale Shipyards	Floating Dry	960	220	35	40/17	
McDermott Fabricators		not available				
Marine Concrete Structures	Building	500	150	12		
Marathon LeTourneau Offshore	Building	1100	150	35		
Brown & Root, Inc.		not available				
National Steel & Shipbuilding Corp.	Building	1000	176		30/28	200
Kaiser Steel Shipbuilding Corp. (Proposed)						
Concrete Technology Corp. (ABAM ENG.)	Graving	500	150	12		
Hawaiian Dredging & Construction Corp.		390	53	30		
Misener Marine Construction	Building	600	100			

These contractors were contacted and presented sketches of the eleven concepts. They were asked to describe their facilities, indicate their preference for steel or concrete, and indicate their assessment of the construction feasibility of each concept in their developed existing facilities with and without modification. Included in the Appendix is a copy of the letter sent and the replies received from the fabricators.

The response to the inquiries was mixed. Certain companies, obviously familiar with the OTEC program, responded in considerable detail. Other companies made only a brief statement. Because of the general information given to the companies, specific conclusions were not expected. A more detailed and comprehensive study with selected prospective fabricators should be made in order to determine their capabilities with regard to specific OTEC platform designs.

SECTION VI

CONSTRUCTION METHODS

Figures 1 thru 11 show the principle dimensions of the selected eleven platforms. The platforms depicted may be constructed of either concrete or steel. This study, in evaluating the feasibility of physical construction, has assumed that the following conditions prevail.

- o Construction materials are available in sufficient quantities.
- o Skilled labor is available for either concrete or steel construction methods.
- o Major machinery items will be completed and available for intergration into the platform construction schedule as required.

Since some of the platform configurations bear little resemblance to any offshore structure built to date. Figures 12 and 13 are presented to show a comparison of the proposed OTEC platforms with the "nearest equivalent" existing offshore structure. The configurations are drawn to approximate equal scale so that relative size can be judged. The largest concrete structure of similar proportions to a spar is the gravity platform "Condeep", built in Norway. The largest steel structure similar to a spar is an oil storage and loading terminal built in Holland. Since the main hull of the storage terminal is not subjected to full hydrostatic pressure, it is of much lighter construction than required for OTEC spars.

CONSTRUCTION FACILITIES

To aid assessment of the constructability of the several OTEC platforms, the following three categories of construction facilities are defined:

1. Existing No major modifications are required to construction facilities or waterways.
2. Modified Existing Extensive enlargement of construction facilities and capabilities would be required. Possible modifications might include:

Figure 12. Comparison of OTEC Spar Configurations with Existing Structures

Figure 13. Comparison of OTEC Ship Configurations with Existing Structures

Enlarging and deepening graving dock or dry docks.
Deepening outfitting basin and waterways.
Adding heavy lift cranes (2000-ton capacity).
Adding concrete batch plant and handling systems.
Adding heavy plate rolling and welding capability.
Building large construction/launch barges.
Building heavy lift derrick barge (200-ton capacity).

3. New Building of a construction facility in essentially virgin territory would be required; for example, building a graving dock or setting up an offshore operation with an on-shore supply base. Each platform configuration is evaluated in relation to these three categories.

CONSTRUCTION PROCEDURES - STEEL

American shipbuilders and fabricators have constructed many varied steel structures for offshore service. The industry's technology and facilities have developed in an evolutionary pattern to meet new demands. This capacity to solve new technological problems can certainly encompass the OTEC program; however, expenses will be incurred where facilities require modification.

Any or several of the following procedures may be required for constructing the larger OTEC platform:

Modular Construction Procedures: There are many instances where different modules of a structure have been built in different facilities, owned by different contractors. These modules have then been towed to an assembly area and joined. Alignment and joining techniques are well developed for either free-floating modules or barge-supported modules. To construct the 1005-foot-long Manhattan ice breaking tanker, five separate hull sections were joined together afloat. Also, the 1000-foot-long ore carrier "Steward J. Cort" was fabricated by inserting a long hull section between cut-apart bow and stern sections.

Launching/Up-Ending Procedures: Several platform concepts may have to be constructed and joined while being supported horizontally on barges. The launching of these platforms requires a "sequenced ballasting" of the barge. This has been successfully accomplished many times. If spar configurations have been constructed horizontally, they will have to be up-ended to a vertical position, hence a "sequenced ballasting" of the spar is required. This procedure has been performed many times for jacket type offshore oil platforms. Several smaller steel spars have been up-ended without incident. Up-ending the steel OTEC spars is within the present state of the art. Design of the platform must consider the compartmentation and loading required during up-ending.

Both barge launch and up-ending procedures are sensitive to sea state. Although both procedures are complex and require much coordination, they can be accomplished.

Rolling and Welding of Thick Plates: Some of the deep draft spar configurations will require shell plate thicknesses up to 6 inches. Rolling and welding of such plates is done routinely at specialized facilities in small quantities. However, the size of the OTEC platform and quantity of plate required is far greater than anything accomplished to date. Larger rolling facilities would be required in most shipyards to handle an OTEC-size platform of the deep spar configuration. Preheating, welding, post-heating, and inspection facilities would have to be expanded to prevent excessive brittleness developing in the materials.

Although the rolling and welding of thick plates in OTEC quantities has not been attempted, there is no technological reason why it could not be successfully completed.

The major facilities improvements required to build large steel OTEC platforms are dependent on many parameters, including:

1. The number of platforms to be built, in what time period.
2. Economic justification for the capital expenditures required

- to meet any proposed construction schedule.
3. The type of OTEC platform to be built.
 4. The geographic location of the building contractor selected and the capabilities of that particular facility.
 5. The degree of modularization of assemblies from various contractors.

An acceptable facilities improvement program is obviously dependent on the number of platforms proposed. One pilot plant of 10/20 MW_e or one demonstration plant of 100 MW does not justify a large capital investment, unless there is a reasonable guarantee that those facilities will be utilized in subsequent OTEC work. On the other hand, a large commercial OTEC program requiring many plants could justify extensive capital expenditure.

Before any definitive study on facilities improvement can be concluded, the OTEC platform configuration must be selected. The facilities required to build a deep spar platform will be very different from those required to build a ship shape platform. Not only will the construction facilities vary, but the construction procedures will be quite different.

If a building contractor has sheltered deep water available, relatively little facilities improvement may be necessary. However, a contractor who has only the typical 20-40 foot water depths may need extensive facility modifications. Many contractors have maximum height and width facility limitations, in addition to water depth. Thus, the geographic location of a particular contractor dictates that a detailed engineering study for each possible location be carried out to determine facilities improvement and construction procedures.

The use of a modular approach to steel construction would alleviate many size-related problems. Facilities with certain size limitations would still be able to contribute to the OTEC program. Facilities with

a particular capability or expertise could concentrate in that field. After fabrication of the modules, they would be transported to an assembly site for integration into a complete platform.

This study can give only a general outline of facilities improvements necessary to build any of the proposed steel OTEC platform concepts.

The detailed construction schemes for each steel OTEC platform will vary depending on platform configuration and facilities of the fabricator. General construction schemes have been developed for each concept. The schemes presented represent the preferred methods expressed by most of the 20 fabricators contacted.

A typical building facility has been assumed, having the following capabilities:

- 1 Graving dock - 1000 ft. long X 150 ft. wide X 30 ft. water depth.
- 1 Outfitting basin with 40 ft. water depth.
- Max. crane capacity in the shipyard - 550 Tons.
- Available derrick barge capacity up to 500 Tons.
- Construction/Launch barges available for construction period.
- 80 ft. deep sheltered water assumed close to shore.
- Very deep sheltered water will probably not be available.

Figures 14 thru 20 indicate typical construction procedures for steel platforms assuming the typical facilities outlined above. Obviously each contractor will have minor variations. Those contractors with facilities exceeding those outlined above will use a construction procedure best suited to their particular circumstances.

The construction of Concepts 2 and 4 were considered to be not feasible in any existing shipbuilding facility. Figure 16 shows a construction scheme assuming the existing facilities of Offshore Power Systems, Inc., Florida. Since they do not have any significant steel fabricating capability, most steel fabricating would probably be subcontracted.

- (1) Construct the Complete Spar Horizontally on a Barge. Can be in Graving Dock, Floating Dry Dock, or Outfitting Basin

- (2) Tow Barge Out to Deeper Water

- (3) Barge is Ballasted Until the Spar Floats Off

- (4) Spar is Up-Ended in Deep Water. Final Outfitting is Completed Prior to Deployment. Detachable Heat Exchangers can be Installed Prior to Tow-Out if Advantageous

Figure 14. Typical Steel Construction Procedure for Concepts 1, 5 and 6 (Concept 6 Shown)

Plan View of Graving Dock

- (1) Modules are Built Horizontally on Barges. Can be in Graving Dock, Floating Dry Dock, or Outfitting Basin. Four Modules could be Built Simultaneously

- (3) Completed Spar is Towed to Deeper Water and Barge Ballasted Until the Spar Floats Off

Plan View of Outfitting Basin

- (2) Barges are Floated Out and Aligned Adjacent to Outfitting Dock. Modules are Joined in Horizontal Position

- (4) Spar is Up-Ended in Deep Water. Final Outfitting is Completed Prior to Deployment

Figure 15. Typical Steel Construction Procedure for Concepts 3 and 7

Plan View of
Graving Dock

- (1) Lower Hull is Constructed in Large Graving Dock or in Modular Form on Barges

- (2) Lower Hull is Floated Out. Modules are Added by Derrick Barge. As Draft Increases, Spar Moves to Deeper Water

- (3) After Upper Hull is Complete, Lower Portions will be Attached

- (4) Final Outfitting is Completed Prior to Deployment

Figure 16. Typical Steel Construction Procedure for Concepts 2 and 4

Figure 17. Typical Steel Construction Procedure for Concept 8

Figure 18. Typical Steel Construction Procedure for Concept 9

- (1) Modules are Built in 4 Graving Docks or Dry Docks. Several Separate Contractors would be Required

- (2) Modules would be Floated Out, Aligned and Joined at One Location

- (3) Platform Towed to Deep Water for Final Outfitting before Deployment

Figure 19. Typical Steel Construction Procedure for Concept 10

Figure 20. Typical Steel Construction Procedure for Concept 11

Concepts 2 and 4 could, however, be built in Kaiser Steel's proposed facility on Puget Sound. No date has been established for completion of this facility.

Table VI tabulates the results of the industry capability survey with regard to steel fabrication in existing and modified existing facilities.

TABLE VI

FEASIBILITY OF STEEL PLATFORM CONSTRUCTION IN EXISTING AND MODIFIED EXISTING FACILITIES

POSSIBLE FABRICATORS	OTEC PLATFORM CONCEPT NUMBER										
	1	2	3	4	5	6	7	8	9	10	11
General Dynamic Corp.	E		E		E	E		E	M		
Seatrain Shipbuilding Corp.	E		E		E	E		E			
Bravo Corp.	No Response										
Bethlehem Steel Shipbuilding Corp.	E				E	E		M			
Sun Shipbuilding & Drydock	Acknowledgement Only										
Newport News Shipbuilding	No Response										
Offshore Power Systems	E1	E1	E1		E1	E1		E1	E1	E1	E1
Inga's Shipbuilding Div.	E							M			
Alabama Drydock & Shipbuilding	No Response										
Avondale Shipyards	E				E	E		E	E	E	E
McDermott Fabricators	E				E						
Marine Concrete Structures											
Marathon LeTourneau Offshore	Acknowledgement Only										
Brown & Root, Inc.	No Response										
National Steel & Shipbuilding Corp.	E		E		E	E	E	E	M	M	E
Kaiser Steel Shipbuilding Corp.	E	M	M	M	E	M	M	M	M	M	M
Concrete Technology Corp. (ABAM ENGS)											
Hawaiian Dredging & Construction Corp.											
Misener Marine Construction	No Response										

NOTE:1. This yard does not have facilities for extensive steel fabrication. A subcontractor would be required.

NOTE:2. To be built at a proposed site on Puget Sound

E - Existing facilities

M - Modified Existing facilities

CONSTRUCTION PROCEDURES - CONCRETE

The use of concrete for constructing floating offshore structures is well established. In the past sixty years, many vessels, barges, and bridge portions have been successfully constructed and deployed.

In recent years, very large concrete gravity structures have been built and deployed in the North Sea. The largest floating concrete structures - ships, barges, and bridge sections - built to date in any country, are considerably smaller than the 400 MW OTEC plants.

The technology required to build floating service concrete barges and ships is established in the U.S. but offshore concrete fabricators are not as numerous as steel fabricators.

The methods used to build the present structures have evolved around available building facilities. The water depth at the construction site is of particular significance. The large gravity structures built in Scotland and Norway were constructed mainly by slip forming in sheltered water depths of up to 600 ft. deep. The largest floating structure built in the U.S. (the Arco LNG barge) utilized cast in place and pre-cast assemblies, which were joined by epoxy and post tensioning methods. Maximum water depth required for construction was approximately 40 ft.

The proportions of the larger OTEC platforms are considerably greater than anything previously built in the U.S. However, assuming a slight extension of present technology, and the availability of new construction sites, it is concluded that all of the OTEC concepts considered could be fabricated of concrete in the U.S.

Table VII tabulates the results of the industry capability survey with regard to concrete fabrication in existing and modified existing facilities. The survey results should not be construed as a lack of endorsement of concrete fabricators since the majority of yards contacted specialize in steel fabrication.,

The feasibility of concrete OTEC plant construction and the development of concrete construction methods were developed assuming the existence of a typical construction facility having the following capacity:

- 1 Graving Dock - 1000 Ft. long X 105 ft. wide X 30 ft. water depth.
- 1 Outfitting Basin with 40 ft. water depth.
- 1 Max Crane Capacity in facility =500 Tons.
- Available derrick barge capacity =500 Tons.
- Construction/Launch Barges available for construction period.
- 80 Ft. deep sheltered water assumed close to shore.
- Very deep sheltered water will probably not be available.

The information available is somewhat limited on some of the concepts. For example hull weight, construction draft, and equipment installation weights and program are lacking. The following describes the results of the assessment of each concept with regard to the typical existing facility described above.

TABLE VII

FEASIBILITY OF CONCRETE PLATFORM CONSTRUCTION IN EXISTING AND MODIFIED EXISTING FACILITIES

POSSIBLE FABRICATORS	OTEC PLATFORM CONCEPT NUMBER										
	1	2	3	4	5	6	7	8	9	10	11
General Dynamic Corp.											
Seatrail Shipbuilding Corp.	M		M		M	M		M			
Dravo Corp.	No Response										
Bethlehem Steel Shipbuilding Corp.											
Sun Shipbuilding & Drydock	Acknowledgement Only							M			
Newport News Shipbuilding	No Response										
Offshore Power Systems	E	E	E		E	E		E	E	E	E
Ingalls Shipbuilding Div.											
Alabama Drydock & Shipbuilding	No Response										
Avondale Shipyards											
McDermott Fabricators											
Marine Concrete Structures								E			
Marathon LeTourneau Offshore	Acknowledgement Only										
Brown & Root, Inc.	No Response										
National Steel & Shipbuilding Corp.											
Kaiser Steel Shipbuilding Corp.											
Concrete Technology Corp. (ABAM ENGS)	M1	M1	M1	M1	M1	M1	M1	E	M1	M1	M1
Hawaiian Dredging & Construction Corp.	E	M2	E	M2	E	M2	M2	E	M2	M2	M2
Misener Marine Construction											

NOTE: 1. To be built in proposed offshore site in Puget Sound

NOTE: 2. To be built in deep water sites close to Hawaiian Islands

E. Existing Facilities

M. Modified Existing facilities

Concept 1 (Figures 21 and 22)

This consists of a spar type structure with a diameter of 79 ft, (24 m) and an overall height of 321 ft. (98 m). The structure is developed for an energy output of 10 MW with internal heat exchangers.

Two alternative construction methods have been considered.

- Slipforming in upright position

The lower 12 - 15 m are constructed in drydock by slip-forming and then floated out with a maximum of 8 m draft. The structure is thereafter towed to the sheltered site with 25 m (80 ft) depth where the slipforming is continued as far as possible within acceptable floating stability. Then the structure is towed to a deeper but not sheltered site for completion before towout to final location.

This method offers great advantage in the construction method by slipforming and allows for necessary installation of equipment during the work. However, due to depth limitations, the structure must be completed at a deep-water site which will be further away from the coast and not in a sheltered area. We believe, however, that it should be fairly easy to design for the increased environmental loadings, so that no significant delay in the construction time should be experienced compared to the sheltered area.

- Constructed horizontally on a barge

An alternative method to the slipforming will be to construct the spar structure on a barge in the dry dock with sufficient capacity to float out of the whole structure. (Launch weight is given as 13,500 tons including heat exchangers).

Figure 21. Concept 1- Concrete 10 MW Spar - Internal Heat Exchangers

Alternative a)

1. Construct lower 12-15 m in dry dock and float out at max. draft of 8 m.

2. Anchor the structure in sheltered water of depth 25 m (80'). Construct max. possible within acceptable stability

3. Tow to deeper site in unsheltered area and complete construction work.

Scale 1:100

Figure 22. Concept 1 - Construction Methods

Alternative b)

①

1. Construct the spar horizontally on a barge in dry dock

②

2. Tow out from dock to sufficient depth.

③

3. Ballast the barge to obtain the spar structure self floating

Scale 1:100

Figure 22.(Cont.) Concept 1 - Construction Methods

Alternative b) (continue)

4. Tow the spar to sufficient depth, turn it into vertical position and install necessary equipments and deck.

④

Figure 22.(Cont.) Concept 1 - Construction Methods

The barge will be towed out and immersed so that the spar will be floating by itself. At sufficient draft, the spar structure will be carefully ballasted to turn to an upright (vertical) position.

In this position, installation of the remaining equipment and the deck can take place.

The disadvantage of this method will be the construction procedure of the spar in a horizontal position. Because of the dimensions, it will be costly and difficult to control the geometry of the cylinder. "Out of roundness" has significant importance in the strength of this type of structure.

Concept 2 (Figure 23)

This consists of a spar type structure with an outer diameter of 328 ft (100 m) and height of 377 ft (115 m). The structure is designed for an energy output of 100 MW with internal heat exchangers.

Due to the limitations in the graving dock (150 ft wide), we see no practical construction method for this 328 ft diameter structure. Not even the use of modular construction seems profitable.

Alternatively, this 328-ft wide part could be constructed on a large barge offshore.

Concept 3 (Figures 24 and 25)

This consists of a spar type structure of 146 ft (45 m) diameter and 688 ft (210 m) height. The structure is designed for 100 MW output with internal heat exchangers. Launch weight is estimated to be 110,000 tons.

Figure 23. Concept 2 - Concrete 100 MW Spar - Internal Heat Exchangers (Shallow Spar)

Figure 24. Concept 3 - Concrete 100 MH Spar - Internal Heat Exchangers (Deep Spar)

The spar structure to be divided in three elements of approximately equal weight.

Each element to be constructed on sufficient barge, horizontally in dry dock, max two elements a time.

Elements towed out and launched at sufficient depth to sink barge.

Scale 1:200/1:500

Figure 25 Concept 3 - Construction Methods

④

When all elements completed join together in appropriate way. (App. B)

⑤

Tow the spar structure to sufficient depth or final location

6

Turn the spar in vertical position and install remaining equipments and deck

Figure 25 (Cont.) Concept 3 - Construction Methods

Due to its size, it can only be constructed in a graving dock or on a barge of sufficient dimensions to take either the whole or modular parts of the structure.

Figure 24 indicates a construction method using barges in the graving dock. The construction can be carried out in three elements, each of about 200 ft (60 m) in length and maximum weight of 35-40,000 tons. If barges of this size are available, two elements can be constructed at the same time.

When elements are completed in the dry dock, they should be towed out to sufficient depth for immersion of the barge so that each element can be floated off by itself. Temporary diaphragms will be required at the ends of the elements.

The elements can then be assembled before towout to a deep water site. The structure can be turned to an upright position for installation of the remaining equipment and the deck.

The method is considered extremely unpractical. The huge cylinder of 146 ft (45 m) diameter is to be constructed in a horizontal position with the tolerance requirements for such structures. See remarks for Concept 1.

The procedure for joining the elements, however, should not represent any serious problem and could, for instance, be carried out as follows:

- Have the elements concreted in an appropriate dock or slip. Floatability may be obtained by some temporary bulkhead on the side to be joined. The periphery of the side is to be fitted with a rubber band for temporary tightening during joining operations. An appropriate arrangement of shear - teeth could facilitate the joining operation.

- Launch the elements in the usual way and have them positioned alongside each other.
- Shift the elements into a correct position, loosely pressed together by appropriate capstan systems.
- Ballast the elements to an appropriate immersion.
- Pump out the water between the bulkheads. At appropriate immersion depth, a useful level of prestressing is achieved from the surrounding water.
- Stress tendons across the joint to achieve sufficient strength capacity.
- Deballast to the least possible draft.
- Grout prestressing ducts and remaining chinks between elements.
- If wanted, remove temporary bulkheads.

Concept 4 (Figure 26)

The concept consists of a spar type structure of 440 ft (135 m) diameter and 430 ft overall height. It is designed for an output of 400 MW with internal heat exchangers.

Because of its dimension (diameter of 440 ft), it cannot be constructed as one unit in a 150-ft wide dry dock, and no division of elements which allows for a joining procedure appears practical. Consequently, it is our conclusion that it cannot be constructed within the assumed construction facility. However, a dry dock could be developed to fit

Figure 26. Concept 4 - Concrete 400 MW Spar - Internal Heat Exchangers

this structure. Its shape is actually very favorable for such a procedure, using conventional slipforming construction.

Concept 5 (Figures 27 and 28)

This concept consists of a spar type structure of 66 ft (20 m) diameter with 269 ft (82 m) height. It is designed for an output of 10 MW with external heat exchangers. Launch weight is 6700 tons.

The method of construction will be very similar to that for Concept 1, constructing the spar structure by slipforming. The lower part, allowing for float out at 30 ft water depth, will be constructed in a dry dock. The structure will then be towed out to a deepwater sheltered site, 80-ft depth where it should be completed.

Deck mating may take place at the final position, if the floating stability at the 80-ft depth is not sufficient.

In our opinion, this is the spar structure with the most favorable dimensions to fit the dock specifications given and at the same time allow for efficient construction method.

Concept 6 (Figures 29 and 30)

This concept consists of a spar type structure of 132 ft (40 m) diameter and 460 ft (140 m) height. It is designed for an output of 100 MW with an external heat exchanger

Construction takes place in a vertical position by slipforming. The lower 10-15 m is to be constructed in a dry dock and floated out at a maximum 8 m draft.

The structure will be towed to and anchored in a sheltered deep water site (80 ft) and slipforming continued to a height of about 40 - 45 m depending on the stability.

Figure 27. Concept 5 - Concrete 10 MW Spar - External Heat Exchangers

1. Construct lower part in dry dock

2. Tow out from dry dock at max 8 m draft and anchor the structure at deepwater site 25 m (80 feet).

3. Complete construction work at the sheltered site

Scale 1:100

Figure 28. Concept 5 - Construction Methods

4. Tow to final location and install equipments and deck

4

Figure 28. (Cont.) Concept 5 - Construction Methods

Figure 29. Concept 6 - Concrete 100 MW Spar - External Heat Exchangers

Alternative a)

1. Construct the lower
10-15 m in dry dock

2. Floatout at max. 8 m
draft, internal ballast
may be used.

3. Anchor structure in
sheltered water max. 25 m
(80 feet) and slipform to
about 43 m.

4. Tow to deeper site
90 - 100 m and complete
construction work
(unsheltered).
Tow to final location.

Scale 1:100/1:200

Figure 30. Concept 6 - Construction Methods

Alternative b)

①

1. Construct the spar structure horizontally on sufficient barge in dry dock.

②

2. Tow out barge with completed structure at max. 8 m draft.

③

3. Ballast the barge for launching of the spar structure.

Tow to final location and turn it into vertical position

scale 1:100
1:200

Figure 30. (Cont.) Concept 6 - Construction Methods

Then the structure should be towed to a site with sufficient depth (about 80 m) to finalize construction work. As this site will not be sheltered, allowance for environmental loadings must be made in the design of the structure and its equipment.

The construction of the lower part, completed in the sheltered sites, is a conventional and economic method and should not represent any major problems. Consideration should be given to the support arrangements at the start of slipforming the outer cylinder. This is only a matter of proper detailing.

Another uncertainty is the effect of the environmental loadings on the structure at the unsheltered construction site. A site can be selected so that the weather conditions do not impose too severe loadings during a reasonable construction period. The distance to shore from the deep water site will influence the cost of the project and should be considered at an early stage in the selection of yards.

An alternative construction method, completing the spar structure on a barge in a horizontal position, has been considered. The problem of size of an adequate barge and the great problems in constructing horizontal cylinders of 132 ft (40 m) diameter make this alternative hardly competitive with the more traditional solution mentioned above.

Concept 7 (Figures 31 and 32)

This concept consists of a spar type structure with an outer diameter of 190 ft (58 m) and an overall height of 413 ft (126 m). It is designed for an output of 400 MW with external heat exchangers. The size of the bottom part of the spar structure does not allow for dry dock construction within the assumed facility.

Figure 31. Concept 7 - Concrete 400 MW Spar -External Heat Exchangers

1. Construct the bottom, abt. 10 m, in two parts in the dry dock. Use temporary bulkheads for flexibility.

2. Tow out the two elements and join together by appropriate method (App. B)

3. Alternative:
Construct the bottom part on a sufficient barge adjacent to the ship yard.

4. Construct max possible high by slipforming in sheltered (25 m) water.

5. Tow to deeper water to complete construction before tow to final location

Scale 1:200

Figure 32. Concept 7 - Construction Methods

An element division of the bottom structure in two parts may allow for construction of this structure in the dry dock. After sufficient floating stability of the two halves is obtained, they can be towed out and joined together by a recognized method.

Subsequently the whole structure can be slipformed in the sheltered deep water site (80 ft deep) up to a certain height of acceptable floating stability, before the structure is towed to a deeper site to complete the construction work. A depth of 50-60 meters may be sufficient, but deeper water is preferred if available.

An alternative method would be to construct the bottom part on a barge anchored adjacent to the yard. At an appropriate height, the structure would be launched and a similar construction procedure as presented above could then be adopted.

From the limited details of the bottom part of this concept available, we cannot foresee all technical and economical consequences involved in joining the two halves together by suitable element division, or if the joining procedure is feasible.

By constructing the lower part on a barge, the required size would be 10,000 tons. This should be an easier and cheaper method. If such a barge is available and anchorage outside the graving dock is possible, this method would be preferable.

For the deepwater construction phases, the unsheltered site should be chosen with care. The environmental conditions can be allowed for by appropriate design.

Concept 8 (Figure 33)

This concept is a ship type structure 377 ft (115 m) long x 121 ft (37 m) wide and 89 ft (27 m) deep. It is designed for an output of 10/20 MW with internal heat exchangers.

Figure 33. Concept 8- Concrete 10/20 MW Ship - Internal Heat Exchangers

As this is a ship type structure with dimensions within the size of the graving dock, this concept can be constructed in a conventional way.

A combination of precast elements and inside concrete may be considered. Due to the depth limitation for tow-out, the structure cannot be completely finished in the dry dock. A maximum of 34,000 tons can be floated out.

The remaining work must be finished in the sheltered water site. The amount of work will depend on the details of the structure. Most likely, construction of parts of the deck and the installation of equipments may be postponed until this stage.

Concept 9 (Figures 34 and 35)

This concept consists of a ship type structure 540 ft (165 m) long, 216 ft (66 m) wide, and 100 ft (31 m) high. It is designed for an output of 100 MW with internal heat exchangers.

Since this structure is too big for the given graving dock, modular construction seems the only solution, if not constructed on a barge.

For modular construction, two solutions seem possible:

- Assembly by a longitudinal joint

In this method, the ship is divided into two elements by a longitudinal joint along the ship centerline. The method assumes construction of one element at a time in the dry dock. After completion of the first element, it will be floated out and anchored in a sheltered area until the second element is completed. Then the two elements are assembled in a floating condition and the joint properly prestressed.

Figure 34. Concept 9 - Concrete 100 MW Ship - Internal Heat Exchangers

Alternative a)

1. Construct the hull of two elements with a longitudinal joint. Only one element can be constructed a time.

2. Tow out and anchor each element.

3. When both elements are completed assemble the two elements in an appropriate way.

4. Finalize the construction and necessary equipment installation in sheltered water.

Scale 1:500/1:200

Figure 35. Concept 9 - Construction Methods

Alternative b)

①

②

③

④

⑤

Scale 1:500

1. Construct the hull of four parts in the dry dock at the same time, using transversal joints
2. Tow out all elements at max. 8 m draft.
3. Assemble the elements two by two, 1 and 3, 4 and 2 with an appropriate procedure
4. Assemble the two halves of the structure in a similar way as for 3).
5. Complete construction work and installation of equipments in sheltered water.

Figure 35. (Cont.) Concept 9 - Construction Methods

After removing temporary arrangements, the remaining construction work will be finalized. This may be structural work and/or installation of equipment and machinery.

- Assemble elements by transversal joints

In this method, the ship structure is to be divided in four, almost equal, parts and assembled by transversal joints. Probably all four modular elements can be constructed in the dry dock at the same time.

After the completion in dry dock, all elements are floated out and assembled two by two. Finally, the two parts are joined together.

Remaining construction work will be similar to that mentioned for the first alternative.

We believe construction of the ship on a barge adjacent to the yard is the most economical method, if it is possible.

Both alternatives imply difficult, but feasible, assembly procedures. The first has only one joining operation, but the great length of this joint requires tight tolerances. For the second alternative with transversal joints, three separate assembly operations will be required. Due to a relatively smaller size of these joints, the operation itself should be easier and tolerance requirements will be less strict. This alternative is preferable. Further, this method allows all modular parts to be constructed in the dry dock at the same time.

Concept 10 (Figure 36)

This concept consists of a ship type structure 984 ft (300 m) long, 361 ft (110 m) wide and 180 ft (55 m) high. It is designed for an output of 400 MW with internal heat exchangers.

Figure 36. Concept 10 - Concrete 400 MW Ship - Internal Heat Exchangers

Due to the dimensions of this structure, a feasible solution within the assumed facility should be based on modular construction.

We consider longitudinal joining of the elements by dividing the ship in three modules to be beyond practical considerations.

By use of transversal joints, the ship could be divided into eight (8) equal elements about 38 m wide. Two elements could be constructed in the dry dock at the same time.

The elements could then be towed out, joined together in a recognized way, and anchored until the next two elements were completed. This process would continue until all elements were joined together.

Because of draft problems, we assume that only the bottom part of the hull can be constructed in this way. The remaining walls and deck construction are to be carried out in a deep water site. Although limited information about details of this hull structure is available, the 80 ft (25 m) deep sheltered area should be sufficient to complete this structure.

As stated above, we do not consider this method as very feasible, mainly because of its complexity and time-consuming construction.

If this structure is to be constructed, a more suitable construction site is needed.

Concept 11 (Figures 37 and 38)

This concept consists of a ship type structure 689 ft (210 m) long 190 ft (58 m) wide and 112 ft (34 m) high. It is designed for an output of 400 MW with external heat exchangers.

Figure 37. Concept 11 - Concrete 400 MW Ship - External Heat Exchangers

①

1. Constructing the lower structure in graving dock, without midship elements. (assuming sufficient stability for floatout at max. draft).

②

2. Floatout at sufficient draft and join the midship elements to the hull structure by an appropriate method.

③

3. Move to deep water site and ballast the structure for easiest installation of deck elements.

Elements made ashore and transportation on barge to the structure.

Figure 38. Concept 11 - Construction Methods

The bottom structure could be constructed in the graving dock without the midship elements, which should be constructed separately. The height of the structure to be completed in dry dock will depend on float out stability. Great effort should be made in the design to allow construction to full height. After towout, the elements at midship should be joined to the hull structure before towing to a deep sheltered site for deck construction and equipment installation. The upper deck should preferably be made of precast elements ashore and lifted into position from barges.

A solution for construction of this concept within the given graving dock limitations seems feasible. An important factor governing the cost of this procedure will be the possibility for towout of the entire bottom structure after completion of the walls. Completion of these walls after towout means extra costs. The installation of the deck as precast elements from a floating barge represents a great advantage, so the effort should be made to design the elements of a size suitable for handling. In general, the detail design of this concept will be dependent upon the method of constructing this ship structure.

SECTION VII

SUMMARY AND CONCLUSIONS

Summary

This study provides an evaluation of the feasibility of constructing either steel or concrete OTEC platforms of both spar and ship shape configurations for a range of platform sizes.

This brief study is quite broad in scope. Many parameters, including plant size; vessel type, size, configuration, and dimensions; position of heat exchangers; existing construction facility size, geographic location, and potential for modification; and availability of undeveloped deep water construction sites affect the conclusions drawn. Nevertheless, the conclusions should remain valid and not change significantly, unless there are major changes in either vessel size or U.S. construction capabilities.

Table VIII presents a summary of the feasibility of construction for the three geographic regions.

In Table IX, the various concepts have been ranked in order of their feasibility and practicality of construction in existing or modified existing facilities and new facilities. It is interesting to note that the ranking was identical for either steel or concrete construction.

TABLE VIII
FEASIBILITY OF CONSTRUCTION FOR THREE GEOGRAPHIC REGIONS

CONCEPT DESCRIPTION	CONSTRUCTION MATERIAL	ATLANTIC REGION		GULF REGION		PACIFIC REGION	
		EXISTING FACILITY	MODIFIED FACILITY	EXISTING FACILITY	MODIFIED FACILITY	EXISTING FACILITY	MODIFIED FACILITY
Concept 1 - 10 MW Spar Int. H.X.	STEEL	✓		✓		✓	
	CONCRETE	✓				✓	
Concept 2 - 100 MW Shallow Spar Int. H.X.	STEEL	✓ ₁					✓ ₂
	CONCRETE	✓					✓ _{2,3}
Concept 3 - 100 MW Deep Spar Int. H.X.	STEEL	✓		✓		✓	
	CONCRETE	✓					✓ _{2,3}
Concept 4 - 400 MW Spar Int. H.X.	STEEL						✓
	CONCRETE						✓ _{2,3}
Concept 5 - 10 MW Spar Ext. H.X.	STEEL	✓		✓		✓	
	CONCRETE	✓				✓	✓ ₂
Concept 6 - 100 MW Spar Ext. H.X.	STEEL	✓		✓		✓	
	CONCRETE	✓					✓ _{2,3}
Concept 7 - 400 MW Spar Ext. H.X.	STEEL					✓	✓ ₂
	CONCRETE						✓ _{2,3}
Concept 8 - 10/20 MW Ship Int. H.X.	STEEL	✓		✓		✓	
	CONCRETE	✓		✓		✓	
Concept 9 - 100 MW Ship Int. H.X.	STEEL	✓		✓			✓
	CONCRETE	✓					✓ _{2,3}
Concept 10 - 400 MW Ship Int. H.X.	STEEL	✓		✓			✓
	CONCRETE	✓					✓ _{2,3}
Concept 11 - 400 MW Ship Ext. H.X.	STEEL	✓		✓			✓
	CONCRETE	✓					✓ _{2,3}

NOTE: 1) Assembly only - Steel fabrication will have to be subcontracted.
2) Proposed facility located on Puget Sound.
3) Proposed facility located in Hawaiian Islands.
4) (✓) means the indicated concept is feasible for construction in the indicated facility.

TABLE IX

<u>SPARS</u>		<u>CONSTRUCTION FEASIBILITY</u>	
<u>RANKING</u>	<u>CONCEPT #</u>	<u>Facility Existing or Modified Existing</u>	<u>Facility New Graving Dock or Offshore</u>
1 (best)	5	feasible	feasible
2	1	feasible	feasible
3	6	feasible	feasible
4	7	feasible	feasible
5	3	feasible, barely practical	feasible
6	2	feasible, not practical	feasible
7 (most difficult)	4	not feasible	feasible

SHIPS

<u>RANKING</u>			
1	8	feasible	feasible
2	11	feasible	feasible
3	9	feasible	feasible
4	10	feasible, not practical	feasible

The evaluations made by the fabricators were preliminary and no doubt, with a more detailed study, several construction technique improvements can be developed. In another platform design iteration, there would be an opportunity to configure the platform to fit specific construction parameters.

A conclusion that has evolved through this study is that the commercial (400 MW_e) platforms with external heat exchangers are more practical to build than the concepts with internal heat exchangers because the overall hull dimensions are much smaller.

The only practical way to build the 400 MW spars with internal heat exchangers requires deep sheltered water. This appears available only in the Pacific Coast and Hawaiian Coastal regions.

The most promising approach to building OTEC platforms in existing facilities would be to utilize a modular program. Many fabricators would construct various modules. These modules would then be assembled at a central site with suitable water depths. The completed platform would then be towed out and deployed. With careful scheduling and dimensional control, many OTEC platforms could be constructed economically in a relatively short period of time and without start-up delays.

A detailed study to evaluate the technological and economic feasibility of an industry-wide modular assembly program would complement proposed studies into new facilities requirement, construction feasibility, and commercialization aspects.

Of the three coastal regions studied, the Atlantic Coast is best suited for ship shape construction (limited sheltered deep water). The Pacific Coast (Puget Sound) and Hawaii (Lahaina Roadstead) are most suitable for spar construction (having sheltered deep water). The Gulf Coast is poorly suited for any complete vessel construction, but would be suitable for modular construction and sheltered water assembly areas.

This study has determined the technological feasibility of construction, and to some extent, the practicality of construction. It has not determined the economic feasibility of construction in existing facilities versus new facilities.

Conclusions

The following conclusions are drawn for each concept, first with regard to steel construction and then with regard to concrete construction. Since no response was received from a few large Atlantic coast fabricators, their capabilities have been assessed by Deep Oil and included in these conclusions.

Conclusions - Steel Construction

Concept 1 Steel - 10 MW_e spar with internal heat exchangers

This spar can be constructed in existing facilities in each of the three geographic zones.

Concept 2 Steel - 100 MW_e Shallow Spar with internal heat exchangers

This spar can only practically be built in one existing facility (Offshore Power Systems, Jacksonville, Fl.). Only erection and assembly would be possible. Steel fabrication would probably be subcontracted. One proposed facility to be located on Puget Sound (Kaiser Steel) could construct this concept.

Concept 3 Steel - 100 MW_e Deep Spar with internal heat exchangers

This spar can be constructed in existing facilities in each of the geographic location.

Concept 4 Steel - 400 MW_e Spar with internal heat exchangers

This spar cannot practically be built in any existing facility. One proposed facility, to be located on Puget Sound (Kaiser Steel), could construct this concept.

Concept 5 Steel - 10 MW_e Spar with external heat exchangers

This spar can be constructed in existing facilities in each of the three geographic zones.

Concept 6 Steel - 100 MW_e Spar with external heat exchangers

This spar can be constructed in existing facilities in each of the three geographic zones.

Concept 7 Steel - 400 MW_e Spar with external heat exchangers

This spar can be practically built in only one existing facility (National Steel Corp., CA.) One proposed facility, to be located on Puget Sound (Kaiser Steel), could construct this concept.

Concept 8 Steel - 10/20 MW_e Ship with internal heat exchangers

This ship can be constructed in existing facilities in each of the three geographic zones.

Concept 9 Steel - 100 MW_e Ship with internal heat exchangers

This ship could be built in two existing facilities on the Atlantic and Gulf Coasts. One modified existing facility on the West Coast could also build this ship.

Concept 10 Steel - 400 MW_e with internal heat exchangers

This ship could be built in two existing facilities on the Atlantic and Gulf Coasts. One modified existing facility on the West Coast could also build this ship.

Concept 11 Steel - 400 MW_e Ship with external heat exchangers

This ship can be constructed in existing facilities in each of the three geographic zones.

SUMMARY OF CONCRETE CONCEPTS

Concept 1 Concrete - 10 MW_e Spar with internal heat exchangers

This spar can be constructed in existing facilities on the Atlantic Coast and the Hawaiian Coast. It can also be constructed in one proposed facility on the West Coast.

Concept 2 Concrete - 100 MW_e Shallow Spar with internal heat exchangers

This spar can only be constructed in one existing facility on the Atlantic Coast. It can also be built in two proposed facilities in Hawaii and the West Coast.

Concept 3 Concrete - 100 MW_e Deep Spar with internal heat exchanges

This spar can be built in existing facilities on the Atlantic and the Hawaiian Coasts. It can be built in a proposed new facility in the West Coast.

Concept 4 - 400 MW_e Spar with internal heat exchangers

This spar cannot be built in any existing facility. It could be built in two proposed facilities on the West Coast and Hawaii.

Concept 5 Concrete - 10 MW_e Spar with external heat exchangers

This spar can be built in existing facilities on the Atlantic Coast and the Hawaiian Coast. It can also be built in a proposed facility on the West Coast.

Concept 6 Concrete - 100 MW_e Spar with external heat exchangers

This spar can be built in an existing facility on the Atlantic Coast. It can also be built in proposed facilities on the West Coast and the Hawaiian Coast.

Concept 7 Concrete - 400 MW_e Spar with external heat exchangers

This spar cannot be built in any existing facility. It can be built in two proposed facilities on the West Coast and the Hawaiian Coast.

Concept 8 Concrete - 10/20 MW_e Ship with internal heat exchangers

This ship can be built in existing facilities in each of the three geographic locations.

Concept 9 Concrete - 100 MWe Ship with internal heat exchangers

This ship can only be built in one existing facility on the Atlantic Coast. It can also be built in two proposed facilities on the West Coast and Hawaiian Coast.

Concept 10 Concrete - 400 MWe Ship with internal heat exchangers

This ship can only be built in one existing facility on the Atlantic Coast. It can be built in two proposed facilities on the West Coast and Hawaiian Coast.

Concept 11 Concrete - 400 MWe Ship with external heat exchangers

This ship can only be built in one existing facility on the Atlantic Coast. It can be built in two proposed facilities on the West Coast and Hawaiian Coast.

SECTION VIII RECOMMENDATIONS

The following recommendations are made for further study to lead to definitive construction planning and to increase confidence in constructability:

1. Perform a detailed study evaluating the technical and economic ramifications of an industry wide modular assembly program for a more specific commercial size OTEC platform
2. Perform a detailed study evaluating the technical and economic ramifications of constructing a new construction facility for a more specific commercial size OTEC platform. Include details of the facility required.
3. Compare the results of the above studies in terms of the number of plants required in assumed time frames to determine the most economical approach.
4. Perform a study to determine the best commercial size plant configuration and construction material.
5. Develop a detailed construction plan in cooperation with selected fabricators of the platform and facility selected from the previous studies.

The above list of recommendations is not based on a comprehensive development plan, but does outline some of the major milestones needed in the constructability area leading to the commercialization of OTEC.

Figure 39 Spar Shape Hull Configurations

Figure 40 Ship Shaped Hull Configurations

October 9, 1978

A SUBSIDIARY OF FLUOR CORPORATION
1280 WINDHAM AVENUE
LONG BEACH, CALIFORNIA 90802

Reference: PGH:78-10-1

Deep Oil Technology is working for the Department of Energy on a feasibility study of constructing the various OTEC (Ocean Thermal Energy Conversion) platforms with in the United States.

The enclosed sketches show eleven different configurations being considered by DOE. Platforms of these proportions will be necessary if the OTEC concept is to be commercially exploited.

Part of our task is to:

- 1) Identify those platform configurations that could be constructed in existing facilities. And to outline a general construction procedure
- 2) Identify those platform configurations that could be constructed if existing facilities were enlarged or modified. Outline the modifications and give a general construction procedure
- 3) Identify those platform configurations which would require the building of a new facility. Outline the requirements for that facility and give a general construction procedure

Deep Oil would appreciate your evaluation of the feasibility of constructing each of those configurations in your facility as outlined in task 1 & 2 above.

With the general data provided, it is realized that only conceptual outlines can be developed, one or two paragraphs on each configuration is all that would be required.

Two construction materials are being considered by DOE, they are concrete

or steel. You no doubt have a preference, but may consider one or both materials feasible for your facility.

The platform launch weights are not provided for all configurations. It must be assumed that considerable supplementary buoyancy will be required to launch and outfit some configurations in the typical 20'-0" to 40'-0" water depths available. The internal heat exchanger concepts are particularly heavy. If equipment is available for lifting machinery components weighing up to 2000 tons, then some supplemental buoyancy can be negated.

Any brochures providing information on your company's capabilities would be of interest.

Your response would be appreciated on or before October 23, 1978. Any assistance you provide will be acknowledged in our final report to the DOE.

Please contact me at the above telephone number if you have any questions.

Thanking you in advance.

Yours truly,

Peter G. Harwood

PGH:glg
Enclosures

STEEL SPAR - 10" x 24" x 12"
CONCRETE 2 1/2" x 12"

10 MW SPAR-INTERNAL HEAT EXCHANGERS

CONCEPT 1

STEEL LAUNCH WT & 38500 LT
 CONCRETE 5116000 LT

DEEP 31

1001W SHALLOW SPAR-INTERNAL HEAT EXCHANGERS

CONCEPT 2

10-1-78

STEEL LAUNCH WT X
CONCRETE

100MW DEEP SPAR-INTERNAL HEAT EXCHANGERS

CONCEPT 3

STEEL TOWER LOT 2
 CONCRETE " 3

400 MW SPAR - INTERNAL HEAT EXCHANGERS

CONCEPT 4 -

STEEL LAUNCH WT. ~	4 100 LT
CONCRETE	6 700 LT

10 MW SPAR-EXTERNAL HEAT EXCHANGERS

CONCEPT 5

STEEL LAUNCH WT $\approx$ 21,800 LT

CONCRETE LAUNCH WT $\approx$ 27,200 LT

100 MW SPAR-EXTERNAL HEAT EXCHANGERS

CONCEPT 6 -

STEEL SPAR - NOT 2
CONCRETE

400 Mw SPAR - EXTERNAL HEAT EXCHANGERS
CONCEPT 7

Steel Lined LT $\approx$ 31500 LT
 Concrete " " $\approx$ 50000 LT

10/20 Mw SHIP-INTERNAL HEAT EXCHANGERS
CONCEPT 8

DEEP OIL

10-1-78

STEEL WEIGHT WT. 83,000 LT

CONCRETE " " 2104,300 LT

100 MW SHIP-INTERNAL HEAT EXCHANGERS

CONCEPT 9

SHELL LAYOUT FOR
 CONCEPT 10

400 MW SHIP-INTERNAL HEAT EXCHANGERS
CONCEPT 10

STEEL LAUNCH WT	~	55000	LT
CONCRETE	"	~	77000 LT (46'-0" DIAFT)

400 MW SHIP-EXTERNAL HEAT EXCHANGERS

CONCEPT II

Seatrain Shipbuilding Corp.

Brooklyn Navy Yard
Building 292
Brooklyn, N.Y. 11205

RECEIVED

OCT 16 1978

D. O. J. ENGINEERING

(169)

October 12, 1978

Deep Oil Technology, Inc.
1280 Windham Avenue
Long Beach, California 90802

Dear Mr. Harwood:

In response to your canvass letter regarding OTEC:

- 1) Our facility could construct concepts #1, 3, 5, 6, 8, provided that they can be built with the central axis in the horizontal and later righted in deep water. Our draft limitations are 35 MLW and we have a height restriction due to the Brooklyn Bridge.

We would be most comfortable with steel construction however, concrete is not beyond our capability.

Our crane capacity would be limited to 400 ton lifts with two cranes.

Very truly yours,

N. T. Haller
Vice President Engineering
and Planning

NTH:vs

GENERAL DYNAMICS

Quincy Shipbuilding Division

97 East Howard Street, Quincy, Massachusetts 02169

October 23, 1978

100-22178-1
001-27-1
001-27-1
207

Mr. Peter G. Harwood
Deep Oil Technology, Inc.
1280 Windham Avenue
Long Beach, California 90802

Dear Mr. Harwood:

With reference to your letter of October 2, 1978, I am pleased to note the results of our review of the material you enclosed.

Our planning department made a cursory review of the adaptability of the various configurations as they would impact our present yard.

Their comments are as follows:

"Of the spar configurations indicated in the attachment to Deep Oil Technology, Inc., letter of 2 October 1978, Concepts 1,3,5 and 6 would appear adaptable for construction at Quincy in existing facilities. In all cases, we assume that supplementary bouyancy would be required to launch and maintain trim control during the tow to the installation site. In each case, the spars would be constructed with the axis horizontal in an existing building basin.

The spars outlined in concepts 2,4 & 7 exceed the limits of existing basin size and the opening at the Fore River Bridge.

The 10/20 MW ship, concept 8, is suitable for construction in conventional fashion in any of the yard's building basins. The other ships, concepts 9, 10 & 11 exceed the capacity of existing basins and the opening of the Fore River Bridge."

Not
Rec'd

I have enclosed a brochure illustrating our facility to give you pictorial reference of our yard.

I hope this material will be of assistance to you.

Sincerely,

Philip L. Ross
Director of Marketing

Telecon: Mr. Danielson Bethlehem Steel

10/18/78

Graving Dock 1200 X 200 Available water 20'-0⁰

Not Concrete

<u>Concept #</u>		<u>COMMENTS</u>
1	YES	
2	NO	(Draft @ Launch and Overall Size)
3	NO	(Draft @ Launch and Overall Size)
4	NO	(Draft @ Launch and Overall Size)
5	YES	
6	YES	
7	NO	(Draft @ Launch)
8	YES	(with buoyancy)
9	NO	(Draft @ Launch and Overall Size)
10	NO	(Draft @ Launch and Overall Size)
11	NO	(Draft @ Launch and Overall Size)

Offshore Power Systems

2000 Highway Express Way
Box 3500 Jacksonville, Florida 32211

191
Hillside House XXXXXX
Enterprise

October 19, 1978

Deep Oil Technology, Inc.
1280 Windham Avenue
Long Beach, CA 90802

Attention: Mr. Peter G. Harwood

Dear Mr. Harwood:

Offshore Power Systems is pleased to comment on the feasibility of constructing the subject OTEC platforms in our planned Manufacturing Facility.

From the data provided, it appears that ten (10) of the eleven (11) concepts using steel, concrete or a composite thereof could be built in our planned facility. It should be understood however that the configuration and the development of the OPS Manufacturing Facility is geared for the manufacturing needs of Floating Nuclear Power Plants (FNPs), and as such would be limited to some degree in construction of a variety of hulls.

Our current planning calls for an FNP keel laying capability by June 1982 and a slipway position by December 1983 in support of FNP manufacturing needs.

Enclosed is a summary of the planned waterside capability at our Blount Island Facility and the comments on the various concepts you submitted. We would also like to call to your attention that should the Spars (concept 1 thru 6) be constructed of steel, a major subcontract would be required for formed plates and shapes since we have no planned capability in this respect.

Page 2
October 18, 1978
Mr. Peter G. Harwood

Offshore Power Systems hopes this information will assist in the execution of your task.

Sincerely,

A. M. Vetere
Contracts Administration

Enclosure

cc: D. P. Maniago
J. L. Norman
J. R. Pope
D. T. VanLiere

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OFFSHORE POWER SYSTEMS MANUFACTURING FACILITY
BLOUNT ISLAND - JACKSONVILLE, FLORIDA
WATER SIDE CAPABILITIES

GRAVING DOCK

- A. Dimensions (clear) - 415' wide x 505' long
- B. Vertical clearance at entrance (-) 21.1' MSL (-20.0 M.L.W.)
- C. Floor elevation - (-) 25.1' M.S.L.
- D. Design floor loading - 3000 psf uniform and 300 tons per keel block for blocks on 10' centers in any 100' x 100' area located more than 75' from any wall

OUTFITTING SLIPWAY

- A. Dimensions (clear) - 415' wide x 924' long
- B. Slipway channel depth (-) 41.5' M.S.L. (-40.4' M.L.W.)
- C. Platform elevation - +9.2' M.S.L.
- D. Design platform live loading - 1500 psf uniform

900 MT GANTRY CRANE

- A. Track gauge - 675'
- B. Lifting height (above rail) - 300'
- C. Lifting height (below rail) - 30'
- D. Rail elevation - +9.375' M.S.L.
- E. Lifting capacity -
 - 1. Total capacity - 900 MT
 - 2. Upper trolley (2 hooks @ 300 MT each) - 600 MT
 - 3. Lower trolley - 300 MHT
- F. Travel distance (stop-to-stop) - 3143' (total coverage, Slipway, Graving Dock and Assembly Platens)

WHIRLER CRANES (Main hook only)

- A. Boom radius -
 - 1. Maximum radius - 268'
 - 2. Minimum radius - 100'
- B. Lifting height above rail -
 - 1. Maximum radius - 215'
 - 2. Minimum radius - 385'
- C. Lifting height below rail - 30'
- D. Rail elevation - +9.375' M.S.L.
- E. Lifting capacity
 - 1. Maximum radius - 55 tons
 - 2. Minimum radius - 125 tons
- F. Travel distance (stop-to-stop) - 1444' (total coverage of Slipway & Graving Dock)

GENERAL MARITIME DATA

- A. Tidal ranges at Blount Island
 - 1. Mean high water - +2.2' M.S.L.
 - 2. Mean low water - (-) 1.1' M.S.L.
 - 3. Mean tidal range - 3.3'
- B. St. John's River - Blount Island to Atlantic Ocean
 - 1. Channel distance - 7.1 nautical miles
 - 2. Channel project depth - (-) 38.0' M.L.W.
 - 3. Channel width - 500' to 1050'

Concept 1

Could be built in OPS facility of either steel or concrete. Vessel would be constructed in the dock in horizontal position. Draft of concrete design (13,500 L.T.) would be approximately 36 feet.

Concept 2

Could possibly be built in OPS facility in the vertical position by leaving off bottom portion below the 328' dia. cylinder until the vessel is towed to deep water. Steel would probably be the more desirable material for performing underwater construction. More information is needed relative to hull arrangement and weight distribution to determine maximum construction in dock without exceeding floor load capacity or structural loadings. The draft for the given steel launch weight would be approximately 36 feet; hence, the vessel could be towed from Blount Island to the deep water at its launch weight.

Concept 3

Vessel is too long for construction as a single unit in the graving dock. Dock size would dictate that the vessel be launched in two sections and joined together in the slipway. Vessel would most likely be constructed in horizontal position and towed to operating site before up-righting. Maximum displacement at which vessel could be towed from Blount Island to open ocean without supplementary buoyancy is approximately 45,000 L. tons.

Concept 4

This configuration would have to be altered slightly by having two straight sides opposite each other not exceeding 410 feet width. The sides would appear as chords on a circle looking in plan view and would be oriented parallel to dock sides. The maximum displacement at which this vessel could be towed to open ocean at 36 feet draft is approximately 85,000 L tons.

Concept 5

This configuration is very similar to Concept 1 and could easily be constructed in the OPS facility in the horizontal position. No problems with towing in horizontal position.

Concept 6

This configuration could be built in graving dock in horizontal position and launched at approximately 12000 tons. This vessel could be towed to open ocean at a maximum displacement of about 30,000 L tons.

Concept 7

No comment.

Concept 8

This configuration could be constructed in OPS facility. Maximum displacement for towing to open ocean would be approximately 46,000 L tons.

Concept 9

This configuration would be altered to limit the length to about 510 feet by eliminating the triangular portion at the aft end. The vessel could then be

built in one section in the graving dock. Maximum displacement for towing to open ocean would be approximately 75,000 L tons.

Concept 10

This concept would dictate construction in the graving dock in two sections and assembled in the slipway. Maximum displacement for towing to open ocean would be approximately 330,000 L tons.

Concept 11

Could be constructed in dock in two sections and put together in slipway.

INGALLS SHIPBUILDING

PO Box 100 Palmdale, Missouri 63467

4319

18 October 1978

RECEIVED

OCT 19 1978

C. J. [unclear]

190

Mr. Peter G. Harwood
Deep Oil Technology
1280 Windham Avenue
Long Beach, CA 90802

Reference: Your letter PGH:78-10-1

Dear Mr. Harwood,

We have examined the package which you sent to us October 2, 1978, regarding the feasibility of constructing various OTEC units and platforms. The following is our response to the various concepts presented in the package.

Concept 1:

Ingalls could construct this unit with present facilities, assuming it would float horizontally at less than 35 foot draft, and that it could be towed horizontally to its final location, and be ballasted to a vertical position.

Concept 2:

Ingalls cannot construct this unit, due to its excessive draft and launch weight.

Concept 3:

Same as Concept 1, but less likely to float at less than 35 feet draft without excessive temporary buoyancy.

Concept 4:

Same as Concept 2, except launch weight unknown.

Concept 5:

Same as Concept 2.

Concept 6:

Same as Concept 2, except launch weight acceptable.

Page 2

Concept 7:

Same as Concept 2 except launch weight unknown.

Concept 8:

Could construct if modify facility for excess weight.

Concept 9:

Same as Concept 2.

Concept 10:

Same as Concept 2 except launch weight unknown.

Concept 11:

Same as Concept 2.

If we can be of any further service to you in this study please do not hesitate to call on us.

Sincerely,

INGALLS SHIPBUILDING DIVISION
LITTON SYSTEMS, INC.

R. R. Roper
Director
Business Development

RRR:lm

AVONDALE SHIPYARDS, INC.
A SUBSIDIARY OF OGDEN CORPORATION

P. O. BOX 50280 NEW ORLEANS, LA. 70150 • PHONE. 436-2121 • AREA CODE 504
WESTERN UNION TELEX:
ENGINEERING AVONENG NLN 58-245
PURCHASING AVONPUR NLN 58-246

October 20, 1978

RECEIVED

OCT 23 1978

189

Mr. Peter G. Harwood
Deep Oil Technology, Inc.
1280 Windham Avenue
Long Beach, California 90802

Subject: DOE Feasibility Study OTEC Platforms

Dear Mr. Harwood:

In response to your letter dated October 2, 1978, reference PGH:78-10-1, concerning eleven OTEC configurations, we are pleased to offer the following remarks:

Avondale is interested in the OTEC concepts which involve steel construction, as we have not been involved in reinforced concrete structures to date. The nature of our yards and the flexibility of our thinking may permit the construction of additional configurations once the structural arrangement has been defined, as the governing criteria is size of launch sections, ability to erect large weights at considerable heights, and obstructions to passage from our yards to the Gulf. Naturally, larger jobs will permit larger investments in facilities, making more configurations possible.

The two fixed obstructions which govern our construction are the Huey Long Bridge, which limits the size of units at the main yard, and the Greater New Orleans Bridge, governing our Westwego yard. The Huey Long Bridge is 153 feet above mean Gulf level of the river and 750 feet between piers. The river in mid-channel is 80 to 90 feet deep. The Greater New Orleans Bridge is 168 feet above mean Gulf level of the river and in 80 to 90 feet of depth of water.

Not Rec'd
Enclosed is a plan of our main yard, but for the purposes of OTEC, the width restrictions are not applicable, as the structure would span the center crane tracks and new, larger cranes would be required on the river and levee side of the combined building area. Our Westwego yard could utilize an area about 260 feet wide by 800 feet long. It is possible that the larger lower sections could be built in the main yard and floated to the Westwego yard, where the smaller upper sections would be fabricated and erected.

Mr. Peter G. Harwood
Deep Oil Technology, Inc.

Page 2
October 20, 1978

Our ability to build the eleven configurations based upon the fixed obstructions and present facilities is as follows:

Concepts 8, 9, and 11, which from appearances are basically ship shaped, can be built in our present facility and launched in a normal manner.

Concepts 1, 3, 5, and 6 would appear to be feasible to construct in our present facilities assuming they could be built on their side, put on a specially designed launch and transport barge, and uprighted into the water once it was on site. An engineering feasibility study would have to be done before a definite conclusion could be reached. More data on the structure, including centers of gravity and ability to ballast, would be needed.

Concepts 2, 4 and 7 could only be handled as several fabricated pieces to be assembled elsewhere, since the diameters of the cylindrical segment would not fit under the bridge. In the case of concept 4, it appears the height of the large diameter segment (250 - 300 feet) is also beyond our limit. We would expect the weights of the individual segments to also be prohibitive with current equipment.

Concept 10, which is a ship configuration with a 361-foot beam, is beyond the capability of our facilities as a single unit. We would expect that this is true of all U. S. yards. One possible approach could be to build it in two 180-foot wide sections and join the halves after launching by either cofferdamming the joint or underwater welding. This technique was used when we built our launching dock. Once again, detailed analysis would be required before a definite answer could be given.

If possible, we would appreciate receiving a copy of your study report. Thank you for thinking of Avondale.

Yours very truly,

AVONDALE SHIPYARDS, INC.

James M. Temenak
Marine Marketing Manager

JMT/le

Enclosures

McDERMOTT STRUCTURAL GROUP

McDERMOTT FABRICATORS DIVISION
McDERMOTT OFFSHORE DIVISIONMcDERMOTT WESTERN DIVISION
McDERMOTT BAYOU BLACK DIVISION

POST OFFICE BOX 188, MORGAN CITY, LOUISIANA 70380

October 20, 1978

RECEIVED

OCT 26 1978

D. C. T. ENGINEERING

193

Deep Oil Technology, Inc.
1280 Windham Avenue
Long Beach, California 90802

Attention: Mr. Peter G. Harwood

Re: OTEC
Feasibility Study

Gentlemen:

We have evaluated the information contained in your transmittal to us of October 9, 1978 regarding OTEC platform concepts. Needless to say, all concepts presented are beyond our normal type of fabrication, but some certainly have our interest. We would limit our consideration to steel construction only.

Unfortunately for us, as regards the type of structure being considered, our accessibility to deep water is quite limited. Present channel depths between our facility and deep water is limited to 15 feet with the possibility that a channel will be provided in the next few years having dimensions of 400 feet in width and 20 feet in depth. The channel is a Corps of Engineers project and is awaiting resolution of legal problems and funding.

As can be seen, the majority of the concepts would require much deeper drafts than we anticipate being available, or as an alternative, maximum supplementary buoyancy.

If launching from a cargo barge is a viable alternate, we presently have in our fleet a cargo barge that could probably handle Concepts 1 & 5, the weights of the other concepts being above our barge capacity.

Our expertise is in welded steel platforms for offshore oil development which includes forming and welding various grades of steel in a variety of configurations. Our fabrication is done on land on skidways and then skidded onto cargo barges for transport. We assume this same approach could be adapted to the fabrication of at least Concepts 1 & 5. The sheer size and weights of the other concepts indicate, that as a practical matter, although we feel we can fabricate them, are not viable concepts at our present facilities.

Deep Oil Technology, Inc.
Attention: Mr. Peter G. Harwood
October 20, 1978
Page 2

We are enclosing a brochure showing some of McDermott's world wide capabilities for your information and use.

It is hoped that this information may be of some benefit to you in your study.

Very truly yours,

McDERMOTT FABRICATORS
A Division of
J. Ray McDermott & Co., Inc.

C. W. Dyerson, Jr.
Division Manager

CWD:sca
Enclosure

Marine Concrete Structures, Inc.

2030 St. Charles Avenue, New Orleans, Louisiana 70130
"INGENUITY IN CONCRETE"

Donald Payne, P.E.
Frank L. Anastasio, Jr., P.E.
James M. McKinnis, Jr., P.E.

October 10, 1978

RECEIVED

OCT 13 1978

D. O. I. ENGINEERING

165

Deep Oil Technology
1280 Windham Avenue
Long Beach, California 90802

ATTENTION: Mr. Peter G. Harwood

Gentlemen:

This will acknowledge receipt of your letter dated October 2, 1978 in which you forwarded sketches of various schemes for constructing OTEC platforms and requested that we comment on same.

I must say that the magnitude of these structures is way beyond our capabilities with the exception of the 10/20 Mw Ship, Concept 8, which we could build at our present facility with only a slight modification; however, the detailing of the structure would have to be such that it could be built in vertical stages, as the draft capabilities at our existing facility is 12 feet and our second outfitting area has draft capabilities of 30 feet.

The remaining structures are of such large sizes that I would have to decline on commenting on the feasibility of their being constructed elsewhere in existing facilities. I am sure, however, with considerable money they could be built. I am sorry that we cannot be more responsive to your request.

Yours truly,

MARINE CONCRETE STRUCTURES, INC.

Donald Payne
President

DP/cjm

MARATHON LeTOURNEAU OFFSHORE COMPANY

KENNETH J. FARMER
President

RECEIVED

OCT 12 1978

OCT 12 1978

166

October 10, 1978

Mr. Peter G. Harwood
Deep Oil Technology, Inc.
1280 Windham Avenue
Long Beach, California 90802

Dear Mr. Harwood:

This acknowledges receipt of your letter of October 2, 1978 which we have forwarded to Mr. Robert E. Bradbury, Jr., president of Marathon Marine Engineering Company, for reply.

As related to you in our telephone conversation, I am sure that some of these units are beyond our practical capability; however, Mr. Bradbury will inform you further in this matter.

Yours truly,

cc: Mr. Robert E. Bradbury, Jr.

NATIONAL STEEL AND SHIPBUILDING COMPANY

RECEIVED

OCT 30 1978

D. O. T. 500-2000

210

October 26, 1978

Mr. Peter G. Harwood
Deep Oil Technology, Inc.
1280 Windham Avenue
Long Beach, CA 90802

Dear Mr. Howard:

With regard to your request to evaluate the feasibility of constructing various configurations of OTEC platforms in our facility at NASSCO we would offer the following analysis.

- Platform Configurations that could be built in our facility as it now exists.

Concept #	Ways # That will Physically Accommodate the Related Concept
1	1, 2, 3, 4
3	1
5	1, 2, 3, 4
6	1
7	1
8	1
11	1

- There may be some limitations to the above which are unknown at this time.
- For example if there are excessive draft requirements then we may have problems with launching off our Ways 2, 3 and 4 and with floating out of our dry dock Ways #1. To some extent this could be overcome by use of floatation tanks.
- Our current capability to roll plates is limited to about 2" thickness. If shell thicknesses exceed this then other alternatives are: (a) to subcontract the rolling of plates, (b) buy plates already rolled from the mills and (c) upgrade the facility with heavier rolls.
- Outfitting at our piers could be a problem due to lack of water depth. Our maximum is about 28 feet. If outfitting required deeper water than this then we would be involved in dredging with attendant problems of environmental considerations and permits etc.

NATIONAL STEEL AND SHIPBUILDING COMPANY

Mr. Peter G. Harwood
Deep Oil Technology, Inc.
October 26, 1978
Page 2

- ° Crane capacity currently at NASSCO enables us to handle lifts upto about 200 S. Tons depending on configuration and outreach. Some concepts could possibly be built in sections within our crane handling capability but without detail of structure and potential weights involved for outfitting it is not possible to predict if 200 Ton capability would be enough. It is suspected that we would need to upgrade capacity significantly in both the ways and outfitting piers to efficiently accommodate heavy lifts.
- ° Methodology for construction would probably be very similar to that currently employed for large 196,000 DWT Tankers. Steel structure would be subassembled on the platen and erected either on the ways or building dock. Outfitting within these structural units would be maximized to the greatest extent possible consistent with capacity of cranes. Launching would be accomplished similar to ships off the sloping Ways #'s 2, 3 and 4 utilizing launching cradles and greased sliding ways. In the Dock (Ways #1) the total steel structure would be floated out by flooding the dock. Outfitting, final topside painting, etc. would be accomplished at an outfitting pier.
- ° Concepts #2, 4, 9, and 10 would require major facility changes or the construction of a new facility. The economics of course would depend on the number of units that would eventually be considered but would potentially be a graving or floating dock of physical dimensions large enough to handle the individual configurations. Large capacity cranes would also be considered to efficiently handle very heavy lifts potentially between 1000 and 2000 Tons.
- ° Finally we would prefer to consider the steel construction alternative as we have no experience with concrete and have no current plans to get into the field of marine hulls of concrete design.

We appreciate the opportunity to comment on the feasibility of the various configurations under consideration and although we have had to be very general in our comments due to lack of detail design information, hope that you will find the information provided to be of use.

NATIONAL STEEL AND SHIPBUILDING COMPANY

Mr. Peter G. Harwood
Deep Oil Technology, Inc.
October 26, 1978
Page 3

The general configuration and physical size of the projects under consideration do indicate that a shipyard facility would be suitable for the purpose and the techniques and trade skills involved would be similar to those employed in the shipbuilding industry.

Enclosed for your information is a copy of our NASSCO Brochure and if we can be of any further help please do not hesitate to contact us.

Yours very truly,

A handwritten signature in dark ink, appearing to read "John Lightbody", is written over a faint, circular stamp or seal.

JOHN LIGHTBODY
Director
Operations Planning

JL:er

CC: J. Murphy

Enclosures

BUILDING POSITIONS

BUILDING POSITION

DIMENSIONS

MAX. SHIP SIZE

NO.	TYPE	L	W	D	LOA	BEAM	DWT
1	BUILDING DOCK	1000	176	-16MLLW	980	170	200,000
2	INCLINED WAYS	675	95-7	-	690	90	40,000
3	INCLINED WAYS	906	115-1	-	900	106	90,000
4	INCLINED WAYS	905	115-1	-	900	106	90,000

U S NAVAL STATION

SAN DIEGO BAY

U S NAVAL STATION

CHOLLAS CREEK

VICINITY MAP

NATIONAL STEEL & SHIPBUILDING CO.
SAN DIEGO, CALIFORNIA

NASSCO - PLOT PLAN

DESIGNED BY: _____
CHECKED BY: _____
DATE: _____
DRAWING NO: _____
SCALE: 1" = 100'

(F)

KAISER STEEL CORPORATION
GENERAL OFFICES • KAISER CENTER
300 LAKESIDE DRIVE • P. O. BOX 58 • OAKLAND, CALIFORNIA 94601

October 18, 1978

RECEIVED

OCT 19 1978

D. O. T. ENGINEERING

183

Mr. P. G. Harwood
DEEP OIL TECHNOLOGY, INC.
1280 Windham Avenue
Long Beach, CA 90802

Dear Mr. Harwood:

In response to your letter, dated October 2, 1978, requesting our evaluation of the feasibility of constructing the various concepts of OTEC platforms in our facilities, we are pleased to submit our comments for your consideration. These comments are predicated on using steel as the construction material and the availability of an existing dry dock or the construction of a new dry dock. The construction of a new dry dock would take place on one of our optioned properties in the Pacific Northwest, as indicated in the attached brochure of our facilities.

Concepts #1 and #5 - (100 Mw Spar)

These concepts can be constructed at our existing facilities with very little modification necessary. These structures could be constructed in our Yard and loaded onto a barge by skidding; then the barge could be towed to the site where the structure is launched in deep water, similar to the method used to construct offshore oil drilling and production platforms. Also, construction could be accomplished in a dry dock by providing supplemental buoyancy to float the structure in a horizontal attitude and towing it to the site where the structure would be upended by selective ballasting.

Concepts #2 and #7 - (100 Mw Spar)

These concepts would be very difficult to construct. The construction would require a new dry dock facility and supplemental buoyancy in order to tow the structures to the site.

Concepts #3 and #6 - (100 Mw Spar)

These concepts would require a new dry dock for their construction. Supplemental buoyancy would be required to float the structure in a horizontal attitude and tow it to the site where the structure would be upended by selective ballasting. The construction of these concepts could be accomplished with much less difficulty than concepts #2 and #7.

Mr. P. G. Harwood
October 18, 1978
Page Two

Concept #4 - (400 Mw Spar)

This concept would require a new dry dock to construct. The construction would have to be in two stages. The first stage would be to construct the lower portion of the structure in the dry dock to a level that could be floated out of the dry dock and towed to deep water. The second stage would be to complete the construction off shore. This concept would be very difficult and expensive to construct.

Concepts #8, #9, #10 and #11 - (10/20, 100 and 400 Mw Ship)

These concepts would require a new dry dock facility for their construction. The construction would be very similar to shipyard construction.

We hope these brief comments will be of value to you; and, if you have any questions on the above, please do not hesitate to contact us. Thank you for your interest in Kaiser Steel.

Sincerely,

KAISER STEEL CORPORATION

H. V. Norgren
Manager, Offshore Contracting

HVN/js

RECEIVED

OCT 16 1978

DATE STAMP

170

13 October 1978

Deep Oil Technology
1280 Windham Avenue
Long Beach, California 90802

Attn: Mr. Peter G. Harwood

Gentlemen:

This letter is in response to your letter of October 2 (Reference: PGH: 78-10-1) requesting comments on feasibility of constructing OTEC platforms. A similar request was made to Concrete Technology Corporation, and this letter constitutes a reply on the behalf of both firms.

First, I might comment on the relationship between Concrete Technology Corporation (CTC) and ABAM Engineers, Inc. The two firms were both founded by the Anderson brothers in 1951. CTC is a prestressed concrete manufacturing firm, and ABAM is a consulting engineering firm. The two firms are now quite separate, and function independently of one another. (In fact, the bulk of the work of each firm does not involve the other firm.) Nevertheless, the "blood-relationship" enables the two firms to function together effectively when the need arises, such as on design/build work. Perhaps our most notable project of this type is the 65,000-ton floating LPG plant illustrated in the enclosed brochure material.

The evaluation of construction feasibility involves both the evaluation of available facilities, and engineering ingenuity in adapting a construction procedure to fit the facilities. A description of the available facilities follows.

Puget Sound is itself an important resource for the construction of large floating structures. The protected deep water sites available here are unique in the forty-eight states. Water depths are from 500 to 700 feet. CTC has applied for a permit for an offshore construction site in approximately 450 feet of water. This site is in Commencement Bay, two miles by water from the existing CTC facility. Structures drawing 400 feet of water could be constructed at this site. It should be noted, however, that deballasting to a depth of approximately 175 feet would be necessary for moving a vessel out of Puget Sound and into the open ocean.

The Concrete Technology plant is located on Blair Waterway, which is a 40-foot deep dredged channel connecting to Puget Sound. The 25 acre site is illustrated in the enclosed brochure material. A drydock is located on the site. The drydock is 500 feet long by 160 feet wide by 13 feet water depth. The drydock can be deepened to around 18 feet by installing tiebacks in the walls, and it may also be lengthened. The width is fixed, as anything constructed at the plant must pass a draw-bridge with a 150-foot wide clearance.

Other facilities exist in the area with the capability of making and installing the OTEC machinery and outfitting.

I believe that all of the eleven concepts can be constructed using the existing CTC facility and/or the proposed offshore construction site. The requirement for a maximum delivery draft of 175 feet would probably require concepts 1, 3, 5 and 6 to be turned on their side during delivery. Concepts 2, 4 and 7 would require deballasting to 175-foot draft. This may be a problem for concept 7.

None of the concepts can be constructed in their entirety in the drydock. However, two proven techniques may be used to construct a vessel larger than the drydock dimensions. First, the hull may be launched when constructed to a partial height, and completed by additional construction while afloat. This technique was used on the ARCO LPG facility (see enclosures) and was also used on the concrete structures used for North Sea oil drilling. Second, the hull may be constructed in sections and the sections post-tensioned together while afloat. This technique was used on three major floating bridges in the Puget Sound region, and also on two floating ferry terminals recently completed in British Columbia. By combining these two techniques, a vessel of almost any size may be constructed.

Concepts 1, 3, 5 and 6 are similar, although of varying size. It is common practice to fabricate small steel spar buoys on their side. However, this is difficult for a large concrete buoy, as the draft would be excessive even when the vessel is on its side. It would probably be better to construct a concrete spar in the vertical position at the deep water site. This would be done by joining work barges together to form a U-shaped work platform. A "starter section" of the spar buoy would be built in the drydock, and towed to the offshore site. Construction would continue at this site, with the spar being ballasted to maintain stability, and to keep the work area as close to the deck of the work barge as is feasible.

Concepts 2, 4 and 7 would require construction of the lower part of the main disc in the drydock, in at least three sections. These sections would then be post-tensioned together while afloat, and construction of the upper parts would be done at the offshore site.

Mr. Peter G. Harwood

Page 3

13 October 1978

Concept 8 would not require use of the offshore site. The lower portion of the hull would be constructed in the drydock, and the upper portion constructed at an outfitting dock alongside the drydock.

Concepts 9, 10 and 11 would be constructed in a manner similar to concept 8, with two additional considerations. The lower portion would be constructed in sections, and post-tensioned together while afloat. The draft requirement may well cause the completion of the upper part of the hull to be done at the offshore site, rather than the Blair Waterway.

I hope the above comments are of some help to you. We are enthusiastic about the OTEC program, and we would like to work with you in developing these concepts.

Very truly yours,

ABAM Engineers, Inc.

A handwritten signature in dark ink, appearing to read "Robert F. Mast", with a stylized flourish at the end.

Robert F. Mast
President

RFM:dmb

Encs.

Hawaiian Dredging & Construction Company

RECEIVED

GOVERNMENT

D. O. T. E. 192

October 19, 1978

Deep Oil Technology, Inc.
1280 Windham Avenue
Long Beach, California 90802

Re: Feasibility Study - Construction of OTEC Platforms

Gentlemen:

Thank you for your invitation to participate in your study of alternate configurations for platforms for Ocean Thermal Energy Conversion plants. We have been following the OTEC program closely for the last several years, as we are confident that the waters off Hawaii are the ideal location for OTEC. While there are many reasons, the prominent factors are the lack of hurricane weather in this area and the existence of an extensive academic-political infrastructure.

The first point that should be addressed is that OTEC platforms to be used in Hawaii should be built in Hawaiian waters. After it is demonstrated that construction costs in the Hawaiian Islands are no greater than at any mainland U.S. locations, it follows that the great expenses of towing large vessels from the mainland to Hawaii will swing the economics in favor of Hawaiian-based construction.

Concrete is the material of choice for the construction of OTEC platforms in Hawaii. There are two major Portland cement manufacturers now active on the Island of Oahu (Cyprus and Kaiser). The limestone which is the major ingredient of Portland cement is of course abundant in these islands. Steel reinforcing bars are manufactured in Honolulu. Lightweight aggregates for the manufacture of low-unit weight concrete are a naturally occurring resource in Hawaii.

Deep Oil Technology, Inc.

October 19, 1978

Page two

In the last year large quantities of Portland Cement and light-weight aggregate have been shipped from Hawaii to the West Coast due to shortages of these materials on the U.S. Mainland. Arraying these facts against the necessity to import structural steel shapes and plates leads to the clear choice of concrete.

As a corollary, the building boom experienced by Hawaii's construction industry over the last few decades, with its emphasis on concrete construction in the latest techniques of conventional pre-casting, pre-stressing and post-tensioning have produced quality control practices and technological experience that are as advanced as any in the world.

Dillingham has been studying the OTEC hull for several years and has participated in various projects which have contributed valuable experience. A few years ago, a small concrete pontoon was constructed under contract to the United States Navy. While this job was a regular commercial contract it was carried out as an in-house demonstration of the methodology necessary to construct concrete barges and other hulls. The concrete pontoon was constructed on a side-launching way constructed especially for this purpose. Construction was in the usual horizontal manner, and then the barge was transferred to the sloping launchways, and successfully side-launched. On a small scale this project demonstrated Dillingham's capabilities in this area.

As part of this project Dillingham identified a launching area and constructed its side-launching facility in that area. This facility is located at Barber's Point on Oahu, in the sheltered waters of the Barber's Point barge harbor. During the last quarter of 1978, the U.S. Army Corps of Engineers is scheduled to begin a major expansion and deepening of the Barber's Point harbor. While the harbor expansion will provide opportunities for re-location and expansion of our launching facility, the original launching facility will be undisturbed by the construction and is still available for use.

Hawaiian Dredging & Construction Company

Deep Oil Technology, Inc.
October 19, 1978
Page three

Honolulu is the home for one of the preeminent structural engineers active in the design of concrete hulls, in the person of Mr. Alfred A. Yee. A fleet of Yee-designed pre-stressed concrete barges has been in operation for more than a decade in the Philippines. Dillingham has worked extensively with the Yee organization, most recently on a team formed by Global Marine Development, Inc. for a proposed LNG storage barge.

With the exceptions of the large U.S. Navy drydocks located in Pearl Harbor, there are not graving docks suitable for OTEC platform construction in Hawaiian waters. Depending on the area selected, construction of a new graving dock could be expected to be problematical. Excavation would be either in basalt or in coral. Both types of rock would require blasting for excavation. Some degree of difficulty could be expected in sealing off the porosity in the fractured basalt and the voids in the limestone formation. Construction of a major new dry dock would certainly arouse environmental concerns. For these reasons, I believe that the side-launching concept has decisive advantages. It should be noted that in Hawaii, where the tidal range is typically 2'-0", the side launching ways do not have to extend below the MLLW datum. Therefore, the construction of these launchways is an entirely shore-related project which does not come under the jurisdiction of the Corps of Engineers for environmental permits.

For concrete platforms which exceed 150' in width, which is the present practical width limit for side launching, the recommended method of construction would be launching in segments followed by joining of the segments while afloat in sheltered water. Dillingham has carried out similar projects for the construction for Ferry Terminals in Vancouver, British Columbia. Internal void spaces such as cold water sumps should be temporarily sealed during the launching phase, in order to take advantage of the available buoyancy.

Deep Oil Technology, Inc.
October 19, 1978
page four

The commercial OTEC hull shapes will all require partial construction on launchways, followed by launching, towing to deeper waters, and completion of construction while afloat. This follows from the great weights and heights involved.

As part of previous concrete hull studies, I have briefly looked at several potential construction sites in the islands. Further work would be necessary to satisfactorily designate these areas, but a brief review illustrates the potential.

1. Barber's Point Barge Harbor: project depth 18':
This is the area of existing side-launch facility. Well sheltered waters.
2. Barber's Point Deepdraft Harbor: project depth 35':
This area will also be well-sheltered. The shoreline and general area are undeveloped. An excellent area for construction of side-launchways or a graving dock.
3. Pearl Harbor, Oahu: certain areas in this harbor may exceed 40' in depth. Subject to national security and Navy requirements, these well-sheltered waters would be ideal for the initial stages of platform construction.
4. Honolulu Harbor, Inland Waters: waters inside a line drawn between Diamondhead and Barber's Point on the Island of Oahu are considered by the U.S. Coast Guard to be part of the inland waters of the port of Honolulu. These waters are semi-sheltered from the prevailing trade winds by the island mass. Water depths range up to 1000' within 2.5 miles of shore.
5. Lahaina Roadstead: These open waters, relatively sheltered between the coastlines of the Islands of Maui, Lanai and Molokai, have been used as an anchorage since the time of whaling ships. The depths run to a few hundred feet.

Hawaiian Dredging & Construction Company

Deep Oil Technology, Inc.
October 19, 1978
page five

6. Kona Coast, Island of Hawaii: waters to the west of the Kailua-Kona area of the "Big Island" of Hawaii, including the Ke'ahole area, have unusually calm sea conditions due to the sheltering affect of the high extinct volcanos on these islands. These waters reach great depths: for example, 3000' water occurs 1.5 miles offshore Ke'ahole Point.

It should be pointed out that OTEC platforms, especially for the Hawaiian Islands, will not be expected to be towed an appreciable distance in the oceans. Therefore, these hulls do not need conventional ship-shape hull characteristics, such as pointed bows or rounded contours. - In fact, important economies can be expected in concrete hull construction if curved surfcaes are kept to a minimum, and doubly curved surfaces are entirely avoided. There are, of course, special cases, such as the advantages of arch-type construction, and the best course is to retain a concrete construction contractor on the design team, concurrently with other designers, consultants and major vendors.

The United States Coast Guard is currently reviewing proposals from industry. These were solicited by the Coast Guard some months ago, for the purpose of writing official Coast Guard specifications for the construction and inspection of concrete vessels. Work under this proposal would also include preparation of training materials for Coast Guard inspectors. Dillingham is a member of a team headed by Global Marine Development, Inc. in this proposal effort.

Heavy lift equipment presently available in Hawaii is typified by the Manitowoc Ringer, with capacity of three hundred tons. For construction and outfitting of an OTEC platform, laying alongside a wharf, it is expected that a relatively simple derrick would be constructed at the job site in order to handle the unusually heavy machinery components.

Hawaiian Dredging & Construction Company

Deep Oil Technology, Inc.

October 19, 1978

page six

In closing, it should be noted that sufficient experience has been gained in the design and construction of concrete vessels to allow a reasonable degree of confidence in the application of parametric pricing to concrete hull concepts. This means that at a relatively low level of funding, conceptual designs can be carried to a point where budget estimates can be prepared with a degree of confidence that has not previously been available.

I would like to close by pointing out our firm belief that construction of a major concrete hull structure for an OTEC platform is a project that is well within the state-of-the-art, and is a project which could commence tomorrow, if required by the OTEC program. In short, we are ready!

Very truly yours,

Frank McHale, P.E.
Energy Projects

cc: W. L. Jones
S. Osada
W. Kawano

Enclosures

FAM:pp

FIGURE 6-1