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MR&S Report No. 5142-6

MASTER MASTER

FINAL REPORT
OTEC PLATFORM CONFIGURATION AND INTEGRATION
VOLUME III
"PROJECT PLAN"

by

M. ROSENBLATT & SON, Inc.
350 Broadway
New York, New York 10013

DISCLAIMER

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FINAL REPORT
OTEC PLATFORM CONFIGURATION AND INTEGRATION
VOLUME III
"PROJECT PLAN"

Prepared For

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Division of Solar Energy
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TABLE OF CONTENTS

Page No.

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIXES

SECTION 1.0
INTRODUCTION

Volume III of the subject report presents the "Project Plan" for the development and integration of a demonstration platform. This volume concerns itself with Task 7 of the subject contract which specifies the development of a plan to construct and deploy a platform which will demonstrate economic viability to utility users of the commercial system while recognizing facility constraints and costs. This is done for the spar and sphere platforms as envisioned in Task 5 concept design.

In the course of this study the following subcontractors supplied input for the development plan:

- Burns and Roe, Inc.
- Waller & Associates, Inc.

The following areas were considered in the development of the project plan:

- Selection of plant size
- Deployment of major components and their integration
- Testing of power plant and support services
- Operating scenario
- Development schedule and major milestones
- Itemized cost estimates and schedules

SECTION 2.0
DETERMINATION OF DEMONSTRATION PLANT SIZE

2.1 Evolution of Plant Sizes

In the course of the OTEC systems development, the power plant size has been increasing by steps. The first two platforms are test platforms of 1 MWe and 5 MWe output. The test platforms are followed by a pilot plant of 10 to 20 MWe output. The last platform size considered in the OTEC system development program is the 400 MWe commercial plant. The demonstration plant is intended to fill the gap between pilot plant and commercial plant development. After consideration of contact made with utility companies and the design of the commercial plant, MR&S has concluded that a 100 MWe plant size should be considered for the demonstration plant.

2.2 Utility Company Inputs

Two utility companies, Florida Power Corporation of St. Petersburg, Florida, and Puerto Rico Water Resource Authority of San Juan, Puerto Rico, were telephone interviewed. Based on the responses received from these utility companies and Burns & Roe's general familiarity with utility industries, the following recommendations were developed. All three companies suggest that the demonstration plant size should be no smaller than 10 MWe and further, it would be desirable to have a demonstration plant equipped with commercial size modules with adequate redundancy so that a meaningful power system evaluation could be conducted. In other words, reliability and economics of an OTEC power system must be demonstrated to gain acceptance as well as support from the utility industries.

2.3 Rationale for Selected Size

The internal arrangement of the spar and sphere platform must also be considered since the internal well or trunk in these platforms forces the selection of multiple power modules symmetrically arranged about the centerline. This was a consideration in choosing 100 MWe for the plant size since two 50 MWe modules could be installed which would permit testing of equipment recommended for use on the commercial plant. If testing of smaller units such as 25 MWe or 12.5 MWe equipment is preferred, this could be done on a 100 MWe platform and symmetry of arrangement maintained. Use of 25 MWe power modules may be desired in order to maximize volume utilization of the sphere and spar platforms.

SECTION 3.0
PRELIMINARY DEVELOPMENT PLAN

3.1 Construction of the Demonstration Plant Site

3.1.1 General

This section is applicable to the Spar and Sphere platforms.

The main hull is assumed to be constructed of reinforced concrete throughout, including bulkheads and decks, which subdivide the hull and are designed to be non-tight. Four vertical bulkheads divide the platform into 4 separate quadrants, each of which will accomodate a 25 MW net output OTEC module.

The cold water pipe is supported along the length of the cold water well for the Sphere. The pipe is attached to the base of the Spar's cold water intake section. It is assumed to be constructed of fiberglass reinforced plastic throughout its length.

It is further assumed that all preliminary design and all principal detailed engineering of the vessel are complete prior to the start of construction. This includes design of all internal components and machinery as well as the basic hull structure. Exact size, weight, shape, supports and services must be known for all heat transfer equipment, pumps, electrical generation, mooring systems, hull outfit, control and monitoring, access, ventilation and accommodations.

It is of course particularly important to designate exact placement and size of major and minor penetrations through internal and external concrete structures prior to construction of the hull. Precast concrete and non-concrete components should be manufactured and made ready for installation if they are to be imbedded or shrouded within the concrete structure.

The overall development plan for construction of the demonstration plant must, like any other large construction project, fully integrate all aspects of the construction process by scheduling time related construction phases with material and equipment manufacture and delivery and supply of support equipment and labor. Planning and scheduling of the project may be carried out by standard critical path techniques and should consider the following major steps:

1. Onshore construction site.
2. Offshore construction sites.
3. Overall construction time.
4. Major equipment design, detail, manufacture and delivery.
5. Hull structure design and engineering detail.
6. Material testing and construction procedures.
7. Hull construction support equipment and structures.

Phase 1

8. Onshore construction site preparation.
9. Supply of hull materials and fittings.
10. Supply of hull outfit materials and fittings.
11. Partial construction of platform on shore.

Phase II

12. Launching and towing of semi-completed hull.
13. Offshore construction site preparation and temporary mooring and support equipment.
14. Complete construction of main hull.*

Phase III

15. Towing to operational site and deployment of permanent mooring.
16. Cold water pipe installation
17. Superstructure construction and platform completion.
18. Installation of electrical transmission line.
19. Initial start-up and test.
20. Operation

*Step 14 is applicable to Sphere only.

Since all of the major construction work will be completed in the open, adjacent to or in the ocean, weather must be accounted for in the overall construction plan. Consideration should not only be given to rain and wind, but also to the probability that the construction period will span at least two hurricane seasons in the Gulf of Mexico. Maximum use of weather "windows" should be planned, and weather related delays should be considered in critical path analyses.

The operational location of the OTEC Demonstration Plant is assumed to be offshore from the Florida coast south of Tampa. The onshore construction site is expected to be within proximity of the Pensacola Bay area.

The site should preferably be along a sheltered river, channel or bay having direct, unobstructed access to the sea. While it would be extremely advantageous to locate the site within close proximity to deep water, it will prove impossible to do so along this coastline. The 10 fathom line is normally at least one mile from the coast and all ports, harbors, anchorages, etc., in the area do not exceed 35 to 40 feet. Construction on the land based site is thus limited to floating out the hull in this water depth. An artificial island, built out into the ocean along this coastline in a manner similar to some other large concrete construction projects should be considered.

The possibility of dredging channels deeper to facilitate movement of a larger structure may be investigated with respect to cost and economic advantage, but the time to file environmental impact statements and receive all necessary permits must be considered. Time to acquire U.S. Corps of Engineers and other permits for excavating the construction site and sheet piling the dam should be considered during site evaluation and planning.

Evaluation of sites should be carried out with the following aspects in mind that will directly effect the cost and efficiency of the entire construction project:

1. Proximity to sea and deep water.
2. Unobstructed route to the deep water site.
3. Area sufficient to construct demonstration plant and possible expansion for construction of commercial plants.
4. Soil or bed rock sufficient to support high static loads.
5. Area to be in close proximity to relatively large population center and skilled labor market.

6. Area to be served by good roads, rail and water transportation.
7. Adequate utility supply, especially power and fresh water.
8. Easy passage of permit applications through local and federal agencies.
9. Support of local authorities and labor unions, if any.

The construction site shall be planned, with room for future expansion, to cover all phases of the construction process and support functions. The following structures, equipment, machinery and services will be necessary to complete the land based phase of the project:

1. Facility boundaries marked, fenced and secured.
2. General administration buildings for management staff, engineering, purchasing, material and quality control and personnel.
3. Electrical, water, telephone and compressed air supply.
4. Sewage and waste disposal.
5. Equipment, machinery and material warehousing.
6. Consolidation of ground in working areas and access roads to support heavy tracked vehicles.
7. Bulkheading of waterfront barge berths, offloading equipment and dam enclosure.
8. Excavation of actual construction area and consolidation of ground.
9. Pumping facilities to maintain a dry area and drainage.
10. Steel fabrication shop and necessary equipment.
11. Machine shop.
12. Hull outfit shops and support equipment.
13. Heavy lift tower cranes.
14. Heavy lift, mobile, crawler cranes.
15. Concrete manufacturing plant.
16. Pre-tensioning and post-tensioning equipment, if required.
17. Sub-assembly manufacturing area and equipment.
18. Supports, forms, towers, scaffolding, etc. for hull construction.
19. General transportation facilities.
20. Barge mooring facilities for cement and aggregates storage.

It is assumed that the onshore construction area will be self supporting with respect to erecting the concrete hull and all concrete components. Additionally, large steel structures will be fabricated at the site or a nearby shipyard along with steel piping systems, intermediate decks, stairways, foundations, bulkheads, etc. The construction site shall thus be supplied with bulk materials by either road, rail, or barge. Due to the large quantities of cement, sand and gravel needed for the project it is assumed that much of it would be delivered by barge.

The offshore operational site in the Gulf of Mexico, or the Atlantic Ocean if the southeast Florida coast is chosen, will not be protected from storm or hurricane. Thus, selection of the Phase II construction site will primarily be based on distance from the land construction site, bottom conditions and the probability of occurrence of winter and summer storms.

While the following proposed construction method outlines specific methods of reinforced concrete hull formation, the possibility of utilizing other methods and systems should not be overlooked when developing cost, quality and construction time estimates. Such methods may include, but should not be limited to the following:

- Conventional cast-in-place construction
- Precasting of components for later assembly, and advanced joining techniques
- Cast-in-place forming of the vertical bulkheads, the cylindrical surfaces, and spherical components of Sphere
- Ground forming of the spherical surfaces
- Composite steel-concrete construction methods

Each of the systems has merit in the construction of the hull to a greater or lesser degree. Their application, however, should be studied with respect to all parts of the hull structure for best cost effectiveness.

Since the hull size is substantially smaller than the projected commercial plant size, the possibility of constructing the vessel of steel was presented. However, it is already determined that the full size hull shall be constructed principally of reinforced concrete and thus, to fully demonstrate the feasibility of both construction technique and operation, concrete was chosen for the demonstration plant.

The construction of large concrete structures for offshore use is of course not new and the technology for forming massive structures on land and moving them to sea for completion has become almost commonplace for the construction of large offshore platforms for the North Sea. The application of this technology to construct a demonstration OTEC plant is thus considered fundamental, offering no new thresholds of expertise except perhaps in the forming of the Sphere's compound curvature hull.

3.1.2 Sphere Platform

a. General

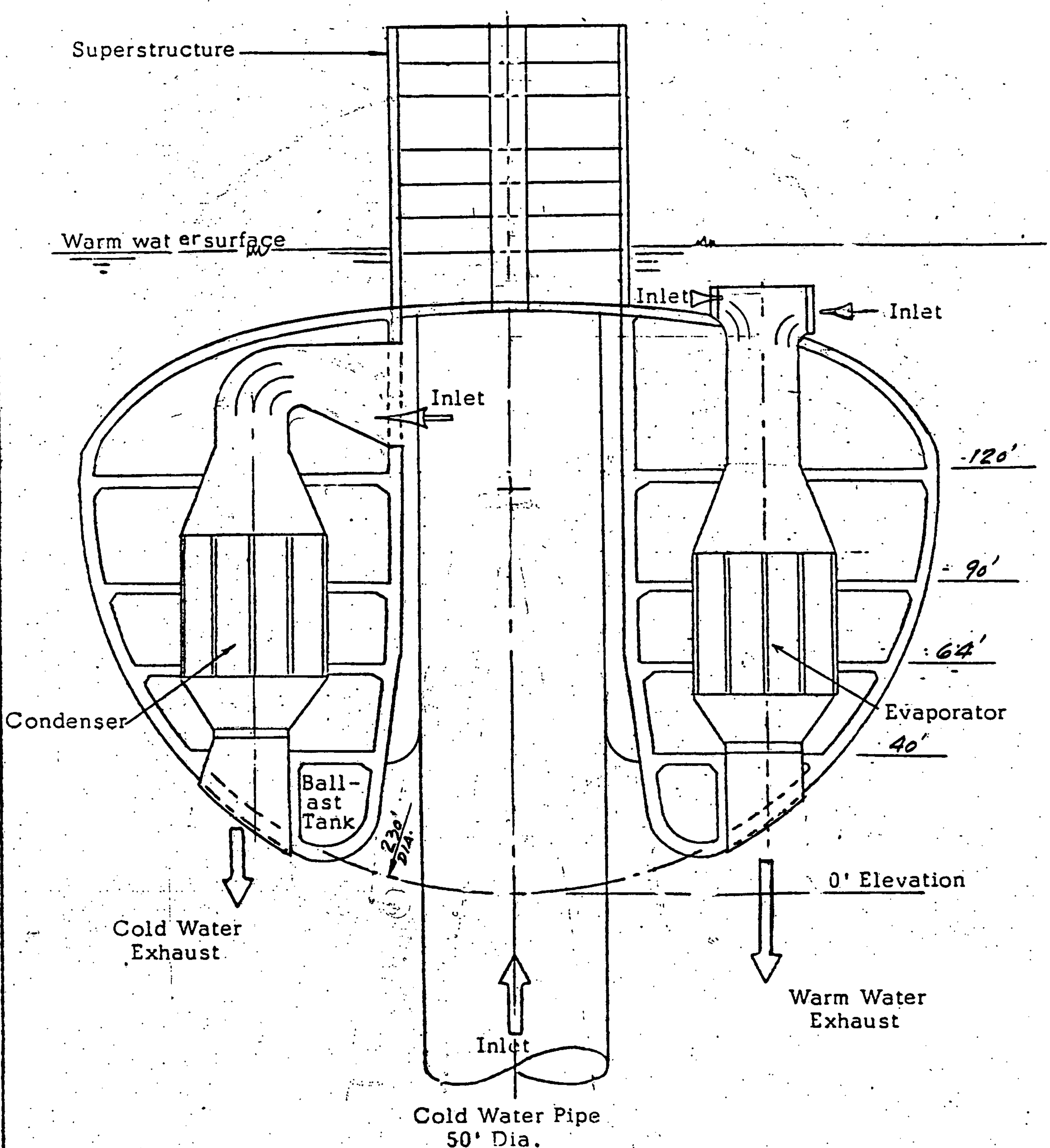
The general layout of the Sphere OTEC demonstration plant is shown in Figure No. I. The vessel is semi-spherical in shape with the entire main hull submerged in the operational condition. A cylindrical superstructure extends 75 ft. above the ocean surface to provide stability to the unit and to house the accommodation areas and test and data collecting facilities.

The proposed method of hull construction assumes, as previously suggested, that the vessel will be constructed in three separate stages at three different sites.

Phase I will be performed at the onshore site to the point of completion where the hull can be safely floated out to the Phase II offshore construction site, and with sufficient freeboard for Phase II construction.

Phase II will be carried out at an offshore site, such as 25 nautical miles off the mouth of Pensacola Bay in about 150 ft. of water, where the remaining hull structure and all outfit will be completed except for the superstructure and the cold water pipe.

Inboard View of Demonstration Platform - 230' Diameter Sphere



Note: Pumps and other equipment not shown for clarity

FIG. No. 1
Scale 1:40

100 MWe Demonstration Platform-Sphere

25 MW POWER MODULE

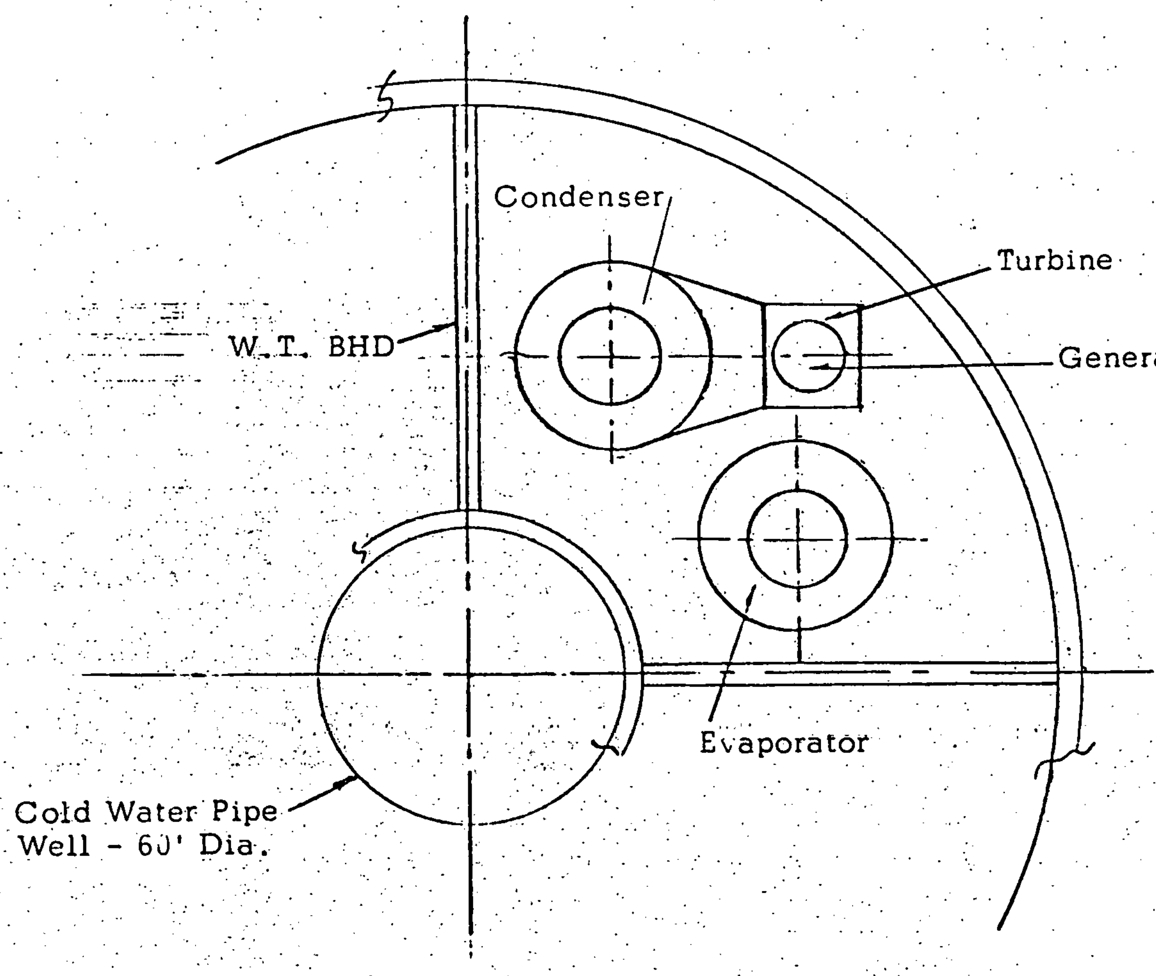


FIG NO. 2

Phase III will take place at the operational site where the cold water pipe will be installed, the permanent mooring system placed, the superstructure constructed and outfitted, and the electrical transmission line laid to shore.

The supply of large, heavy machinery and steam generation components to the site could possibly pose a major problem depending upon their location of manufacture and method of transportation. It is unlikely for instance, that the evaporators and condensers would be transported as a completed unit over the road or by rail. Water borne transportation would be the only method of moving them to the site in completed form, which assumes that the manufacturing plant is adjacent to water and suitable docks. There is a possibility that heat exchanger components will be transported to the site and erected on the ground or in place. Approximate weights of major power generation components are given below:

Major Component Weights - 25 MW Plant*

Vertical shell and tube heat exchanger (dry)	714 L.T.
Turbo generator	134 L.T.
Demister	268 L.T.
Intake Screen	155 L.T.
Seawater pump	300 L.T.

*Weights are approximate, they are also applicable to the Spar.

The Phase II offshore construction site will be chosen in close proximity to the land based site for completion of the main hull structure and final outfit. Since the demonstration plant is relatively small (compared to the 400 MWe Sphere) with comparatively light draft, a single construction site with sufficient water depth for the fully constructed and outfitted hull weight should be chosen. A water depth of 150 feet should suffice for the completed 100 MW hull which floats at about 140 foot draft without the cold water pipe, based on the weight breakdown in Appendix A. A site about 25 nautical miles off the mouth of Pensacola Bay has a 25 fathom depth of water.

Once the platform is complete except for installation of the cold water pipe and superstructure, the hull will be towed to the operational site, permanently moored in position, the cold water pipe will be installed along with the electrical transmission cable and the superstructure will be completed.

b. Phase I Construction

The following construction procedure for the lower hull assumes that the site is fully prepared and ready to begin construction of the demonstration plant. The excavated assembly site is prepared to a depth somewhat lower than the projected float-out draft of the hull and the site bed is consolidated. Depending on soil conditions, it may be necessary to sink piling in way of main support areas and footings to insure adequate support of the hull structure. The procedural steps presented here represent one method of construction through the entire building process. There are other methods and other approaches which may or may not prove feasible and desirable for this application. An in-depth analysis of all possible methods is thus suggested prior to settling on any given one.

1. Drive sheet steel piling forming an enclosure about 430 ft. in diameter.

2. Prepare a concrete annular footing to support the sphere at its base during Phase I construction. Design footing to support total load of hull, machinery and construction equipment.

3. Prepare a concrete footing at the center of the cold water pipe intake to bear the load of a concrete or steel plug, crane tower and the crane's maximum load.

4. On top of the concrete support, item 3, ground form the lower plug to be used to support the crane tower during phases 2 and 3. Pour the concrete plug in one piece or set the prefabricated steel plug in place.

5. Erect a heavy, high capacity self-erecting building crane of the horizontal counterweighted boom type on top of the plug. The crane shall be fitted with a lower turntable to support two form struts and an upper turntable to attach the form strut elevating lines.

6. On top of the concrete annular footing, item 2 above, ground form the lower hull shape in way of the outer hull and cold water pipe connection up to at least the lower deck at the 40 ft. W.L. Install 4 precast concrete condenser and 4 evaporation discharge pipes with temporary W.T. plugs in lower ends. Precast water discharge pipes and bell mouths should be fitted for each of the four power module quadrants even though only one power module may be installed at the outset. It is likely that it may prove impossible to retrofit these discharge tubes at a later date. Utilize internal movable form covering a 22° - 30' segment of bottom hull and pour two opposite units simultaniously. Continue pours at alternate segments to allow for cooling and shrinkage until complete. The hull should not be directly connected to the previously constructed lower plug in order to permit later removal of the plug.

7. Erect reusable sectional forms for vertical bulkheads and pour. Repeat until all lower bulkheads, watertight and non-watertight, are complete below the 40 ft. deck.

8. Lay lower deck in segments utilizing heavy duty, pre-stressed, pre-cast concrete forms and flat form the upper surface.

9. From the lower deck level, erect jump forms and construct the tapering cylindrical wall of the cold water pipe intake well to the point where it intersects with the constant cylindrical shape.

10. Construct the exterior and interior spherical surface forms for forming the outer hull. Interior and exterior forms shall be attached to an upper framework by either pins or hinges so that they can be simply lowered over and removed from the outer shell. The lower ends of the forms shall include a frame for attachment to an-

chors at the upper face of the previously poured hull structure. The entire form shall thus be carried out using these forms, two at a time, simultaneously on opposite sides of the vessel. The form struts may be rotated through 360° such that alternate segments may be poured until the next level is complete.

11. Install main foundations for evaporator and condenser units and other heavy or bulky machinery, equipment, trunks, valves and piping materials that will not pass through access openings in the 64 ft. deck. Make all necessary connections and make watertight.

12. Erect bulkhead forms and pour radial watertight bulkheads through the 64 ft. deck level. Erect 64 ft. deck level supports in the form of precast pillars or, if used, install precast concrete outer jackets for the heat exchangers.

13. Lay 64 ft. deck similarly to method outlined in Item 7 leaving openings for heat exchangers, piping systems, trunks and access.

It is estimated that with the lower plug in place and assuming a 35 to 40 ft. water depth, the buoyancy of the platform will not allow construction of the hull to advance much beyond the 64 ft. level. The platform must therefore be floated out at about this point of completion.

At this stage the external hull and center well are constructed as high as possible, with careful control of weight being added to the vessel. It may be advantageous for cost reasons to maximize the amount of concrete construction at the onshore site, thus the inclusion of the center well plug for float out buoyancy. Trade-offs should be made of the minimizing of heavy equipment installed to reduce machinery weight vs. maximizing concrete hull weight poured in Phase I.

The partial installation of heavy machinery items at the shore site, principally the vertical heat exchangers, is desirable and appears feasible from the weight calculations. Completed heat exchanger weight, in excess of 700 tons each, would require the use of several mobile heavy lift cranes or the installation of a special heavy lift derrick. Alternate methods of skidding completed units onto the vessel or installing units in smaller components are suggested whether accomplished in Phase I or II. The stability of the structure at the float-out stage should be investigated and the use of floatation barges made up to the structure during tow-out should be considered.

The possibility of increasing the structural hull weight completed onshore with the use of float-out barges is worthy of evaluation. Space within the excavated area could be allocated for the positioning of two large oceangoing deck, or bulk liquid barges, on either side of the vessel to increase net float-out buoyancy. There are already in existence specialty vessels designed for sinking and lifting heavy marine structures which may also be used, or conventional barges could be modified to be ballasted and subsequently deballasted to support a considerable load. A net advantage of some 20,000 tons of extra hull structural material could be formed on land by using this method. Additionally, the use of barges would lend stability to the partially completed hull, reduce the tendency to roll and possibly eliminate the need to completely dismantle the central tower crane and offer directional stability for the tow to the offshore site.

Assuming that the latter method proves both technically and economically sound, the combined units should be floated from the onshore construction site as follows:

1. Remove majority of material used to ground form lower hull section. Support hull with wood or steel "bilge blocks".

2. Tie lower plug into center cold water well with substantial welded structures and seal cavity with epoxy to insure watertight enclosure.

3. Attach lower permanent mooring connections to hull and install chain leads topside hull for later attachment to Phase II mooring system.

4. Tie off hull to land mooring connections to hold in place during flooding operations.

5. Through previously installed dewatering system flood excavated basin to level of adjacent water system. Remove earthen dam and supporting sheet piling. At this point, the entire excavated basin is flooded and open to the adjacent channel, river or waterway. The structure floats at the predetermined draft ready to be towed out to sea.

6. With the float-out barge method the hull remains in position still situated on the pre-formed annular ring. Move barges into the construction area and attach to the concrete hull either by mooring attachments, cable lift or structural cantilever to barge main deck. Flood supporting barges to pre-determined draft and tighten up on connection system. Deballast supporting barges and raise platform structure from excavated floor.

7. Once platform structure is raised from floor, connect towing tugs and move to the Phase II offshore construction site.

c. Phase II Construction

The partially completed hull is towed to the offshore site where temporary mooring anchors and pendant buoys have been preset. The hull is positioned by tugs and mooring lines are attached to the pre-connected chains. Each of the attendant barges is ballasted, detached from the hull and removed unless required to stabilize the platform. A stability and motion response analysis should be made for the platform in this condition and all subsequent conditions during construction to determine the stability characteristics and the possible advantage of ballasting and/or utilizing barges to improve stability and motions while under construction.

Support vessels and equipment will be needed to continue construction as soon as the vessel is moored. Portable diesel power generation will be required on board or on an adjacent floating platform to supply electrical power for lighting, ventilation, electric drive mixers, pumps, cranes and hoists. Engine-driven equipment may also be used. One or more barges supporting complete concrete mixing plants, with tanks for fresh water will be moored next to the hull, possibly with supply barges for aggregates and cement laying alongside. Care must be exercised to protect the materials from being sprayed or wet by salt water.

The platform, barges and plant will be supplied with men and materials by a supply vessel, tugs and barges. It is assumed that construction offshore would continue on a 24 hour per day basis using a 12 hour shift system. Men may be ferried to the vessel by crew boat or helicopter, if a temporary helicopter platform is provided, depending upon distance from shore. The loss of time used to ferry workers to and from the vessel by crew boat may be more costly than using helicopter which may prove a viable alternative.

The Phase II construction procedure should then be carried out as follows:

1. Using the tower crane and form supporting struts, continue to form outside shell up to the 120 ft. level. Simultaneously slip-form the internal cold water well and radial watertight bulkheads. Install pre-cast pillars and supports between decks and construct, using pre-cast forms, the 90 ft. deck level.

2. At the point where the external and internal watertight shells are far enough advanced to install major equipment, mobilize a heavy lift derrick barge. Lift heat exchangers or components from supply barge and lower into position. Additionally, lift and place turbo-generator, demisters, etc.

3. Install all other equipment, piping, machinery, fittings, trunks, etc. that must be placed below the 120 ft. deck level. Erect concrete or steel piping to heat exchangers. Install major electric power cables and machinery.

4. Form and construct deck level at 120 feet.

5. Dismantle form struts on tower crane.

6. Erect forms below main arched deck and ring system. Install pre-cast warm water inlet trunks at all four quadrants and pour deck. Complete slip-forming of central well up to the deck.

7. Remove tower crane from platform.

8. Remove support barges and equipment from around platform. Cut attachments of plug to cold water pipe well and ballast plug so that it's free to fall. Pump water into cold water pipe well until sufficient head is applied to force plug out. Salvage plug if necessary. Remove temporary condenser and evaporator discharge plugs. Prepare platform for tow.

At this point the platform is fully fitted out with the exception of the cold water pipe and the superstructure. The necessity to install intermediate decks within the well after installation of the cold water pipe should be investigated for the demonstration plant. Testing and instrumentation of the cold water pipe would indicate that the well should remain accessible, especially to permit inspection of the CWP supports.

d. Phase III Construction

The platform, floating at approximately 135' draft, is towed to the operational site and moored to preset anchors and chain. The moored platform will then float at about 140 draft with 10' freeboard. Floatation barges are now attached to raise the platform out of the water so that it will have sufficient freeboard with the cold water pipe deployed to permit completion of construction.

The sequence of operations will be as follows:

1. Deploy permanent mooring. (See 400 MW Platform scenario.)

2. Deploy cold water pipe:

The cold water pipe for the plant is assumed to be about 50 feet in diameter, of GRP, and to weigh about 5,000 Long Tons in water.

The pipe will be preconstructed in sections of 100 to 150 feet length and connected in place with glued joints or mechanical fasteners.

The pipe sections are transported to the platform by supply vessel and then rolled on a wheeled carriage into place over the well. The first section is lowered into the well until its upper end is level with the hydraulic jack system. A supporting collar is then attached to a number of hydraulic jacks. The total number of jacks is sized to support twice the total weight of the completed cold water pipe so that alternate jacks are used for each collar attachment.

With the first section lowered and collared, its weight supported by the jacks, the next section is rolled on board and lowered by jacks onto the first section where it is aligned and connection is made. A second collar is then attached to this section of pipe with support from the remaining jacks and the weight of the two joined sections is held by this upper collar. The lower collar is then detached and the two pipe sections are lowered into the well. The next section of pipe is then brought on board, connected to the pipe string, lowered into the well and the cycle is repeated. All cold water pipe sections (3,000 ft. total) are lowered and connected similarly.

When all joints are lowered and connected, the pre-constructed CWP support assembly is lowered into position and installed. The upper end of the cold water pipe is then attached to the support assembly. Finally, the watertight seal is installed.

3. Investigate the possibility of construction superstructure of concrete utilizing steel or concrete decks. Concrete may prove better and cheaper to support the high compression and loads generated by the cold water pipe installation.

Alternatively, prefabricate steel superstructure at shore site in sub-assemblies sized for transportation to platform and lift by derrick barge. Tower crane and support would be removed from vessel for installation of the CWP but could be reinstalled after CWP deployment if advantageous for completion of the platform.

Construct the upper steel deck at the shore site and erect derrick at the upper level of the superstructure. Deck must be designed to support two high capacity ringer cranes.

4. Erect platform's cranes on deck.

5. Lay electrical transmission cable to shore.

6. Check out all systems and installations.

7. Start up plant.

8. Initial test and demonstration.

3.1.3 Spar Platform

a. General

The general layout of the Spar OTEC demonstration plant is shown in Figure No. 3. The vessel is cylindrical in shape with the entire main hull submerged in the operational condition. A cylindrical superstructure extends 75 ft. above the ocean surface to provide stability to the unit and to house the accommodation areas and test and data collecting facilities. The superstructure is made of concrete with a steel deckhouse structure.

Construction of the hull and installation of all equipment is proposed to take place in three separate phases at three different sites.

Phase 1 shall be performed at the onshore site to the point of completion where the hull can be safely floated out to the offshore site.

Phase 11 shall be carried out at the immediate offshore site where the platform will be entirely constructed to deck level 410 requiring at least 150 feet of water depth.

Phase 111 shall take place at the operational site where the mooring system and CWP will first be connected and the remainderof the platform constructed.

b. Phase 1 Construction

The lower hull onshore construction site is expected to be within close proximity to the Pensacola Bay area. Site preparation shall consist of the following stages:

1. The excavated assembly site is prepared to a depth somewhat lower than the projected float-out draft of the hull. The float-out channel is dredged to allow for the above mentioned draft. An artificial island should be considered as an alternative site.

2. Lay in the hydraulic piping.

3. Float in the preconstructed steel plug and after Stage 4 dewater the site, let the plug land in place and erect a heavy, high capacity self-erecting building crane of the horizontal counterweight boom type on top of the plug.

4. Drive in the sheet piling and push sand up around it.

5. Push sand into rough shape of the grapefruit (bottom hemisphere).

100 MWe DEMONSTRATION PLANT
SPAR

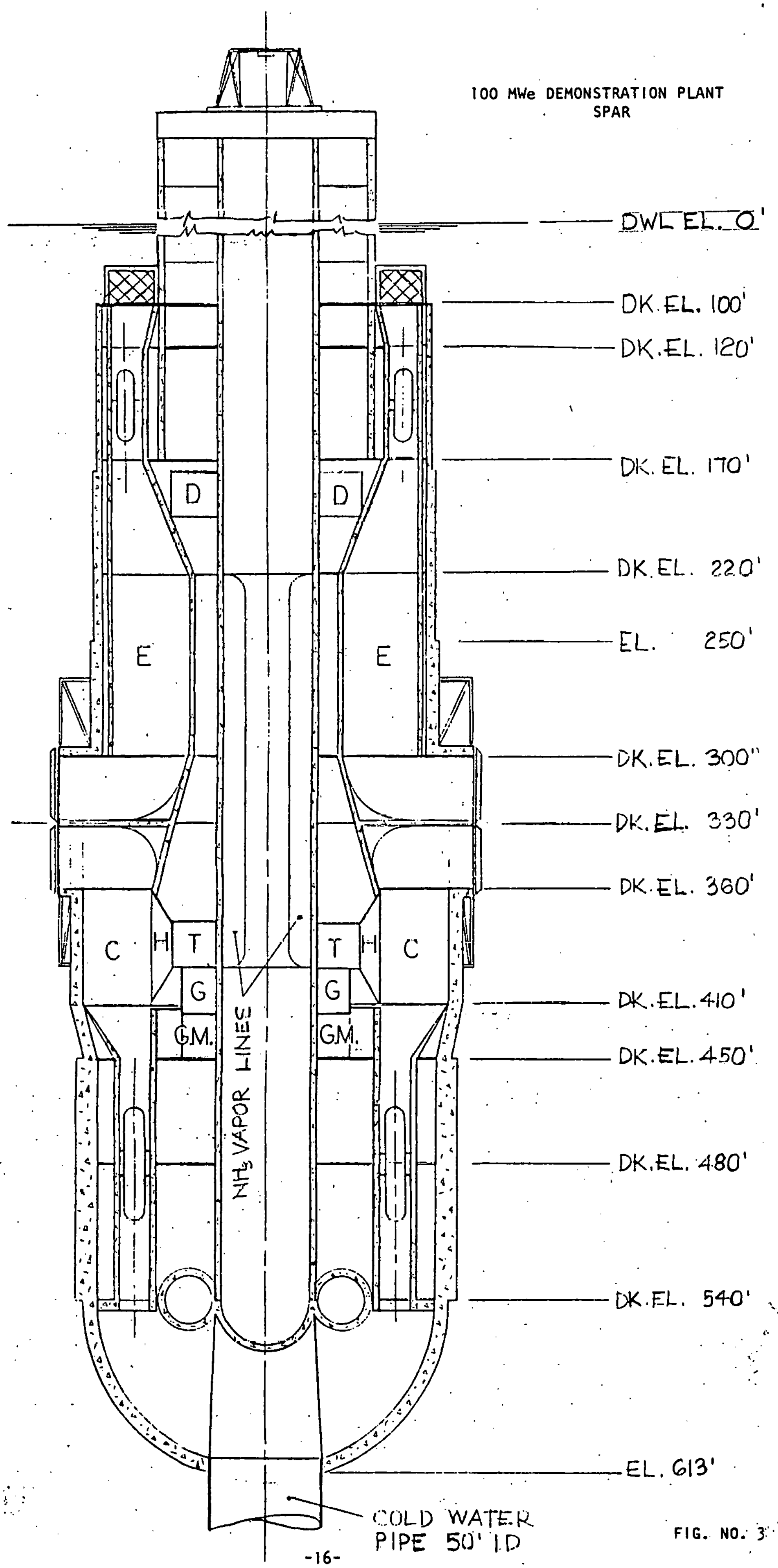
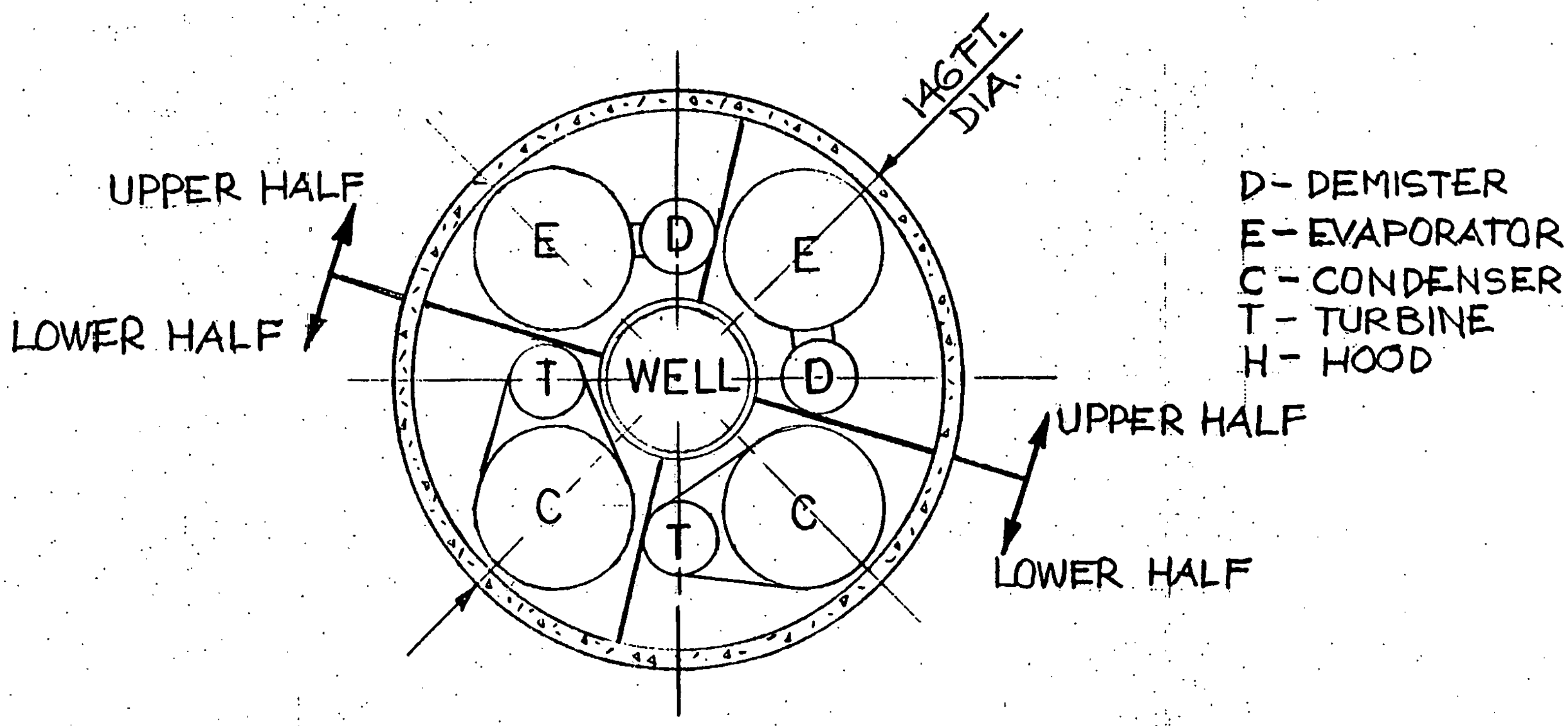


FIG. NO. 3

100 MWe DEMONSTRATION PLATFORM
SPAR



PLAN AT EL. 220 FT.,
AND EL. 410 FT.

FIG. NO. 3a

6. Prepare a concrete annular footing to support the spar at its base during Phase I construction process.

7. Place the upper and lower traveling tracks and give the sand final shaping and stabilization.

The amount of the lower structure constructed on land will be about the same as would be accomplished for the commercial plants, the major reason being that the demo plant's total depth is over 90 percent of the proposed commercial plant depth.

Regarding the above, the lower grapefruit is cast incrementally utilizing the internal movable form in opposite 22 1/2 degree segments to a height of around 60 feet. Through previously installed dewatering system flood excavated basin to level of adjacent water system. Remove earthen dam and sheet piling in way of float-out channel. At this point, the entire basin is flooded and the grapefruit afloat. Simultaneously tugs are positioned and the unit is towed to the Phase II construction site where mooring anchors and their pendant buoys have already been preset.

c. Phase II Construction

Support vessels and equipment will be needed to continue construction as soon as the vessel is moored. Portable diesel power generation will be required on board or on an adjacent floating platform to supply electrical power for lighting, ventilation, cranes and hoists. A deck barge supporting a complete cement mixing plant, with lower tanks for fresh water will be moored next to the hull possibly with supply barges for sand and cement laying along side.

The vessel, barges and plant will be supplied with men and materials by a supply vessel, tugs and barges. It is assumed that construction offshore would continue on a 24 hour per day basis using a 12 hour shift system. Men may be ferried to the vessel by crew boat or helicopter depending upon distance from shore. The loss of time used to ferry workers to and from the vessel by sea may prove to be more costly than using air transportation. It may thus prove a viable alternative.

The Phase II construction procedure should then be carried out as follows:

The tower crane is consistently utilized in the following scenario. The upper grapefruit is poured in opposite segments using jump forms. In all concrete pouring stages discussed the reinforcing steel is assumed to be positioned and welded. The grapefruit bulkheads are poured via slip forming techniques. The torus segments are precast on shore and shipped to the site where they are assembled and secured. Deck 540 is poured in place with cold water intake valve foundations and valves incorporated. Using slip forms pour the outer shell from elevation 540 to 480. Place precast and shipped central trunk sections to the above elevation and proceed to do the same with the precast cold water intake sections and precast bulkheads. Deck 480 is poured in place. Repeat the same procedure for constructing shell, trunk, cold water pipes, and bulkheads from elevation 480 to 450. Install pump foundations, cold water pumps, upper cold water intake pipes, and pour deck 450 in place. Follow earlier steps for constructing shell, trunk, bulkheads and cold water intake flare pipe sections from elevation 450 to 410. Pour deck 410 in place with generator, turbine, hood and condenser foundations incorporated. At this point the tower crane must be raised to a higher level and the hemisphere central trunk closure is poured. Phase II is complete and the platform is towed to the deep water ocean Phase III site where the mooring system is deployed as per section 3.2.1.

d. <u>Phase III Construction</u>

The cold water pipe is assembled and connected as per section 3.2.1. Construct shell and central trunk from elevation 410 to 360 then place precast condenser housing, condenser, hood, turbine generators and pour radial bulkheads. From elevation 360 to 330 place central trunk, bulkheads, separator diaphragms, hull segments and pour deck 330. This completes the structure to its mid point and the same scenario used for constructing from elevation 480 to 330 is used in reverse order from elevation 330 - 100 except of course the warm water systems are installed during the sequence. The main body of the spar is complete. The upper shell elevation 100 to 75' above the DWL is slip formed, the central trunk, the concrete bulkheads, and steel sub-division bulkheads are placed in, and decks 100 through LL 55 are poured, all done in logical sequence. The last step is placing the pre-fabricated steel deckhouse on top of the spar platform and all superstructure components are installed.

Table 1: Concrete Spar Characteristics

Cylindrical Shell

Design	Elev. below DWL	Actual Pres. P, psi	Do, ft.	Req'd. t, ft.	Actual t, ft.
100 MW	100	44.4	140	1.221	1.25
	300	133.2	140	3.732	3.75
	500	222.0	140	6.341	6.42

Shell End Closure

Location	Size	Actual Thickness
Bottom Closure (Complete half sphere)	100 MW	3.58
	200 MW	5.33
	400 MW	7.83

3.2 Integration and Deployment

3.2.1 Cold Water Pipe

a. General

Recent studies on the 400 MW_e Commercial Plant indicate that filament wound fiberglass reinforced plastic is the most feasible material for the cold water pipe. Therefore, this is the material selected for the CWP for the 100 MW_e Demonstration Platform.

There are no existing facilities in the U.S. today capable of manufacturing the required 50 ft. diameter pipe. A new fabrication facility must be built and this should be considered in the economic evaluation of the CWP.

Transportation by truck or rail of a 50 ft. diameter by 100 or 125 ft. long section of pipe is generally impossible, depending on the route and distance. Water transportation thus appears the only feasible method of transportation. The fabricator must therefore have access to water transportation or set up a new fabricating facility near the land based platform construction site where the CWP sections can be fabricated, loaded on a barge and transported to the operational site for deployment.

b. Cold Water Pipe, Spar

The cold water pipe GRP sections are proposed to be constructed at a shoreside facility. The section dimensions are 100 ft. long x 50' ID x 3.5" thick. Most likely a shed will be constructed near the water with the CWP mandrel within for spinning the pipe. The CWP sections are transported on barges to the operational site and assembled using a drop through method through the submersible barge similar to the scenario used for the 400 MW_e Sphere.

The submersible barge is designed and constructed specifically for the task of deploying the CWP. The barge has a 60 foot moon pool, a system of hydraulic jacks and the capability of separating in two sections along the length and surfacing once the CWP is connected to the Spar.

In order to connect the CWP, the barge holding the CWP string is submerged to a depth of approximately 500 feet and is maneuvered below the platform by tugs with lines to the surface. Acoustical and video aids are used to facilitate the alignment process. The barge is slowly made positively buoyant until the pipe is mated with the opening in the center lower portion of the Spar. The method of permanently connecting the CWP may be understood by examining MR&S drawing No. 47919 developed for the 400 MW_e Spar design.

The drop through assembly of the CWP is performed on the barge at the operational site during the Phase II construction of the Spar and is connected to the Spar at the start of Phase III, (see section 3.1). Construction and deployment costs of the CWP are estimated in section 4.1.

c. Cold Water Pipe - Sphere

The CWP is proposed to be fiber glass, fabricated in sections 50 ft. diameter by 100-125 ft. long.

After the main hull is completed (less the superstructure) and is permanently moored at the operational site, the CWP is deployed by lowering each section through the 60 ft. diameter center well of the platform by a system of jacks similar to the method proposed for the 400 MW_e platform.

Each section is brought out to the platform by barge, transferred by wheeled dolly to the deck of the platform and individually lowered and attached to the previously deployed section until the full 3,000 ft. of pipe is deployed. The CWP string is then connected to the platform by means of the permanent connection in the well or on deck.

The handling of these large sections of pipe and joining section to section with fairly close tolerances may dictate waiting for relatively calm seas for deploying the CWP.

The method of deploying and attaching the CWP may be understood by examining MR&S drawing No. 47926 developed for the 400 MW_e Sphere design.

3.2.2 OTEC Equipment

The principal components of the OTEC plant consist of:

Vertical Condenser

Vertical Evaporator

Demister

Turbine

Generator

The 230 ft. diameter Sphere and 146 ft. diameter Spar are sized to accept either 4-25 MW power modules (one module per hull quadrant) or 2-50 MW_e modules (1 heat exchanger per hull quadrant). To fit 2-50 MW_e modules on the Spar will require opening up portions of 2 of the quadrant bulkheads to permit the heat exchanger vapor connections and the turbo-generators to be located in the adjacent quadrant. This should present no complications in compartmentation since the quadrant bulkheads are designed to be non-tight. Four smaller (than 25 MW_e) power modules such as 5 MW_e, 10 MW_e or 12 ½ MW_e should fit either platform since they require less space and weigh less than the 25 MW modules.

However, additional ballast may be required to bring the platform to its normal operating draft with the smaller modules installed. The total weight of 4-25 MW_e modules is approximately equal to the weight of 2-50

MW_e modules, therefore, there should be no ballast or displacement adjustments required with either of these installations.

One of the basic considerations in the construction of the OTEC equipment is that the various items must be capable of being lifted on board the platform by the available cranes. It is anticipated that the OTEC units must be capable of being broken down into crane-size components or super lift cranes must be utilized in the platform construction phase. Considering the scarcity of heavy lift cranes and the cost of renting such equipment it would appear advisable to reduce the required crane size by breaking the units into components of reasonable weight.

A further consideration in the design of OTEC components is that they must be broken down into sizes capable of being shipped by road or rail unless they can be shipped by water, in which case they can travel fully assembled.

The details of OTEC component design details, materials, etc. are not discussed here since they are amply covered in numerous DOE reports.

3.2.3 Platform Service and Support, Spar and Sphere

The integration and deployment of the OTEC mooring system falls under the topic of platform service and support. It has been determined that a passive mooring system utilizing the high holding strength to static breaking strength capabilities of the hollow cylindrical link (HCL) mooring leg is necessary. At one end the links will be attached to the platform, and at the other to a disc type, floodable, free fall designed deadweight anchor. Post-tensioning of the platform hull at the level where the links are attached is desirable.

The first link attachment to the hull shall be made during Phase II construction at the point in time when the hull connection is above the water surface. Several of the links will be attached as the platform's draft increases during construction. This is accomplished by barges equipped with high capacity deck winches stationed next to the platform.

When the platforms are being towed to the deep water site for Phase III construction, the links will be held aloft by temporary winches located on top of the hull.

Located at the deep water operational site will be the remainder of the mooring system. The links there have been constructed on land, placed and assembled in lengths on barges for tow out to the deep water site. The buoyant anchors are constructed on a dry dock, floated off and towed out with the links. There, the links are connected to the aforementioned links on the platform and to the anchors. The anchors are sunk one at a time thereby deploying the system.

To visualize some of the above steps, see MR&S drawing No.'s 47916 and 47927 developed for the 400 MW_e Spar and Sphere designs.

It is estimated that the drag on the 100 MWe platforms, both Spar and Sphere, due to wind and current will be approximately one half and one third respectively of the 400 MWe designs. The sizing of the 100 MWe mooring system may be adjusted accordingly from the 400 MWe mooring designs. The sources used for determination of the same are applicable.

3.3 Testing and System Checkout, Spar and Sphere

The purpose of the 100 MWe demonstration plant is to test the OTEC system performance. Therefore, there shall be additional testing devices to check temperatures, flow rates, and pressures that would normally be required for a commercially operated plant. The major systems which will necessitate such testing are as follows:

- Heat Exchangers
- Warm and Cold Water Circulation Systems
- Cold Water Pipe
- Turbines and Generators
- Evaporator and Condenser Discharge
- Main Hull
- Mooring System
- Ammonia System

1. Heat Exchangers

Tests will be analyzed for determination of performance data on the heat exchangers and moisture separator to verify design assumptions. The Amertap system shall be tested for its effectiveness.

2. Warm and Cold Water Circulation Systems

The warm water intake screens shall be periodically checked for corrosion. Temperature, pressure drops and velocity through the screening will be recorded. Warm and cold water ducting must be checked for corrosion. Circulating pump performance data shall be analyzed under varying operating conditions.

3. Cold Water Pipe

Internal pressures, temperatures and velocities shall be recorded. The motions of the pipe can be studied through use of underwater photography. Stress concentrations at the hull/CWP interface shall be watched for.

4. Turbines and Generators

Actual turbine shaft power output and generator power output shall be compared with design assumptions.

5. Evaporator and Condenser Discharge Effects

The effect on the warm systems by the cold water discharge plume is unknown and warrants investigation. The plume will sink to a certain depth, disperse and may or may not affect the warm water intake temperatures.

The effect on local biological life by the warm and cold water discharge shall be studied for the magnitude of the environmental impact.

6. Main Hull

Tests on the exterior hull shall be conducted to observe the extent of biofouling over extended periods of time. This would involve measurements of growth at various levels and photographs to aid the marine biologist in preparing a report of such. Periodic examinations of the accessible areas of the interior and exterior of the hull for stress concentrations and leaks shall be performed.

7. Mooring System

The HCL mooring legs will require checking via submersibles and cameras for possible defects.

8. Ammonia System

Pressure, temperatures, the possibility of leaks and chemical impurities shall be consistently monitored at various locations in the system.

3.4 Operating Scenario

3.4.1 Normal Operation, Spar and Sphere

a. Personnel and Work Schedules

The operating personnel aboard the OTEC platform shall consist of three distinct groups, as follows:

1. The OTEC crew, which would have the responsibility for operation, analysis, and maintenance of all OTEC equipment on the platform.

2. The Platform crew which would be responsible for operation and maintenance of the platform, and support of the OTEC crew, as required.

3. The catering staff, which would be responsible for preparation and distribution of food, and for hotel services such as cleaning of facilities and laundry. This staff would be contracted on a per-man/per-day rate from a catering service.

Platform work schedules are assumed to be similar to current drilling rig practices. These practices, would employ personnel on the basis of a "one week on-one week off" type schedule. The working day would be divided into two 12-hour shifts for the platform crew and catering staff. This shall be extended to a 13-hour day for the watch personnel to allow for adequate transition time during shift changes.

b. Support Vehicles

Three types of vehicles can be expected to interface with the OTEC platform to facilitate its local and transport operations.

1. Helicopters

Current scenarios generally include helicopters ranging in size up to 50,000 lbs. for such duties as personnel transfer, VIP shuttles, mail and hard copy data transfer, airborne mission support, rapid delivery of small supplies and medical evacuation.

2. Boats

Various types of boats will be expected to interface with the platform during its life cycle.

- Crew Boats and Supply Boats

  The periodic restocking of expendables such as food and office supplies, and the removal of waste end products from the platform at regular intervals would be performed by these vessels. Landings would be common and frequent, in all likelihood occurring at intervals of a week or less. Boat sizes of 50-100 ft. are envisioned.

- Launches and Whaleboats

  These smaller boats would be used for diver support and inspection at random intervals. It is anticipated that the platform would have facilities to store, supply and handle at least one boat of this type assigned to it.

- Workboats and Barges

  In the event that major repairs or maintenance could not be performed by facilities on the platform, workboats or barges would probably serve as support vessels for the duration of the operation. It is anticipated that deployment, startup, major repairs, refitting, and other operations of a similar scale would be handled in this manner. These vessels would not be expected to physically dock with the platform as would be the case with the launches and crew/supply boats.

3. Submersibles

The subject of various forms of underwater support was covered extensively in MR&S Report 5132-3, "Results of Task 3, Technology Review" (9).

4. Supply Handling

Movement of supplies from the point of onloading into storage and from storage to their final point of use is a necessary function for smooth operation of the platform. The following equipment should be considered to accomplish this task:

- Crane for overside and on-deck handling
- Pallet trucks
- Hand trucks
- Monorail (overhead) and/or portable conveyor system
- Elevators and dumbwaiters
- Fuel transfer system

3.4.2 Maintenance Procedures, Spar and Sphere

Routine maintenance is the duty of the OTEC crew. These duties include, but are not limited to, daily policing of the plant, cleaning, lubrication, maintenance of working fluid levels, routine repair and replacement, and similar duties. Most equipment of the platform is expected to have a periodic maintenance schedule which would be performed by the crew.

A transient work force would be available to the OTEC platform for any duty the crew is not able to handle. This forces duties would include major casualty repairs. Major painting, coating, biofoulant removal, and inspection tasks could be assigned either to the platform crew or the transients. In the event that major repairs or maintenance could be performed by facilities on the platform, workboats or barges would probably serve as support vessels during the operation.

For the seawater system, corrosion control to extend heat exchanger tube life is accomplished by use of the Amertap system. As a rule of thumb, use a 10% ratio of balls to number of tubes. The effective life of the ball is one month.

3.4.3 Manning for Phases, Spar and Sphere

As the Phase III construction of the OTEC platform nears completion, the OTEC personnel will gradually be familiarized with the platform and OTEC equipment, and will have to be trained accordingly. As is common with ship construction, the Master and Chief Engineer will wish to familiarize themselves in detail with the OTEC platform and plant subsequent to start-up operations. The remainder of the administrative staff will be briefed by their aforementioned superiors and will require time for familiarization. It is envisioned that the construction crew and engineers who have been responsible for supervising and designing the OTEC facility will gradually train the platform control and maintenance, and the OTEC control operating crews for eventual facility takeover. The hotel staff will require only "last minute" familiarization in order to perform their prescribed duties. It can be seen from the organization chart, Figure 3.4.1, that a basic OTEC crew for a normally arranged 100 MW_e platform would have approximately 36 members. Using current drilling industry practices of 2 watches per day, the crew would divide into a day watch of 25 plus a night watch of 11. Allowing for 12 transients, accommodations and facilities would be needed for a total of 48 people. The following summary clarifies the organization of the OTEC crew:

a. Administrative and Command

The administrative staff consists of those persons responsible for the overall operation of the platform. The proposed administrative staff appears in Figure 5. Titles follow drilling industry practice. As "executives", these positions are primarily on the day watch.

b. Platform Control and Maintenance

This group is primarily in control of the platform machinery, although its services would be available to the OTEC power plant operations at any time. Equal personnel levels are assigned to each watch. See Figure 5.

c. OTEC (Power Module) Control

The operation and routine maintenance of the OTEC power plant is largely in the hands of this group, as it appears in Figure 5. As shown there, a group is able to operate a maximum of 20 to 30 power modules, depending on the arrangement of the modules within the hull or hulls. Additional groups would be required for larger plants.

d. The Hotel Staff (Caterers)

While catering services may in most likelihood be contracted out to an independent catering company, an estimate of the staff size is included in Figure 5.

In addition, personnel will be required for the transport operations mentioned in section 3.4.1.

3.4.4 Contingency Plan, Spar and Sphere

In severe weather conditions it has been proposed to submerge the OTEC platforms approximately 20 ft. lower than the normal operating condition. This will result in easing the platform heave motions expected due to greater wave heights and corresponding frequency excitation. It is estimated that lowering the platforms under severe weather conditions will help keep the warm water flow at the normal design rates. Otherwise an unspecified overall efficiency loss of the plant may occur. A detailed study of the effects on water flow rates due to the platform motions and wave action has yet to be performed.

The power modules are designed to operate independently of one another. Therefore, the breakdown of one 25 MW_e unit will result in a 25% output power loss until repairs are made.

In the case of repair which resulted in the replacement of a major component, the plants would have to be shutdown and the platforms surfaced. The Sphere has the necessary hatches, internal monorail and gantry crane for such an operation. The Spar has a 40 foot ID access well throughout its depth, internal monorail and gantry crane to facilitate major repair operations.

3.5 Schedule and Major Milestones

The construction period for the main hull and superstructure are estimated in the Appendix.

The construction of both the Spar and the Sphere platforms is assumed to comprise 3 separate phrases:

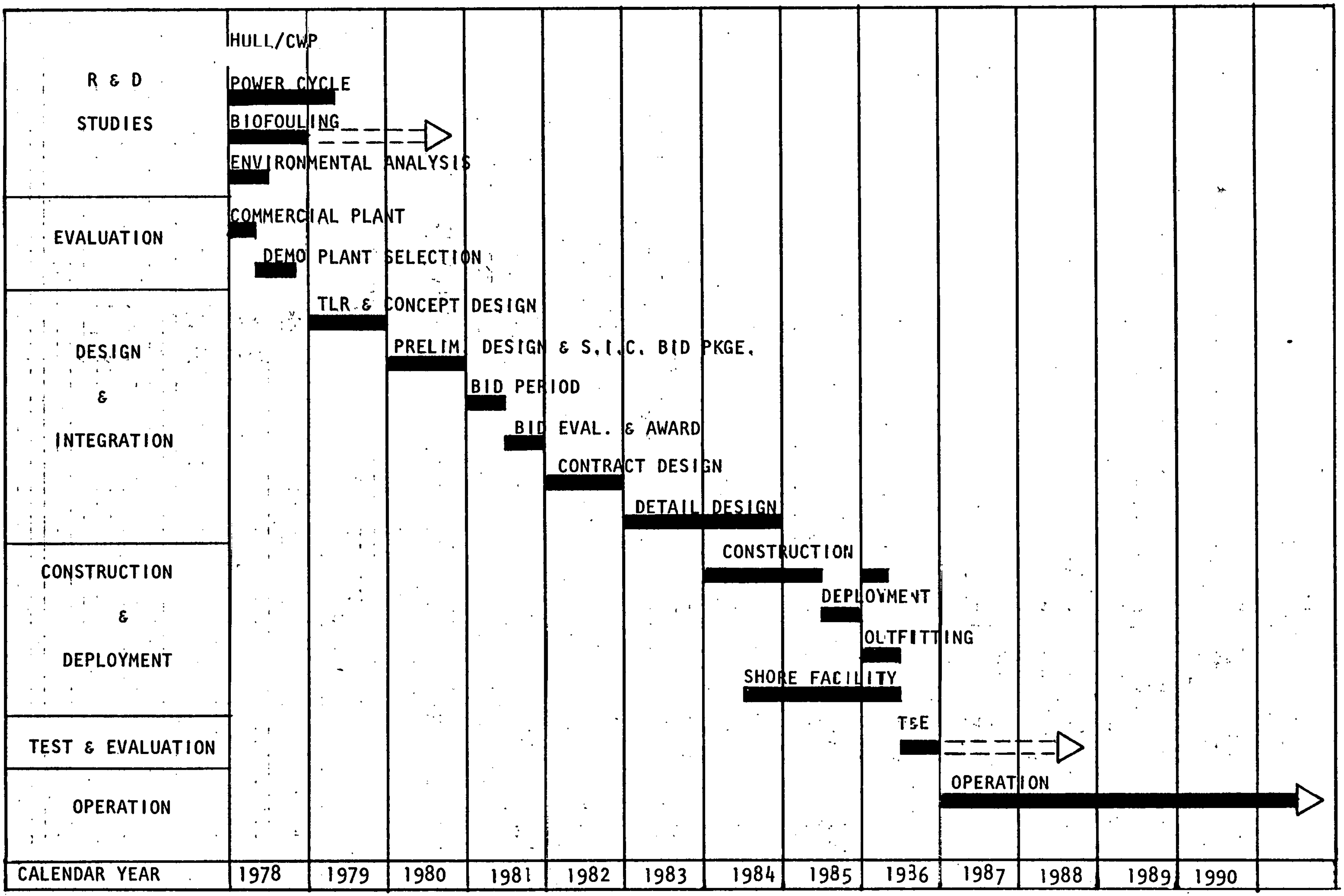
Phase I - Construction of the lower portion at the shore construction facility.

Phase II - Further construction and initial installation and outfitting at an intermediate offshore location as close to shore as possible.

Phase III - Completion of construction and final outfitting at the OTEC operation site.

The most optimistic construction period for the Spar is 1 1/3 years while for the Sphere it is 1 year. These periods do not allow time for float out of the partially completed structures from the shoreside construction site nor time to tow the platforms to the operational site, nor development time. These should be added to the above times to arrive at total time elapsed from commencement to completion of construction.

The schedule, Figure 4, shows the proposed R&D, Design and Integration, Test and Evaluation and Operational elements of the OTEC Demonstration Plant.



SCHEDULE
OTEC 100 MW DEMONSTRATION PLANT

FIGURE NO. 4

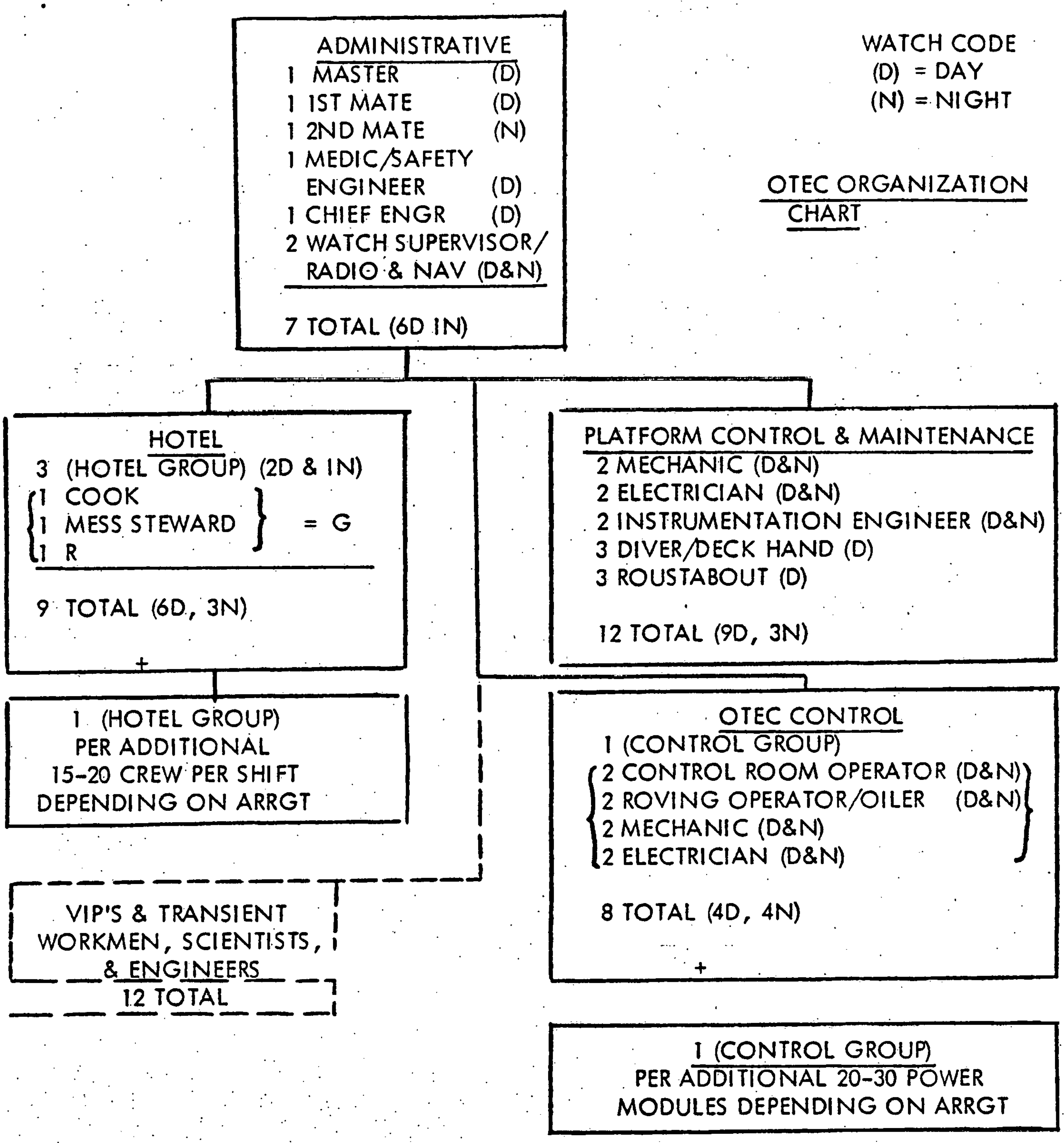

WATCH CODE
(D) = DAY
(N) = NIGHT
OTEC ORGANIZATION CHART
ADMINISTRATIVE
1 MASTER (D)
1 1ST MATE (D)
1 2ND MATE (N)
1 MEDIC/SAFETY ENGINEER (D)
1 CHIEF ENGR (D)
2 WATCH SUPERVISOR/ RADIO & NAV (D&N)
7 TOTAL (6D 1N)
HOTEL
3 (HOTEL GROUP) (2D & 1N)
1 COOK
1 MESS STEWARD
1 R
= G
9 TOTAL (6D, 3N)
+
1 (HOTEL GROUP) PER ADDITIONAL 15-20 CREW PER SHIFT DEPENDING ON ARRGT
VIP'S & TRANSIENT WORKMEN, SCIENTISTS, & ENGINEERS
12 TOTAL
PLATFORM CONTROL & MAINTENANCE
2 MECHANIC (D&N)
2 ELECTRICIAN (D&N)
2 INSTRUMENTATION ENGINEER (D&N)
3 DIVER/DECK HAND (D)
3 ROUSTABOUT (D)
12 TOTAL (9D, 3N)
OTEC CONTROL
1 (CONTROL GROUP)
2 CONTROL ROOM OPERATOR (D&N)
2 ROVING OPERATOR/OILER (D&N)
2 MECHANIC (D&N)
2 ELECTRICIAN (D&N)
8 TOTAL (4D, 4N)
+
1 (CONTROL GROUP) PER ADDITIONAL 20-30 POWER MODULES DEPENDING ON ARRGT

FIGURE 5

4.0 Demonstration of Unit Management Plan

4.1 Engineering Cost Estimates

4.1.1 Approach Used in Cost Estimates

The cost estimates as requested in [1], are to follow the standardized WBS for the OTEC plants. A discussion of specific WBS items is given below followed by a statement of basic assumptions made in arriving at the cost estimates for major WBS items and a description of the approach used in estimating costs.

2.1 Work Breakdown Structure

The systems for which cost estimates are required by the platform contractors are the following:

1.0: Platform System (1.1 thru 1.8)

2.0: Cold Water Pipe System (2.1 thru 2.5)

5.0: System Engineering and Integration (5.1 thru 5.2)

6.0: System Test and Evaluation (6.1 thru 6.3)

7.0: Operational Support (7.1 thru 7.6)

8.0: Deployment Systems and Services

9.0: Industrial Facilities

10.0: Environmental, Legal, Licensing, Regulatory, and Insurance

11.0: Project Management (11.1 thru 11.6)

Power systems costs, Item 3.0 of the WBS, are not to be addressed by the platform contractors, nor are the energy transfer systems costs. However, the cost of installing the power systems equipment on the platform are included in MR&S cost estimates.

Similarly, for the energy transfer systems, the installation of the electrical transmission system interface, i.e. the power conditioning equipment, with the hull, is included.

The costs for all of the above WBS items are based on the conceptual designs developed by MR&S for the two platforms.

Costs for systems integration are based on the conceptual design and on the construction and deployment sequence as well as on the operating scenario.

The deployment costs for the cold water pipe and the platform hull are also developed on the basis of the conceptual design. They reflect the costs for the West Coast of Florida site which is baseline site assigned to MR&S.

Industrial facilities costs (item 9 of the WBS) are analyzed in the light of the construction methodology developed for the two platforms.

All other quantitative and qualitative assumptions for the Engineering Cost Estimates may be found in Vol. II, Section 7.0.

4.1.2 Engineering Cost Estimates, Spar

WBS No.	Item	($000) Cost		
1.0	Platform Systems	118,969	Total	
1.1	Platform Integration Engineering	750		
1.2	Hull & Structure	41,736		
1.3	Position Control Sys.	26,035		
1.4	Platform Service Systems	9,552		
1.5	Outfit & Furnishings	4,800		
1.6	Assembly Support Sys.	5,978		
1.7	Sea Water Systems	28,347		
1.8	Biofouling & Corrosion Control	1,771		
2.0	Cold Water Pipe System	24,739	Total	
2.1	CWP System Design & Integration	500		
2.2	Pipe Sections	23,774		
2.3	Inlet & Screens	225		
2.4	CWP To Hull Transition	240		
2.5	CWP Biofouling & Corrosion Control	—		
2.6	CWP Mooring & Flotation	—		
3.0	Power Systems (By Others)	100,000	Total	
4.0	Energy Transfer System (By Others)	4,750	Total	
5.0	System Engineering Integration	13,000	Total	
5.1	System Design & Analysis	2,000		
5.2	System Integration	11,000		
6.0	System Test & Evaluation	1,500	Total	Non-Recurring
6.1	Test Planning	500		

Table 2

WBS NO.		Item	($000) Cost		
	6.2	Special Test Facil.	1,000		(Non-Recurring)
	6.3	Independent Test & Evaluation	1,000		yr
7.0		Operational Support	5,322	Total	
	7.1	Spare Parts	3,622		1,811/yr
	7.2	Expendable Mtls.	827		yr
	7.3	Peculiar Support Equip.	328		yr
	7.4	Common Support Equip.	264		yr
	7.5	Personnel	1,200		
	7.6	Technical Manuals	500		(Non-Recurring)
8.0		Deployment Systems & Services	3,419	Total	
9.0		Industrial Facilities	1,689	Total	
10.0		Environmental, Legal, Licensing, Reg., & Insur.	500	Total	97/yr
11.0		Project Management	10,800	Total	
	11.1	Planning, Budgeting & Control	4,000		
	11.2	Data Management	1,200		
	11.3	Configuration Management	1,600		
	11.4	Quality Assurance	800		
	11.5	Contract Management	1,600		
	11.6	Financial Management	1,600		200/yr

Table 2 Continued

4.1.3 Engineering Cost Estimates, Sphere

WBS No.		Item	($000) Cost	
1.0		Platform Systems	106,306	Total
	1.1	Platform Integration Engineering	750	
	1.2	Hull & Structure	32,447	
	1.3	Position Control Sys.	15,621	
	1.4	Platform Service Systems	9,552	
	1.5	Outfit & Furnishings	4,800	
	1.6	Assembly Support Sys.	7,315	
	1.7	Sea Water Systems	33,780	
	1.8	Biofouling & Corrosion Control	1,771	
2.0		Cold Water Pipe System	27,927	Total
	2.1	CWP System Design & Integration	500	
	2.2	Pipe Sections	26,925	
	2.3	Inlet & Screens	225	
	2.4	CWP To Hull Transition	277	
	2.5	CWP Biofouling & Corrosion Control	______	
	2.6	CWP Mooring & Flotation	______	
3.0		Power Systems (By Others)	100,000	Total
4.0		Energy Transfer Systems (By Others)	4,750	Total
5.0		System Engineering Integration	13,000	Total
	5.1	System Design & Analysis	2,000	

Table 3

WBS No.		Item	($000) Cost		
	5.2	System Integration	11,000		
6.0		System Test & Evaluation	1,500	Total	
	6.1	Test Planning	500		
	6.2	Special Test Facil.	1,000		(Non-Recurring)
	6.3	Independent Test & Evaluation	1,000		
7.0		Operational Support	11,841	Total	
	7.1	Spare Parts	3,622		Per yr 1,811
	7.2	Expendable Mtls.	827		Per yr
	7.3	Peculiar Support Equipt.	328		Per yr
	7.4	Common Support Equipt.	264		Per yr
	7.5	Personnel	1,200		(Non-Recurring)
	7.6	Technical Manuals	500		
	7.7	Personnel	5,100		Per yr
8.0		Deployment Systems & Services	3,352	Total	
9.0		Industrial Facilities	1,689	Total	
10.0		Environmental, Legal Licensing, Reg., & Insur.	500	Total	$97 /yr
11.0		Project Management	10,800	Total	
	11.1	Planning, Budgeting & Control	4,000		
	11.2	Data Management	1,200		
	11.2	Configuration Management	1,600		
	11.4	Quality Assurance	800		
	11.5	Contract Management	1,600		

Table 3 Continued

WBS No.	Item	($000) Cost	
11.6	Financial Management	1,600	200/yr

Table 3

4.2 Schedule of Expenditures

Table 4 presents the projected estimated cash flow for the 100 MWe Spar Demonstration Plant* in 1978 dollars.

The various elements adhere to the Work Breakdown Structure used in estimating the 400 MWe Commercial Plant Costs.

The basis for the cost allocation developed in the Schedule of Expenditures is the Schedule, figure 3.

Finer adjustment of the allocated expenditures might give slightly different results for any one or more years, but the overall total expenditures would remain as presented herein.

*Due the apparent similarities between the Spar and Sphere construction scenario, the Schedule of Expenditures has been developed for the Spar only.

CALENDAR YEAR	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
1.0 Platform Sys.														
1.1 Plat.Int.Eng.		125	125	125	125	125	125							750
1.2 Hull Struct.							20,868	10,434	10,434					41,736
1.3 Position Con. Sys.					4,339	8,678	8,678	4,340						26,035
1.4 Plat.Serv.Sys.						2,388	2,388	2,388	2,388					9,552
1.5 Outfit&Furn.								2,400	2,400					4,800
1.6 Assembly Suppt						2,656	1,328	1,328	666					5,789
1.7 Seawater Sys.		1,890	1,890	1,890	7,559	15,118								28,347
1.8 Biof.& Corrosion					177	177	708	709						1,771
1.0 SUB-TOTAL		2,015	2,015	2,015	12,220	29,142	34,095	21,599	15,889					118,789
2.0 Cold Water Pipe														
2.1 CWP SYS.Des & Int.		166	167	167										500
2.2 Pipe Sections					2,377	8,559	8,559	4,279						23,774
2.3 Inlet&Screens		15	15	15	60	60	60							225
2.4 CWP/Hull Conn.		16	16	16	96	96								240
2.5CWP Biof/Corros														
2.6 CWP Moor & Flot														
2.0 SUB-TOTAL		197	198	198	2,533	8,715	8,619	4,279						24,739
3.0 Power System		6,600	6,700	6,700	35,000	35,000	5,000	5,000						100,000
4.0 Energy Transf. Sys.		316	317	317	1,900	1,900								4,750
5.0 Sys.Eng & Integ.														
5.1 Sys.Des.&Anal.						1,000	1,000							2,000
5.2 Sys Integration		500	3,500	3,500	3,500									11,000
5.0 SUB-TOTALS		500	3,500	3,500	3,500	1,000	1,000							13,000

SCHEDULE OF EXPENDITURES ($000)
100 MW Demonstration Plant (Spar)

Table 4

CALENDAR YEAR	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTAL
6.0 System T&E														
6.1 Test Planning							125	250	125					500
6.2 Spec'l Test Fac.							250	500	250					1000
6.3 Indep. T&E									500	1000	1000	1000	1000	4500
6.0 SUB-TOTALS							375	750	875	1000	1000	1000	1000	6000
7.0 <u>Oper'l Supp't</u>														
7.1 Spare Parts									3622	1811	1811	1811	1811	10866
7.2 Expend. Mtls.									414	827	827	827	827	3722
7.3 Pec Supp't Equip.									164	328	328	328	328	1476
7.4 Com Supp't Equip.										264	264	264	264	1056
7.5 Personnel							300	3150	5400	5100	5100	5100	5100	29250
7.6 Tech. Manuals								250	250					500
7.0 SUB-TOTALS							300	3400	9850	8330	8330	8330	8330	46870
8.0 Deployment S&S							855	2564						3419
9.0 Indust. Facil.					1689									1689
10.0 Environ., Legal, Etc.		250	250											500
11.0 <u>Project Mgmt.</u>														
11.1 Plan, Budget Control		500	500	500	500	500	500	500	500					4000
11.2 Data Mgmt.		150	150	150	150	150	150	150	150					1200
11.3 Config. Mgmt.	200	200	200	200	200	200	200	200	200					1800
11.4 Quality Assur.		100	100	100	100	100	100	100	100					800
11.5 Contract Mgmt.		200	200	200	200	200	200	200	200	200	200	200	200	2400
11.6 Finance Mgmt.		200	200	200	200	200	200	200	200					1600
11.0 SUB-TOTALS	200	1350	1350	1350	1350	1350	1350	1350	1350	200	200	200	200	11,800

SCHEDULE OF EXPENDITURES ($000)
100 MW Demonstration Plant (Spar)

Table 4

CALENDAR YEAR	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	TOTALS
PRELIM. DESIGN			750											750
CONTRACT DESIGN					1500									1500
DETAIL DESIGN						2250	2250							4500
TOTAL CASH FLOW	400	10978	14830	14080	59672	79357	53840	38942	27964	9530	9530	9530	9530	338183
CUMUL. CASH FLOW	400	11378	26208	40288	99960	179317	233157	272099	300063	309593	319123	328653	338183	

NOTE: 4 yrs operation assumed. Additional operating years may be added at 9530 per yr. additional cost.

SCHEDULE OF EXPENDITURES ($000)
100 MW Demonstration Plant (Spar)

Table 4

TABLE 5

SPAR ACQUISTTION COST BREAKDOWN

COST ITEM	APPLICABLE WBS NO.	COST ($000)
Hull, Outfit, Machy. & CWP	1.2-1.8, 2.2-2.4, 3.0, 4.0	$241,230
Construction Site	1.6	5,978
Deployment	8.0	3,419
Engineering Design & Integration, T&E	1.1, 2.1, 5.0, 6.0 (part), PD, CD, DD	22,500
Industrial Facilities	9.0	1,689
Special Test Facilities	6.2	1,000
		$275,816

ANNUAL OPERATING COSTS

WBS NO.	TITLE	ANNUAL COST ($000)
6.3	Independent T&E	$1,000
7.1 (part)	Spare Parts	1,811
7.2	Expendable Materials	827
7.3	Peculiar Support Equipment	328
7.4	Common Support Equipment	264
7.5	Personnel	5,100
10.0 (part)	Insurance	97
11.6 (part)	Management	200
		$9,627

TABLE 6

SPHERE ACQUISITION COST BREAKDOWN

COST ITEM	APPLICABLE WBS NO.	COST ($000)
Hull, Outfit, CWP & Machy.	1.2-1.8, 2.2-2.4, 3.0, 4.0	$230,148
Construction Site	1.6	7,315
Deployment	8.0	3,352
Engineering Design & Integration, T&E	1.1, 2.1, 5.0, 6.0 (part), PD, CD, DD	22,500
Industrial Facilities	9.0	1,689
Special Test Facilities	6.2	1,000
		266,004

ANNUAL OPERATING COSTS

WBS NO.	TITLE	ANNUAL COST ($000)
6.3	Independent T&E	$1,000
7.1 (part)	Spare Parts	1,811
7.2	Expendable Materials	827
7.3	Peculiar Support Equipment	328
7.4	Common Support Equipment	264
7.5	Personnel	5,100
10.0 (part)	Insurance	97
11.6 (part)	Management	200
		9,627

SECTION 5.0
SUMMARY AND CONCLUSIONS

The Spar and Sphere offshore platforms are feasible concepts for the demonstration of a near full size OTEC plant to determine its validity and to gather data for use in the construction, design and operation of commercial OTEC plants. A hull size suitable to support a 100 MWe net output plant was chosen. Either 50, 25 or 12.5 MWe power modules could be used.

Selection of 50 MWe modules would permit the testing of equipment recommended for the commercial plant. The use of 25 MWe modules would permit optimal hull volume utilization. The size hull selected for both platforms represents a reasonable increase above the pilot plant, providing design and construction problems similar to those that may be found in a hull size commercial plant.

Since the hull size is substantially smaller than the projected commercial plant size, the possibility of constructing the vessel of steel was presented. However, it is already determined (Task 5) that the full size hull shall be constructed principally of reinforced concrete and thus to fully demonstrate the feasibility of both construction techniques and operation, concrete was chosen for the demonstration plant. The superstructure of the sphere is all steel and for the spar, concrete with a steel deckhouse. The cold water pipe for both platforms is fiberglass.

Construction of the hull and installation of all equipment is proposed to take place in three separate phases at three different sites. The overall plan proposes:

1. A shoreside construction site
2. An offshore site in sufficient water depth to complete the hull erection and
3. Installation of the cold water pipe at the demonstration site. The methods of construction, towing, material supply, equipment installation and deployment of cold water pipe, outlined here, are not new and are in most instances quite conventional in offshore construction.

SECTION 6.0
REFERENCES

1. NoAA letter to MR&S dated March 9, 1978

2. Gilbert Commonwealth Memos to NoAA dated August 15, 23, 26 (1977) and DoE letter to NoAA dated January 10, 1978

3. Simplex Corp. letter to MR&S dated March 22, 1978

4. Telephone conversations and meetings with Mr. A. Potter of Price Brothers, Inc. dated March 20 and March 15, respectively

5. Telephone conversation with Mr. James Ford of Owens Corning Fiberglass Co. of March 20, 1978

6. Lockheed Presentation to the DoE, December 7, 1977 (Presentation of Mr. R. Mast of ABAM Engineers)

7. Private Correspondence between U.S. Steel Research Lab. and SYMONS corp., February through March 1978

8. 1978 Dodge Guide to Public Works and Heavy Construction Costs - McGraw-Hill, 1977

9. Telephone conversation with McDonough Marine Service, March 16, 1978

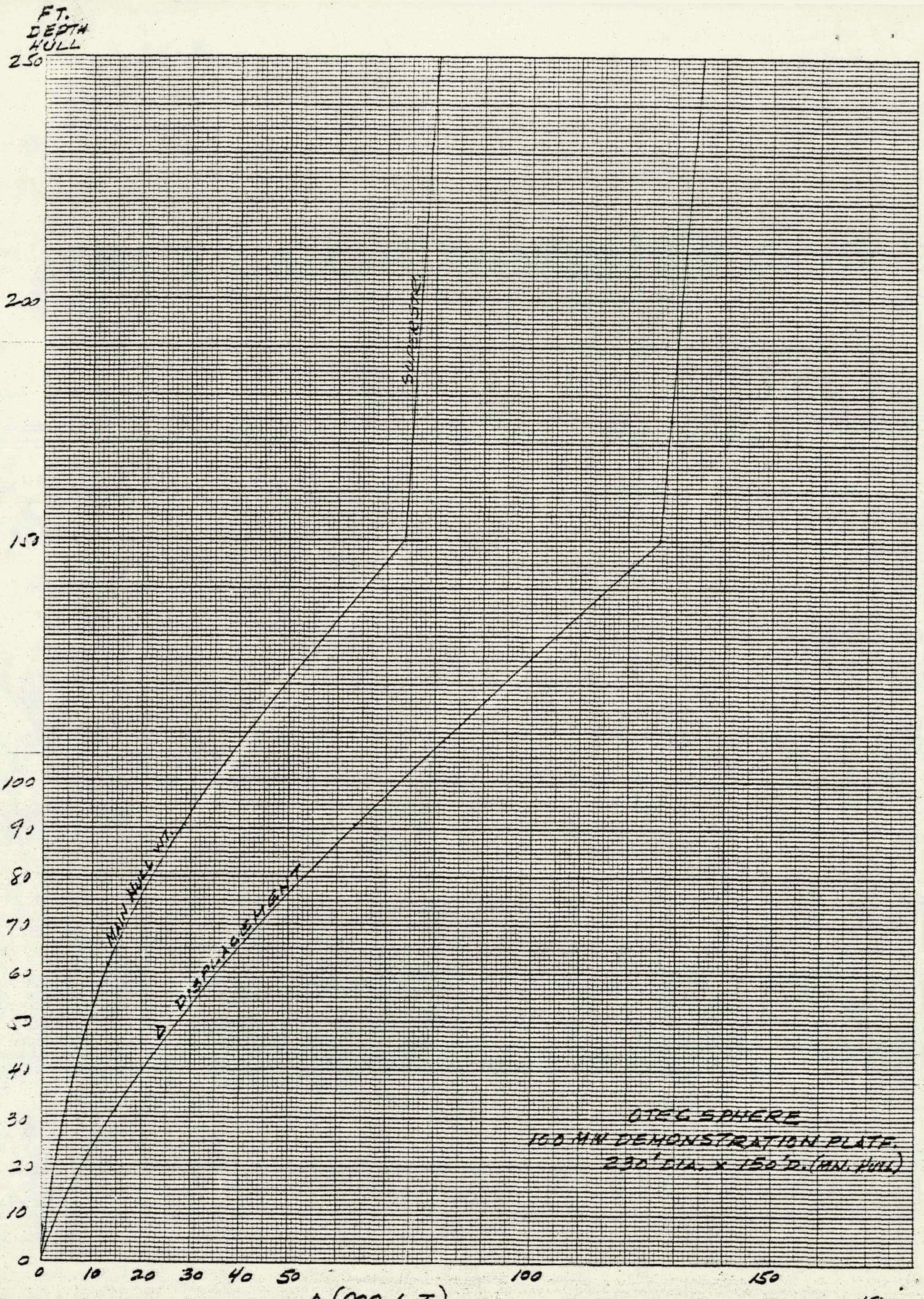
10. Gulf Oil Corp. - International Marine Fuel Oil Price Schedule - Feb. 1976

11. TRW PB-246 181 Vol. IV. Test Program Plan

Appendix A.

Displacements, Weights, Stability

Sphere and Spar


FT. DEPTH HULL
250
200
150
100
90
80
70
60
50
40
30
20
10
0
SUPERSTRT.
MAIN HULL WT.
Δ DISPLACEMENT
OTEC SPHERE
100 MW DEMONSTRATION PLATF.
230' DIA. x 150' D. (MN. HULL)
0
10
20
30
40
50
100
150
Δ (000 L.T.)

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DESIGN CALCULATION SHEET

No.
Sheet 49 of

Subject WEIGHTS
Ship or Project 100 MW DEMO. SPHERE
Section
Prepared by [signature] Date 4-17-78 Checked Reviewed [signature]

PLATFORM WTS. –	100 MW (4 MODULES) L.T.		25 MW (1 MODULE) L.T.
HULL	58,205		58,205
SEAWATER SYS. (WET)	19,849		4,962
PLATF. SERVICES	1,118	x.7 =	783
MISSION SUPPORT	95		95
OTEC POWER	36,049		9,012
ACCESS	160		160
	115,476		73,217
MOORING LOAD	3,200		3,200
CWP (6" THK) IN WATER	5,000		5,000
	123,676		81,417

100 MW { 129,999 L.T. Δ = 190' draft = MAX. OPERATING DRAFT
115,476 L.T. Δ = 140' draft = MAX. CONSTRUCTION DRAFT.

25 MW { 87,740 L.T. Δ = 115' draft BALLAST TO 190' MAX. OPER. DFT.
73,217 L.T. Δ = 100' draft = MAX. CONSTRUCTION DRAFT

40' = MAX. AVAILABLE DEPTH OF WATER FOR TOW-OUT.

@ 40' DRAFT, Δ = 20,000 L.T. = MAX. CONSTR. WT. ON SHORE

25 MW	L.T.
HULL TO 66' W.L.	15,000
1/2 SEAWATER SYS (DRY)	1,241
OTEC EVAP. & COND.	1,429
CONSTR. EQUIP.	500
TOTAL WT.	18,170
Δ @ 40' DRAFT	20,000
MARGIN	1,830

100 MW	
HULL TO 48' W.L.	8,700
1/2 SEAWATER SYS. (DRY)	4,964
OTEC HX	5,716
CONSTR. EQUIP.	500
TOTAL WT.	19,880
Δ @ 40' DRAFT	20,000
MARGIN	120

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DESIGN CALCULATION SHEET

No.

Sheet 50 of

Subject DISPL & WT.

Ship or Project 100 MW DEMO. SPHERE

Section Prepared by [signature] Date 4/14/78 Checked Reviewed [signature]

MAIN HULL

400 MW SPHERE Δ = 971,995 L. TONS (237' R = 474' D)

$\pi \times 237^2 \times 270.5'(D) = 47{,}732{,}462$

$47{,}732{,}462 \div 971{,}995 = 49.1077$ = vol. factor

ALLOW FOR INNER CORE

$(\pi \times 237^2 - \pi \times 60^2) \times 270.5 = 44{,}673{,}179$

$44{,}673{,}179 \div 971{,}995 = 45.960$ = vol. factor

100 MW SPHERE @ 230' DIA.

$(\pi \times 115^2 - \pi \times 30^2)150 = 5{,}808{,}019$

$5{,}808{,}019 \div 45.960 = 126{,}371$ L. TONS Δ TO 150' W.L.

CUBIC NUMBER ≈ $126{,}371 \div 971{,}995 = .130$

SUPERSTR. - 100 MW

ASSUME 40' HULL SUBMERGENCE + 75' = 115' × 60' DIA

$\Delta = 30^2 \times \pi \times 115 = 9{,}290$ L.T. = 80.783 L.T./FT.

MAIN HULL WT (CONC.) INCL. BHDS + DKS

400 MW = 562,750 L.T.

$562{,}750 \text{ L.T.} \div (\pi \times 237^2) 270.5 = .01179$

$100\text{MW} = \pi \times 115^2 \times 150 = 6{,}232{,}134$

$6232134 \times .01179 = 73{,}477$ L.T.

(FROM MR+S TASK 4, APP. 2D HULL WT. = 58,205 L.T.)

SUPER STR. WT. (STEEL)

400 MW = 4,653 L.T.

$100\text{MW} = 4{,}653 \times \dfrac{\pi \times 30^2 \times 115'}{\pi \times 58^2 \times 175} = 818$ L.T. $\div 115' = 7.113$ LT/FT.

100 MW SPHERE WTS

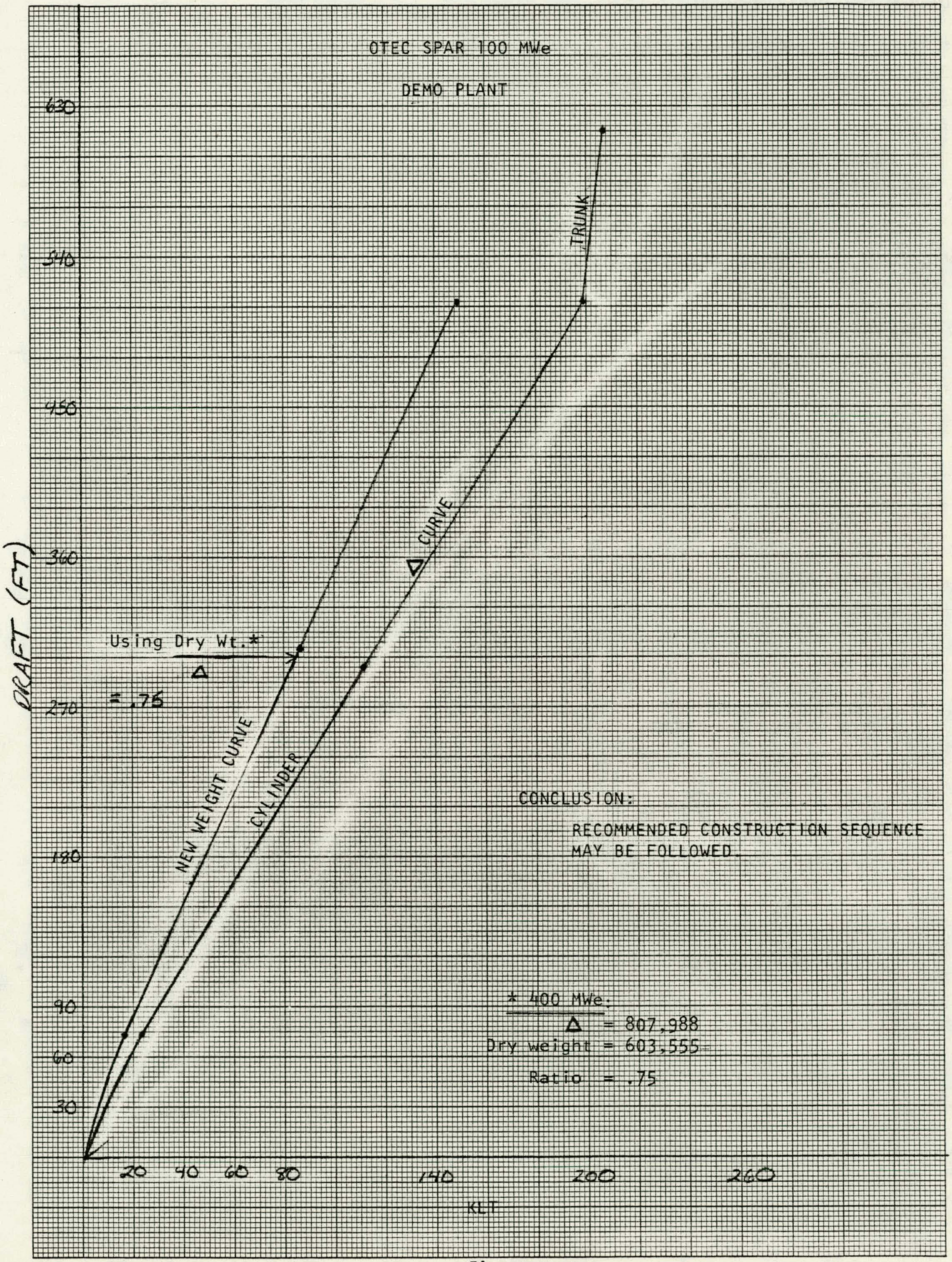
MAIN HULL	73,477	= 150' DEPTH
SUPERSTR.	818	= 115' DEPTH
	74,295 L.T.	

WT. 400 MW @ 111' W.L. = 102,098 LT (SHELL WT.)

$111' = \dfrac{111}{270.5} = .41D$ $\quad 102{,}098 = \dfrac{102{,}098}{562{,}750} = .181 \times$ MN. HULL WT.

WT. 100 MW @ $.41 \times 150' = 61.5'$ WT = $.181 \times 73{,}477$ LT = 13,300 L.T.

Δ @ .606D = .5Δ (@ 90.9D = 63,186 LT)



OTEC SPAR 100 MWe
DEMO PLANT
630
540
450
360
270
180
90
60
30
DRAFT (FT)
Using Dry Wt.*
Δ
= .75
TRUNK
Δ CURVE
NEW WEIGHT CURVE
CYLINDER
CONCLUSION:
RECOMMENDED CONSTRUCTION SEQUENCE MAY BE FOLLOWED.
* 400 MWe.
Δ = 807,988
Dry weight = 603,555
Ratio = .75
20
40
60
80
140
200
260
KLT

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DESIGN CALCULATION SHEET

No. ____ Sheet ____ of ____

Subject: 100 MWe Spar
Ship or Project: Otec
Section: BSDD Prepared by: BEF Date: 4/17/78 Checked: ____ Reviewed: [signature]

Displacement (Dimensions mostly from task 4 report)

1. Bottom Hemisphere $r = 73'$ $\frac{4\pi (73)^3}{6} \div 35 = 23,279$ LT

2. Hull Cylinder, ht. = 440'; r = 73' $(\pi (73)^2 440) \div 35 = 210,465$ LT

3. Access Trunk, ht. = 100', r = 45' $(\pi (45)^2 100) \div 35 = 18,176$ LT

$$\Delta = 251,920 \text{ LT}$$

Cubic Number $(L \times B \times D) \div 100$

400 MWe Spar

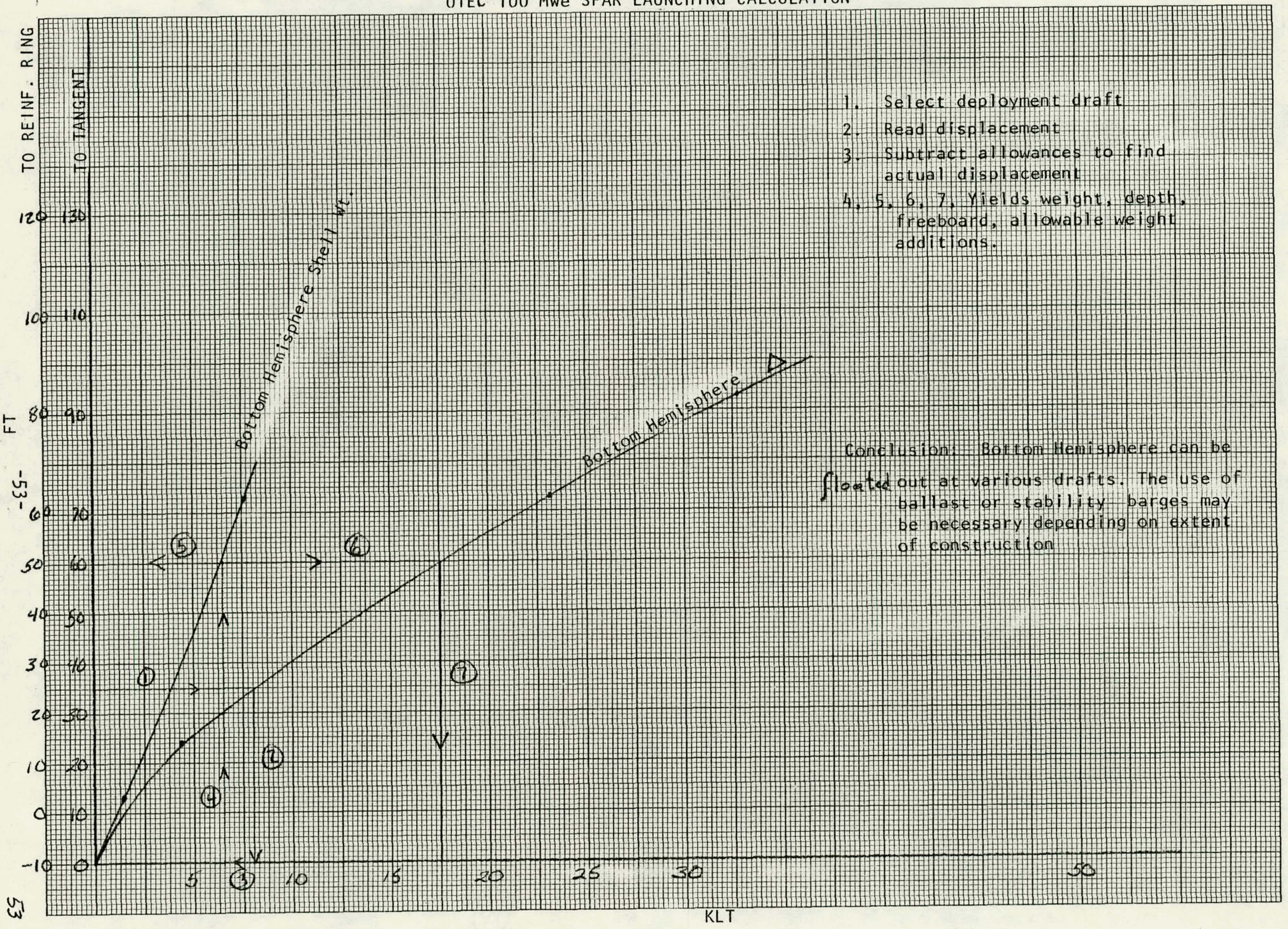
$$\text{Cubic \#} = \frac{600(240)^2}{100} = 345,600$$

100 MWe Spar

$$\text{Cubic \#} = \frac{513(146)^2}{100} = 109,351$$

Ratio $\frac{100\text{ MWe}}{400\text{ MWe}}$ Cubic #'s $\equiv 0.316$

OTEC 100 MWe SPAR LAUNCHING CALCULATION



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DESIGN CALCULATION SHEET

No.

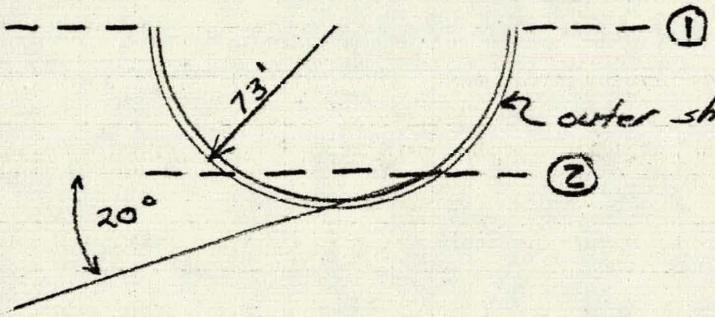
Sheet 54 of

Subject 100 MWe Spar

Ship or Project Otec - Demo

Section BSOD Prepared by [initials] Date 4/15/78 Checked Reviewed [signature]

Weight Calculation of the Bottom Hemisphere



(1)

Surface Area = $\frac{4\pi r^2}{2}$ = 33,483 ft²

ds 3.58' thick, weight = $\frac{2}{3}\pi(73^3 - 69.4^3)$ 150 lb/ft³

÷ 2240 = 7680 LT @ 73'

≡ total weight

(2) assume is a flat disk of radius ≈ $\frac{40'}{\cos 20°}$ ≈ 43'

∴ weight ≈ [π(43²) 3.6'(150)] ÷ 2240

= 1400 LT @ 13'

Appendix B.

Construction Time

Sphere and Spar

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No.
Sheet 56 of

Subject: CONSTRUCTION TIME - HULL

Ship or Project: OTEC 100 MW SPAR DEMO. PLATFORM

Section | Prepared by [signature] | Date 4-14-78 | Checked | Reviewed [signature]

CONCRETE IN HULL & SUPER STR. = 360,261 (400MW) × .335 (CUBIC NO.) = 120,687 LONG T.
÷1.8 = 67,049 CU. YD.

PLACING CONC.

ASSUME 1 CONC. MIXER + PUMP MIXES & PLACES 288 C.Y./24 HR. DAY
67,049 CY ÷ 288 = 233 MIXER/DAYS (24 HR)
w/ 4 MIXERS & PUMPS OPERATING = 233 ÷ 4 = 58 DAYS

FORMING

FORM A = 1,742,100 FT² (400MW) × ($\frac{.146}{.250} \times \frac{543}{600}$) [0.53] = 920,735 FT²
ASSEMBLE 920,735 ÷ 12.5 = 73,659 M.H.
ERECT & ALIGN 920,735 ÷ 9.375 = 98,212 MH.
98,212 MH ÷ 10 - 4 MAN CREWS = 2455 CREW/HRS
÷24 = 102 (24 HR) DAYS + START ASSEMBLY 28 D = 130 DAYS

REBARS

@ 11#/FT² FORMS = 11# × 920,735 FT² = 10,128,085# REBARS
÷ 300#/MH = 33,760 ÷ 24 = 1407 MAN DAYS (24 HR)
÷ 12 MEN = 117 DAYS

STEEL

14,395 L.T. (400MW) × 0.53 = 7630 L.T. × 150 MH/LT = 114,440 M.H.
÷24 = 4,768 MANDAYS ÷ 100 MEN = 48 DAYS

ALUM

319 L.T. (400MW) × 0.53 = 169 L.T. × 250 MH/LT = 42,268 MH
÷24 = 1761 MAN DAYS ÷ 50 MEN = 35 DAYS

HULL CONSTR. TIME = 388 DAYS + WEATHER DELAYS = 1 1/3 YRS

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DESIGN CALCULATION SHEET

No.
Sheet 57 of

Subject CONSTRUCTION TIME – HULL

Ship or Project OTEC – 100 MW SPHERE DEMO. PLATFORM

Section | Prepared by [signature] | Date 4-14-78 | Checked | Reviewed [signature]

REF: DODGE GUIDE, 1978

CONCRETE IN MAIN HULL ≈ 73,477 L.TONS
@ 150#/FT³ = 150×27 = 4050# = 1.8 L.T./CU.YD.
73,477 L.T. ÷ 1.8 = 40,820 C.Y. CONC. IN MAIN HULL

PLACING CONC.

CONC. PUMP (30HP) PLACES 28 CY MAX. PER HR.
ASSUME 14 CY VERTICALLY PER HR.
@ 1 BATCH PER HR., A 12 CY MIXER AVERAGES 12×24 HRS.
= 288 CY / 24 HR DAY.
TOTAL 40,820 CY ÷ 288 = 142 MIXER/DAYS (24 HR)
w/ 4 MIXERS & 4 PUMPS OPERATING = 142 ÷ 4 = 36 DAYS

FORMING

FORM AREA = $2\times\pi D^2$ (SHELL)
= $2\times\pi\times 230^2$ = 332,380 FT²
CORE = $2\times\pi\times 60\times 150$ = 56,549

BHDS & DKS = 280' × 503'D = 140,745 FT² (DKS)
80' × 140' × 4 × 2 = 89,600 (BHDS)
TOTAL 619,274 FT²
@ 300 FT²/8 HRS/3 MEN = 12.5 FT²/MH ASSEMBLING
@ 300 FT²/8 HRS/4 MEN = 9.375 FT²/MH ERECT & ALIGN
ASSEMBLE – 619,274 ÷ 12.5 = 49,542 MH.
ERECT – 619,274 ÷ 9.375 = 66,056 MH. (ASSUME SIMULTANEOUS w/ASSEM)
66,056 MH ÷ 10 – 4 MAN CREWS = 1651 CREW/HRS
÷ 24 = 69 (24 HR) DAYS + START ASSEMBLY 31 DAYS = 100 DAYS

REBARS

@ 11#/FT² FORMS = 11# × 619,274 FT² = 7,604,014# RETBARS
÷ 300#/MH = 25,347 M.H. ÷ 24 = 1056 MAN DAYS (24 HR)
÷ 12 MEN = 88 DAYS

SUPERSTR (STL) 818 L.T. × 150 M.H./L.T = 122,700 M.H.
÷ 24 = 5113 M.D ÷ 100 MEN = 51 DAYS

HULL CONSTRUCTION TIME = 275 DAYS + WEATHER DELAYS = 1 YR.