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FLIPPABLE BARGE FOR OCEAN ENGINEERING SUPPORT

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Scripps Institution of Oceanography

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This report is a final summary of investigations involving preliminary design and study of task capabilities of a flippable barge employed in support of ocean engineering missions. The study was sponsored by PMS 383, U. S. Naval SEA Command and the Oceanographer of the Navy and extended from 1 Jan. 1974 to 31 July 1974. In the course of earlier very large stable platform studies conducted for Advanced Research Projects Agency, Department of Defense, Scripps has developed a concept for an ocean

engineering support craft capable of carrying out tasks not easily accomplished at sea. The craft resembles a large ocean going barge with tanks and piping arranged such that one end can be flooded and the vehicle rotated into a vertical position. In this attitude it would be a deep draft work platform with stability comparable to FLIP but with much larger payload, allowing performance of much more demanding missions.

A major advance is the capability to move large pieces of machinery or research equipment through the air-sea interface using the transition between horizontal and vertical. Loads of up to 4000 tons in-air weight can be carried on deck in the horizontal and swung below the waves when the vehicle flips to vertical. In this position the loads (perhaps much lightened by buoyant forces) would then be lowered from a suspension point on the stable platform with drastic reduction of requirement to meet dynamic loadings usually encountered at sea. Similarly this transition from horizontal to vertical could be used to move intermediate size submarines (e.g. up to 90-100 ft long) from air deep into the water (150-200 ft) from which point they could detach themselves or re-attach in a passive environment. Smaller submarines could be tended completely in the vertical mode with the submersible landing on a platform well below the effects of surface waves and being raised in controlled fashion to above the water surface for tending.

A one-eighth scale model (45 feet long) of the barge has been built and tested at sea by Scripps, including successfully flipping, deploying and recovering a deck load of spar buoys, which were coupled together top and bottom to form a triangular frame structure approximately 40 ft on a side and 35 ft deep.

(continued from Block 19)
KEY WORDS

FLIP
ORB
Spar Buoy
Payload Envelopes

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I. INTRODUCTION

This is the concluding report for limited design study of a flippable barge conducted by Scripps Institution of Oceanography under funding by the Naval SEA System Command under ONR Contract N00014-69-A-0200-6012. The flippable barge concept represents an outgrowth from large stable floating platform investigations conducted by Scripps from 1968 to the end of calendar year 1973 for the Department of Defense Advanced Research Projects Agency (ARPA). The ARPA investigations were further influenced by the experience gained from successful Navy funded design, construction and continuing operations of Scripps special platforms FLIP and ORB.

During the final phase of the investigations concluded for ARPA (Spiess, 1974), Scripps examined the aspects of assembly on site of a large column stabilized platform designed for employment as an open ocean floating airfield. A major consideration was the logistics of both how to transport legs and connecting struts to the operating site and how to construct the platform once the individual pieces were on site. The legs and connecting struts could be towed, but at significant costs in sea keeping qualities and transit speeds.

With some a priori knowledge of ocean going barge technology, particularly the large load carrying capability of deck cargo barges such as those employed by the Pac Companies (Pac Companies, no date) to transport large loads of pipe to the Alaskan oil fields, a concept of employing a barge to haul the construction materials was developed. With further study the concept evolved into a flippable barge that married flippable spar technology with that of ocean deck cargo barges. This allowed the barge and cargo once on site to be flipped as a package into the more stabilized vertical operating mode. Then the barge acted as a hotel and work platform from which the majority of construction would be conducted.

As part of the ARPA study, Scripps conducted 1/100 and 1/8 scale model tests of the barge and a small modular section of the platform which consisted of the barge and two stabilized columns that formed a triangular shaped platform. The feasibility of on site construction (Figures 1A and 1B) using the barge as a work platform was amply demonstrated in the 1/8 scale tests constructed at sea off San Diego with typical significant wave heights of 2.5 feet (20 feet full scale). The flippable barge performed even better than anticipated in all evolutions. It confirmed preliminary considerations of its employment as an ocean engineering support platform.

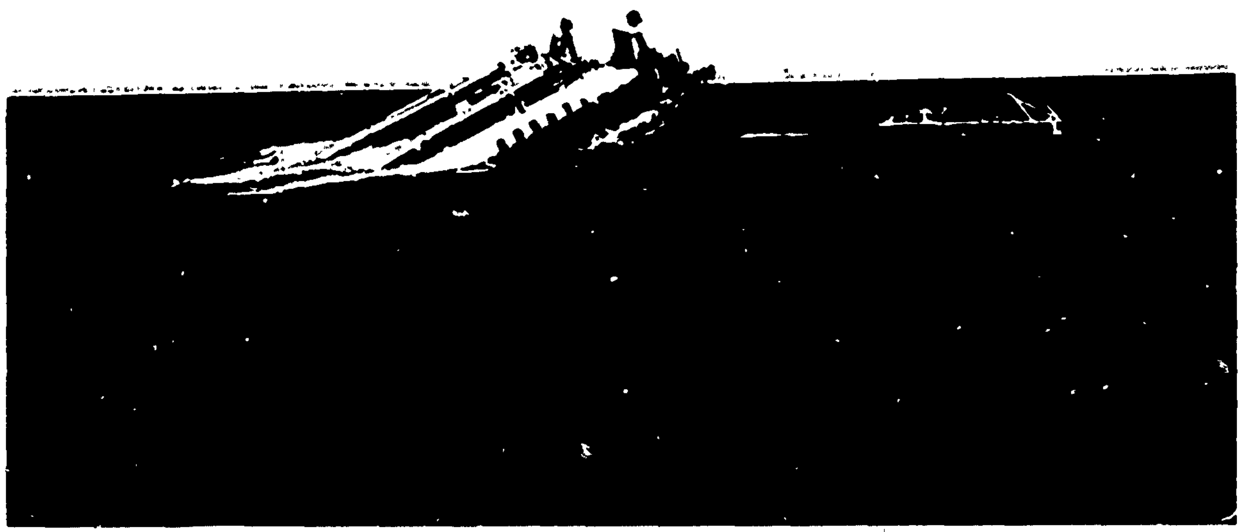


Figure 1A. 1/8 Scale ARPA Flippable Barge, Partially Flipped with Deck Load.

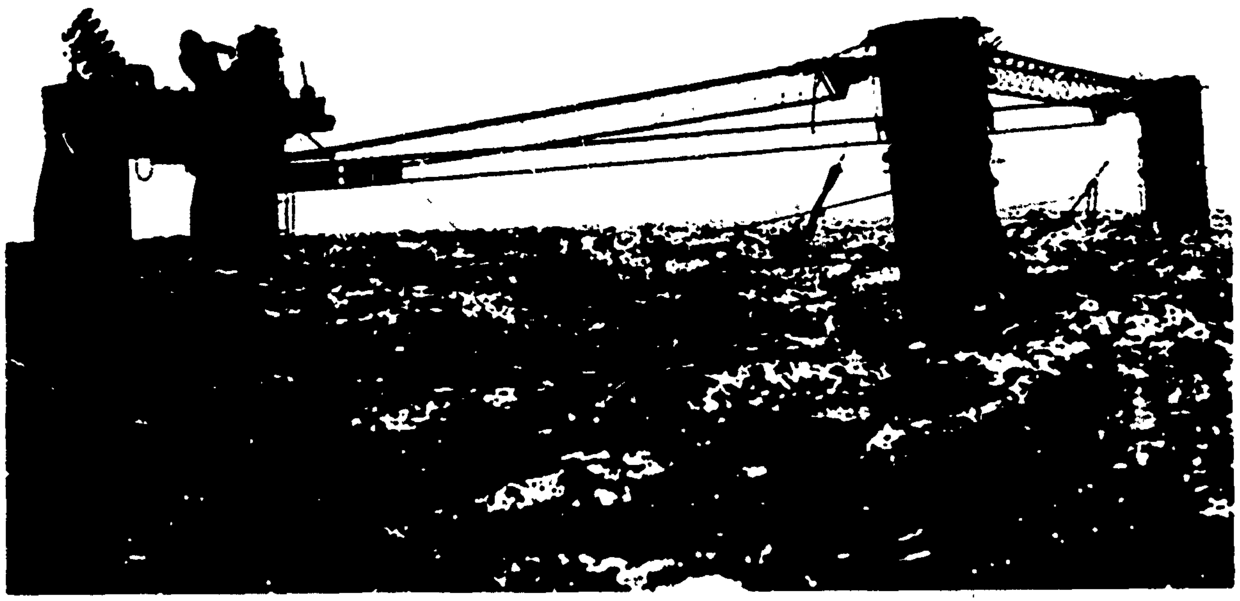


Figure 1B. 1/8 Scale ARPA Large Stable Platform.

Section II of this report presents a general Operational Concept for the flippable barge when employed in ocean engineering support. Subsequent sections of the report and appendices discuss the specific limited contractual areas proposed by Scripps for study and subsequently funded by NAVSHIPS. Areas studied were design configuration options, payload capability, barge response characteristics, mooring and station keeping, costs, and in particular, the preliminary study of a very limited number of potential mission areas. The latter were restricted in scope only because of available funding and consequent time available.

The study project was under the direction of F. N. Spiess, Director of the Marine Physical Laboratory of Scripps Institution of Oceanography. Other principal Scripps contributors have been A. E. May, L. S. Tomooka and D. R. Bellows. Valuable assistance was provided by L. Glosten and D. Laible of the consulting marine architecture and engineering firm of L. R. Glosten and Associates.

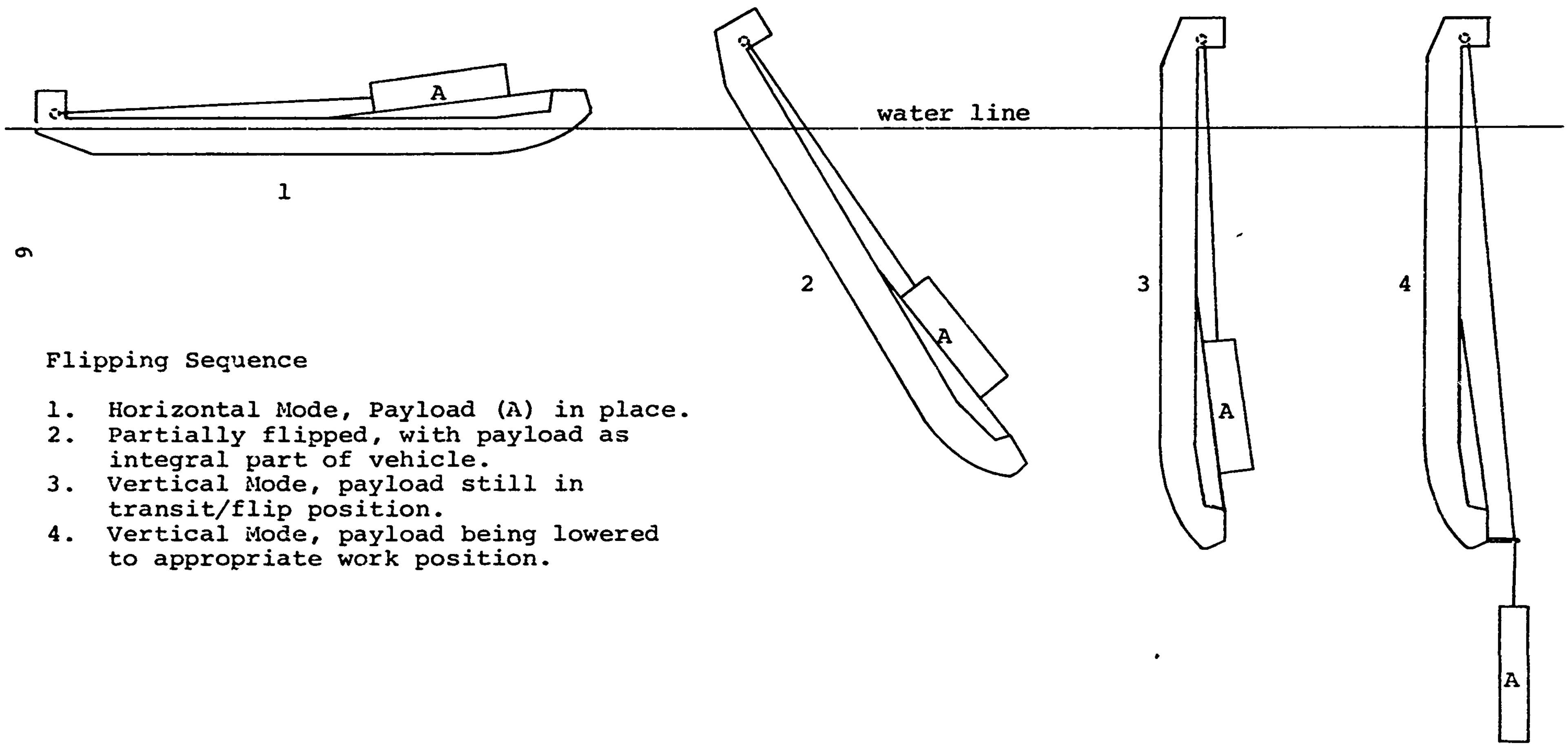
II. OPERATIONAL CONCEPT

Early in the airfield construction studies, it became increasingly apparent that the flippable barge enjoyed capabilities that extended its performance range well beyond that originally conceived. Most notable was the ability to move large, heavy objects through the interface by the flipping action (Figure 2). This avoided the requirement for large cumbersome crane or winch equipment on vessels limited severely by sea state to handle large objects with substantial weight in air. A second important capability is to provide a stable suspension point from which objects can be lowered into the water, tended while operating in the water column or on the bottom, then recovered. Finally, there is the basic barge capability to transport large deck loads to a work area at sea.

These capabilities, singly or in combination, will allow the flippable barge to carry out a number of ocean engineering missions in the ocean engineering area with performance under more severe sea conditions than with other types of craft. The 1/8 scale model large platform tests at sea mentioned above in Section I confirmed the anticipated capabilities of the barge. It performed at sea under conditions more severe than might be found in full scale. The sea spectrum often contained appreciable energy in the 8-10 second wave areas which scale up to the area of computed design heave resonance for full scale (27 seconds). The heave motions experienced near resonance were not severe. The barge further operated as a work platform at times in typical sea state 6 conditions with occasional wave heights during assembly and disassembly as high as forty feet when scaled up to full scale.

The potential tasks are extensive. First are those already performed by FLIP (Spiess, 1968; Bronson, 1969) and similar deep draft vehicles (e.g. Cousteau's Buoy Laboratory in the Mediterranean). The large superstructure and weather deck area in the barge when compared to FLIP will permit a much wider range of similar tasks to be performed. The barge also can perform tasks currently conducted by craft resembling barges such as ORB (operated by Scripps), ELK RIVER and MONAB.

In addition to the established tasks a number of other tasks fall within the broad capabilities of the flippable barge. Tending of submersibles, support of large scale sea floor work systems, large object salvage, support of saturation diving systems, and large area antenna array construction and support are among the missions that are easily within the performance potential of the barge.



Flipping Sequence

1. Horizontal Mode, Payload (A) in place.
2. Partially flipped, with payload as integral part of vehicle.
3. Vertical Mode, payload still in transit/flip position.
4. Vertical Mode, payload being lowered to appropriate work position.

Figure 2. Flipping/Handling Sequence

Support of submersibles has been divided into three primary support tasks with a further "emergency egress" capability. Most smaller submarine operations are drastically limited because of sea states. Operational problems are compounded by the requirement to forecast what recovery conditions may be a number of hours in the future at termination of submerged operations. In many ocean areas this could be a major problem.

Smaller submersibles of the size of TURTLE, DEEP STAR, ALVIN or smaller can be supported using an elevator type landing platform with the barge in the vertical mode. The submarine lands on the elevator platform then is raised to the surface for crew rest and system replenishment. A second method of recovery would be for submarines up to slightly less length than the barge beam width. These would be supported using the flipping capability while taking advantage of the ample dimensions and heave stability of the barge. The submarine would moor on a platform at depth, then would be flipped to the surface for servicing and crew rest. The cradle would be suspended with a gimbal like mechanism to permit the submarine to remain upright during the flipping process. A third type of submerged support would be readily adaptable to any submersible with a top or bottom hatch that could be mated to a pressure proof compartment at some 200 feet depth. Crew are moved to surface areas in a transfer capsule while system replenishment was provided at depth.

The sea floor work mission includes task support for smaller work system packages such as RUM (Remote Underwater Manipulator) (Anderson, et al., 1970), RUWS (Remote Underwater Work System) (Naval Underwater Center, 1970), or CURV III (Cable Controlled Underwater Vehicle) (Talkington, 1974) as well as the support of a large system such as an underwater mining complex. Considering the latter task, one must visualize the machinery package weighing a few hundred tons (up to 1000 tons) in air and of sizeable dimensions. The complex or package is transported to an operating area as deck cargo (Figure 2). It would represent an easy load for a cargo barge even if fairly tall. Once on station the barge is flipped with cargo intact to the vertical, placing the package into the water with its center of mass one to two hundred feet below the surface. At this point although its inertial mass would be somewhat greater than its corresponding in-air weight, its actual net gravitation pull downward would be very much less, and in fact could be made close to zero by providing enough displacement to give a buoyant force close to the in-air weight. The advantages of such a design are readily apparent both for work in the water column and on the bottom. The main winch equipment is designed to handle such a package

The winch and wire system for such a large bottom package is relatively simple compared to that required in a conventional ship which requires supporting the full air weight and is much more sea state limited. It contains an accumulator that compensates for the relatively modest vertical motion experienced. Otherwise, the winch system has only to handle a minimal line tension. This allows it to be designed to provide logistic support (electric or hydraulic power, a fuel of some kind plus remote control telemetry or other support equipment). Resulting reductions in cost and complexity might be the difference between feasibility and non-feasibility of the actual sea floor machinery.

The salvage of a large object may require provision of large forces employed over short distances to make an initial breakout from enclosing bottom sediment. In this situation the barge could provide a short, strong pull of precalculated value. With proper barge design this could be in the order of 10,000 tons although the safe pull for the barge configuration discussed in Section III would be limited to 2000 tons safe pull. The heave response is minimized for such a craft to simplify the problems associated with rigging the cables necessary to connect the barge to the object to be salvaged.

Support of deep diving is another mission with high potential. This requires a mixed gas decompression chamber in the superstructure and a personnel transfer capsule handled by a winch and wire system for transport from the bottom of the barge to the superstructure. An alternative system would be a bottom habitat transported as deck cargo, then flipped through the air-sea interface and placed on the bottom at the operational site.

The large antenna array mission requires a completely different type of support requirement. Instead of massive, the load is fragile. A good way of placing an array of individual antennas in the water is to mount each on an individual slim spar buoy with considerable draft (up to several hundred feet) giving it a stability comparable or better than that of the barge or FLIP. The barge protects them from the forces of the sea in transit. With response characteristics similar to the barge and in close proximity as deck load, they can be flipped to and from vertical without damage. Similarly, the individual pieces can be assembled and withstand sea motions using the barge as a work support craft. Although the ARPA airfield studies concentrated on assembly of large, massive construction pieces (legs and cross struts), the coupling techniques developed and demonstrated in 1/8 scale tests at sea (Spiess, 1974) (Figure 1A and 1B) are equally applicable to this mission. Further, a support mission combining several tasks appears feasible. For example, simultaneous support of a submersible, diving system and "1 atmosphere" work capsule is applicable to commercial petroleum operations.

The flippable barge is designed to operate with a tug or offshore support vessel (e.g. the AGOR 21). In many extended missions the support ship can be diverted to other tasks, returning at termination to tow the flippable barge back to port. This concept is similar to that currently employed in FLIP and ORB operations.

III. DESIGN CONSIDERATIONS

General Design Characteristics

The task and mission concepts could be realized with a wide range of barge dimensions and configurations. The Oceanographer of the Navy has, however, moved to investigate the possibility of including a craft of this type in his ocean science and engineering support ship construction program and thus, with support from U. S. Naval SEA System Command (PMS 383) we have carried out a preliminary study of a particular design with these ends in view.

The work barge configuration used in the ARPA study seemed to be close to what would be desirable in this ocean engineering support context. Its stability in heave is as good as that of FLIP, it can handle a work party of reasonable size (15 crew, 25 work personnel) and can be ballasted to cope with the wide range of payloads which are implied by the variety of possible tasks. This was thus used as a starting point for the study.

The hull form (Figure A-2, Appendix A) relies heavily upon existing barge technology. The general dimensions and shape are similar to typical ocean-going deck loading cargo barges, of which the payload and sea-keeping characteristics (10-12 thousand long tons (LT) up to 25 ft above deck, at 8-10 knots) are well known. This barge is expected to display similar characteristics in the horizontal mode. The design also draws on the technology gained from the manned spar buoy concept of which FLIP (Fisher and Spiess, 1963) is a successful example. Thus, the overall concept can be viewed as a marraige of the two technologies.

The flippable work barge has a short, high forecastle and a well on centerline aft. The forecastle functions as a water ballast tank and is needed for flipping control, as explained below. The well (about 44 ft wide and 90 ft long) is necessary to provide the proper variation of cross section along the vessel's length to give the desired heave response in the vertical mode. Outboard of the well, the hull is formed into columns or legs with square cross section and rounded corners. An after superstructure, 20 ft by 20 ft by 90 ft, connects the legs at the stern, and provides the major shop and living spaces.

The vessel is subdivided by transverse watertight bulkheads, spaced 30 to 40 ft apart. There is also a longitudinal bulkhead on centerline and a lateral watertight flat at half depth, which subdivides each section into four quadrants in order to allow for trim in the vertical mode.

Upon being towed on-station in the horizontal mode, the vessel is flipped to the vertical by gravity flooding the forward compartments. In the usual case, this would require flooding the ballast tanks up to about 150 ft from the bow (except for the center portion of the forecastle tank, which is always void), for a total salt water ballast weight of around 7,000 LT. The longitudinal centerline bulkhead allows for separate control of the port and starboard tanks, thus providing stability and control during the flipping process. In addition, the centerline bulkhead reduces the free surface sloshing effects of the liquid ballast in each tank during flooding. This is also important for stability in the phase where the bow of the vessel is just submerged and the vessel's metacentric height is at its minimum.

In the vertical position, the vessel would normally be ballasted to a 290 ft draft and would maintain a minimum separation between centers of buoyancy and gravity (BG) of 5 ft. The sequence in which the ballast tanks are flooded during the flipping operation is designed for minimum structural stresses and maximum control and stability. The process is reversed for flipping from vertical to horizontal with 250 psi air used as the primary means for expelling the water. The air is stored in eight 7-ft diameter by 42 long cylinders which are charged by two 125 hp compressors rated at 420 ft^3/min each. Thus about 4-1/2 hours is required to fully charge the air bottles once they have been depleted. For missions where it is important to be able to flip from vertical to horizontal at any time, the air battles would be fully charged before the initial flip is made. In flipping from vertical to horizontal the forecastle ballast tank is blown first. This ensures that the vessel flips in the proper direction.

The hull form was selected so as to be the dynamic equivalent of the catamaran configuration shown at the upper left of Figure A-1 in Appendix A. Its characteristics were selected on the basis of considerable experience with FLIP and also with the 1/8 scale catamaran models. In the vertical, the barge has motion stability similar to FLIP. Figure 3 shows the heave response (heave amplitude/wave amplitude) vs wave period. Figures 4 through 10 show response curves for surge and sway at the mass center, surge and sway at the top of the superstructure, pitch, roll and yaw.

The distribution of cross sectional area is chosen as a function of length along the vehicle to give the heave resonance at about 27 second period, well beyond any appreciable energy in the surface wave spectrum (Horrer, 1969). Resonant periods in pitch and roll are much longer, 64 and 57 seconds, respectively.

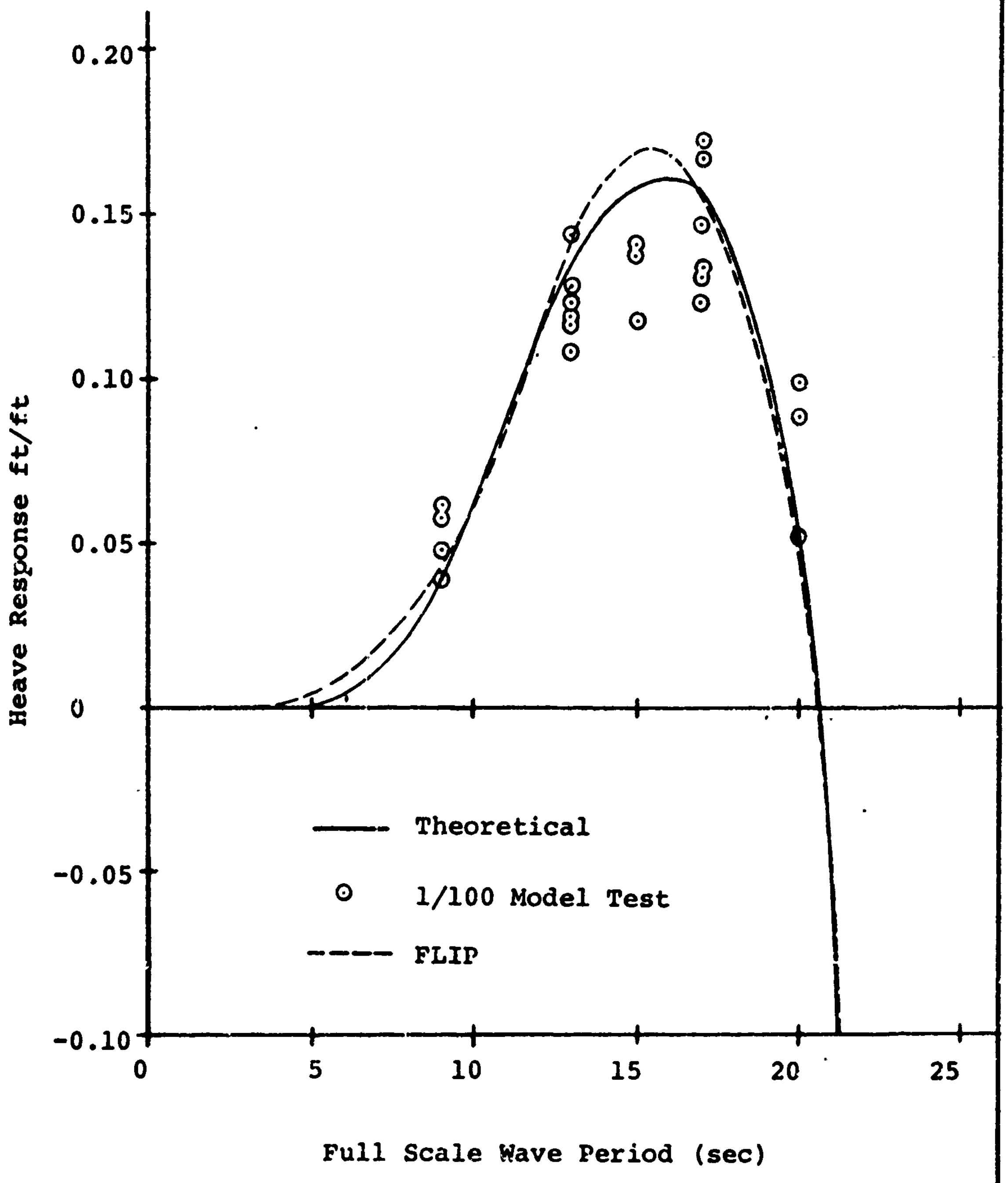


Figure 3. Heave Response of Flippable Work Barge

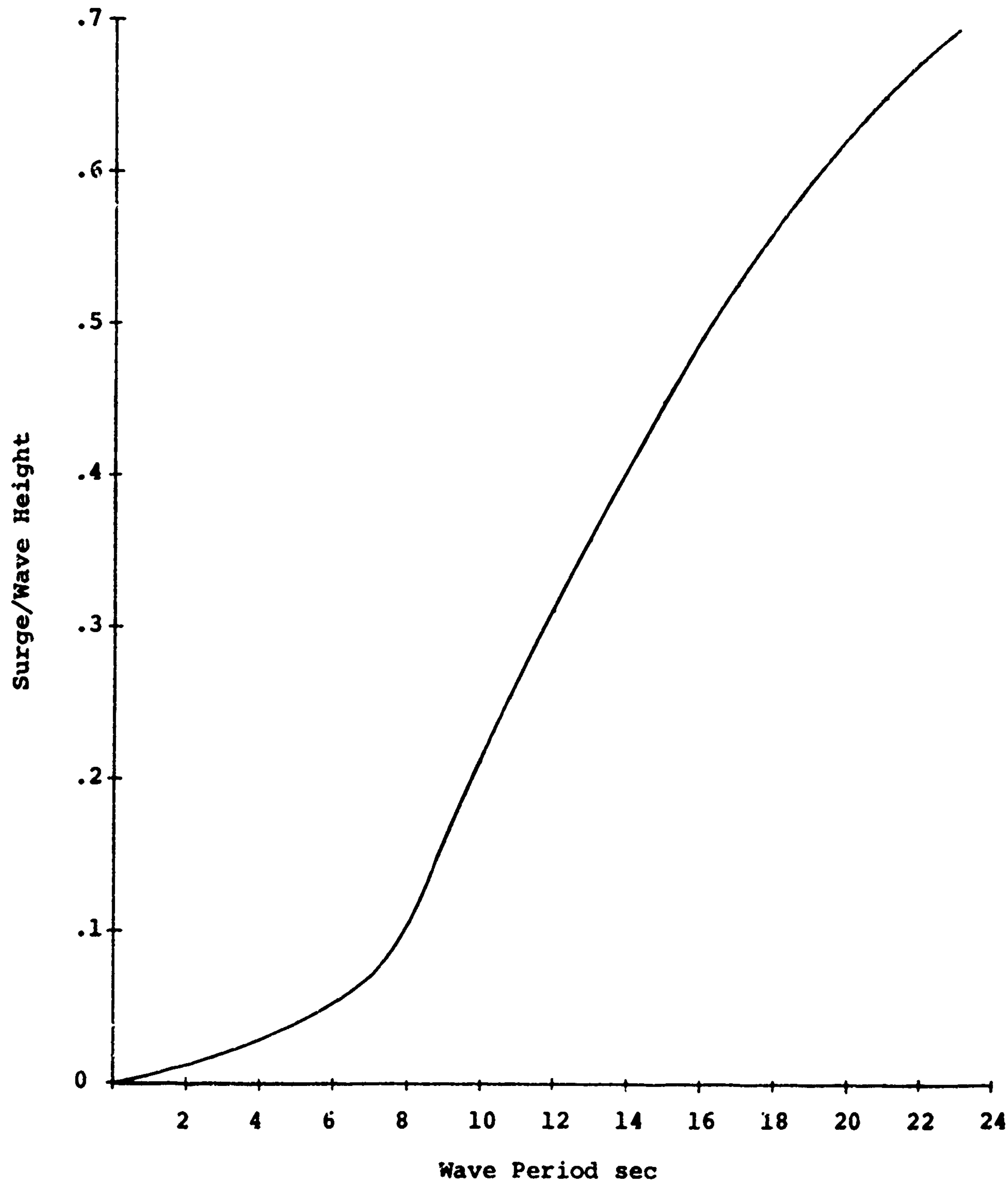


Figure 4. Surge Response at Mass Center for 0° Heading

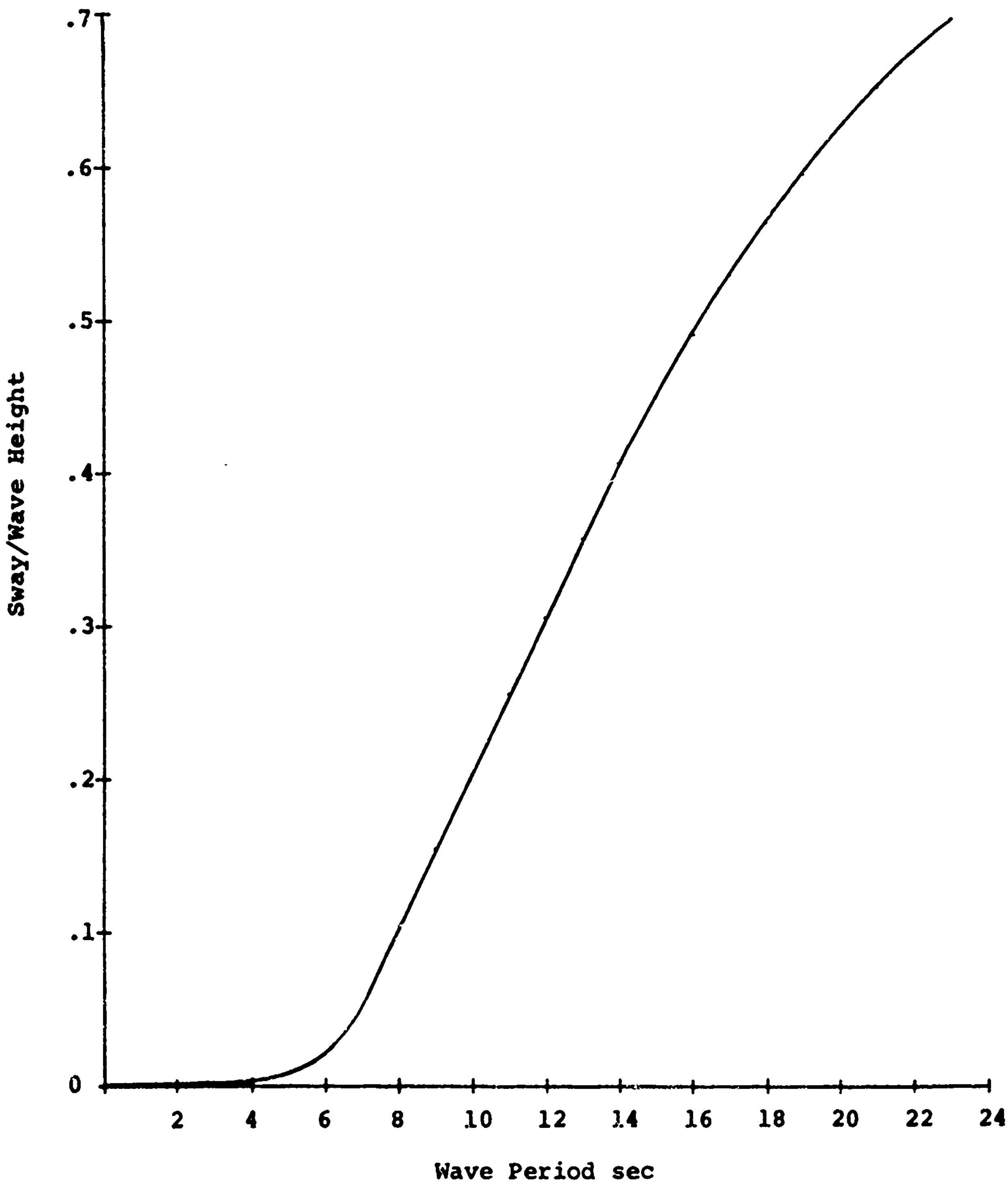


Figure 5. Sway Response at Mass Center for 90° Heading

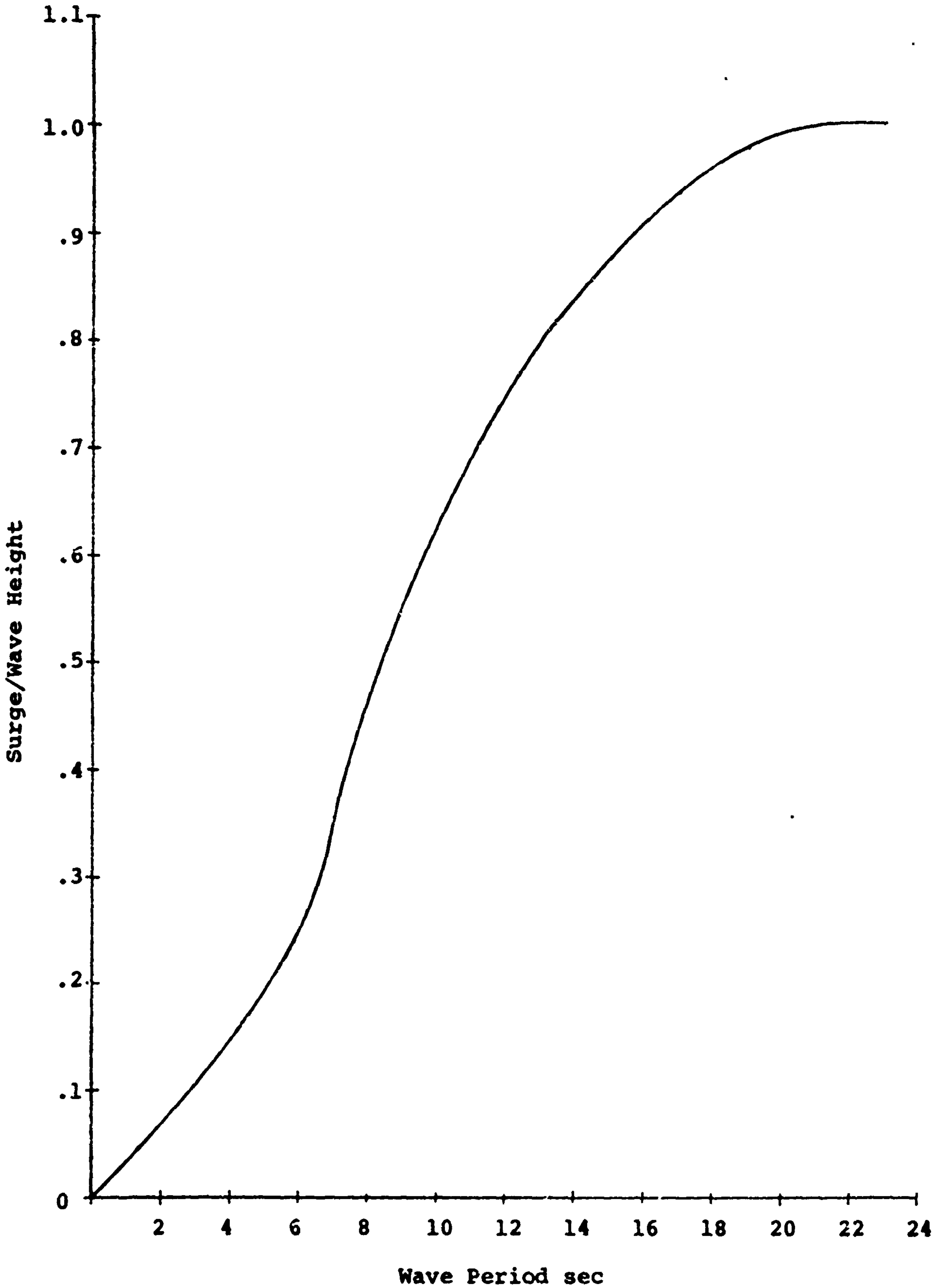


Figure 6. Response at Top of Platform Due to Surge and Pitch for 0° Heading

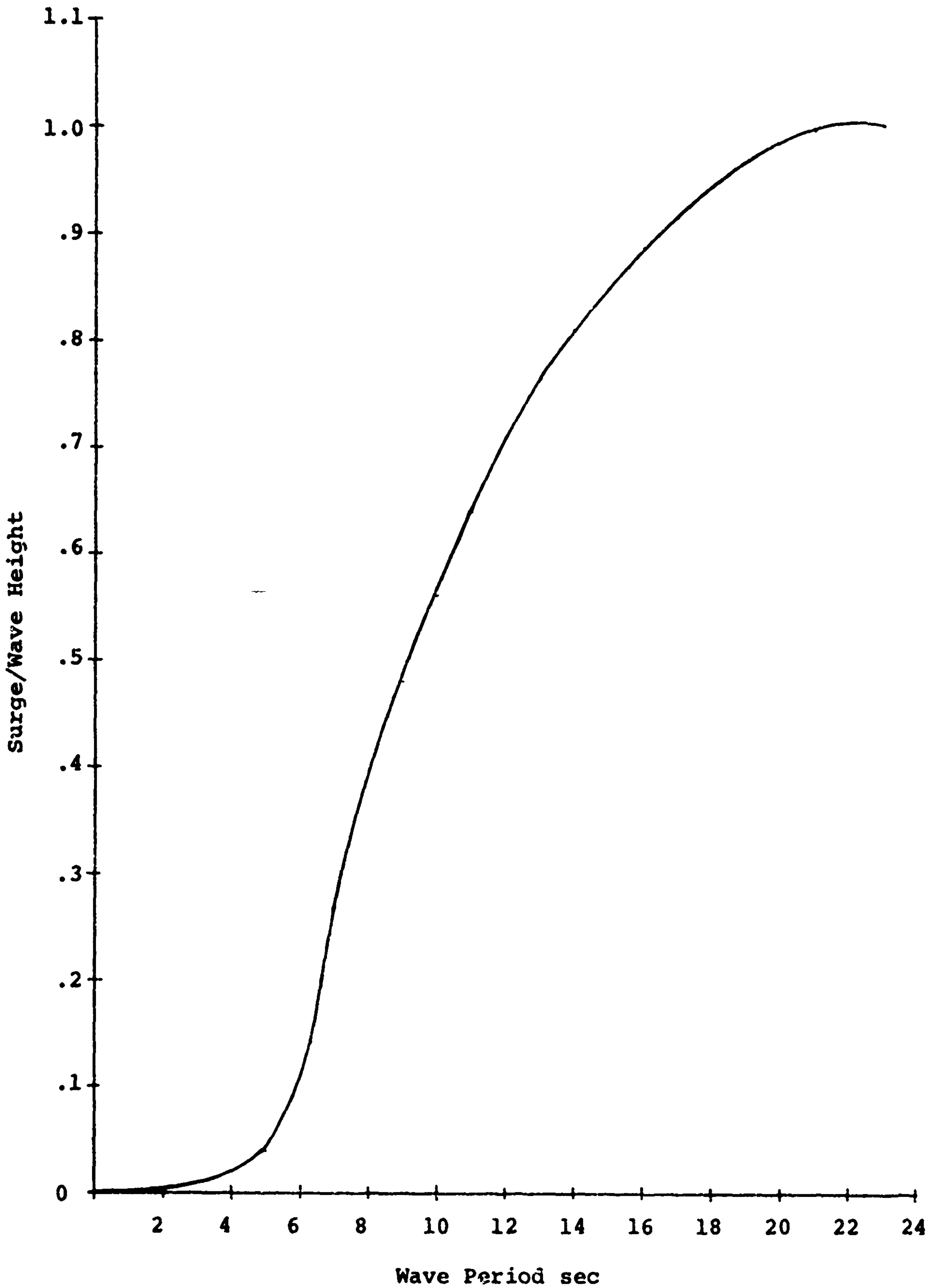


Figure 7. Response at Top of Platform Due to Sway and Roll for 90° Heading

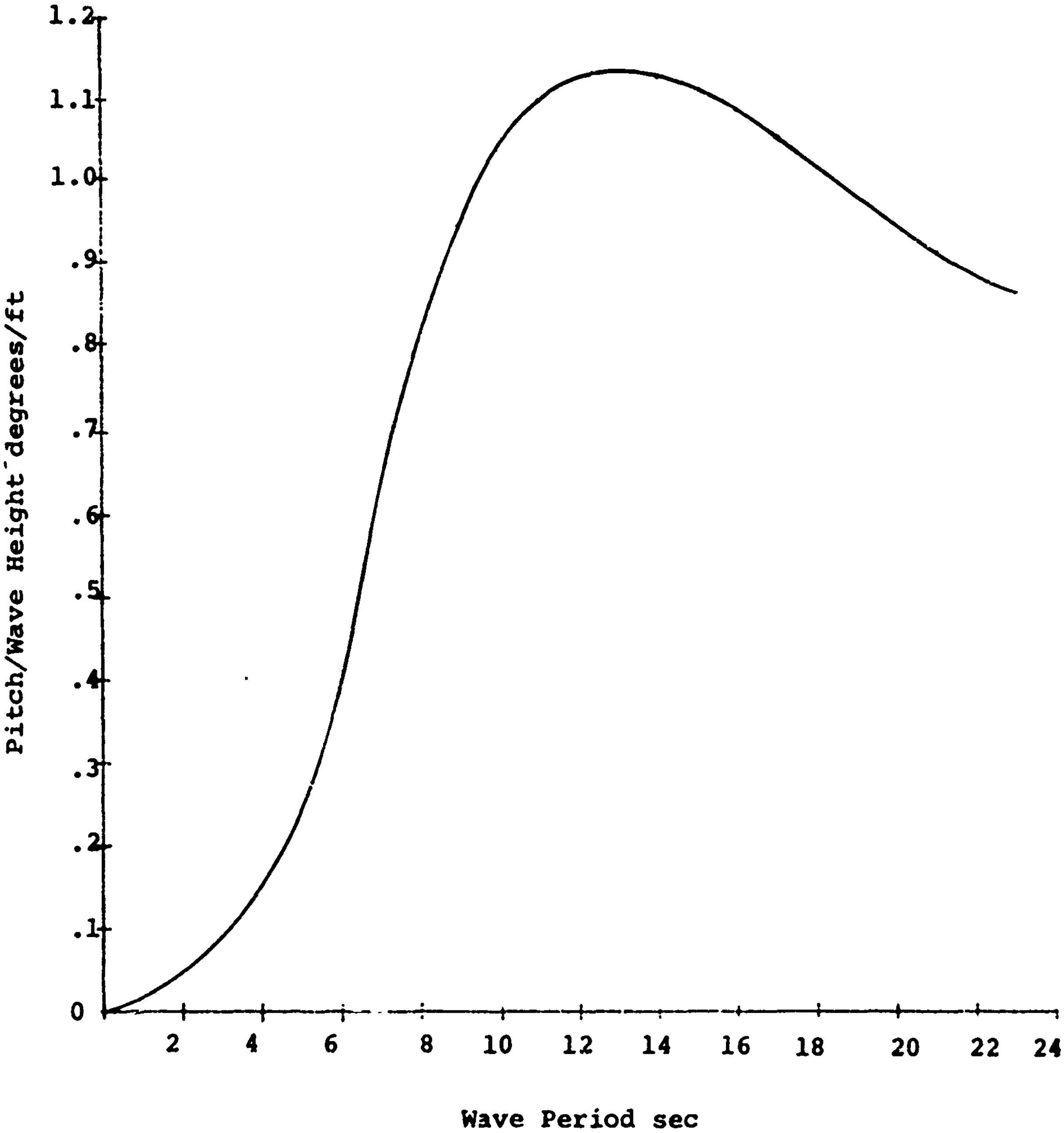


Figure 8. Pitch Response Degrees/Ft Wave Height for 0° Heading

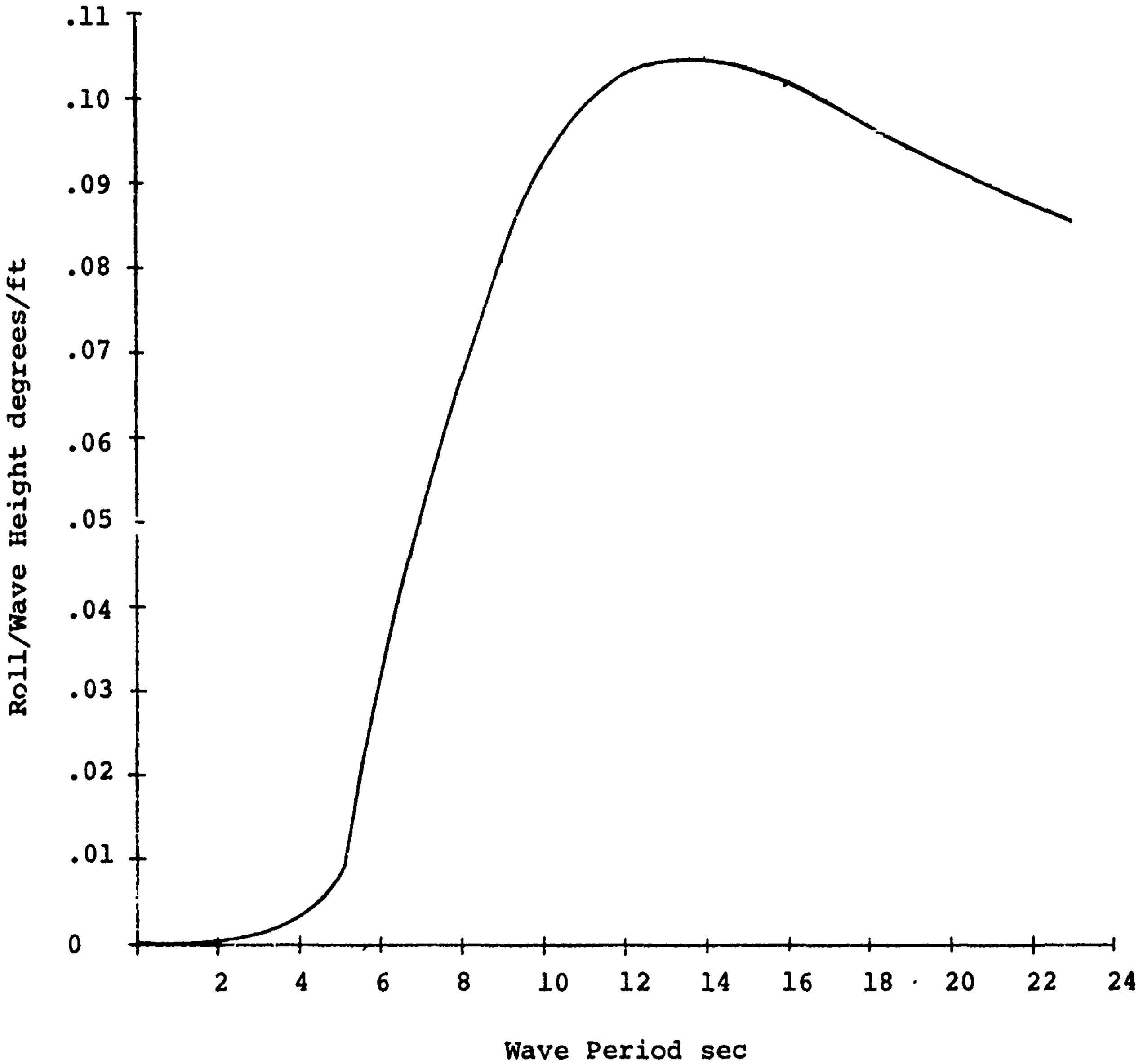


Figure 9. Roll Response Degrees/Ft Wave Height for 90° Heading

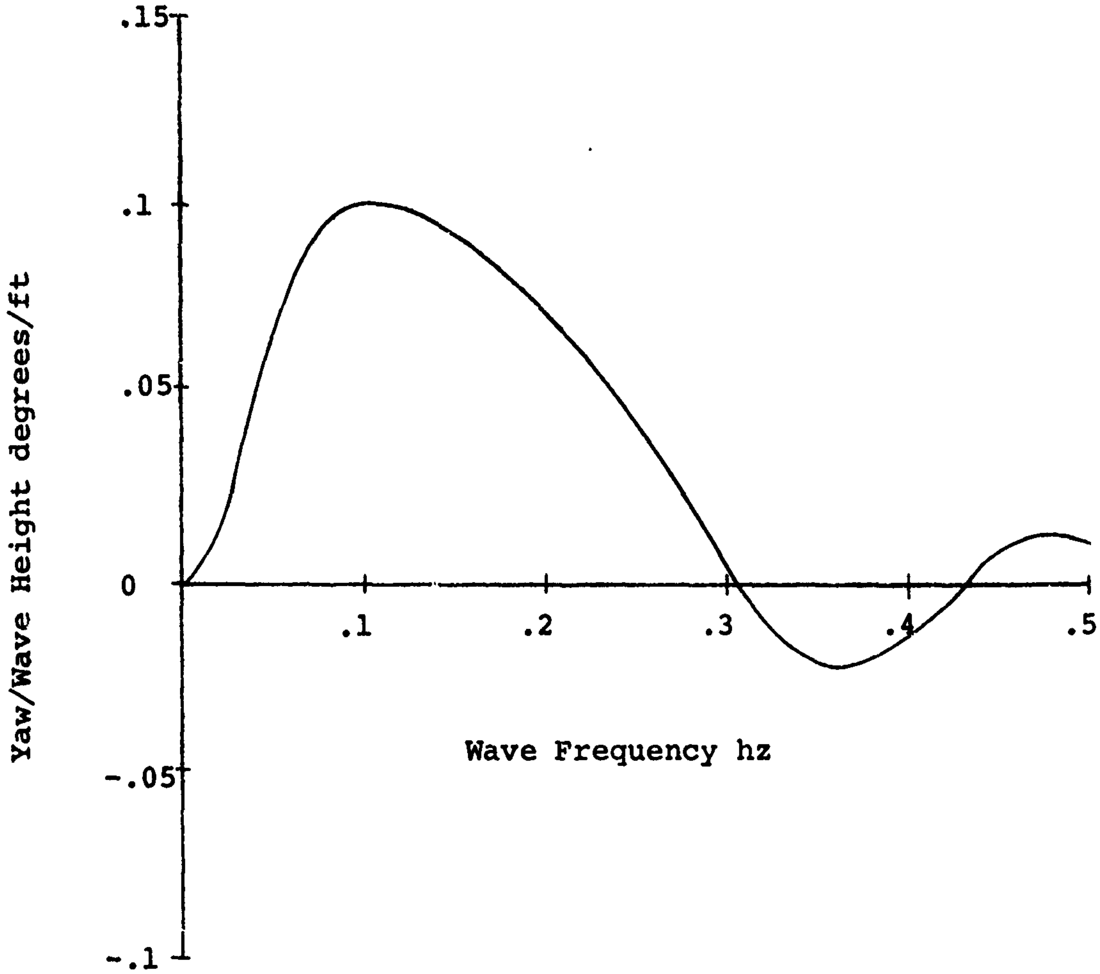


Figure 10. Yaw Response for 54° Heading

The design formulation used, for example by Rudnick (1965) or Spiess (1968), has now been well verified by application to spar buoys ranging in draft from 3 to 300 ft with measurements made in both regular waves in tanks (Bellows, 1973) and in the real seaway (Rudnick, 1967) with a wide range of frequencies and directions present simultaneously. In this approximation the drag forces are neglected and the driving waves are assumed to be infinitesimally small. The principal regions of lack of agreement are those in the vicinity of resonances. In some of our work with small models in relatively large waves the resulting non-linear effects grow in importance, resulting, for example, in feeding energy into the heave resonant frequency band from the region at double that frequency. On the other hand, work at sea with large models seems to indicate that response to energy at the resonant period is not severe.

Figure 11 shows the wave energy spectrum off the Coronado Strand in San Diego, California, during 1/8 scale model tests of a large triangular platform, of which the flippable barge model was an integral part. There is a significant amount of wave energy at 10 second period, which is the resonant period of the platform. Therefore, it can be considered a valid test of the model's response at and around resonance. Figure 12 shows the model's heave response for the same test. The test data point of interest is the one at resonance, where the maximum response of 2.7 is far less than would be calculated from theoretical considerations with no damping -- again an indication of non-linear effects taking over to produce increased damping with increased amplitude of motion.

In order to study the problem analytically the IBM Continuous System Modeling Program (Bellows, 1973) was used to simulate the model's heave response. In this model a square-law drag term was used, with drag coefficients of .34, 1.0 and .71 for the transition cone (shoulder), bottom of legs and crosstube, respectively (Snyder, 1965). Also, the model's vertical displacement was included in the variation of wave pressure along the leg axis. That is, the wave pressure was proportional to $e^{k(Z + z)}$, where k is the wave number, Z is the depth from still water level to the element of the model being considered, and z is the vertical displacement of the model. In the Rudnick and Spiess models this term is approximated as e^{kZ}, since z is small relative to Z in general.

The results of the CSMP study are shown in Figure 13. The figure was obtained by running the program many times with closely spaced wave periods. Again we see that at resonance the model's response is relatively large, but limited, the peak response being about 5.0. It should be noted that the secondary

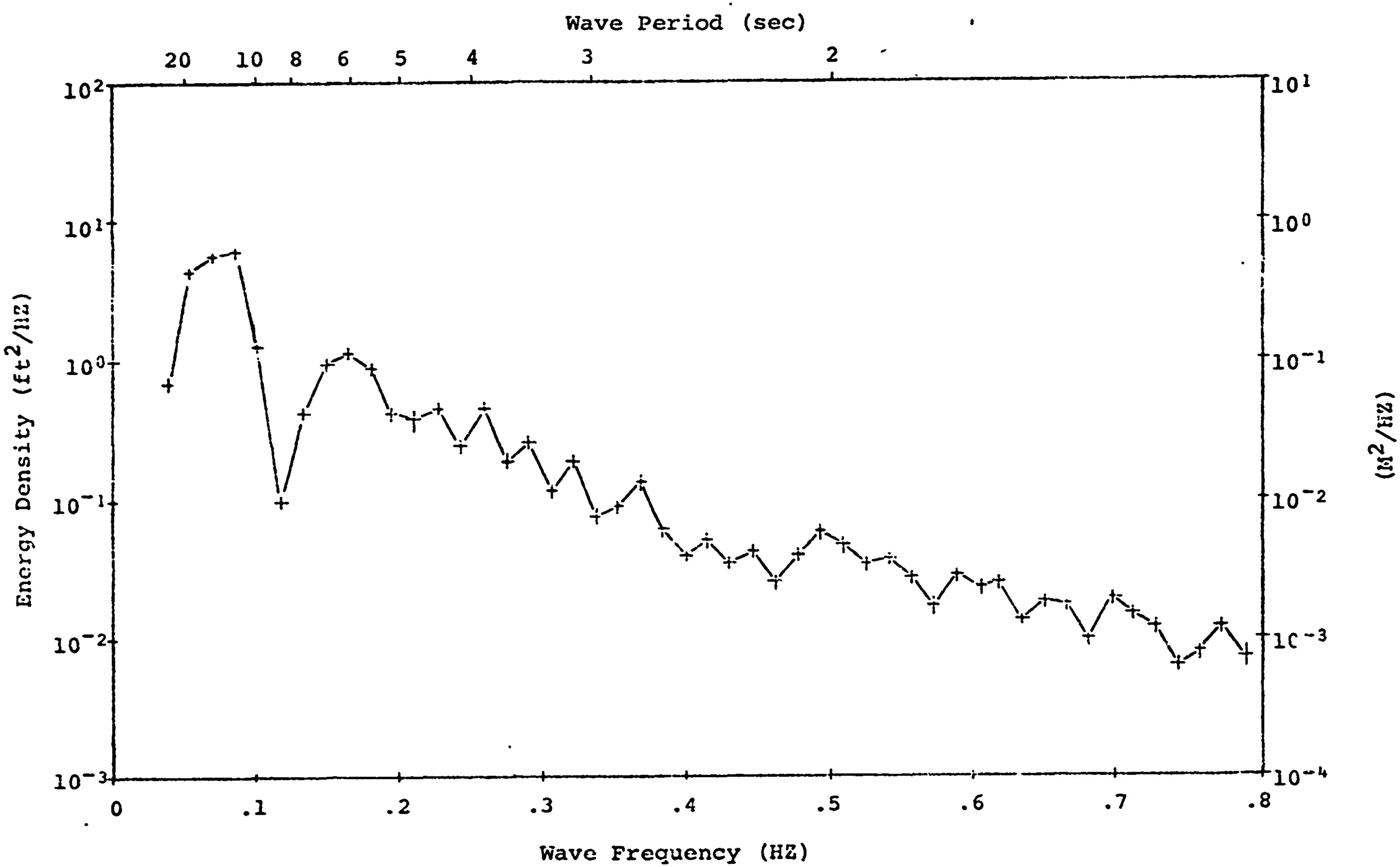


Figure 11. Wave Spectrum During Triangular Platform Test

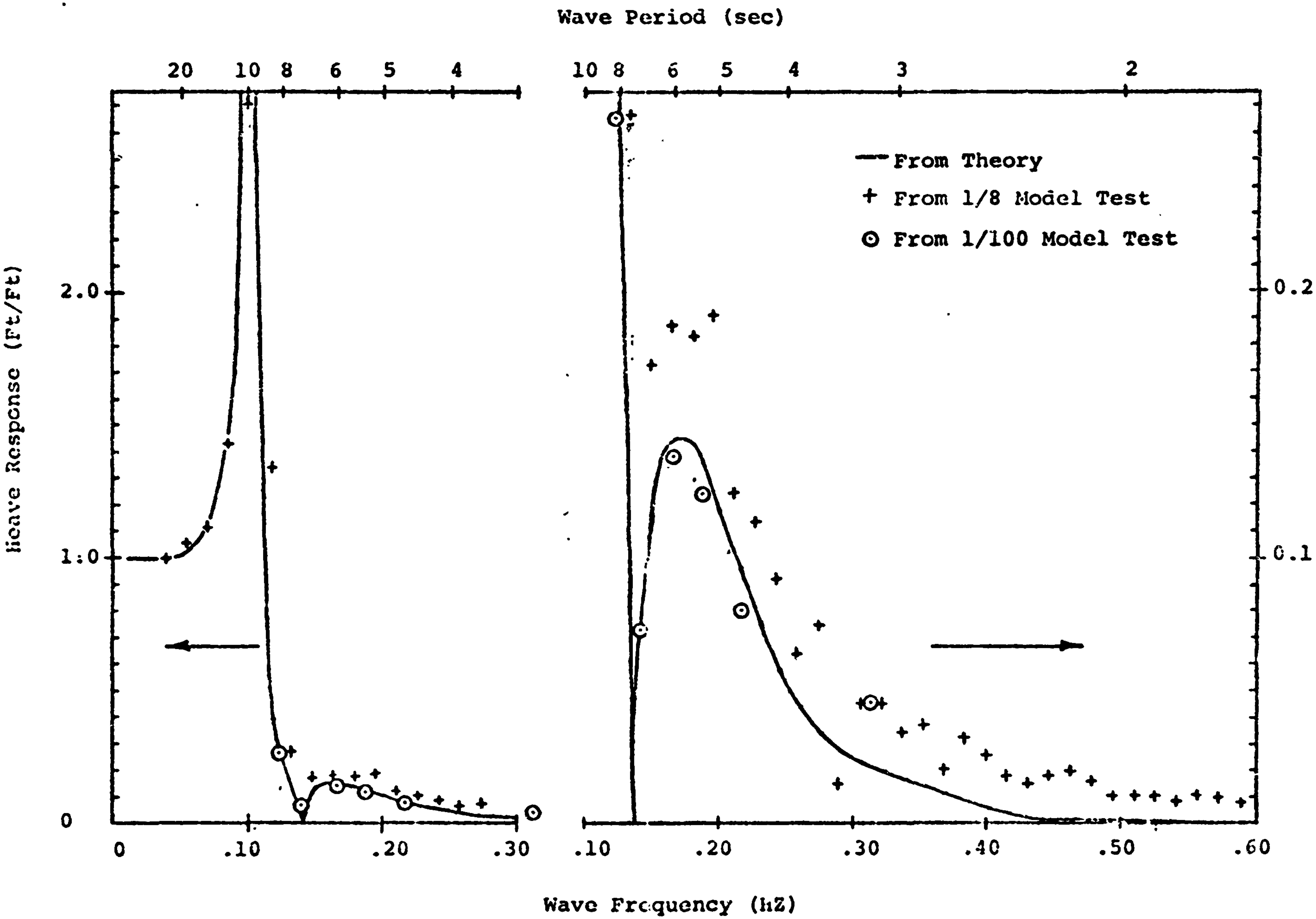


Figure 12. Heave Response of Triangular Platform

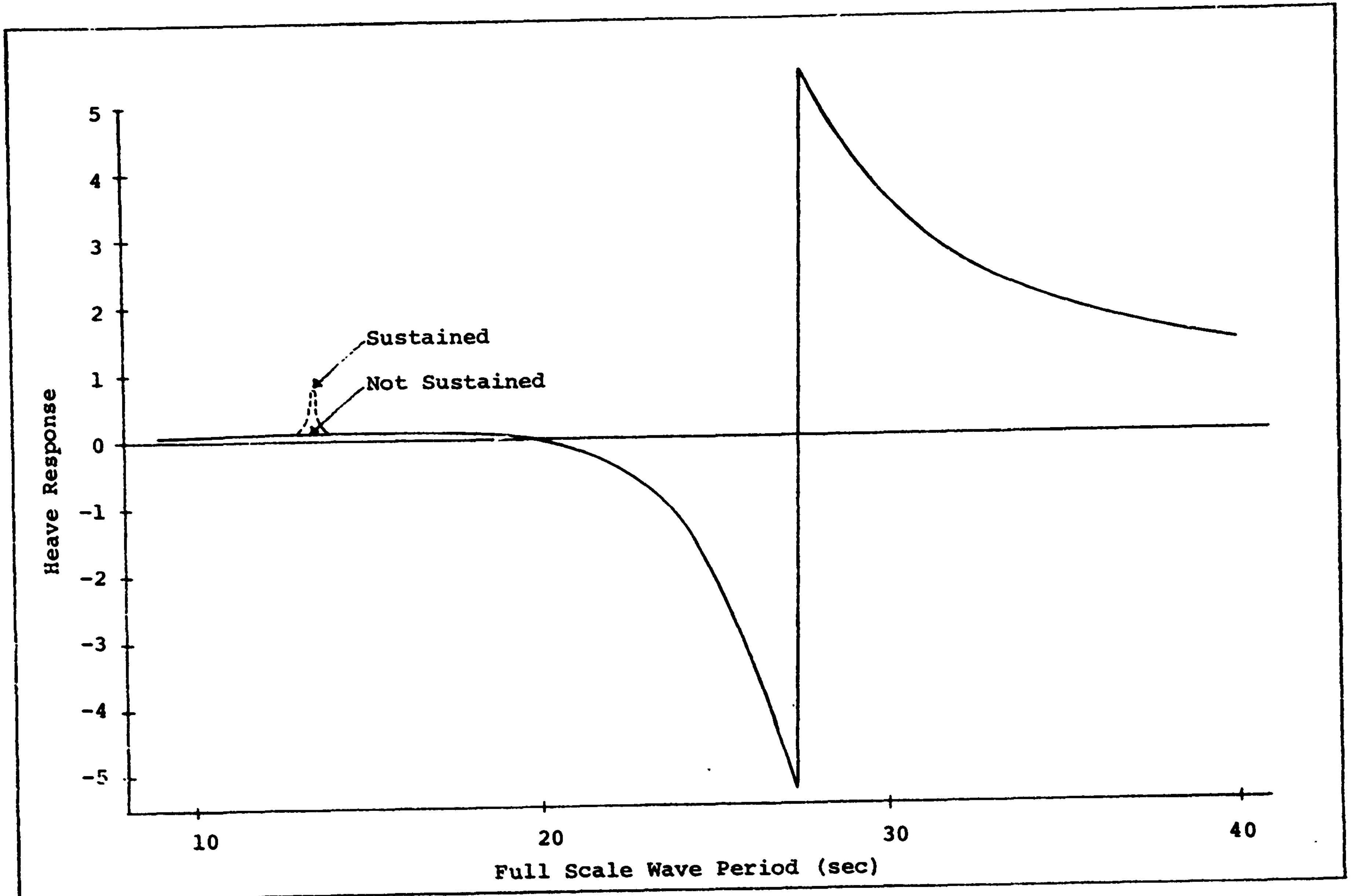


Figure 13. Heave Response of Flippable Barge as Modeled by CSMP

peak at 13.5 second period represents a model heave at 27 second period when driven at a wave period of 13.5 seconds for 10 minutes or longer. This supports earlier analytical work done by Corell and reported by Bellows (1973) which showed resonant motions at half-resonant wave periods. The low level response and long build-up time, however, indicate that the energy transfer from half-resonant to resonant periods is very weak, especially when damping is present. Probably because of the weak coupling, no evidence of this phenomenon has been found in 1/8 scale model testing.

It may thus be that the conservatism in the design of the flippable barge, in which the resonant period was chosen at 27 seconds (well beyond the 18 to 20 second period which is the longest associated with appreciable energy in the worst seaway), is not truly necessary. For example, it may well be that the after centerline well can be reduced in width or the length of the ship decreased while still maintaining sufficient stability. This is further discussed in the section on Alternate Configurations. Other modifications could include alterations to the shape of the well or forecastle to beneficially affect the damping factor and near-resonance response. It is therefore recommended that further analytical and experimental work be funded to study these aspects, since they could allow large cost savings at little or no expense to performance.

Alternate Configurations

From the results of the near-resonance studies conducted, it appears that the conservatism in the barge design, in which the resonant period was chosen at 27 seconds (well beyond the 18 to 20 second period which is the longest associated with appreciable energy in the worst seaway), may not be truly necessary. Therefore, two alternate designs were briefly studied, one having a reduced shoulder area (design A), and one with no shoulder at all (design B). For comparative purposes, dimensions of both alternate designs were selected so that they had the same displacement and same effective bottom depth as the original (baseline) design. Dimensions and characteristics of the three designs are given in Table I below and Figures 14 and 15.

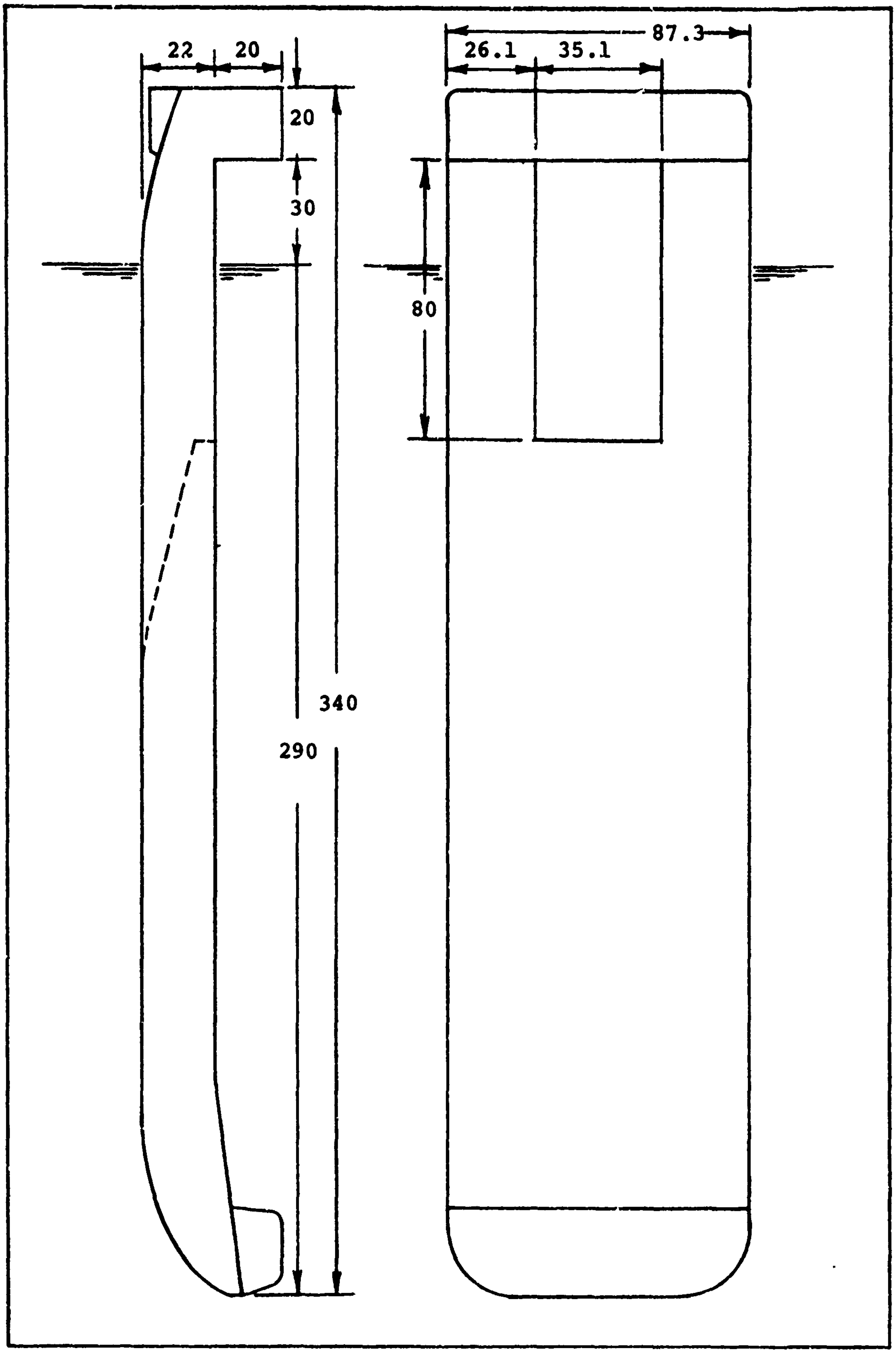


Figure 14. Alternate Design A Dimensions in Feet

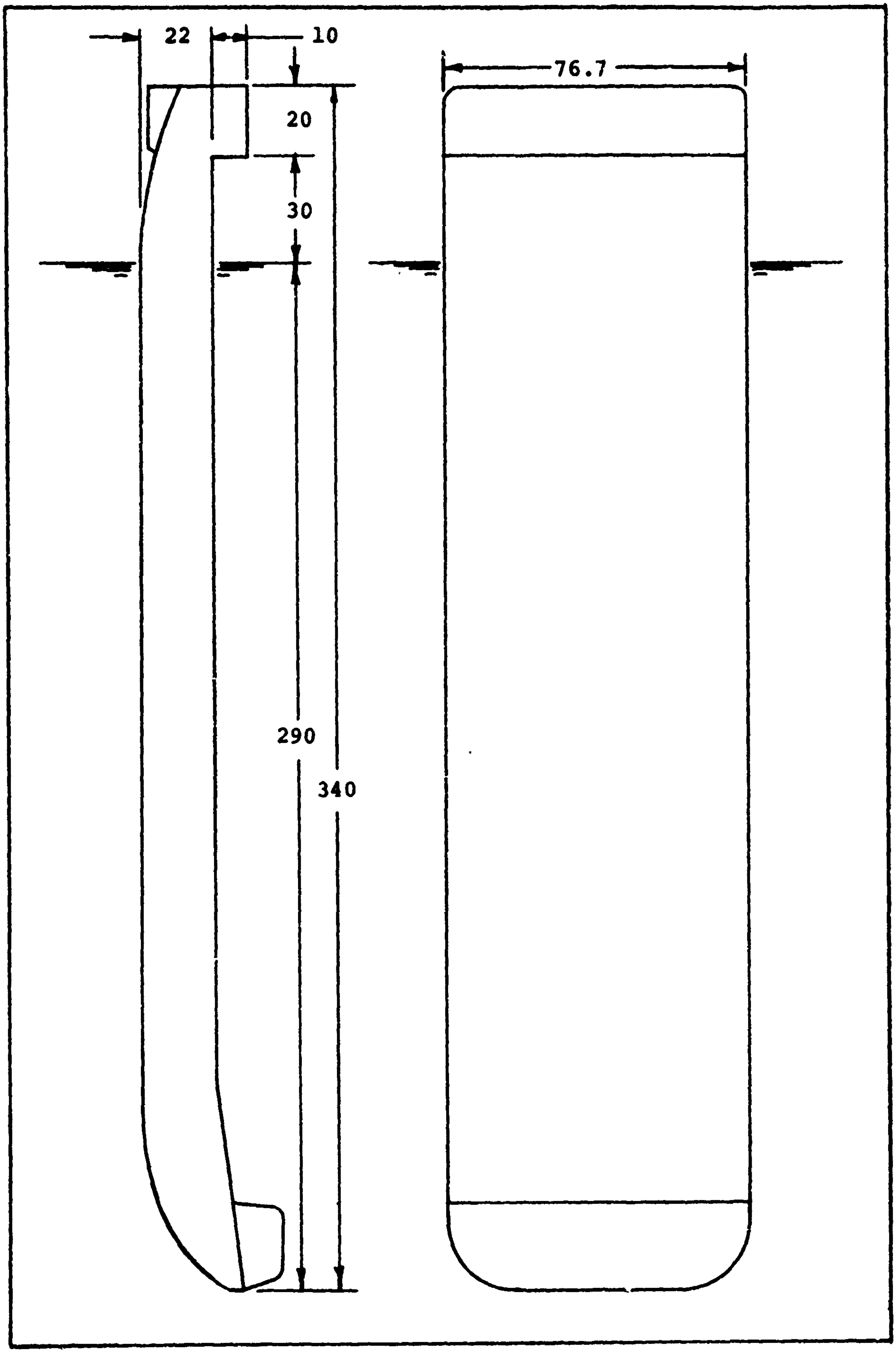


Figure 15. Alternate Design B Dimensions in Feet

TABLE I

Alternate Configuration Dimensions

	Baseline	Alt. A	Alt. B
Displacement (LT)	13,750	13,750	13,750
Draft	280'	280'	280'
Depth to shoulder	80'	80'	-
Beam	90'	87.3'	76.7'
Width	22'	22'	22'
Area at waterline	917.6 ft^2	1061.3 ft^2	1630 ft^2
Area at bottom	1915.4 ft^2	1857.4 ft^2	1630 ft^2
Resonant period (sec)	26.0	24.2	19.5
Null period (sec)	20.5	18.2	-

Heave response curves for the three configurations are shown in Figure 16. The heave response for the baseline has a maximum value below resonance of almost 16 percent at a 16-second wave period. It is zero at the null period of 20.5 seconds, and reaches resonance at 26 second wave periods.

Decreasing the shoulder area for alternative design A has three effects, which can be seen in its heave response curve. In order to decrease the shoulder area while maintaining constant displacement and draft, the waterplane area was increased and the area at the bottom was decreased. This increased the ratio of waterplane area to displacement, which lowers the resonant period to 24.2 seconds. This also decreased the ratio of shoulder area to bottom area, so that the null period is lowered to 18.2 seconds. Third, since at short period the barge is primarily driven by wave pressure forces acting on the shoulder area, the peak response below resonance is decreased to about 10 percent. Thus over the greater part of the normal sea spectrum design A has a better response than the baseline, but at the expense of allowing the possibility of being excited to resonance.

Design B has no shoulder and therefore has no null period. Its resonant period depends only on the draft, and to a lesser extent, the displacement of the bottom crosstube (forecastle). In order to have a resonant period comparable to the baseline designs, it would need a draft of about 550 ft. At a 280 ft draft, the resonant period is 19.5 seconds, which can lie within the range of appreciable energy in the seaway. However, because design B can only be driven by wave pressure on the bottom surface, its response to short period waves is much better than the

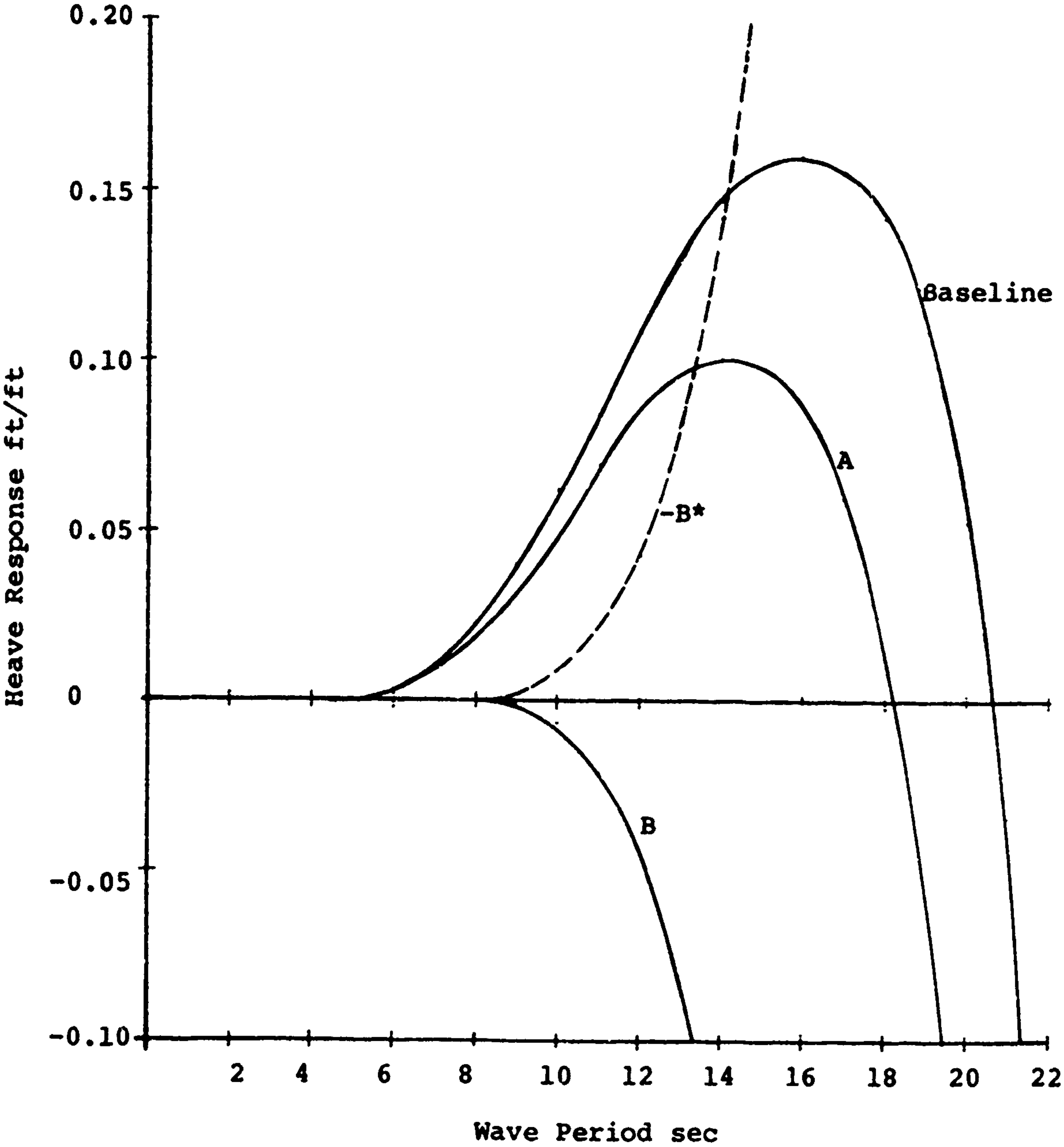


Figure 16. Heave Response for Alternate Barge Configurations
*(the negative of heave response for configuration B is plotted for comparative purposes)

baseline or design A. In Figure 16, the negative of the response curve for design B is plotted for comparative purposes. Its heave response is better than the baseline's for wave periods shorter than 14 seconds, and is better than design A's response for wave periods below 13 seconds. If, as possibly indicated by the near-resonance studies, the vessel's resonant response can be limited to reasonable magnitudes, or if the vessel will be operated solely in regions, such as the Mediterranean, where waves are predominantly of short period (Spiess, 1968), then design B could be superior to the others.

The baseline and design A are similar structurally, but the increased area in the upper portion of design A may allow lighter construction, since longitudinal strength is the controlling structural design criterion. Design B, being about 17% narrower in beam and structurally simpler, would be expected to represent a significant decrease in weight and cost.

Detailed weight and moment studies were not carried out on the alternative designs, so payload capacities could not be calculated, but some qualitative assessments can be made. Design A and B have more displacement closer to the waterline than the baseline, so the center of buoyancy will be higher. However, the ballast tank capacities are decreased, so that the center of gravity would also rise. The overall effect on superstructure payload is difficult to assess without quantitative data, but will probably be small. Since design B has a lower light ship weight than the others, the weight savings would be split between additional solid ballast, water ballast and payload. Therefore, design B would require more salt water ballast tank capacity. Since the displacements of all three designs are equal, this means that design B has less volume below the waterline available for engine rooms, laboratories, etc. On the other hand, there is more space available above the waterline, due to the greater waterplane area of design B.

In general, arrangements will be simpler, since the problem of cross connections between the legs through the superstructure has been eliminated. Piping systems, electrical systems, ventilation, and air conditioning systems will all be simpler, lighter, and less expensive for design B. Additionally tankage arrangements for fuel and fresh water and the associated pumping requirements will be improved.

The availability of some below-decks space near the stern of the vessel enables the overhang of the superstructure to be reduced from 20 feet to 10 feet on design B. This will allow for easier operations over the side in the vertical condition and will allow for more compact arrangement of laboratories and control spaces, with better outside access. This also allows payloads to be mounted further away from the main deck.

The deck area on design B is now equivalent to a barge of the same dimensions. Thus in the horizontal, there is more deck area available and more flexibility in the use of the deck area. The opportunity to use the space between the legs in the baseline design for work in the sea when the vessel is in the horizontal has been forgone in design B.

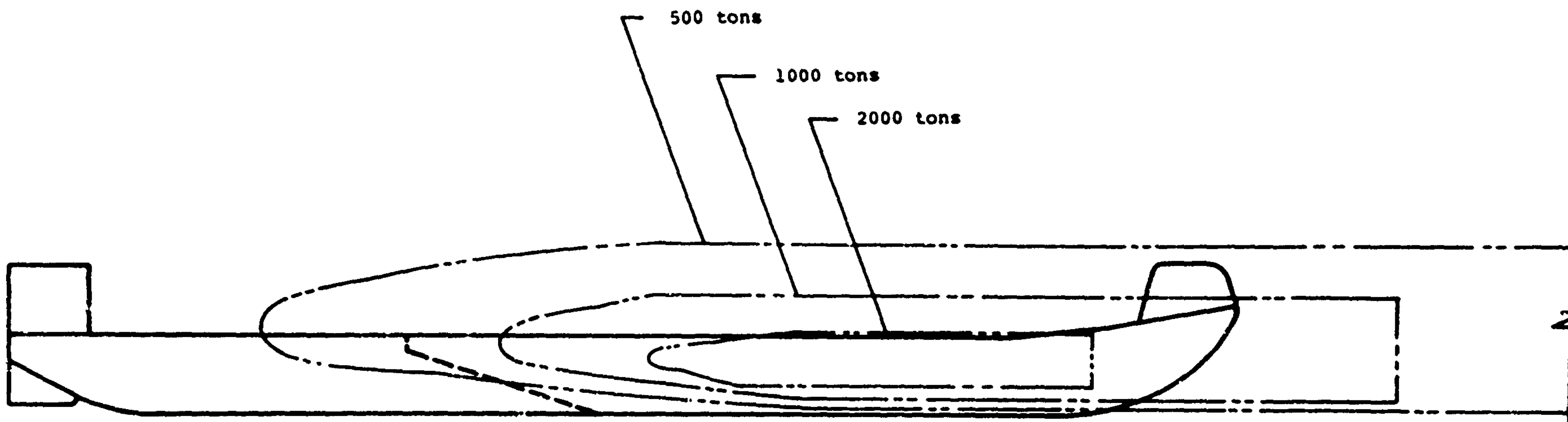
During the flipping operation, designs A and B expose a larger water plane and more sail area to wind and sea. Consequently, added difficulty in controlling the flipping operation due to the action of wind, waves, and currents may be experienced. Also, since greater quantities of water ballast will be required, larger compressors or longer ballasting and deballasting times will be required.

In general, designs A and B offer somewhat lower cost, a possibility of increased payload, more room for machinery and hotel facilities, and better motion responses in the short period wave regime, at the expense of worse responses at long periods and the possibility of resonant excitation.

Payload

Defining the payload capacity of the work barge is a complex thing, involving a large number of parameters, such as the amount and distribution of payload, the amount and distribution of its buoyancy, and the amount of solid ballast used, as well as the weight, center of gravity, center of buoyancy and tank shapes and dimensions of the barge itself. Further complicating the question are qualitative parameters used to describe the limits of the payload envelope.

To simplify the calculation and presentation of payload capabilities, the payload is considered to consist of two parts: the superstructure payload, which has its center of gravity located at the center of the superstructure; and the submerged payload, which comprises the remainder. In the vertical mode only the in-water weight of the submerged payload need be considered as long as the load is reasonably compact. In the horizontal mode, the weight in air is used. The payload envelope for a given amount of superstructure payload can then be presented as the range of allowable locations of the submerged payload. Figure 17 shows several examples of payload envelopes using the configuration of Figure A-2, Appendix A. One such envelope can be drawn for each combination of superstructure and submerged payload. The limits are based on the requirement that liquid ballast can be shifted to give a center of buoyancy-center of gravity spacing of at least 5 ft with the vehicle vertical and that the ship can be flipped from vertical to horizontal by blowing the bottom-most ballast tanks dry.



Allowable Locations for Submerged Payloads
of 500, 1000, and 2000 tons (weight in water)
Superstructure Payload = 100 tons

Figure 17.

The presentation can be further simplified by calculating only the minimum and maximum allowable VCG and LCG, corresponding to the vertical and horizontal extremes of the envelopes in Figure 17. Then, with the VCG (or LCG) plotted against submerged payload, two families of curves, with superstructure payload as a parameter, can be drawn, one showing the allowable range of VCG and the other the allowable range of LCG (Figures 18 and 19).

The maximum payload capability with the barge horizontal is a total of 4,350 tons (in air) with center of gravity at LCG = 143 ft, which puts the combined center of gravity at the horizontal center of buoyancy. As the center of gravity of the payload moves away from this point, liquid ballast must be taken on to reach zero trim, so the payload capacity must drop accordingly. This payload number is based on maintaining, in addition to zero trim, a draft of no greater than 17 ft (5 ft freeboard).

The above calculations were made based on use of 2,100 tons (in air) of 175 lbs/ft^3 density concrete evenly distributed along the keel between the 30 and 160 ft points (Figure A-2, Appendix A). The craft could actually be designed with only 700 tons of ballast. This would allow larger payloads in both horizontal and vertical modes, but would drastically restrict the allowable locations, particularly when modest superstructure loads were desired with no submerged payload. Since most missions visualized emphasize the stability of the craft rather than extremely large payload size, the range described above was chosen.

Preliminary Fitting Out and Arrangements

A basic fitting out package has been formulated that generally will be applicable to any of the hull design configurations that have been examined above. The package contained in Appendix A is predicated on the 340 foot length barge hull with trunks and well like configuration shown in Figure A-2, Appendix A.

A prime consideration in this study was to keep the design of the craft simple and to create a housekeeping and mission oriented fitting out package that would allow the barge to perform many ocean engineering tasks that are similar to or extensions of those now performed by FLIP and ORB (or other similar craft). Addition of special mission oriented equipment and structure could be included in the initial package to perform one of the major missions delineated in Section II above. This approach was successfully followed in the design of MELVILLE and KNORR (AGOR 14 and 15). Additionally, space is allotted for equipment for the other known potential missions to be performed by the craft.

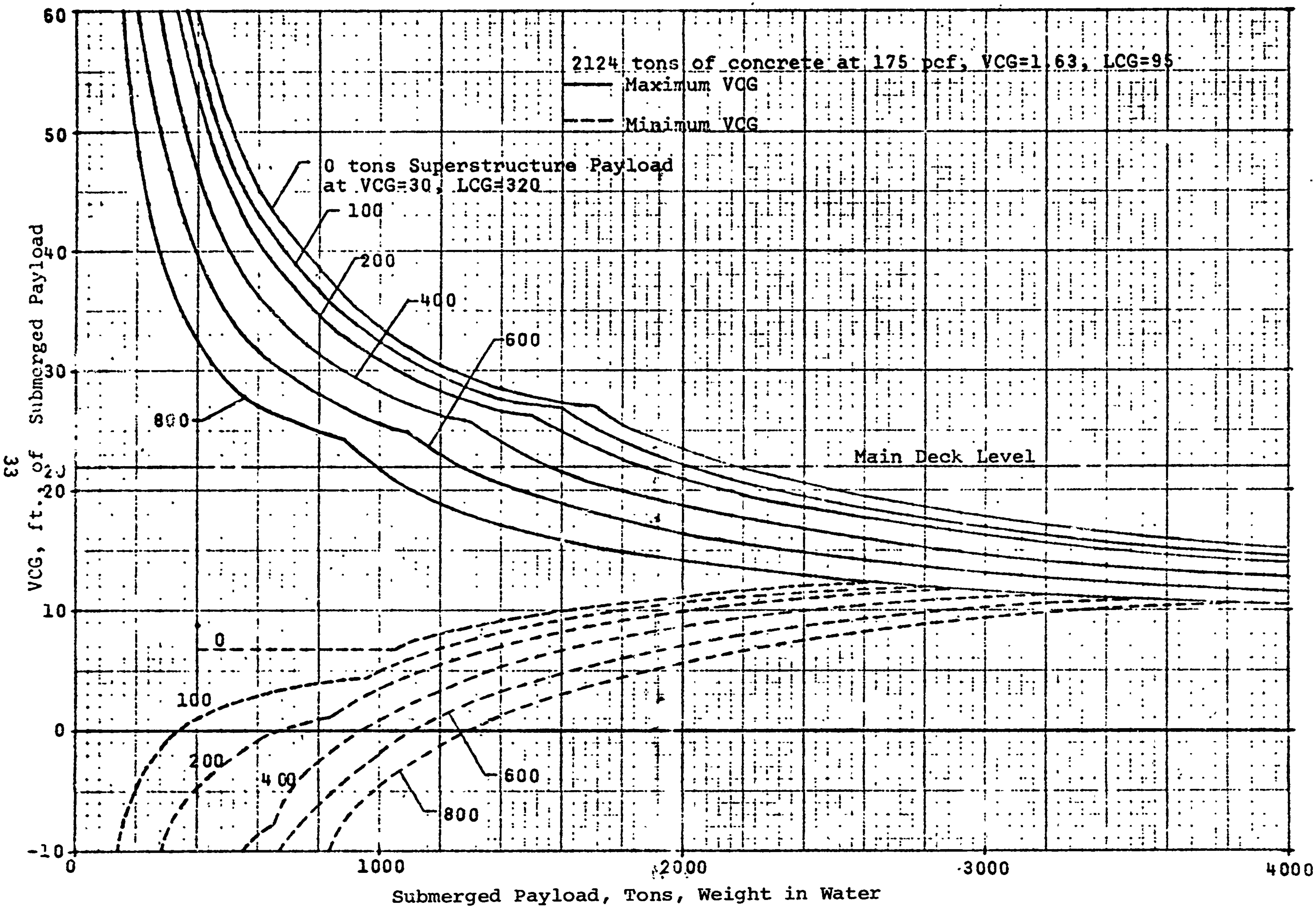


Figure 18. VCG Payload Envelope

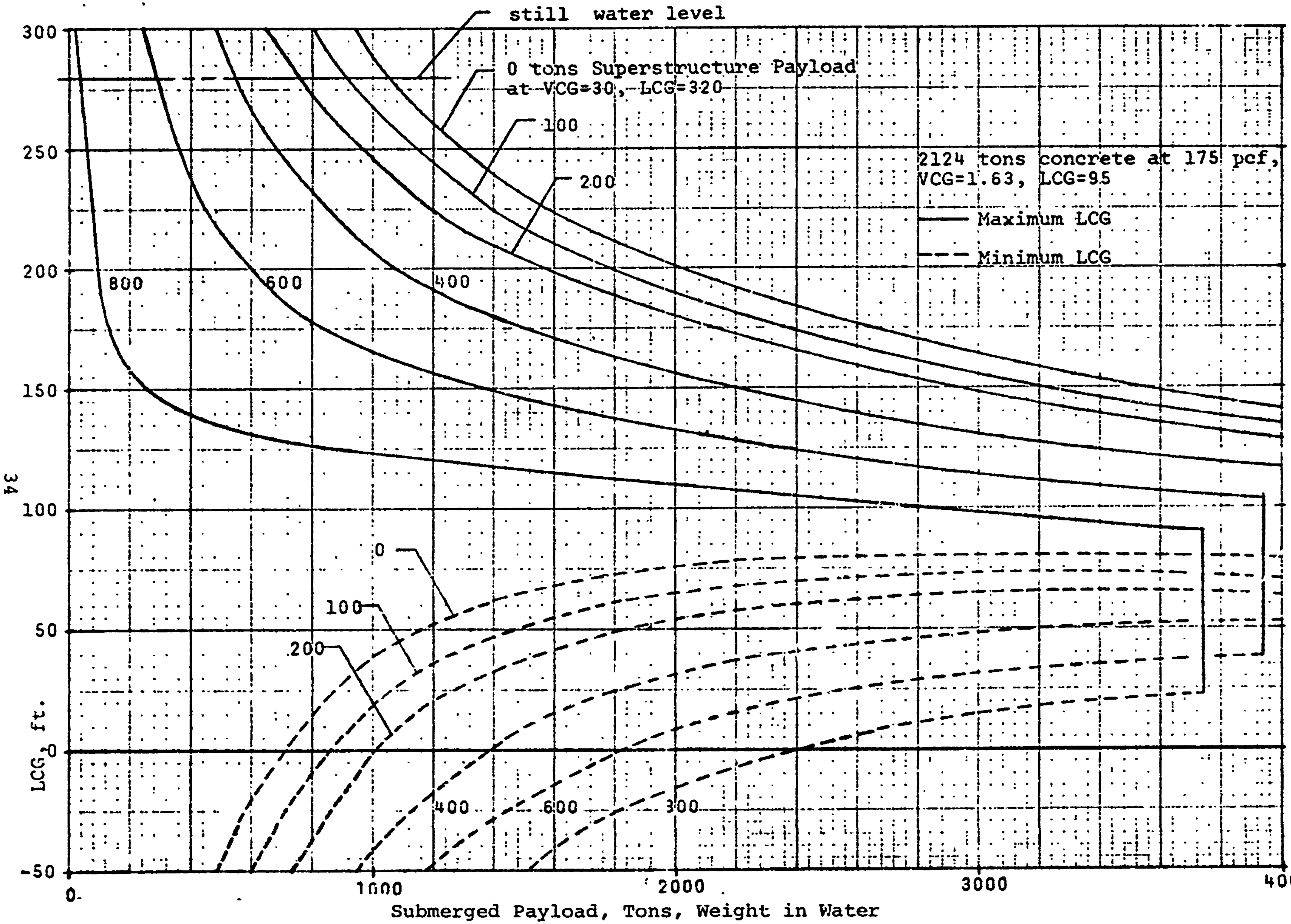


Figure 19. LCG Payload Envelope

The preliminary fitting out and arrangements package reflects Scripps operating experience with non-propelled craft, e.g. FLIP and ORB and with more conventional survey ships such as MELVILLE, THOMAS WASHINGTON and ALPHA HELIX.

The superstructure which connects and strengthens the two trunks has been set aside primarily for a combination of housekeeping areas (berthing and messing for 15 crew and 25 support personnel) and scientific/engineering work and equipment spaces. A ship control center also is located in the superstructure area. Machinery required for ballast control (air compressors and flood/vent controls), ship's service equipment (fire/potable water/fuel system pumps) and auxiliary power are located in machinery spaces in upper sections of trunks (Figures A-2 and A-3, Appendix A). The air bottles required for blowing tanks are located in the trunks below the machinery spaces.

The winch and crane group (Appendix B) was the most difficult portion of the fitting out package to define, and perhaps the most important. The cost alone represents a significant percentage of the overall cost of the fitted out barge. Although the bulk of the package will be located in work spaces in the superstructure, any power equipment and the drum for the main winch should be located as far down as feasible relative to access and maintenance and to also benefit the center of gravity and superstructure payload.

The winch and crane as defined gives a flexibility that permits a wide range of support tasks to be performed, some simultaneously when appropriate. The hydrographic winch with a center core conductor and boom will be employed in routine oceanographic sampling. The intermediate winch can be deployed with center core power cable or straight wire. Its wire rope of 1/2" size lends itself to a wide variety of tasks such as the raising and lowering of hydrophones and general purpose usage.

The main winch has a flexibility with rope size between 7/8" and 1 1/4" and with or without center power single or coaxial power source. Minimum breaking strengths of up to 80 tons are attained, depending on cable selected or available. Bottom work systems can be handled readily. Large bulky acoustic transducers or arrays can be operated at a point in the water column limited only by the cable length available. Other heavy "in air" objects such as sea floor habitats, mining complexes, well head or other offshore petroleum equipment can be lowered to the bottom if designed to have sufficient buoyancy in water to permit safe handling with the winch package available. A motion compensating device is included in the main winch installation. The main winch options were selected on the tradeoff of lift capability, size and weight versus cost. The finalized main winch is an acceptable compromise that can support a wide variety of tasks.

The 2 1/2 ton crane and two capstans support a variety of housekeeping and mission tasks. The two capstans are necessary for maintaining constant tension in the mooring lines.

Station-Keeping and Orientation

With regard to positioning and orienting the flippable barge while in the vertical mode, the design requirement selected was the ability to maintain either position or heading, but not both simultaneously. Thus, depending on mission requirements, the barge would be either drifting free while maintaining a fixed or controlled heading, or maintaining a fixed position with its heading such that the station-keeping power requirement was minimized.

By selecting this approach, a wide variety of missions requiring some sort of position or attitude control in the horizontal plane can be accommodated while keeping the investment in power, equipment and installed machinery to a reasonable level. If it were required to maintain both position and heading, then the power requirements would be established by the worst condition where the wind and current were in the same direction and perpendicular to the broadest dimension of the vessel. This requires roughly four times more power than the present situation where, for station keeping, the vector sum of current and wind drag forces can always be kept perpendicular to the vessel's narrowest dimension.

Implicit in the above is an unstated decision about the time constant of the control system to be designed. The time constants of the positioning systems to be considered here are considerably longer than the period of the wave-induced forces, which average close to zero for a suitably long averaging time. Thus the heading and position control systems will react to changes in direction and speed of the wind and current, but will not react to wave-induced motions. Instead, we rely upon the shape and dimensions of the vessel to minimize its responses to wave action. The positioning and orientation systems are therefore designed to counteract the steady state drift and yaw due to changing wind and current conditions.

Position will be maintained by a three-point moor, using neutrally buoyant line and sacrificial bottom tackle; or by thrusters operating on both sides of the vessel, parallel to its wider dimension. Design conditions selected are a 1 kt current and a 60 kt wind in the same direction. With the beam of the vessel into the current, it has a projected area of 6400 ft^2 below the waterline and 1500 ft^2 above the waterline. Using drag coefficients of .94 for the area above the waterline and .70 for the area below the waterline, the drag force is 29,000 pounds. This includes the assumption that the surface current extends unchanged in direction or magnitude down to 300 ft depth.

Orientation will be by thrusters positioned as far apart as possible so as to make maximum use of available horsepower to produce yawing moment.

a. Mooring

Scripps has had much experience in establishing three-point moors in the deep ocean with FLIP (Bronson, 1971). Three-point moors have been made in depths up to 3000 fathoms using combinations of Samson brand Multifilament Polypropylene (MFP) and Power Braid (see Figure 20). The combination has slight positive buoyancy, and thus all of its strength (45,000 lb for the 1 1/2" dia. rope) is available for mooring stresses rather than partial self support. The bottom tackle is about 9 tons of scrap chain and a 750-lb Danforth anchor on each leg. The bottom tackle is sacrificed, shear pins allowing recovery of the mooring lines.

For the Flippable Barge under the severest design conditions and assuming a line length to water depth ratio of 1.5 to 1, the line tension would be 40,000 lb, requiring 1 3/4" dia. rope, with a breaking strength of 90,000 lb. For a 3000 fathom moor, each leg would require 27,000 feet of line and 14 tons of scrap iron. Thus the equipment requirements are comparable to those for mooring FLIP.

Mooring the Flippable Work Barge, however, will not be as simple as mooring FLIP, because of the requirement to keep the beam of the barge oriented in a direction to minimize the drag of wind and current. The barge must be able to rotate relative to the mooring lines in order not to exceed the design strength of the lines under the severest conditions. Under better conditions this is much less of a problem. For instance, with a 1/2 kt current and a 45 kt wind, the three-point moor described above could easily maintain the barge in position broadside to the wind and current, since the drag forces in that condition would be only 23,000 pounds. In order to meet the worst conditions, the moor must be made to a point above the top deck of

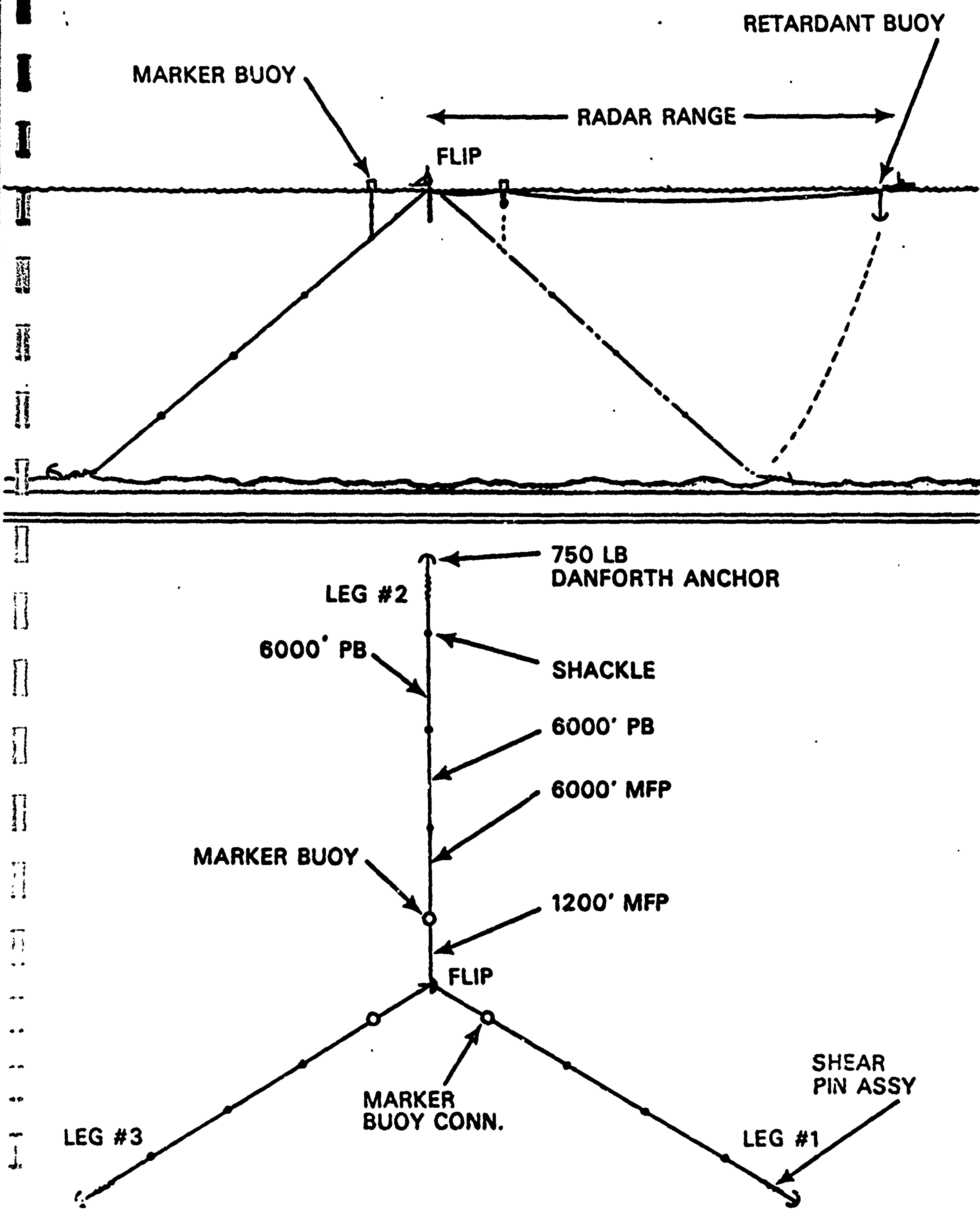


Figure 20. FLIP 3-Point Moor (Bronson, 1971)

the barge. Fair leads on tracks or rollers would guide the lines over the edges of the deck, and would be positioned so as to properly orient the barge (see Figure 21). The unbalanced moment due to the lines being moored so high over the water surface would cause the vessel to heel over only about 1.1 degrees.

b. Thrusters

For a thrust-to-power ratio of 40 lb/hp, about 750 hp, or 560 KW, is required. With two thrusters as shown in Figure 22, propellor diameters would be about 7 feet in order to obtain a proper power to fan area ratio (Hoyt, 1962). In the configuration shown directional control can be maintained by varying the power to the two thrusters. In addition, if the thruster on the keel can be rotated to face fore-aft when the barge is horizontal, then the barge would also have some propulsive and maneuvering capability.

Cycloidal propeller thrusters could also be used, as shown in Figure 23. The advantages of such a system are 1) thrust can be delivered in any direction perpendicular to the axis of rotation without the need of a rotatable thruster housing; 2) variable pitch of the cycloidal propellor allows greater use of available power under varying conditions. Thrust to power ratio is about 39 lb/hp for a Voith-Schneider size 14E cycloidal propeller, which has a diameter of 6.2 feet (Voith-Schneider, 1971), so space and horsepower requirements would be about the same.

c. Orientation

Estimating the thrust and horsepower requirements for orientation is far more difficult than for station-keeping. Two approaches are available for obtaining this estimate. One is to generate an analytical prediction of the required power and the other is to obtain an estimate from model experiments.

The use of analytical techniques to estimate the required power is not very promising. The moments which must be resisted in order to maintain a mean orientation are intimately connected with real fluid flow effects, section asymmetries, and resulting circulation in an unsteady flow field. These problems involve state-of-the-art techniques, and in fact may exceed available public data or techniques, especially when it is considered that the sections involved are arbitrary bluff sections of substantial thickness.

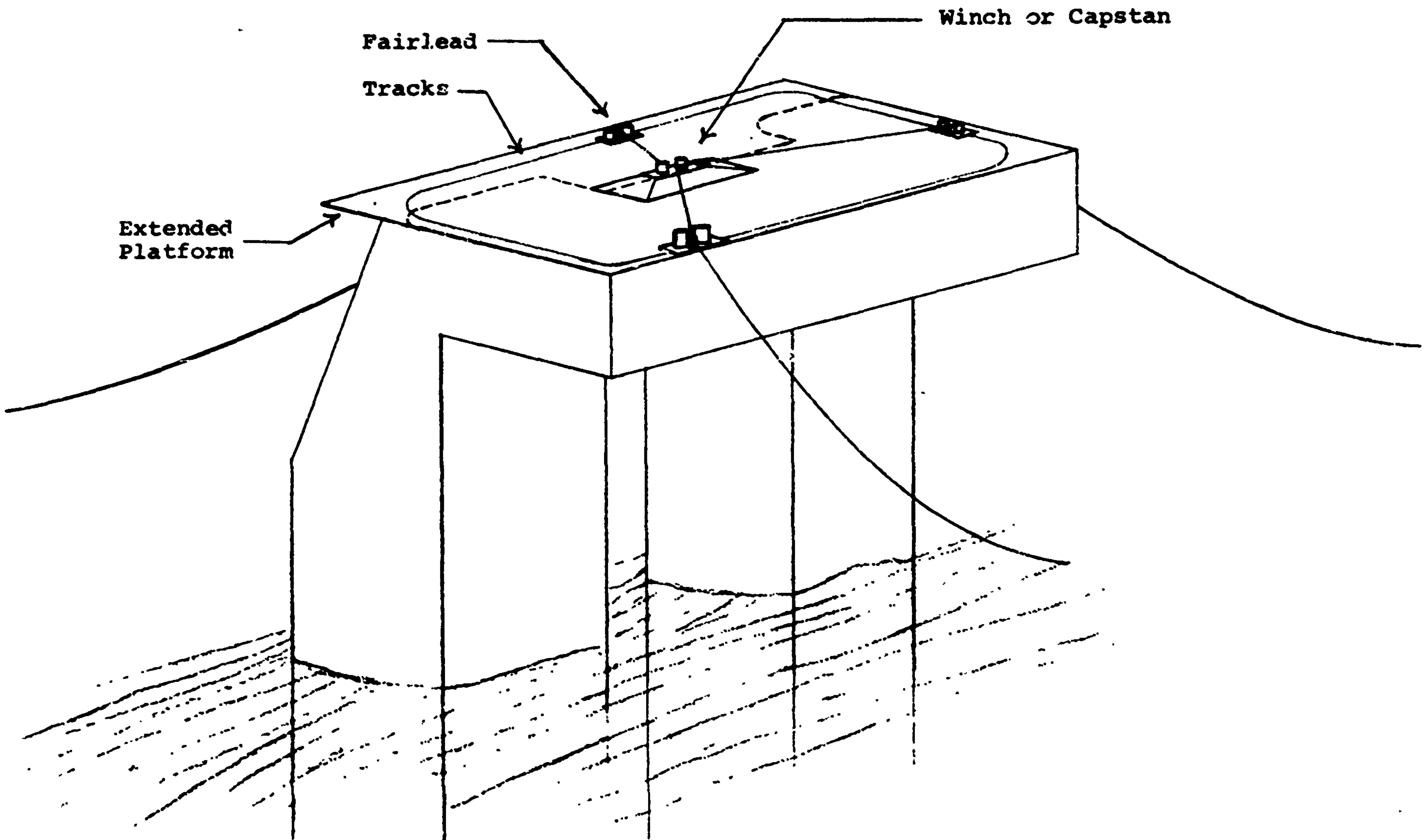


Figure 21. Controllable Heading for a 3-Point Moor

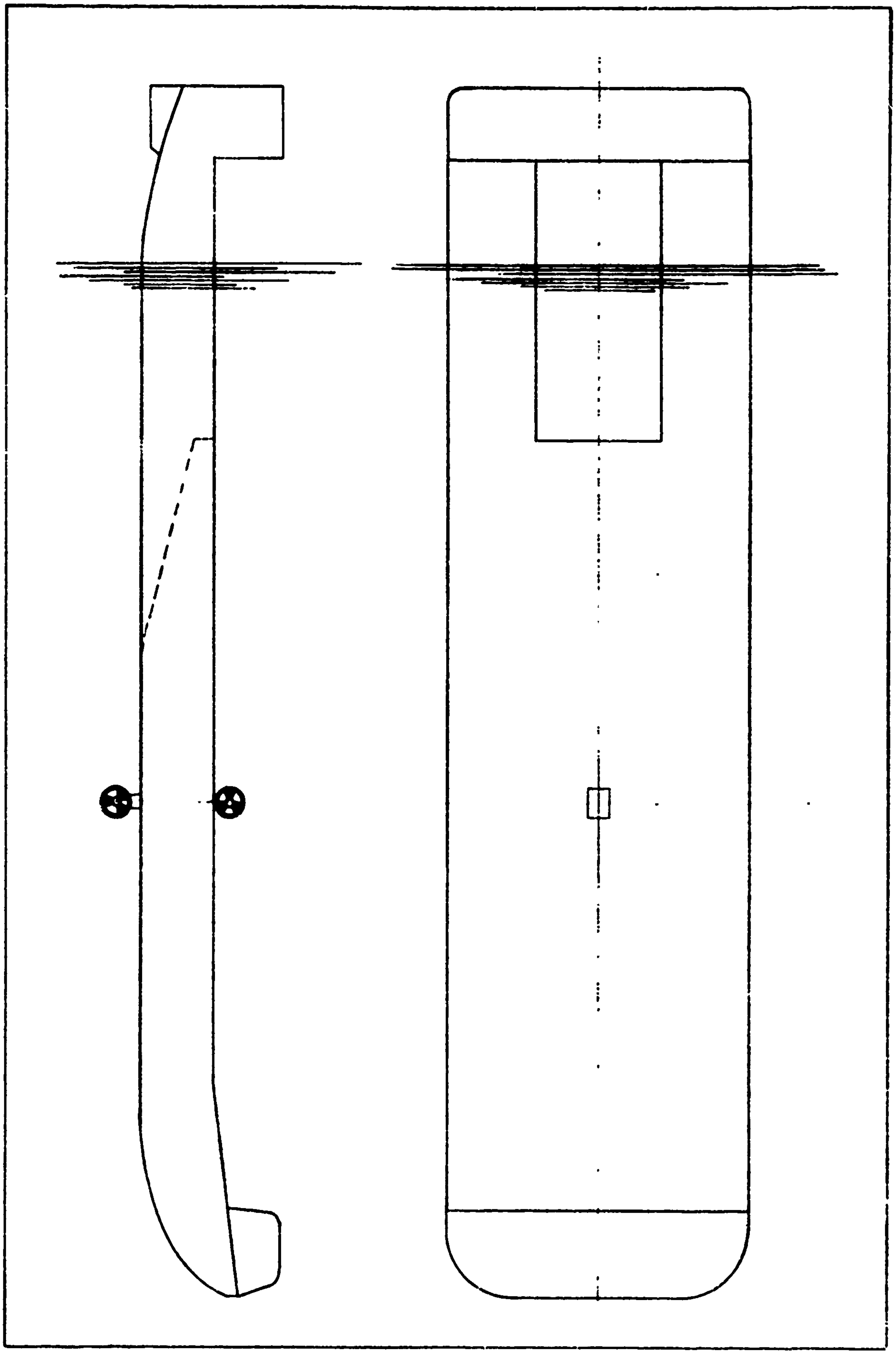
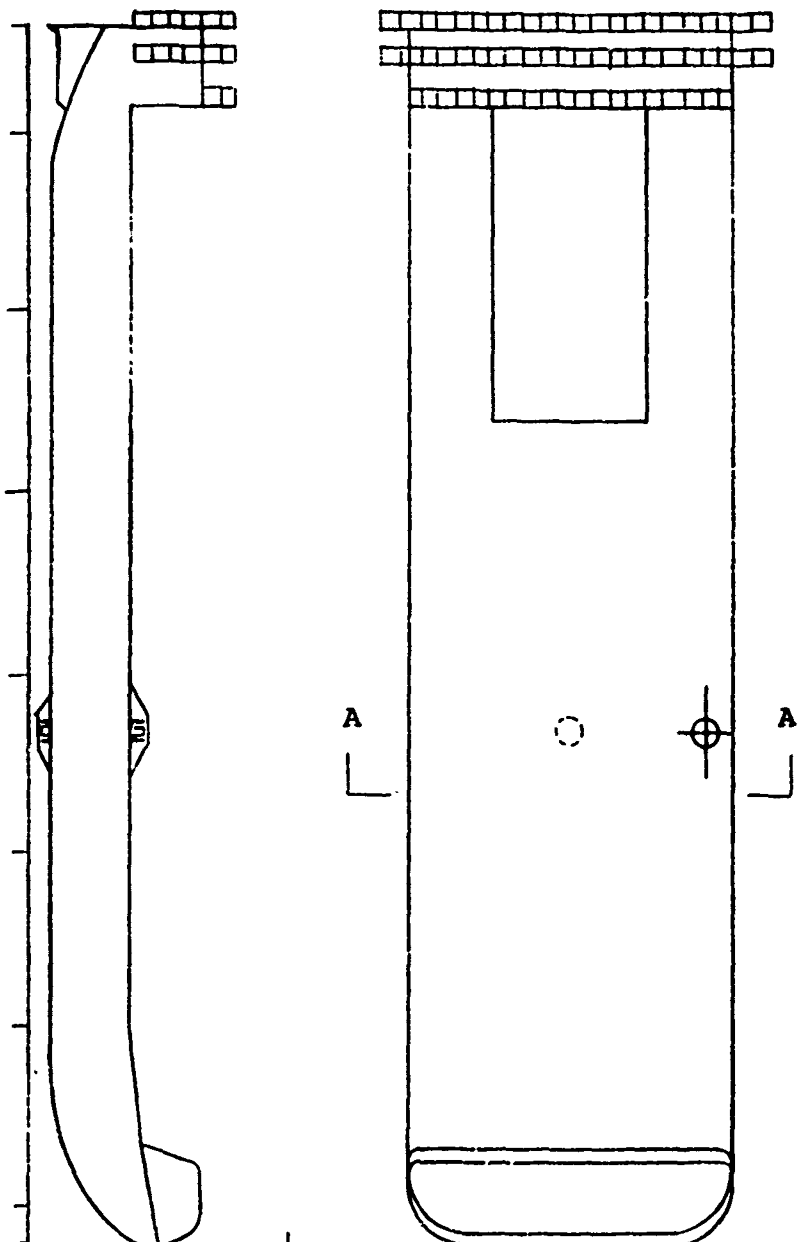
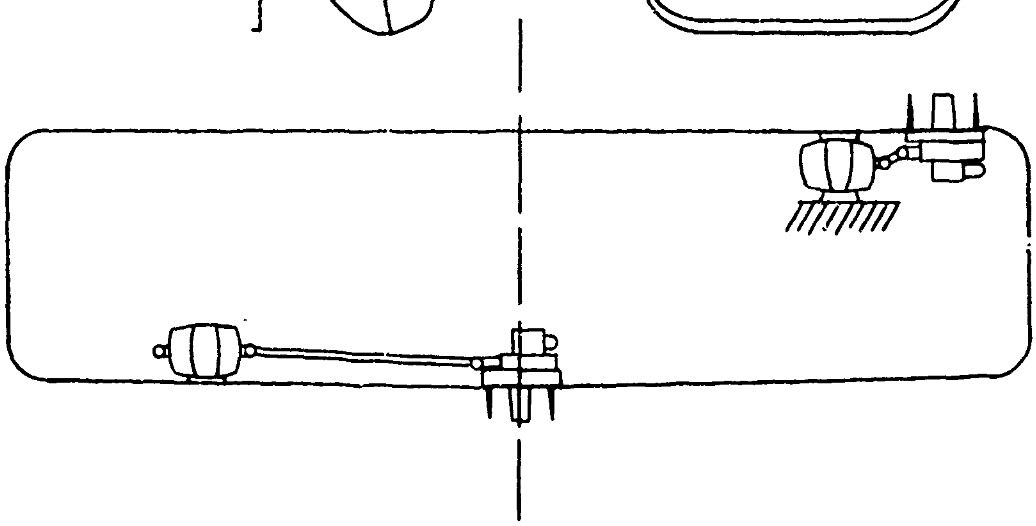


Figure 22. Thrusters for Station-Keeping





Section A-A (Not to Same Scale)

Figure 23. Cycloidal Propellor Thruster Arrangement for Station-Keeping

The magnitude of the symmetric harmonic moments which cause equal yaw about a mean heading was studied, in order to determine the feasibility of using thrusters to correct for wave-induced yawing motion. The moments were found to be exceedingly high. The yaw response (and hydrodynamic moment) depends on the mean heading relative to the wave direction as well as wave frequency, as shown in Figure 24, which plots yaw response contours on a frequency-heading map. The harmonic moment on the vessel depends on frequency and heading in the same way. In the absence of a directional design spectrum with which to integrate the moment responses, the well-known Neumann spectrum (Kinsman, 1965) was used to find the significant (average of highest 1/3) moments for fixed heading, assuming the sea spectrum to be unidirectional. For a 20-ft significant wave height, the significant moment exerted by the waves on the barge was a maximum of 2.4×10^7 ft-lb at a heading of 40° relative to the wave direction. With thrusters approximately 100 ft apart, this would require 120,000 lb of thrust developed at each thruster. Thus, the power required is much too great for orientation on a rapid time scale to be feasible.

Unfortunately, the steady drift moment is not as amenable to analytical solution. The approach of using model experiments to estimate the required orientation power is much more promising, particularly considering the existence of the 1/8 scale model. The chief concerns involved in the model test approach are properly modeling the ocean environment, and scale effects. Previous experience with the 1/8 scale model lends credence to the hope that the ocean environment can be modeled. The large scale of the 1/8 scale model minimizes the risk of scale effect error. It is therefore recommended that estimates of the power required for orientation be determined by experiments with the 1/8 scale model using instrumented variable power thrusters and direct observation of orientation behavior in a model scale ocean environment. Since these data are not available, for cost purposes it was assumed that two 500-horsepower thrusters would be required.

The thrusters would be mounted at the port and starboard sides, to produce the maximum moment from the available horsepower (Figure 25). The thruster housings can be made to rotate for propulsion in the horizontal mode. Again, this could be eliminated if cycloidal propeller units were utilized.

It should be reiterated that whether conventional or cycloidal thrusters are used, only two units are required. The same two units are used both for position keeping and for orientation, but are mounted in different locations. It is presumed the mission requirements are known in advance, so that the thruster units can be relocated appropriately while in port.

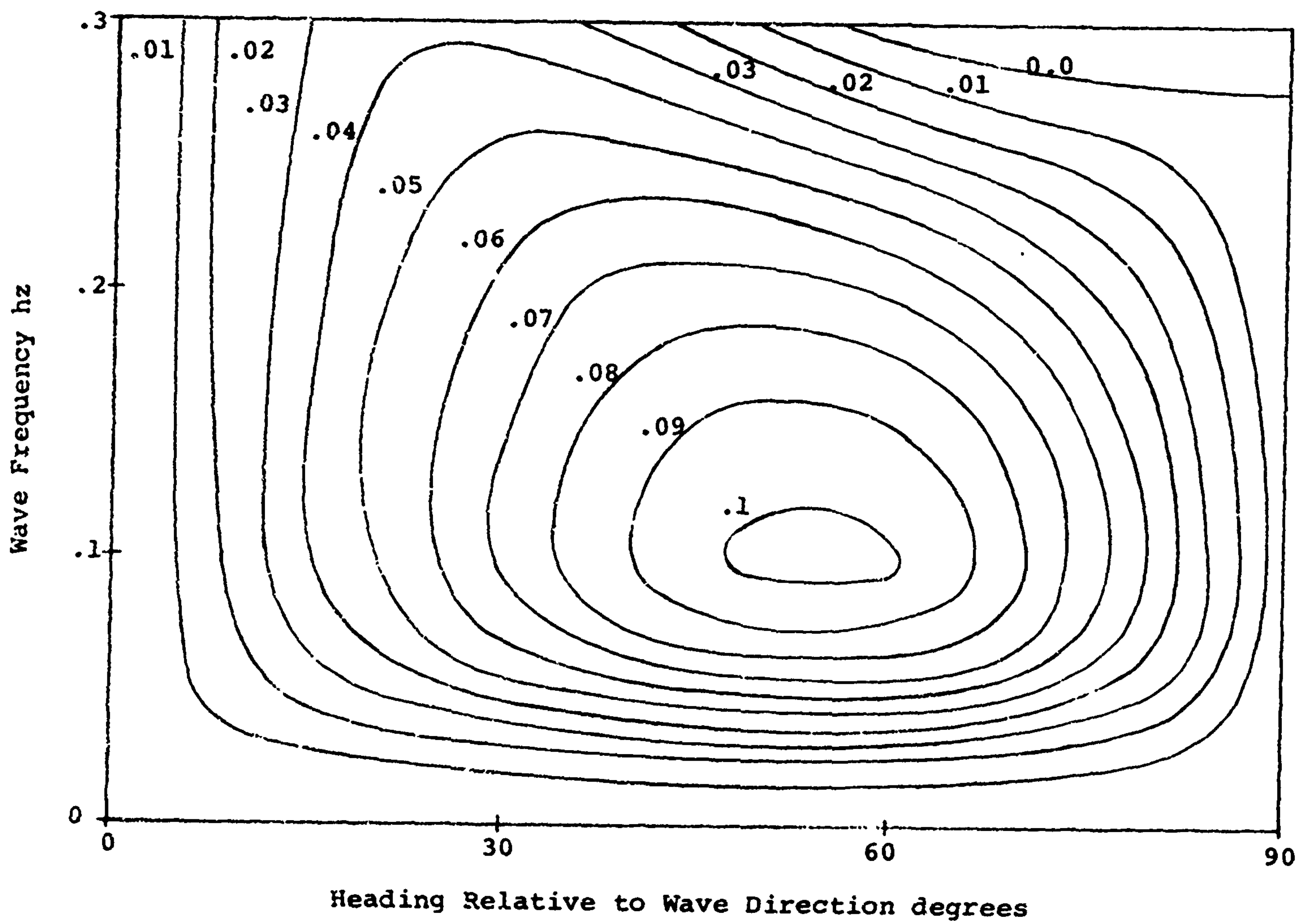
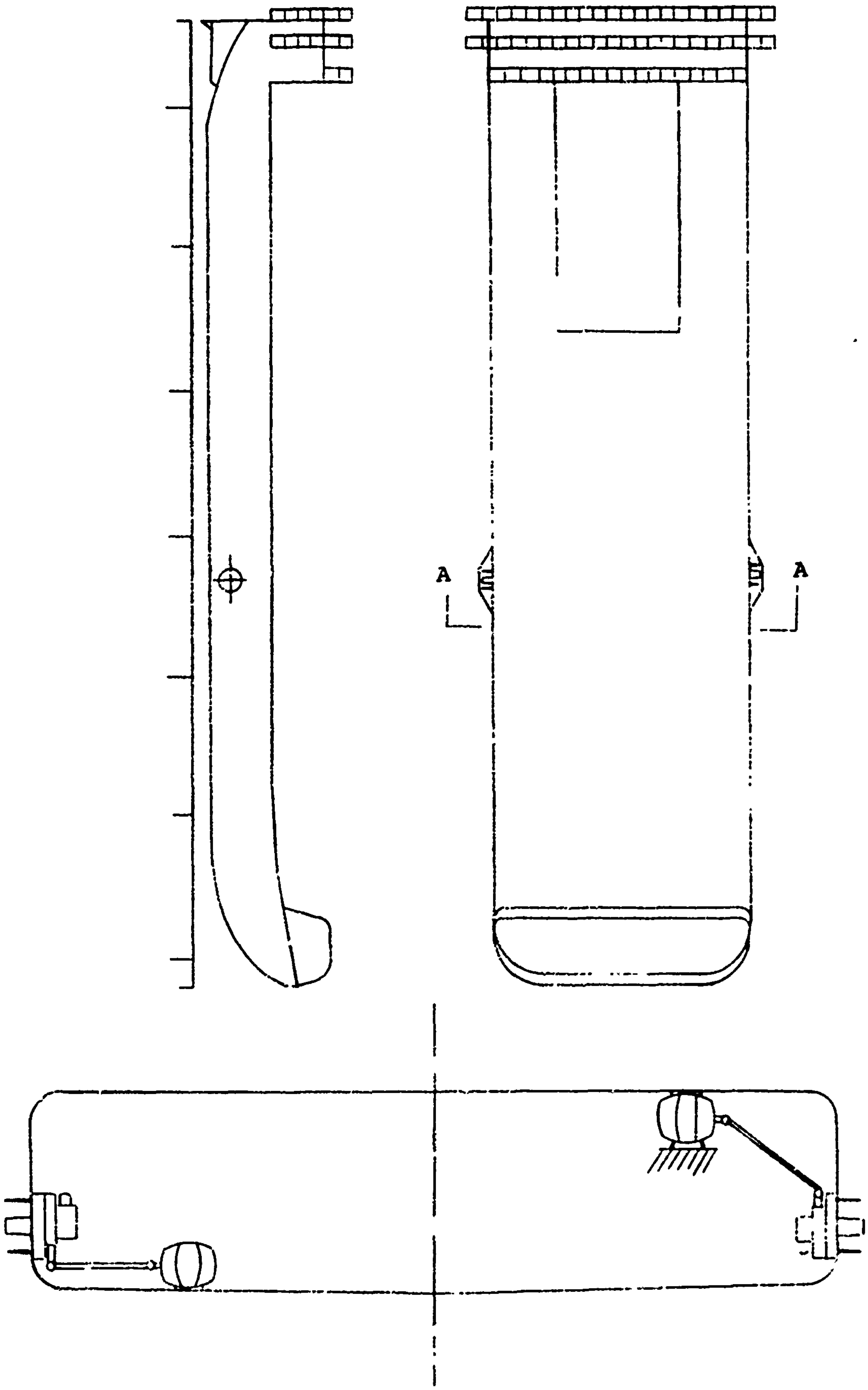


Figure 24. Yaw Response Contours, Degrees/Ft Wave Amplitude



Section A-A (Not to Same Scale)

Figure 25. Cycloidal Propellor Thruster Arrangement for Orientation

IV. SPECIFIC MISSION/TASKS INVESTIGATED

General

Scripps submitted a proposed concept for investigations that was divided into two phases. NAVSHIPS funded the first phase. This included limited task investigation of some missions which were similar to those performed by FLIP, ORB and smaller specialized craft and two submarine tending missions.

It was soon evident that a number of missions, in particular those currently supported by FLIP, ORB and other similar vessels, were already well defined in terms of logistics and support. Some tasks, such as internal wave studies or acoustic studies with several suspended hydrophone arrays requiring spatial separation of instruments are currently handled on FLIP with a set of booms (Figure 26). These tasks are easily handled and can be extended considerably on the larger barge platform. Development of the preliminary fitting out package (Appendices A and B) reflects the anticipated requirements of many such missions.

Other tasks which are not so well defined and which are discussed below are handling large acoustic transducer systems, bottom work systems, submarine tending, and submarine rescue and recovery.

Large Acoustical Transducer System

A large transducer or acoustic array system can be readily supported at great depths. To better illustrate we have taken an approximation of a very large acoustic array currently under preliminary design study. The dimensions, weights and general design including thrusters are considered realistic in terms of state of the art and future possible acoustic developmental requirements.

The array weighs over 180 tons in air with general dimensions of 88 feet by 29 feet by 20 feet. It is mounted on a ramp structure to permit it to clear the high bow area once the barge flips to the vertical operating mode (Figure 27). The array is transported to the operating site and flipped 90 degrees through the air/sea interface. At this point the top of the array is located well below the mean water line.

Once the barge has been stabilized in the vertical mode, the array with a designed submerged weight of about 10 tons can be lowered to the desired operating depth. The array initially will be guided while riding in tracks until it clears the bow. Looking transversely, a guide plate will ride just behind the array until the plate runs against stops. It then acts as the suspension point for the array as it is lowered to the desired

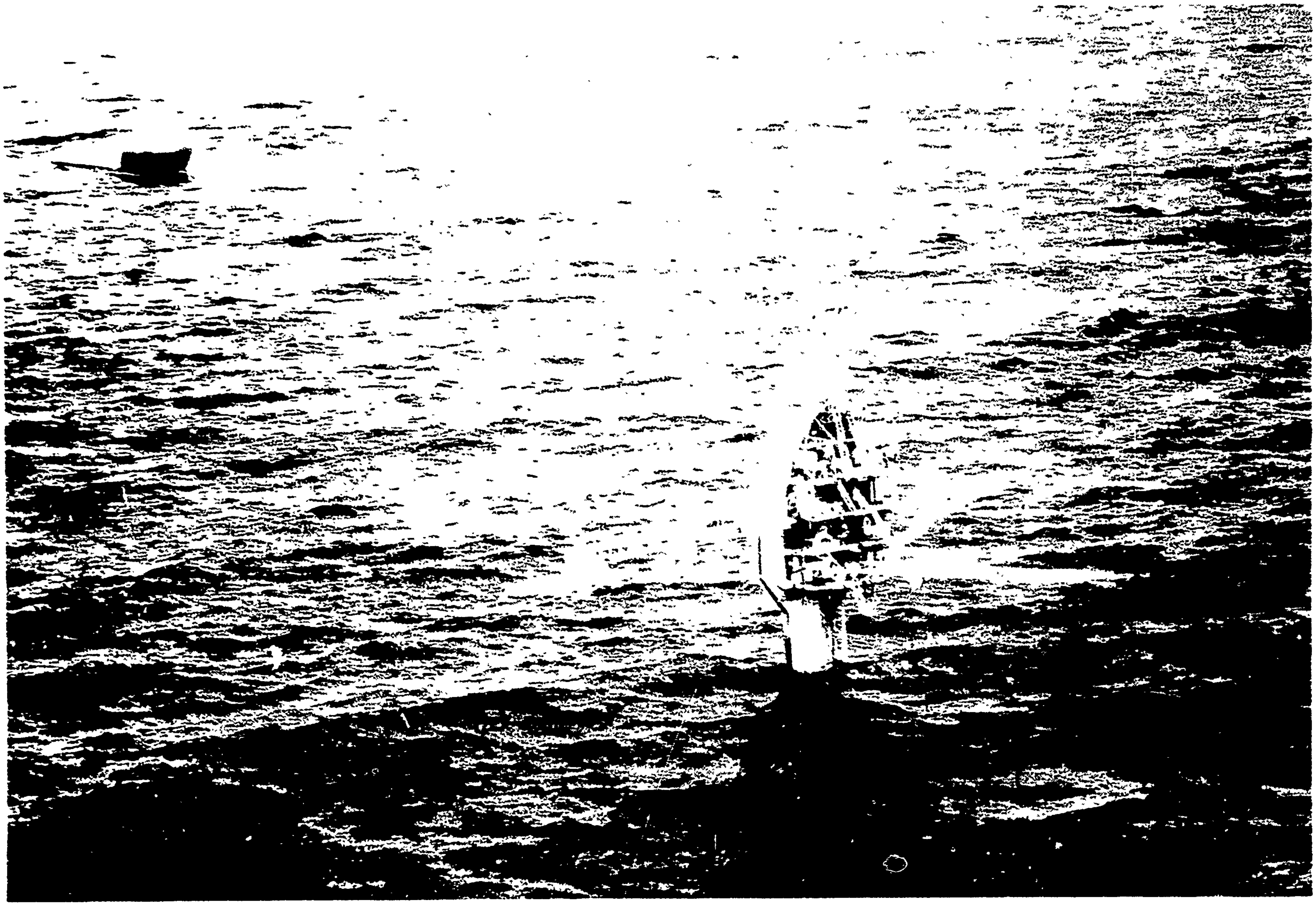
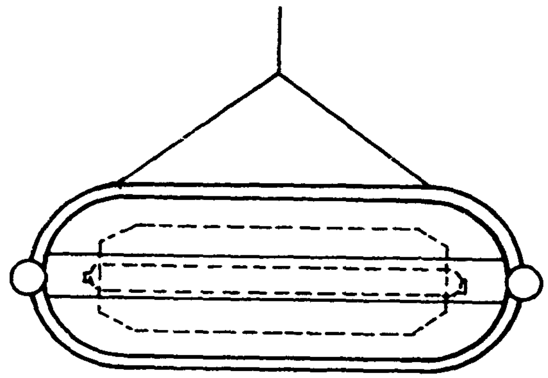
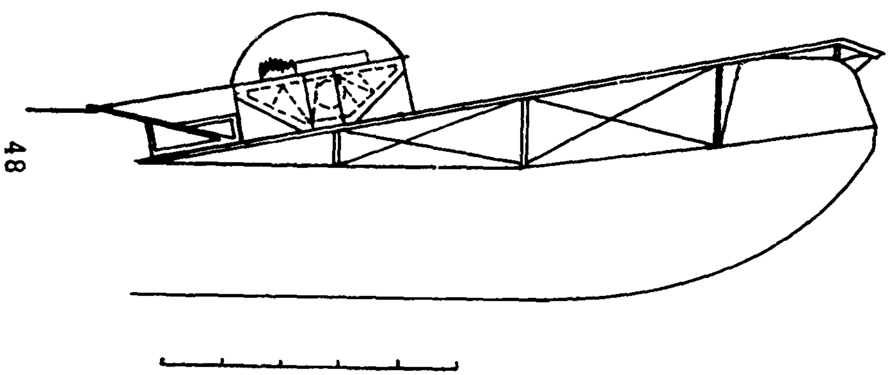


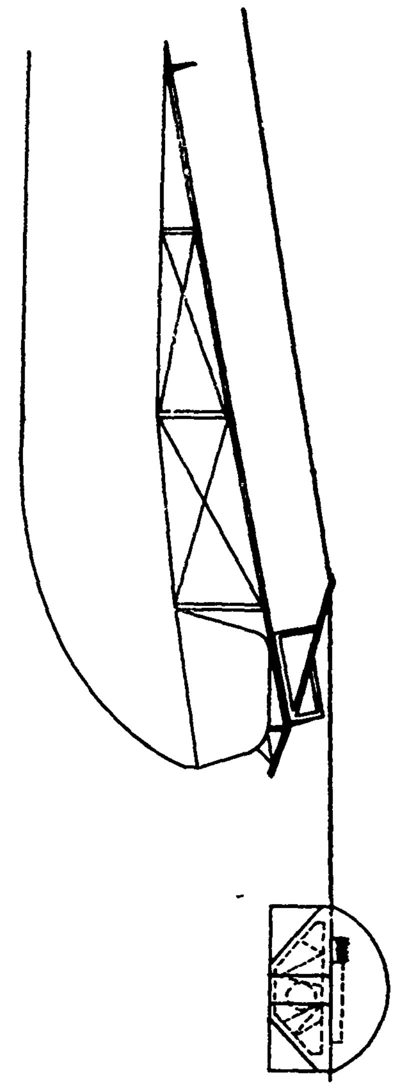
Figure 26. FLIP Rigged With 3 Booms



A. Large Acoustic Array



B. Array Housed



C. Array Suspended Below Hull

Figure 27. Support of a Large Acoustic Array

operating depth. The winch cable acts both as a suspension cable and power source using a center core coaxial cable. Controls, winch and instrumentation are located in the superstructure area. By means of a simple accumulator, the limited vertical excursions of the barge, normally 10 percent or less of the wave height, can be easily handled so that the transducer would feel only minute accelerations. Thus line tension due to inertial forces are eliminated and the winch system has only to cope with relatively small forces due to the transducer's negative buoyancy.

When the operation is completed the array is winched back up to the barge where it is guided into the tracks as it seats against the traveling guide. It then is housed in the deck load position where it can be flipped back to the horizontal mode.

Currently, such large arrays either have to be handled as deck load under severely limited sea state conditions or be carried below a craft such as done employing ORB. In the former case the size and weight of the array are severely limited by the problems of deployment and retrieval in the worst anticipated sea state, and in the latter case maintenance and repair are quite difficult without a very large well structure.

Bottom Work Systems

Bottom work systems are classified as small or large. In the case of the former, a fairly large amount of design operational experience already exists. Systems include RUM, CURV III and RUWS. RUM (Anderson, 1970' will be taken as an example of a small system. The handling and operation of RUM as a viable system using ORB (Scripps operated and manned Oceanographic Research Buoy) has already been successfully demonstrated over a period of several years. On ORB, RUM is housed in a center well with doors that open to provide a bottom opening to lower RUM during planned operations. In employment of RUM or similar system on the flippable barge, the vehicle is housed and serviced in the superstructure support areas on the lower superstructure deck (in vertical mode). When lowered for operations, the vehicle will be controlled from the superstructure. Using the center telescopic boom (Figure A-3, Appendix A), the vehicle is moved out clear of the trunks and lowered to the bottom. RUM has an air weight of approximately 23,000 pounds which is reduced by built-in buoyancy to about 10,000 pounds to permit the vehicle to hug the bottom when "crawling" on a mission. RUM is suspended and controlled by a specially constructed wire cable with a coaxial center core. The strength of the cable must reflect not only the weight of the vehicle and additional vertical motion tensions not otherwise compensated for, but also the increasing weight of cable that is paid out. The latter can be considerable. For example, 20,000 feet of 7/8" diameter wire rope could have a submerged weight of up to approximately 10 tons. Fortunately current cable (wire rope) technology allows some additional buoyancy to be built into cables where the overall submerged weight (cable, equipment and device) becomes critical.

Other small systems will be similarly handled with the exception of RUWS when deployed with its own motion compensating crane unit. In this case, the crane will be mounted (Figure A-3, Appendix A) on the weather deck. The RUWS package will be housed so as to be readily accessible to the crane. Space will be available for the crane drum in one of the trunks. Considering stability, it is advantageous to position it as low as possible (vertical mode).

Any detailed study of a larger bottom work system package (such as mining complex) was not within the purview of the NAVSEA study objectives and funding.

Submarine Tending

Scripps in the original proposal delineated three potential areas of submarine tending for investigation (Section II). NAVSEASYSCOM funding permitted examination of two areas discussed below along with emergency egress and recovery.

In the course of the study a considerable amount of effort was expended in examining commercial and military state of the art. We felt this expenditure of time would pay off in terms of endeavoring to keep things practical and to take full advantage of developments to date.

Early in our ARPA investigations, we could see the potential employment of the flippable barge in a submarine tending role. The barge in the vertical mode enjoyed stability that gave responses that were only a fraction of that experienced with more conventional craft currently used for tending. Also, the capability to flip large bulky objects in and out of the water presented an additional capability.

DSV or Smaller

The first method of submarine tending investigated is that relating to the smallest submersibles. The upper limit has been taken as 25 tons and approximately 26 foot length and 12 foot diameter. These are the general characteristics of the Navy DSVs, TURTLE and SEA CLIFF (Murrill, 1974). Included in this large group of submersibles are various vehicles including ALVIN and models of CUBMARINE and PISCES.

The concept includes a portal to portal operation. The submarine is transported to operating site. The barge flips to the vertical with the submersible allowed to remain upright in gimbal like suspension. When the barge reaches the stable vertical mode the submersible is lowered to a depth well below the surface on elevator like landing platform from which it can launch for operations. When operations are completed, the craft moors on the platform and is raised to the surface for replenishment of vital system and crew rest. When ready to return to port the barge flips back to the horizontal. During flipping, the submersible again rotates in gimbal mountings.

A major portion of effort devoted to this method of tending focused on how best to raise and lower the submersible between the superstructure and a point well below the surface of the sea. From the latter position the craft launches from and moors in relatively quiet water to a highly stable platform whose motion decreases as one progresses to deeper water along its hull.

Existing elevator and other hoist mechanisms were examined. A number of "state of the art" options are available but not necessarily adaptable either to the marine environment or the general configuration of the flippable barge, or acceptable in terms of amount of payload. As our investigations looked at power sources, consideration was given to the amount of 250 psi air readily available for blowing tanks during the flipping operation. Initial examination indicated that use of this air as a lift force was feasible. Ultimately, a concept was developed that evolves around use of a buoyancy lift chamber elevator (Figure 28). The principal advantage of such a design is that the weight of its structure is easily absorbed as deck load and submerged payload of the barge with minimal effect on superstructure payload. By comparison, another highly potential alternative could use a double drum overhead crane with a two point platform lift. The installation would be generally comparable to half that employed to raise a DSRV. Although the crane package is feasible, it could create undesireable superstructure payload and space requirements, particularly in terms of a multi-mission type of operation.

Figure 29 shows a schematic of a possible buoyancy lift elevator package. Individual components are an air chamber 20 feet high and 13 feet in diameter, a support tower 38 feet high and 10 feet in diameter, and finally, a cradle assembly 30 feet in length by 15 feet in width and 10 feet high. All dimensions are approximate subject to final design.

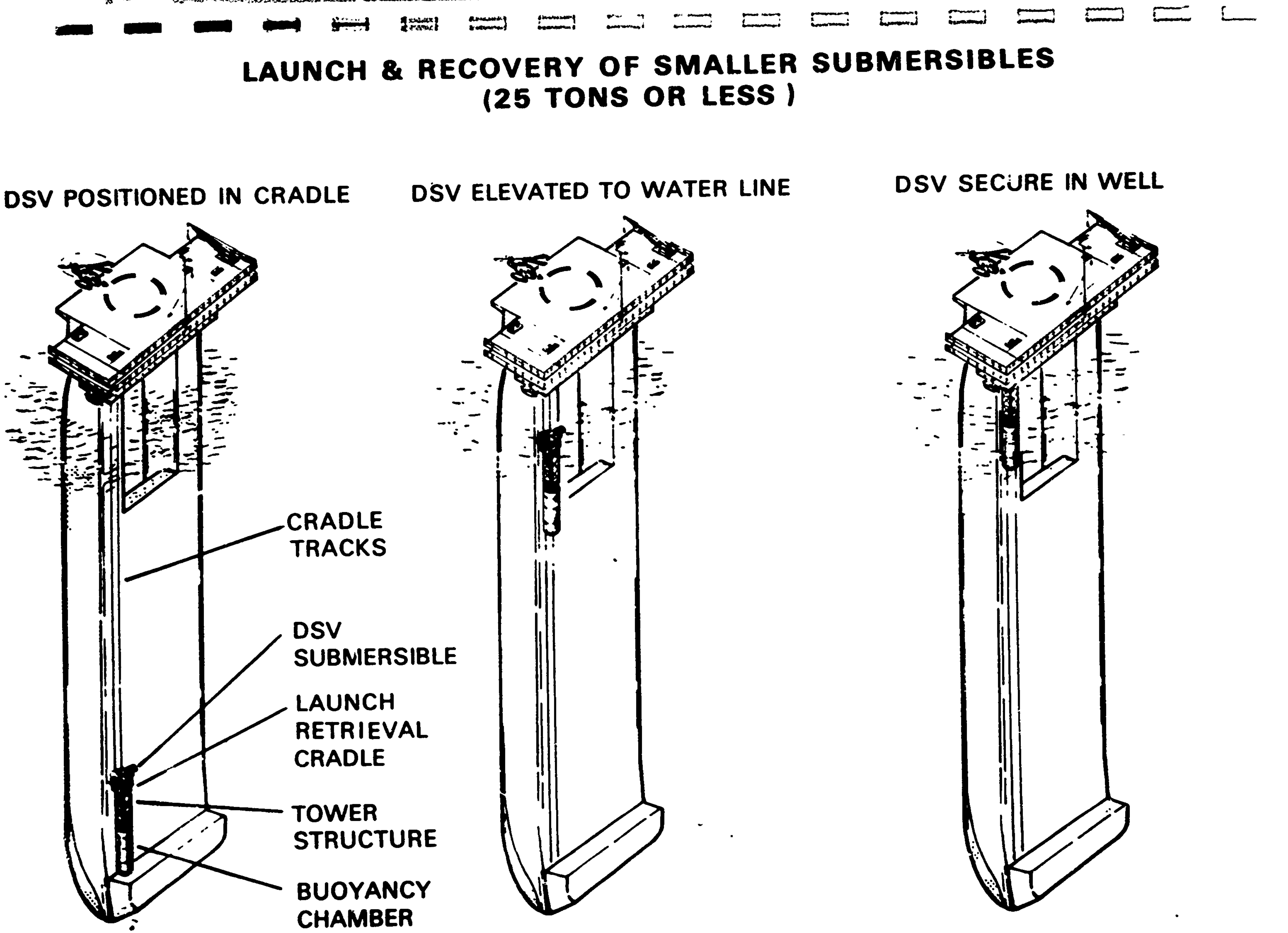


Figure 28. Support of Submersible Under 25 Tons

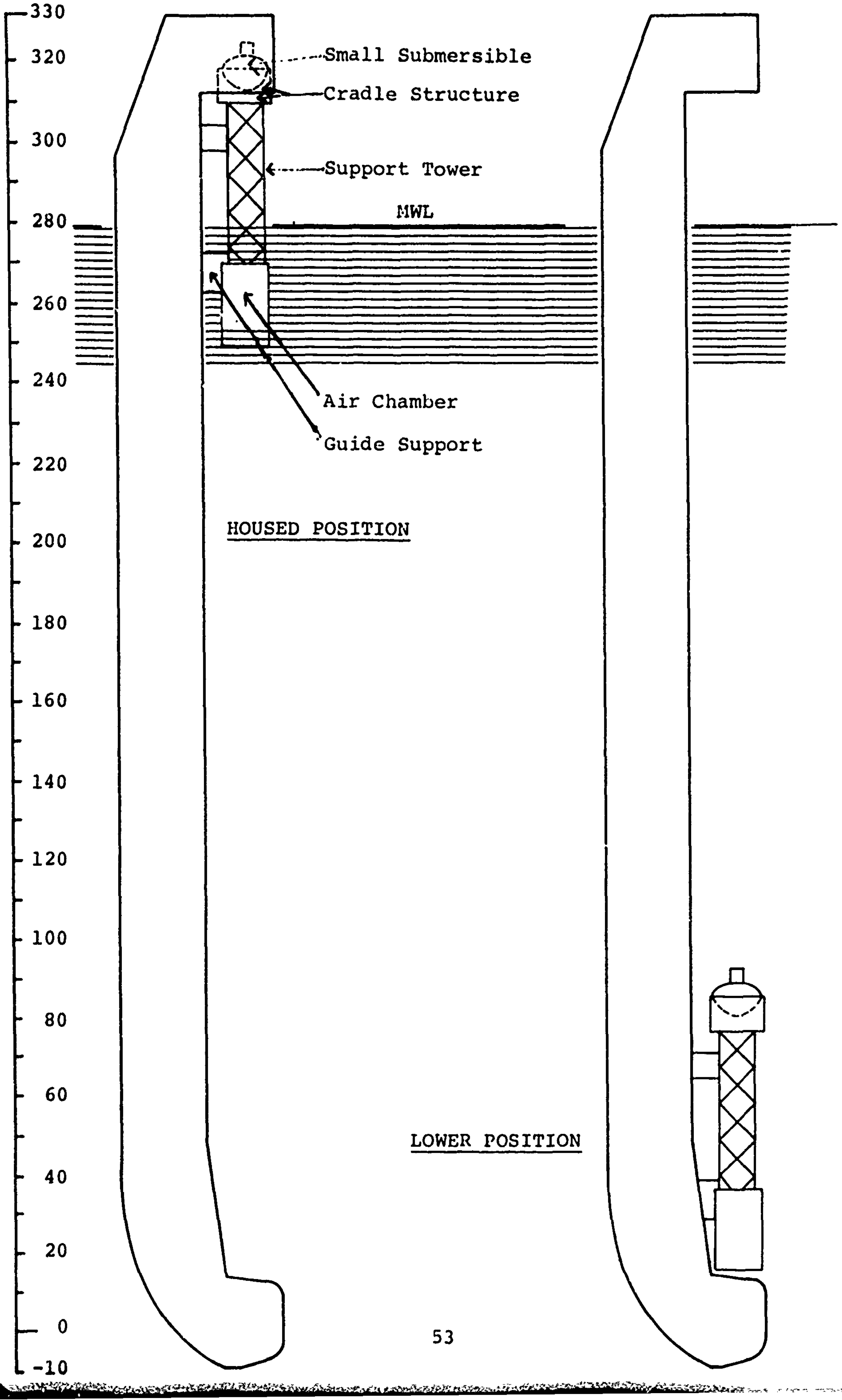


Figure 29. Buoyancy Lift Elevator for Small Submersibles

The air chamber is constructed of high grade steel capable of withstanding a minimum of 160 psi interior and exterior pressure. It must be able to support and lift up to approximately 48 tons of tower, cradle and submersible (Table II). As the submersible breaks through the ocean surface it also will have to counter downward wave forces computed to be up to approximately 7 short tons (this uses a wave of 10 seconds period and 20 feet wave height).

TABLE II

Elevator Structure Weights*

Section	Air	Submerged
Submarine	25	Near Neutral
Cradle Structure	10.1	8.8
Tower	12.3	10.9
Air Chamber (empty)	11.2	9.8
Total	58.6	29.5

Air Chamber (buoyancy) 84.5

*Short tons

The air chamber uses ports to control the upward thrust created by the buoyancy generated by the air bubble. Ports located at the base of the chamber are always open. Upper ports would be located at approximately 10 feet above chamber base and are opened and shut by remote control. The upper ports are closed as chamber is blown to a point necessary for initial vertical motion. When upward movement commences, the ports are opened and remain so until the submarine reaches a depth of say 50 feet. This allows the air to spill out as it expands. At this point the upper ports are closed and the chamber is blown dry to give the additional buoyancy to complete the lift of the submersible to the superstructure. In the superstructure, the craft is disconnected from the elevator and locked in place. The air chamber is vented permitting the assembly to return to the lower position where it normally is housed when not in use.

When lowering the submersible, it first is mated to the cradle on the elevator which has been brought to the upper position. The air chamber then is vented enough to commence downward movement. The system is designed so that the air chamber does not break the surface under conditions up to 20 foot wave heights.

The elevator will ride in guide tracks in the barge hull. Friction brakes and shock absorbers at each end will be employed as an arresting system. Such a system appears well within the state-of-the-art in elevator construction.

The lift platform cradle is constructed as a free flooding rectangular girder framework, open at the top and to some extent on the ends, within which the submersible can moor or launch. The final design will be tailored to the submersible being supported. The box like shape requires a submersible that can be readily maneuvered in the vertical direction. Once in place, it is locked by pins electrically or hydraulically actuated (most recent experience during shakedown of U.S.S. Pigeon (configured to support DSRV) indicates the latter power source force for the pins may be preferable). With weight not a problem in the proposed design, it was felt that the additional structure was appropriate as it could provide some additional cushioned support of the submersible in the upright in addition to the pins, while being raised or lowered.

When the submersible is lifted to the superstructure, it is locked into the gimbal device. In normal service, additional restrainers are connected at the base of the submersibles (skegs or other hard points). Restrainers also are employed in the horizontal mode. In either case, they are removed during the flipping process.

The size and weight of smaller submersibles gives a high feasibility to being able to gimbal them during flipping operations. Major equipment on FLIP is handled this way including a galley package, diesel-generator sets and air compressors. While none represent the size and dimensions of a DSV, a device shown in Figure A-4, Appendix A shows a method of allowing the submarine to rotate remaining upright as the barge flips. The submersible (a DSV is shown) is connected to the device using the suspension points (padeyes) currently used to crane lift the craft. Cross cables are hooked to preclude excursions from vertical. The submersible and suspension device are supported by two large curved I-beam like guide rails. As the barge flips 90 degrees, the wheels of the suspension device are free to travel, permitting the submersible to rotate at a point within its hull configuration, thereby greatly reducing the inertial moments generated and the space required.

The tower structure serves the function of separating the air chamber and the landing platform cradle. It must be strong enough both to support the cradled submersible in air and withstand the wave forces while exposed to the latter.

Finally, the elevator requires air hose, power cables, and possibly hydraulic power hoses running from the superstructure to appropriate points on the air chamber and cradle. Consolidation of cable and hose into single-package is feasible and should be included in final design. A simple constant tension winch located at the superstructure can handle the cable/hose.

The buoyancy method is an untested conceptual design and requires further study prior to final engineering. Our initial examination indicates a most reasonable degree of feasibility. The backup availability of proven overhead crane designs that can lift the cradled submarine gives the concept of tending DSVs or small submersible from a flippable barge a very high real world feasibility that can extend operations to higher sea states.

DSRV

A second method of submersible tending was studied. In this case, the flippable barge is configured to provide crew rest and submerged replenishment of vital systems to extend the operations of some submersibles into higher sea states. Launch and recovery are accomplished when sea conditions were favorable using a more conventional craft as a tender.

This method of support is applicable to any submarine fitted with an upper or lower hatch that can be mated to another hatch. The submarine will mate similar to the way a DSRV mates to a mother (tending) submarine or a disabled one. In this concept (Figure 30) the submarine mates to a general purpose capsule (GPC) fitted with two access hatches. The crew is transferred to the surface in a personnel transfer capsule (PTC) via the second hatch. This method of support is applicable to such submersibles as the DSRVs and the Canadian commercial submarine TAURUS. Lockheed's DEEP QUEST can be fitted with such a capability as can other small submarines.

Replenishment of vital systems is accomplished either through the access hatch from the general purpose capsule or by use of plug-in fittings using either remote manipulators or divers. In keeping with one of the basic premises of this study, i.e. to endeavor for cost reduction, the preliminary engineering efforts have concentrated on a relatively simple construction package that can effectively support the mission.

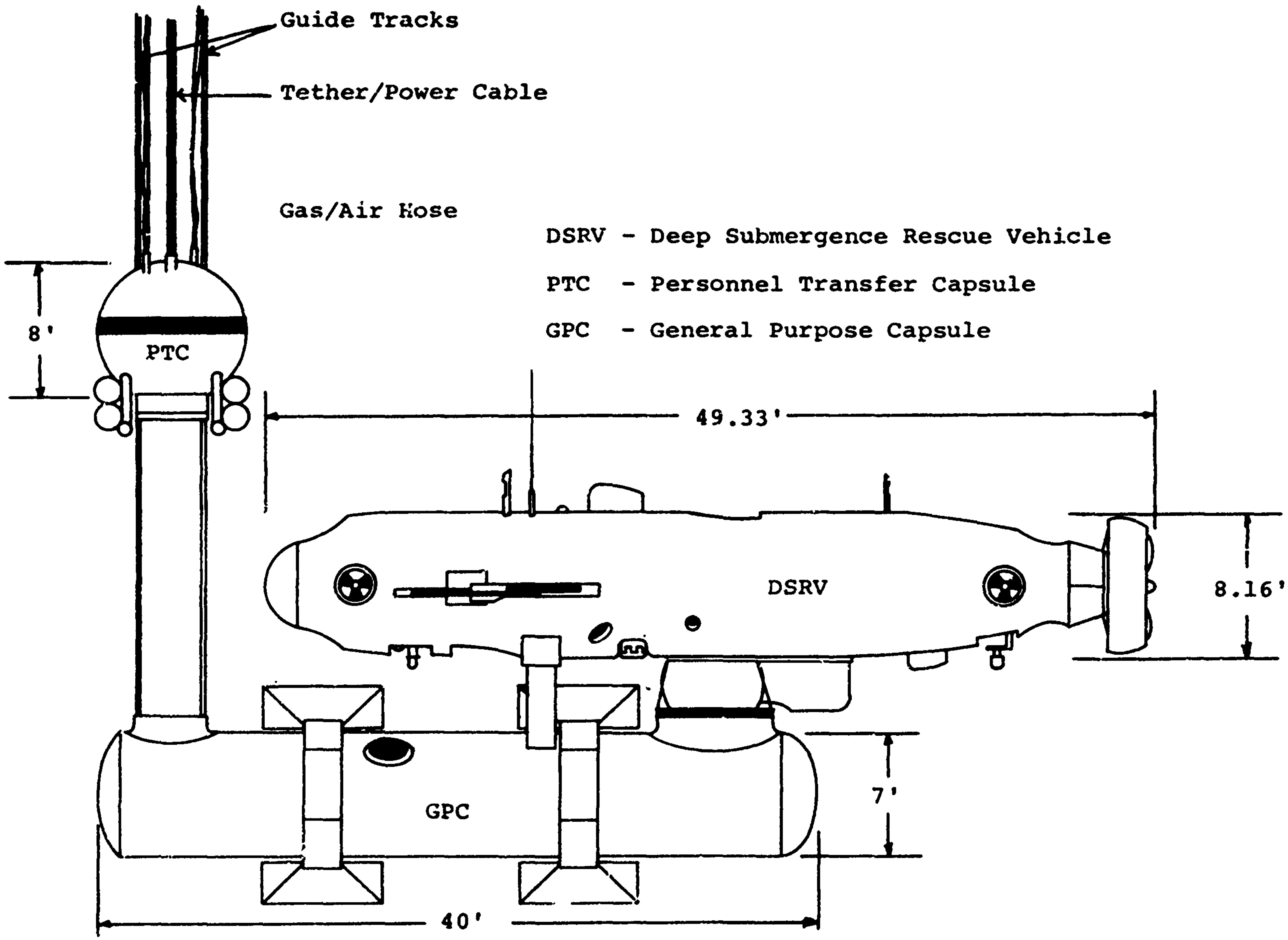


Figure 30. Submerged Support of a DSRV

The GPC dimensions of approximately 40 feet length and 7 feet diameter have been chosen to support a DSRV. The base of the GPC is positioned at frame 50 of the barge. In the vertical mode this would place the base 230 feet below the mean water line. The top of the DSRV is approximately 210 feet below the water line. The capsule will not be part of the hull but rather will be fastened to the hull with strap type brackets. The tended submarine will have at least one saddle type support bracket in addition to that support provided by the mated hatches.

The design specifications of the general purpose capsule must reflect both NAVSEA safety requirements and the fact that the capsule will be submerged a portion of the time with possible corrosive problems. The chamber must be capable of withstanding a total of the normal depth plus the amplitude of the highest wave expected and the possibility of being ballasted deeper than the normal draft of 290 feet. 320 feet external sea pressure was selected as the maximum expected. A further requirement of being able to withstand 150 psi internal pressure was established. This allows flooding in the bottom part of the capsule to be controlled. It also gives a limited decompression capability if required.

A tentative wall thickness of 1/2" high grade steel was selected (subject to final engineering) to reflect the above requirements, particularly safety. Weak areas near hatches and penetrating fittings would be built up similar to techniques currently used in construction of pressure vessels used in the diving industry. The GPC is designed as a single chamber (Figure 30) but could be configured as in the artist concept (Figure 31) when finally engineered.

The GPC will contain fittings and equipment for replenishing vital systems of the submersible tended. Additional housekeeping requirements such as air replenishment and revitalization, humidity control, communications and power outlets also will be provided for. Hull penetrations on the capsule except for the two major access hatches and air/gas fittings should be located below the vertical center of the compartment. The capsule will create some buoyancy (approximately 50 tons) which is easily handled by the ship's ballast system.

The PTC is primarily employed for transfer of submarine personnel from the GPC to the superstructure. It should be configured to support divers to 350 feet maximum depth, acting as a diving decompression chamber when required. The latter capability would not be employed to support sustained diving operations, but, more appropriately, occasional diving required to effect submerged inspection and minor repairs of the submarine

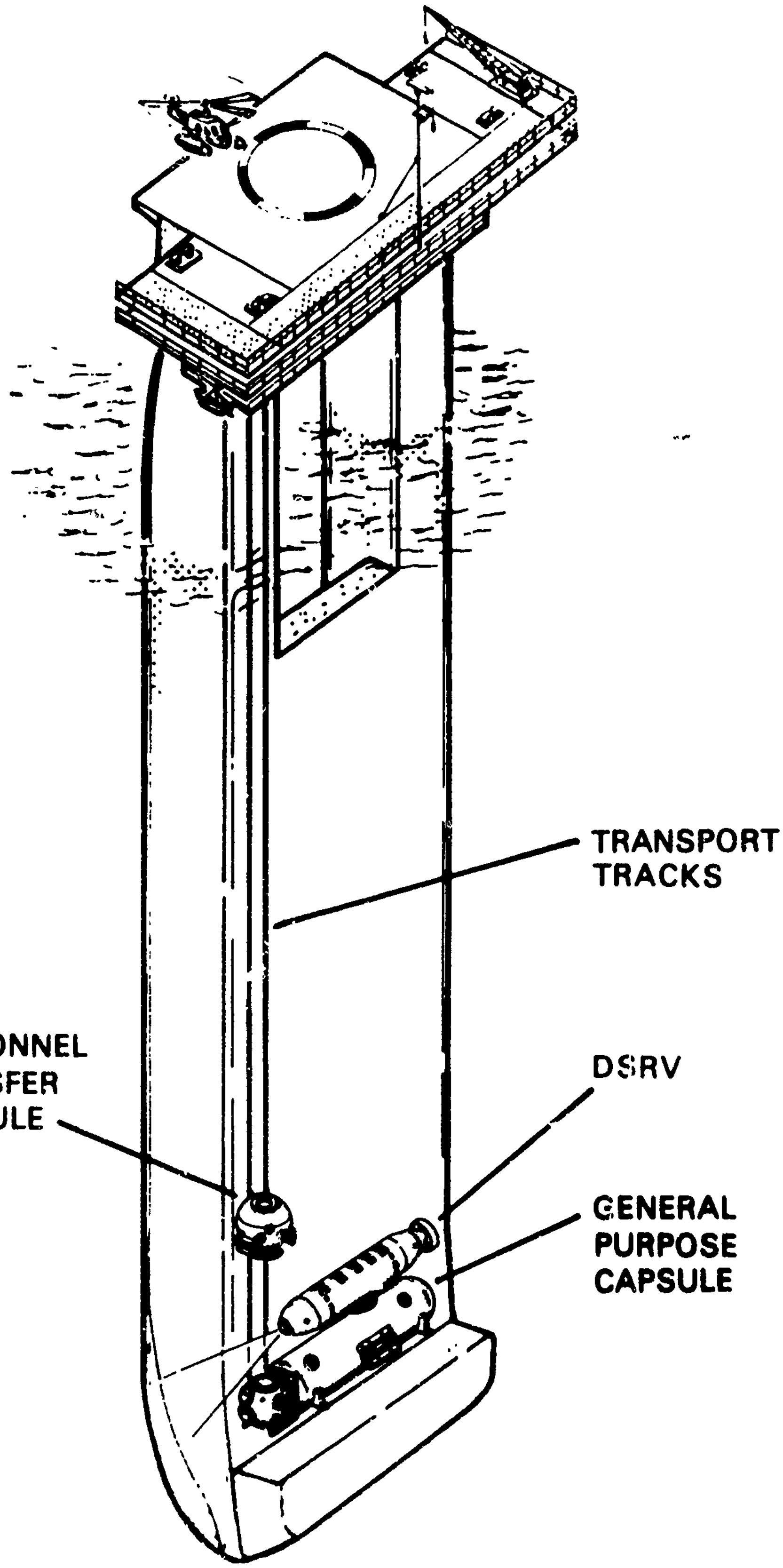


Figure 31. Submerged Support

or flippable barge. The PTC is not satisfactory for decompression more than several hours because of its cramped quarters. Study of support of a sustained saturation diving mission for the barge was not within the purview of this study. If such operations were contemplated as a mission, the Navy MKI (portable) or permanent MKII systems appear to be feasible for installation and support. The former would cost approximately $5 million.

The PTC is constructed of high quality steel with wall thickness and build up around hatches and fittings similar to the GPC discussed above. It will be approximately spherical in shape with an extension at the base for a mating/access hatch. Fittings are on the top for lines to the superstructure for supply of breathing mixtures and pressure buildup as required. It requires a breathing mixture revitalization system. Power for lights, communications and other electrical equipment will be supplied through a combined tether/power cable.

The PTC rides in guide tracks along the vertical hull (Figure 30) between the superstructure and the GPC serving as an elevator. A simple winch and tether cable assembly is required in the superstructure for raising and lowering. With a maximum anticipated assembly air weight of approximately 16,000 lbs, the PTC can be raised at speeds up to 100 FPM with an electric-hydraulic power system requiring output of 50 hp.

Emergency Egress and Recovery

While looking for alternate methods of submerged tending for submersibles not fitted with mating hatches or small enough for the elevator lift, a concept less desirable than the method using a GPC and PTC was considered. It provides a tank with the bottom open and located at some intermediate depth against the barge hull. An air bubble can lower the water in the tank, say to its mid depth. This would permit a suitably configured (that can equal interior pressure with external) submarine to surface inside for crew evacuation and replenishment. Such a concept is applicable only to submarines with a capability to equalize compartment pressure with sea pressure in the tank.

An undesireable feature was that the personnel would have to be exposed to sea pressure with associated problems. The advantage, of course, was that it allowed dry personnel transfer and a certain amount of replenishment dependent on how the submersible is fitted.

Concurrent with the preliminary development of the submarine tending concepts discussed above, it became apparent that by providing the capability for small submersibles to operate in higher sea states, consideration should be given to some means for emergency surface and egress if the need exists. In lower sea states, most small submarines have so little free board even with a built up conning tower that they enjoy at best a slim safety margin when egress is required. In the upper sea state force 5, lower force 6 seas to which the flippable barge is expected to extend certain submarine operations, rapid egress at the surface would be extremely hazardous.

The open tank with an air bubble offers a simple means for emergency personnel evacuation from a suitably configured submarine. Without a PTC elevator for lifting personnel to the surface or to provide decompression if desired, the alternative is to have the tank located on the barge in the vertical at a relatively shallow depth. If too shallow, undesireable actions from the existing wave spectrum might be experienced inside the tank. As a point of departure one hundred feet appears to be an acceptable compromise between wave action and time available before decompression is required. Up to 25 minutes is available at that depth before decompression is required according to available tables. If a decompression chamber is not available, personnel would have to move to the surface either in free ascent or with SCUBA gear available in the tank. In heavy seas neither is considered satisfactory so an elevator (PTC) with decompression capability is recommended as part of the installation (Figure 32). A portable deck is shown that would fold upwards being lowered after submarines surface. Also a portion of a possible air bag installation is shown. These act as bumpers while protecting the vital parts of the submersible during what relative motion may be concentration in the tank. A ladder and portable upper decking would provide access to the elevator (PTC) which rides in guides along barge hull to ensure easy mating. The emergency egress tank would be constructed of high grade steel of appropriate thickness dependent on depth selected. Limited vital system replenishment would be installed if desired.

Another emergency capability is provided with the main winch (Appendix A). This would use the standard swimmer assist hook up practice employed on MAXINE D (currently tending SEA CLIFF and TURTLE) and similar tenders. The submarine is then raised to the superstructure for crew rest and systems replenishment.

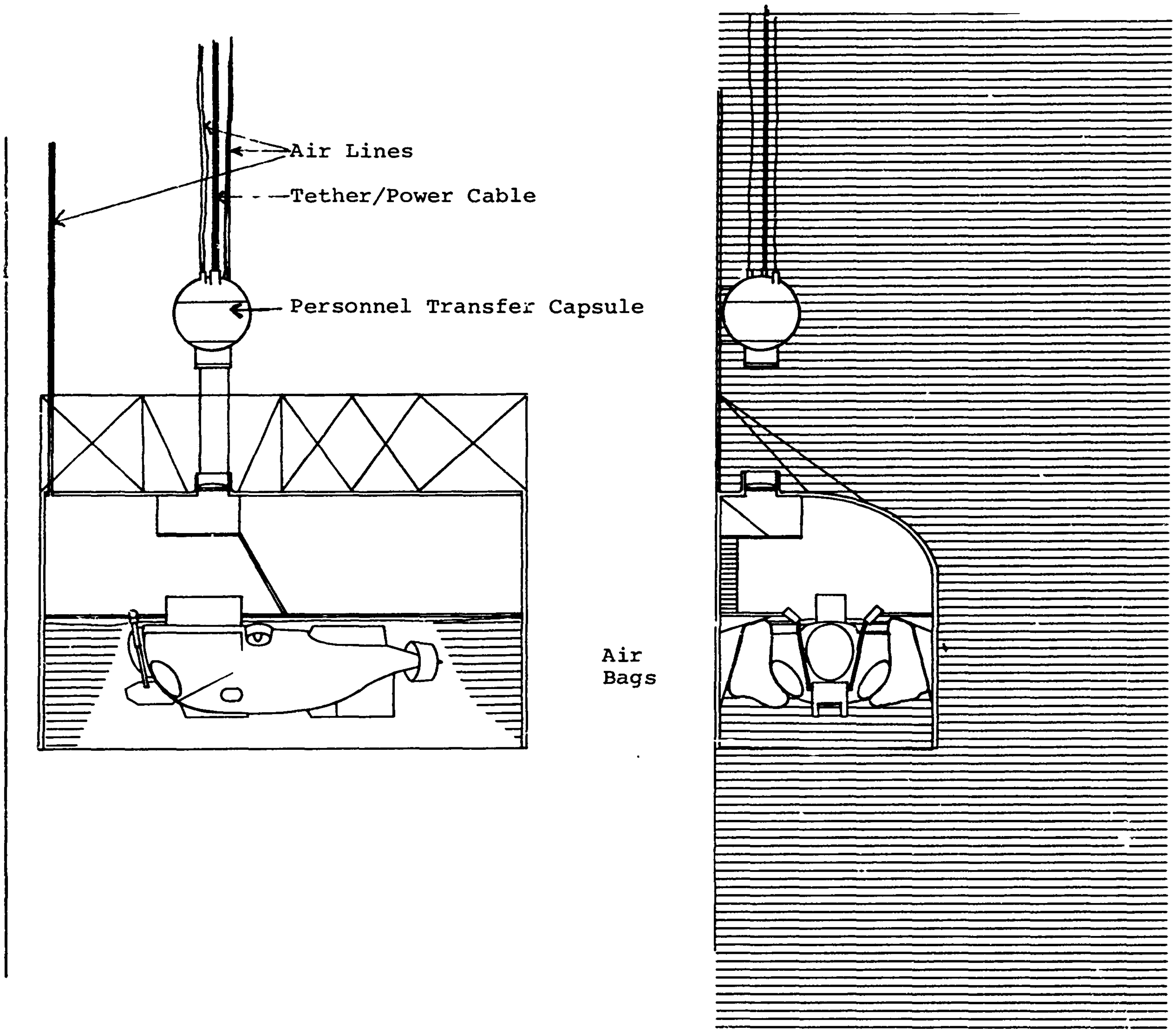


Figure 32. Emergency Egress Chamber

V. COST ESTIMATES

The climate for obtaining cost estimates changed radically from when Scripps made its proposal in the fall of 1973. Shipyard overloading, material shortages, inflation and manufacturer's back logs made it difficult to obtain realistic estimates. For example, in some of the winch/crane packages, there were quotes that varied as much as 100% when not an off-the-shelf item. To try to firm up a realistic cost package, we established a base of mid-fiscal year 1974 (about 1 January 1974). Prices could then be based on fact. Even with this base established, it was difficult to get vendors to not put their own anticipated cost growth. As a result some of the costs probably are conservative (high) for the established base.

The basic package cost including the winch/crane group was $8.8 million. This includes final design, construction and completed fitting out.

The propulsion group cost of $.5 million is predicated on four foundation installations and two thrusters. The latter will be installed on a mission basis either for rotational orientation or position keeping.

The mooring costs of $.2 million are based on synthetic lines and fittings (exclusive of scrap expendable bottom tackle) (Bronson) to make a 3-point moor in 3000 fathoms. The costs to moor at other depths should increase or decrease almost on a linear ratio with the depth.

The Personnel Transfer Capsule/General Purpose Capsule was difficult to price. Informal discussion with industry representatives indicated that the price at mid-FY74 would be at or under $.8 million. This was based on simplicity and relative shallow depth requirements of our proposed package.

No cost estimates could be obtained from industry on the package for raising DSVs and smaller submersibles. The cost estimate of up to $1 million is based on consulting advice.

A complete package with 3000 fathom mooring capability, thruster group and one or the other of the submarine tending tasks would be very close to $10.5 million at the base time of 1 January 1974. These costs are all informal. A formal shipyard bid on 360 foot barge designed for the ARPA project was furnished directly to PMS 383 (NAVSEASYSCOM) by Halter Marine in February 1974.

The investment in the barge and support vehicle is considered to be highly competitive with other types of vehicles that support ocean engineering tasks.

VI. RECOMMENDED INVESTIGATIONS

Although the ARPA flippable barge performance as an ocean engineering support platform in 1/100 and 1/8 scale tests was even better than expected, it was designed and tested for a specific purpose, i.e. construction at sea of a large stable platform. Accordingly some further investigations including model testing is recommended as beneficial to eventual fixing of final design.

Responses of the 1/8 scale model barge were not actually recorded during instrumented tests at sea. Rather, our efforts were focused on the assembled large stable platform of which the barge was a vertical unit (Spiess, 1974).

Model testing would concentrate on investigation of optimum shape, dimension changes, effectiveness of well versus solid hull, determination of drag forces for various conditions and responses near resonance frequencies.

Relatively minor changes to the model hull are required for these investigations. The cost would be small and lead to a more cost efficient and operationally capable final design.

ACKNOWLEDGEMENTS

A number of Navy activities provided advice and support. We are particularly grateful for the many hours of active liaison freely provided by Commander, Submarine Development Group One, members of his staff and subordinate units, and Commanding Officer, U.S.S. Pigeon ASR 21.

REFERENCES

Anderson, V. C., et al. 1970 RUM II - Remote Underwater Manipulator, Vol. I. MTS 6th Annual Preprints.

Bellows, Donald 1973 Subharmonic and Divergent Motions of Floating Platforms. SIO Ref. No. 73-37, August 1973.

Bronson, E. D. 1969 Floating Instrument Platform. International Assoc. of Lighthouse Authorities, Paris, France, Bulletin No. 41, July 1969.

Bronson, Earl 1971 Three-Point Anchoring in the Deep Ocean. Marine Physics Lab, Scripps Institution of Oceanography, MPL-U-43/71.

Fisher, F. H. and Spiess, F. N. 1963 FLIP--Floating Instrument Platform. J. Acoust. Soc. Am., Vol. 35, pp. 1633-1644.

Horrer, P., et al. Bendix Marine Advisors 1969 Revised Preliminary Wave Information at Five Example Locations, 2 May 1969. Appendix to SIO/AOEL Letter Serial 684 of 18 Dec. 1972.

Hoyt, E. D. 1962 Note on Bollard Pull. Naval Engineers Journal, Nov. 1962.

Kinsman, Blair 1965 WIND WAVES--THEIR GENERATION AND PROPAGATION ON THE OCEAN SURFACE. Prentice-Hall, 1965.

Murrill, R. L. 1974 Deep Submergence Systems Summary and Characteristics Manual. Commander, Submarine Development Group One, Jan. 1974.

PAC Companies No date. Brochure (Pacific Inland Navigation, Alaska Barge & Transport, B&R Tug and Barge, Sea Pac).

Rudnick, P. 1965 Vertically Compensated Spar Buoy. U.S. Pat. 3218655, Nov. 23, 1965.

Rudnick, P. 1967 Motion of a Large Buoy in Sea Waves. J. Ship Res., Vol. 11, No. 4, pp. 257-267, Dec. 1967.

Snyder, Robert M. 1965 A Practical Approach to Hydrodynamic Drag. Geo-Marine Technology, 1965.

Spiess, F. N. 1968 Oceanographic and Experimental Platforms. OCEAN ENGINEERING (J. Brahtz, ed.), Chapter 15, pp. 553-588, John Wiley and Sons, New York.

Spiess, F. N. 1974 Stable Floating Platform Project. SIO Ref. No. 74-17, Scripps Institution of Oceanography.

Talkington, H. R. 1972 Ocean Engineering Programs at Naval Undersea Research and Development Center. NURDC, June 1972.

Talkington, H. R. 1974 U.S. Navy Participation in the Rescue of the PISCES III. Vol. 8, No. 1, Marine Technology Society Journal, Jan. 1974.

Voith, J. M. 1971 Voith-Schneider Propulsion. 2500 8 62 2nd Edition, GMBH Ship Technical Division.

APPENDIX A

PRELIMINARY DESIGN REPORT FOR

OCEAN ENGINEERING SUPPORT PLATFORM

Prepared by

ADVANCED OCEAN ENGINEERING LABORATORY

Scripps Institution of Oceanography

University of California, San Diego

With Consulting Assistance of

L. R. GLOSTEN & ASSOCIATES, INC.

Naval Architects - Marine Engineers - Ocean Engineers

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REFERENCE DRAWINGS

This report should be read with reference to the following drawings:

Figure A-1	Lines and Offsets
Figure A-2	General Arrangement
Figure A-3	Platform Arrangement
Figure A-4	Gimbal Device For A Small Submersible

I PRELIMINARY DESIGN DESCRIPTION

A. GENERAL

The Flippable Barge Ocean Engineering Support Platform (OESP) is designed to operate in both vertical and horizontal modes and is capable of performing a number of tasks in each mode. Some specific design tasks are:

a. To provide a large platform to move large objects/weights to an operating area and flip platform through air-sea interface to vertical, conduct operations, and then recover as appropriate.

b. To provide a stable platform from which to conduct Deep Ocean Technology developmental and research programs.

c. To provide a platform from which to support bottom work systems.

d. To provide a stable platform capable of handling and servicing a submersible.

e. To provide a stable platform from which to conduct large object salvage operations.

f. To provide a stable platform from which to launch, retrieve, and operate large transducers.

The flippable barge design incorporates the operational principles and characteristics of a flippable stable floating platform evolving from design, construction, and operation of FLIP (Floating Instrument Platform) and subsequent model design and test (1/8 scale at sea) by Scripps Institution of Oceanography. The design described in detail in this report is a fully equipped OESP capable of operating as an individual unit.

In the horizontal mode, the OESP designed to operate individually incorporates the seakeeping and payload capabilities of large deck cargo barges currently in service. It has the capability to lift heavy loads and equipment to an operating area and flip them through the air-sea interface to a stable vertical position. In the vertical, the OESP serves as the platform from which tasks involving the use of equipment aboard the vessel, including the flippable payload, are performed.

When operations are completed, the loads can be retrieved and flipped to the horizontal. Vessel arrangements have been established to provide easy changeover in port, without the use of shipyard facilities, from one major payload or discipline to another. Space is allocated for later installation of additional power generating or other equipment, recognizing future requirements for imaginative further applications.

For ease of at-sea operations and flexibility of use, the following features are incorporated into the design:

(1) Platform's service facilities are strategically located to service transient payload components.

(2) Gimbal-like devices for operating equipment where required for transition from horizontal to vertical and return (designs similar to those used in FLIP).

(3) Interior working spaces and exterior decks, shell, and bulkheads in working areas fitted for bolting payload equipment in place.

(4) Maximum possible access between interior spaces and weather deck areas.

The OESP can be moored at unlimited depths from multiple points. It also is provided with a position keeping/rotational orientation package that allows one or the other mode. The one selected will depend on the mission.

The design provides for good seakeeping characteristics when hove-to in either horizontal or vertical modes and permits the weather decks to remain as dry as practical in all operation conditions.

The platform is designed as part of a two-unit system, the other being an Offshore Support Ship similar to the extended 4,000-horsepower AGOR21. Among the functions of the support ship are towing capability, mooring and positioning the OESP (including providing and laying ground tackle), resupply of the OESP while on station, electronics suite to supplement and complement the OESP electronics suite, and quarters and supplies for additional OESP personnel.

The general characteristics of the OESP are as follows:

Horizontal

Length Overall	340'- 0"
Beam	90'- 0"
Draft (Full Load)	17'- 0"
Beam (Upper Hulls)	22'-10"
Depth	22'- 0"
Displacement (Full Load)	10,180 LTSW

Vertical

Freeboard	50'- 0"
Air Gap	30'- 0"
Draft	290'- 0"
Displacement	13,720 LTSW

The total complement, including scientists, payload operators, technicians, and crew, will not exceed 40. Provisions, stores, and fuel for 35 to 90 days of operation can be stowed aboard the vessel depending on the specific operation under considerat...

The pla... ...its machinery, and outfitting shall meet the requiremen... ...the American Bureau of Shipping, the United States Coast Guard ...the U. S. Public Health Service, and the Federal Communications Commission.

B. PRINCIPAL COMPONENTS

1. Hull Form and Structure

The vessel is generally barge-shaped with a short, high forecastle and a centerline well aft. The centerline structure, forward of the well, ends in a typical barge rake. Outboard of the well, the hull is formed into cylinders, with a square cross section and rounded corners. An after superstructure, 20' x 20' x 90', connects the legs at the stern. In the vertical mode, a deck on top of the superstructure can be expanded to a 45' x 60' helicopter platform. Skegs designed to permit good towing characteristics will form the base of the helicopter platform.

The vessel is longitudinally framed. Transverse web frames are spaced 5 feet 0 inches from the bow to Frame 9 and from Frame 21 to the stern. Transverse web frames between Frames 9 and 21 are spaced 3 feet 4 inches. The controlling design load for structure forward of Frame 21 is the hydrostatic load when the vessel is vertical (for both hard and soft tanks). Aft of Frame 21, longitudinal bending loads are the most severe and are thus the design loads.

The vessel is subdivided by transverse watertight bulkheads, spaced about 40 feet apart, to form nine compartments. The forecastle is also a separate compartment. A longitudinal bulkhead on centerline runs from the bow to the end of the centerline rake at the beginning of the centerline well. There is a lateral watertight flat at half-depth through a portion of the midbody.

The structural layout and details are similar to that of an ABS-classed liquid cargo barge. Scantlings satisfy the ABS requirements for deep tanks on an ocean-going liquid cargo barge. All steel is ABS approved ordinary strength steel. No high strength steels are employed. Slightly over 2100 long tons of permanent concrete ballast is installed to permit the vessel to be operated in the vertical mode. The concrete ballast has a density of 175 lbs/ft^3.

2. Electric Plant

Main and auxiliary power is provided by three Caterpillar D398 diesel generator sets rated at 645 KW continuous each. The diesel generator sets are gimbal-mounted, with exhaust, fuel, and cooling lines located near the center of rotation to permit the use of swivel joints and fixed piping and ducting. Power will be provided through parallel switchboards, located in the Engineering Operating Station. Power available will be both 440 volt, 3 phase, AC, and 110 volt, 3 phase, AC.

Control and monitoring of the electric plant is from the remote Engineering Operating Station near but isolated from the engine room. The engine room is unattended and completely automated. Spark arrestor silencers are used. Particular attention is paid to sound isolation and reduction and to limiting vibration. Acoustic quieting of airborne and waterborne noise is provided where feasible including the use of air suspension for rotating machinery, etc.

3. Communication and Control

A Main Control Center is located in the superstructure aft. The Control Center includes a chart room, radio room, and some scientific controls. Located in this room are radar, sonar, depth sounder, RDF, Loran, satellite receiver, Omega, Gyro, single sideband radio, VHF radio, and weather facsimile receiver. Additionally, the high and low pressure air manifolds, the thruster controls and closed circuit TV and some scientific instrument controls are in this space. All instruments requiring vertical orientation for proper operation are either bolted in place in the horizontal with an alternate location for bolting in place in the vertical mode or are gimbal-mounted.

4. Auxiliary Systems

a. Heating, Air Conditioning, Ventilation, and Refrigeration

The entire superstructure, including all accommodations, laboratories, control spaces, and mess are climate controlled by a central heating and air-conditioning system. The system consists of a heating coil and cooling coil, a gimbaled reciprocating air-conditioning chiller and ventilation fans, all located in the engine room and reheat coils with thermostat controls in each space. The engine rooms are forced draft ventilated.

Reefer stores are kept in a 20-foot reefer container, prepacked prior to a voyage and installed on gimbals in the superstructure. The van is a self-contained unit, powered by ship service electrical power.

b. Oil Handling Systems

The diesel generators take suction on fuel oil day tanks located in the engine rooms and use engine mounted fuel oil pumps. Fuel oil transfer pumps are located in the pump room in Tank 7-C to transfer fuel from the fuel tanks to the day tanks. A hand stripping pump is provided for the day tanks.

Lubricating oil pumps are installed to transfer fresh lubricating oil from small storage tanks in the engine room to the diesel engines. A contaminated oil holding tank for used lubricating oil, bilge oil, and other oily waste is located in the engine room. A contaminated oil pump enables this waste oil to be pumped to a pier or barge alongside the OESP. The bilge pumps, located in the pump room in Tank 7-C pump directly to the holding tank.

A small independent JP-5 fuel tank located on or near the helicopter deck, served by a small local pump, provides the capability for refueling transient helicopters.

c. Salt Water Systems

Large salt water supply pumps located in the pump room in Tank 7-C provide a steady flow of salt water to each engine room. All other salt water systems take suction on this line. These systems include engine cooling, salt water sanitary service, and the firemain. An engine mounted pump provides the engine cooling raw water. The salt water sanitary system includes a gimbal-mounted self-contained sewage treatment plant. A salt water service pump takes suction on the salt water supply line and delivers salt water to a pressure set, which supplies the sanitary system.

d. Fresh Water Systems

A gimbal-mounted, 2,400-gpd evaporator provides fresh water to the fresh water storage tank, located in the engine room. A fresh water service pump delivers fresh water to a pressure set which provides cold fresh water directly and hot fresh water after passing through a hot water heater.

e. Fire Extinguishing Systems

The fire extinguishing system includes the fire main and portable fire extinguishers for the superstructure, a CO_2 system for the engine rooms and deck foam monitors for the helicopter deck.

f. Hydraulic Power System

A small, self-contained hydraulic pump and motor will be installed for ballast system valve controls.

g. Ballasting and Deballasting Systems

Flipping is accomplished by gravity flooding ballast tanks in the proper sequence. Manifolds for controlling flipping use 3-way 2-port valves to provide venting for ballast operations, and air bottle or compressor connections for deballasting operations. Eight 7-foot diameter and 42-foot long air bottles store 250 psi air, enough to flip up. These bottles can be totally charged in four hours by two gimbal-mounted compressors, located in the engine room. Once the OESP has flipped to the horizontal, two gimbal-mounted low pressure compressors can be directly connected to deballast the remainder of the vessel. The low pressure compressors are rotary vane compressors to prevent contamination of the discharged ballast water with oil.

h. Position Keeping/Rotational Control

The barge will be configured either for the position keeping mode or the rotational control mode depending on mission requirements. Power is provided by two 500-horsepower thrusters, remotely controlled from the main control center.

i. Deck Machinery

Deck machinery to be installed includes a main winch, an intermediate winch, a hydrographic winch, a light crane (2 1/2 tons), and two mooring line handling capstan winches.

5. Outfit and Furnishings

a. Hull Fittings

A towing bridle and other hull fittings required for a barge of this size are included.

b. Boats

Two 18-foot utility workboats with gimbaled suspension and launching systems to permit launching when the OESP is in horizontal and vertical modes are included. Four 20-man ocean service inflatable liferafts are provided. Other requirements will be in accordance with Coast Guard Regulations.

c. Ladders and Gratings

Permanently installed ladders to permit access throughout the engine rooms and the superstructure are provided. Ladders will be of standard marine construction with non-skid tread. Retractable catwalk type exterior deck gratings will be provided on the front and sides of the superstructure deck levels, providing access between interior spaces and outside working areas in the vertical mode of operation.

d. Non-Structural Bulkheads

Non-structural bulkheads will be of hollow construction or single thickness construction as applicable to meet U. S. Coast Guard regulations.

e. Painting

Surfaces that will become decks in either mode of operation will be painted with nonskid marine paint. All ballast tanks will be coated to reduce corrosion. Other painting will conform to standard good marine practice.

f. Hull Insulation

All surfaces in occupied spaces exposed to temperature differentials will be temperature insulated. The engine rooms will be acoustic insulated. Insulation will be according to standard good marine practice.

g. Shop Facilities

A workshop will be located in the engine room, including a workbench, hand tools and storage space, and a lathe, drill press, power saw, portable welding machine, and grinder.

h. Galley

A galley capable of serving 40 people in two shifts cafeteria style will be installed. Tables, seats and appropriate galley equipment (such as refrigerator, stoves) will be gimbaled.

i. Living Spaces

All living spaces will meet the requirements of Coast Guard Regulations.

j. Laboratories and Control Spaces

Laboratories and control spaces will be provided with furniture and equipment depending on the specific task of the individual voyage. Provision will be made for easy changeover in port between voyages.

k. Hospital

A hospital with two bunks, a table, and storage space is included.

II PRELIMINARY OESP EQUIPMENT LIST

Group No.	Item	Location	Qty	Description
3-300	Diesel Generator (g)	Engine Room	3	Cat D398 w/standard equipment and engine and remote mounted controls, alarms, heat exchangers, exhaust fittings, air start, crankcase explosion relief valves
3-300	Silencers	Engine Room	3	Kittell SR series spark arrestor
4-400	10 CM Radar (g)	Super-structure	1	Kelvin Hughes type 21/16 C (S band) with dual display and controls
4-400	Precision Depth Recorders (g)	Super-structure	2	Simrad Model EN Navigation Sounder
4-400	Echo Sounder, shallow (g)	Super-structure	1	Raytheon DE 719
4-400	Echo Sounder, deep, narrow beam (g)	Super-structure	1	Simrad Model EK 38 with dual display and controls
4-400	Underwater Telephone	Super-structure	1	Dual controls
4-400	Loran A/C (g)	Super-structure	2	Mieco Model 6811 auto track, 3 displays and controls
4-400	Radio Direction Finder(g)	Super-structure	1	Benmar ADF 200
4-400	Satellite Receiver (g)	Super-structure	1	Satellite Positioning Corp. SCS-100, dual display and controls
4-400	Omega Receiver (g)	Super-structure	1	Mieco Model 833

NOTE: (g) = gimballed items.

Group No.	Item	Location	Qty	Description
4-400	Gyro Compass (g)	Super-structure	1	RCA GY-MC
4-401	Single Side Band Radio-Telephone	Super-structure	1	Northwest NW6 10 channel marine SSB transceiver
4-401	VHF-FM Radio-Telephone	Super-structure	1	Intech Model V110 55 channel transceiver
4-401	Facsimile Receiver (g)	Super-structure	1	Benmar FAX-750 weather facsimile receiver
5-500	Heating Coil	Engine Room	1	Trane Type W
5-501	Ventilation Fans	Engine Room	10	Trane Size 36 Model Q, 2" SP fans
5-502	Recip A/C Chiller (g)	Engine Room	1	Trane CG WA-200M, 20 ton
5-502	Cooling Coil	Engine Room	1	Trane Type W
5-502	A/C Fan	Engine Room	1	Trane Size 21 Model Q, 2" SP fan
5-502	Reheat Coil w/Thermostat	Super-structure	35	Indeeco 3/4 KW coil
5-502	A/C Circ Water Pump	Engine Room	1	Paco 1250-5 centrifugal motor driven - 60 gpm, 3500 rpm, 40 psi, 2 hp
5-503	Reefer Van (g)	Super-structure	1	20' reefer container
5-504	L.O. Transfer Pump	Engine Room	2	Roper Series A size 08 - 14 gpm, 1800 rpm, 50 psi, 1-1/2 hp - rotary motor driven
5-504	Contaminated Oil Pump	Tank 9	2	Roper Series A size 21 - 30 gpm, 1800 rpm, 50 psi, 2 hp - rotary motor driven

NOTE: (g) = gimballed items.

Group No.	Item	Location	Qty	Description
5-505	Sewage Treatment (g)	Engine Room	1	Aquanox Model 402, self contained unit
5-506	S.W. Supply Pump	Tank 6-B	3	Paco 4015-5 Centrifugal motor driven, 750 gpm, 1750 rpm, 65 psi, 40 hp
5-506	S.W. Service Pump and Pressure Tank	Engine Room	2	Paco 1250-5 Centrifugal motor driven, 60 gpm, 3500 rpm, 40 psi, 2 hp
5-506	Fire Pump	Engine Room	2	Paco 2095-1 Centrifugal motor driven, 200 gpm, 3500 rpm, 110 psi, 20 hp
5-506	Bilge Pump	Tank 7-C	2	Paco 1070-5 Centrifugal motor driven, 70 gpm, 3500 rpm, 65 psi, 5 hp
5-507	CO_2 System	Engine Room		3500 # CO_2 in cylinders plus alarms, release fittings, controls, etc.
5-507	Deck Foam Monitors	Super-structure	2	National Foam System, suitable for 60' x 45' helicopter deck
5-507	Portable Fire Extinguishers	Super-structure	16	Various types
5-508	Flood and Discharge Valves	Ballast Tanks 5,6,7	7	Keystone Fig 100 butterfly valves, 12"
5-508	Hydraulic Pump & Motor	Engine Room	2	BE-GE Model PM-230, 20 gpm @ 1000 psi self contained tank unit
5-509	F.W. Service Pump & Tank	Engine Room	2	Paco 1250-5 Centrifugal motor driven, 35 gpm, 3500 rpm, 40 psi, 2 hp
5-509	Hot Water Heater	Engine Room	1	National Steel Construction Model HGL-500C
5-511	F.O. Transfer Pump	Tank 7-B	3	Roper Series A size 21 - 30 gpm, 1800 rpm, 150 psi, 5 hp - rotary pump, motor driven

NOTE: (g) = gimballed items.

Group No.	Item	Location	Qty	Description
5-511	F.O. Stripping Pump	Engine Room	2	Blackmer Model PA 210 rotary hand pump
5-513	H.P. Compressors (g)	Engine Room	2	Dresser-LeRoi 256S2 420 cfm @ 250 psi, motor driven, 125 hp
5-513	L.P. Compressors (g)	Engine Room	2	Dresser Roots LAL Spiraxial 712, 856 cfm @ 30 psi, motor driven, 115.3 hp
5-513	Air Cylinders	Tank 8	8	7' diameter, 42' long cylinder with domical heads
5-513	Manifold Valves (HP)	Super-structure	6	Rockwell Fig 5205, 3-way, 2-port
5-513	Manifold Valves (HP)	Super-structure	23	Rockwell Fig 2245, carbon steel valves
5-513	Manifold Valves (LP)	Super-structure	11	Rockwell Fig 5205, 3-way 2-port
5-513	Manifold Valves (LP)	Super-structure	3	Rockwell Fig 2245, carbon steel valves
5-517	Distilling Plant (g)	Engine Room	1	Cuno Model HJ-50, 2400 gpd, pumps, etc., included
5-518	Thrusters	Tank 6	2	Pluger AE 59-7-500, 500 hp - motor internal to hub
5-520	Main Winch		1	As designated, 20,000 feet of 7/4 to 1 1/4 wire rope, 60,000 # line pull @ 60 fpm (109 hp)
	Traction Unit	Super-structure		
	Drum	Engine Room		
5-520	Intermediate Winch	Super-structure	1	As designated, 20,000 feet of 1/2" wire rope 14,000 # line pull @ 100 fpm (42 hp)

NOTE: (g) = gimballed items.

Group No.	Item	Location	Qty	Description
5-520	Hydrographic Winch	Super-structure	1	As designated 30,000 feet of 1/4" (max) conductor cable, 5,000 # line pull @ 140 fpm (21 hp)
5-520	Heavy Crane	Super-structure	1	Marco W4049 (2 1/2 ton)
5-520	Capstans	Super-structure	2	As designated 60,000 # line pull at 15 fpm (27 hp)
6-601	18' Utility Workboats(g)	Super-structure	2	Fed Stock #1940-116-7319 with davits
6-601	Inflatable Liferafts	Super-structure	4	Elliot, 20-man, ocean service liferafts

NOTE: (g) = gimballed items.

III PRELIMINARY WEIGHT SUMMARY

PAGE ___

ESTIMATE OF WEIGHT FOR SHIPS, SUMMARY SHEET
HULL STRUCTURE - GROUP I
NAVSHIPS 4616A-3 (REV. 5-65)

U.S.S. OESP

HULL STRUCTURE - GROUP I

8/1/73

SUB GROUP	DESCRIPTION	WEIGHT (Tons)	ABOVE AS	MOMENTS	CENTER OF GRAVITY: REFERRED TO FRAME NO.: FWD	MOMENTS	AFT	MOMENTS	REFERRED TO: PORT	MOMENTS		MOMENTS
100	SHELL PLATING OR PLANKING	2711.7	13.85	37557.05			14081	381834.48				
101	LONGITUDINAL AND TRANSVERSE FRAMING											
102	INNER BOTTOM PLATING											
103	PLATFORMS & FLATS BELOW LOWERMOST CONTINUOUS DECK											
104	FOURTH & LOWER CONTINUOUS DECKS											
105	THIRD DECK											
106	SECOND DECK											
107	MAIN DECK OR HANGAR DECK											
108	FOCSL & POOP DKS											
109	GALLERY DECK											
110	FLT. DK., LDG. PL. & SPL. PURP. DKS. ABV. WEATHER DK.											
111	SUPERSTRUCTURE	108.0	32.00	3456.00			32000	34560.00				
112	FOUNDATIONS FOR PROPULSION PLANT MACHINERY	50.0	17.80	890.00			272.00	13600.00				
113	FOUNDATIONS FOR AUXILIARIES & OTHER EQUIPMENT											
114	STRUCTURAL BULKHEADS	299.9	11.89	3565.81			12729	38174.27				
115	TRUNKS AND ENCLOSURES											
116	STRUCTURAL SPONSONS (SKEGS)	4.9	4.50	22.05			32200	1577.80				
117	ARMOR											
118	AIRCRAFT FUEL SADDLE TANK STRUCTURE											
119	STRUCTURAL [illegible]NGS, FORGINGS, & EQUIVALENT WELDMENTS											
120	SEA CHESTS											
121	BALLAST AND BOUYANCY UNITS FIXED OR FLUID											
122	DOORS AND CLOSURES, SPECIAL PURPOSE											
123	DOORS, HATCHES, MANHOLES, & SCUTTLES - NONBALLISTIC											
124	DOORS, HATCHES, MANHOLES, & SCUTTLES - BALLISTIC											
125	KING POSTS AND SUPPORT FRAMES											
127	SONAR DOME											
128	MASTS, TOWERS, TETRAPODS & SERVICE PLATFORMS	3.6	42.00	151.20			33000	1188.00				
130	WELDING, RIVETING, AND FASTENINGS	79.5	14.36	1141.62			14924	11864.58				
131	FREE FLOODING LIQUIDS											
	TOTALS, TONS	3257.6	14.36	46783.73			14821	482794.13				

COMPUTING BY

COMPUTING CHECKED

ESTIMATE OF WEIGHT FOR SHIPS, SUMMARY SHEET
ELECTRIC PLANT - GROUP 3
NAVSHIPS 4616A-3 (REV. 5-65) SHEET 4

U.S.S. OESP

ELECTRIC PLANT - GROUP 3

DATE 8/1/73

GROUP	DESCRIPTION	WEIGHT (Tons)	ABOVE [illegible]	MOMENTS	REFER [illegible] TO FRAME NO. [illegible]	[illegible]	AFT	MOMENT	REFERRED TO [illegible]	[illegible]	[illegible]	[illegible]
300	ELECTRIC POWER GENERATION	25.5	11.00	280.50			27000	6885.0				
301	POWER DISTRIBUTION SWITCHBOARDS	4.5	27.00	121.50			31500	1417.5				
302	POWER DISTRIBUTION SYSTEM (CABLE)	2.5	21.50	53.75			31000	775.0				
303	LIGHTING SYSTEM (DISTRIBUTION AND FIXTURES)	1.0	30.00	30.00			31500	315.0				
350	ELECTRIC PLANT REPAIR PARTS	2.0	17.00	34.00			32000	640.0				
351	ELECTRIC POWER GENERATOR FLUIDS	4.6	11.00	50.60			28300	1301.8				
	TOTALS, TONS	40.1	14.22	570.35			28265	11334.3				

COMPUTING BY

COMPUTING CHECKED BY

ELECTRIC PLANT - GROUP 3 - SUM

ESTIMATE OF WEIGHT FOR SHIPS, SUMMARY SHEET
COMMUNICATION AND CONTROL - GROUP 4
NAVSHIPS 4616A-3 (11-57) SHEET 5

U.S.S. OESP

BUDGET BUREAU - 45-R281
REPORT - BUSHIPS-9291-4 8/1/73

SUB GROUP	DESCRIPTION	WEIGHT (Tons)	CENTER OF GRAVITY ABOVE BASE	MOMENTS	REFERRED TO FRAME NO. FWD	MOMENTS	AFT	MOMENTS	REFERRED TO PORT	MOMENTS	ST'BD
400	NAVIGATIONAL SYSTEMS AND EQUIPMENT	2.0	37.00	74.00			32500	650.0			
401	INTERIOR COMMUNICATION SYSTEMS	0.3	32.00	9.60			32000	96.0			
402	ARMAMENT CONTROL SYSTEMS										
403	COUNTERMEASURE & SHIP PROT. SYS. (EXCEPT ELECTRONICS)										
404	ELECTRONIC SYS. INCLUDING ELECTRONIC COUNTERMEASURES	0.5	32.00	16.00			32000	160.0			
450	COMMUNICATION AND CONTROL REPAIR PARTS	0.2	27.00	5.40			31500	63.0			
	TOTALS, TONS	3.0	35.00	105.00			32300	969.00			

COMPUTING BY

COMPUTING CHECKED

COMMUNICATION AND CONTROL - GROU

AUXILIARY SYSTEMS - GROUP 5
NAVSHIPS 4616A-3 (REV. 5-65) SHEET 6

U.S.S. OESP

AUXILIARY SYSTEMS GROUP 5 8/1/73

PAGE

SUB GROUP	DESCRIPTION	WEIGHT (Tons)	ABOVE BASE	MOMENTS	FWD	MOMENTS	AFT	MOMENTS		MOMENTS		MOMENTS
500	HEATING SYSTEM	0.5	32.00	16.00			32000	160.00				
501	VENTILATING SYSTEM	4.0	21.00	84.00			31000	1240.00				
502	AIR CONDITIONING SYSTEM	2.5	16.00	40.00			31000	775.00				
503	REFRIGERATING SPACES, PLANT AND EQUIPMENT	4.0	37.00	148.00			32500	1300.00				
504	GAS, HEAT, ALL LIQUID CARGO PIPING, OXYGEN-NITROGEN & AVI. LUB. OIL SYS.	1.4	32.00	44.80			33500	469.00				
505	PLUMBING INSTALLATIONS	3.2	20.00	64.00			31000	992.00				
506	FIREMAIN, FLUSHING, SPRINKLER, WASHDOWN & S.W. SERVICE SYSTEMS	2.4	20.00	48.00			31500	756.00				
507	FIRE EXTINGUISHING SYSTEM	4.0	15.00	60.00			31500	1260.00				
508	DRAINAGE, BALLAST, TRIMMING, HEELING & STABILIZING TANK SYSTEM	2.5	5.00	12.50			13000	325.00				
509	FRESH WATER SYSTEM	3.5	20.00	70.00			31000	1085.00				
510	SCUPPERS AND DECK DRAINS	1.2	22.00	26.40			16500	198.00				
511	FUEL & DIESEL OIL FILLING, VENTING, STOWAGE & TRANSFER SYS.	6.4	5.00	32.00			22000	1408.00				
512	TANK HEATING SYSTEMS											
513	COMPRESSED AIR SYSTEMS	187.8	11.02	2070.00			24635	46253.75				
514	AUXILIARY STEAM, EXHAUST STEAM AND STEAM DRAINS											
515	BUOYANCY CONTROL SYSTEM (FLOODING & VENTING FOR SUBMARINES)											
516	MISCELLANEOUS PIPING SYSTEMS	5.5	13.00	71.50			28500	1567.50				
517	DISTILLING PLANT	1.2	10.00	12.00			31000	372.00				
518	STEERING SYSTEMS (THRUSTERS)	8.5	11.00	93.50			13500	1147.50				
519	RUDDERS											
520	MOORING, TOWING, ANCHOR & AIRCRAFT, HANDLING SYSTEM & DECK MACHINERY	29.5	45.00	1327.50			32000	9735.00				
521	ELEVATORS, MOVING STAIRWAYS, STORES STRIKEDOWN & STORES HANDLING EQUIPMENT	2.0	27.00	54.00			31500	630.00				
522	OPERATING GEAR FOR RETRACTING & ELEVATING UNITS											
523	AIRCRAFT ELEVATORS											
524	AIRCRAFT ARRESTING GEAR, BARRIERS AND BARRICADES											
525	CATAPULTS AND JET BLAST DEFLECTORS											
526	HYDROFOILS											
527	DIVING PLANES & STABILIZING FINS											
528	REPLENISHMENT AT SEA & CARGO HANDLING											
550	AUXILIARY SYSTEMS REPAIR PARTS	2.0	16.00	32.00			32000	640.00				
551	AUXILIARY SYSTEMS OPERATING FLUIDS, BASES & STABILIZER FLUIDS	0.5	15.00	7.50			31000	155.00				
	TOTALS, TONS	272.6	15.82	4313.7			25850	70468.25				

COMPUTING BY

COMPUTING CHECKED

AUXILIARY SYSTEMS - GROUP 5 - SUM

ESTIMATE OF WEIGHT FOR SHIPS, SUMMARY SHEET
OUTFIT AND FURNISHINGS - GROUP 6
NAVSHIPS 4616A-3 (REV. 5-55) SHEET 7

U.S.S. OESP

OUTFIT AND FURNISHINGS
GROUP 6

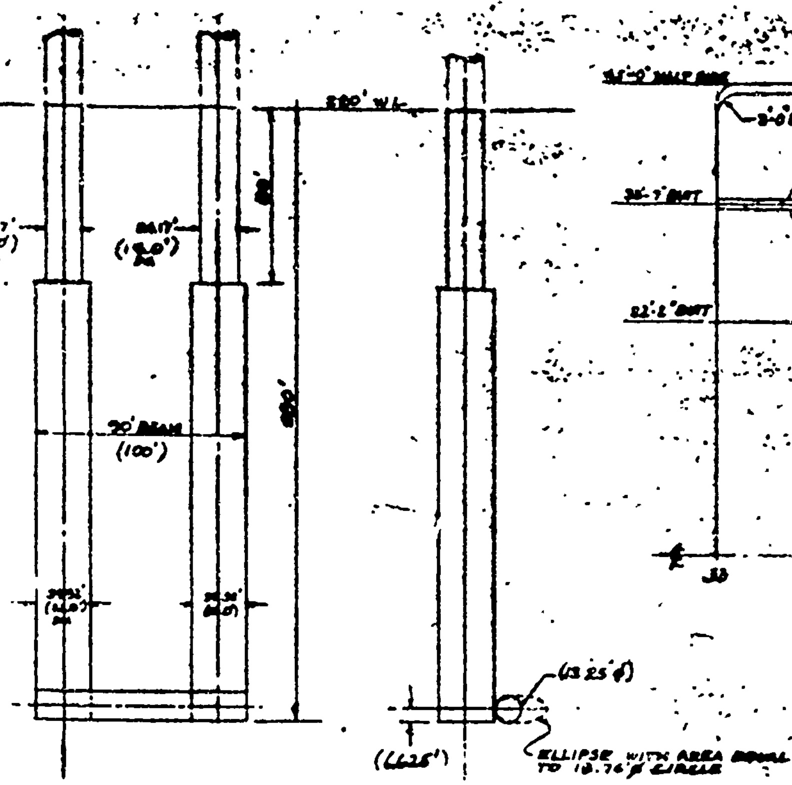
DATE 8/2/73

PAGE

SUB GROUP	DESCRIPTION	WEIGHT (Tons)	CENTER OF GRAVITY: ABOVE BASE	MOMENTS	REFERRED TO FRAME NO.: FWD	MOMENTS	AFT	MOMENTS	REFERRED TO: PORT	MOMENTS	STBD	MOMENTS
600	HULL FITTINGS	3.0	27.00	81.00			17500	525.00				
601	BOATS, BOAT STOWAGE AND HANDLING	30.0	32.00	960.00			31000	9300.00				
602	RIGGING AND CANVAS											
603	LADDERS AND GRATINGS	47.0	26.00	1222.00			30400	14288.00				
604	NONSTRUCTURAL BULKHEADS & NONSTRUCTURAL DOORS	44.0	31.00	1364.00			31900	14036.00				
605	PAINTING	45.0	15.00	675.00			13500	6075.00				
606	DECK COVERING											
607	HULL INSULATION	10.0	23.00	230.00			31100	3110.00				
608	STOREROOMS, STOWAGES, AND LOCKERS											
609	EQUIPMENT FOR UTILITY SPACES	1.0	32.00	32.00			31500	315.00				
610	EQUIPMENT FOR WORKSHOPS, LABORATORIES & TEST AREAS											
611	EQUIP. FOR GALLEY, PANTRY, SCULLERY & COMMISSARY OUTFIT	3.0	38.00	114.00			32600	978.00				
612	FURNISHINGS FOR LIVING SPACES	5.0	32.00	160.00			32100	1605.00				
613	FURNISHINGS FOR OFFICES, CONTROL CENTERS & MACHINERY SPACES	2.0	32.00	64.00			31500	630.00				
614	FURNISHINGS FOR MEDICAL, DENTAL & PHARMACEUTICAL SPACES	1.0	27.00	27.00			32600	326.00				
615	RADIATION SHIELDING											
650	OUTFIT AND FURNISHINGS, REPAIR PARTS											
651	OUTFIT & FURNISHINGS - OPERATING FLUIDS											
	TOTALS, TONS	191.0	25.81	4929.00			26800	51188.00				

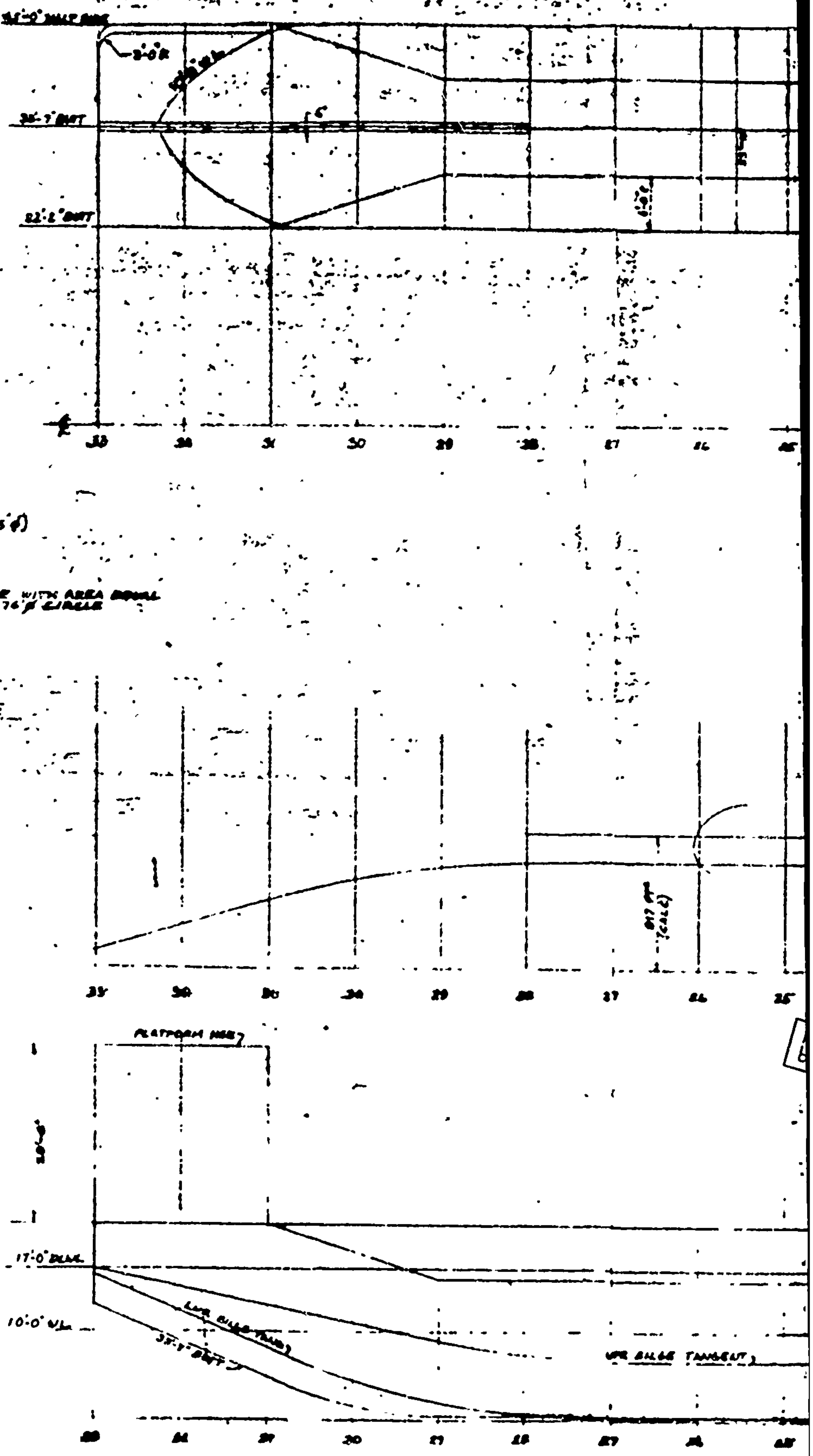
COMPUTING BY

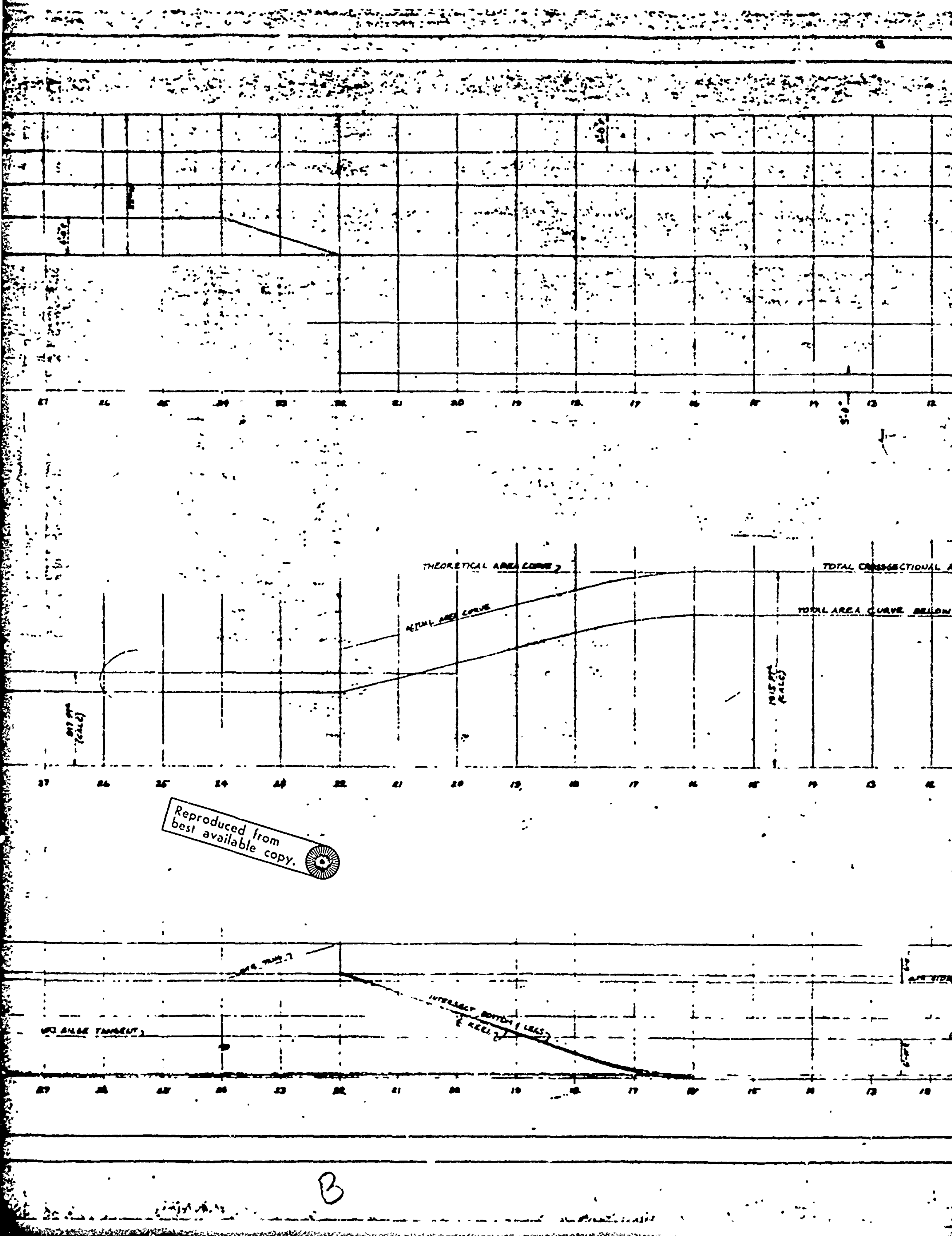
COMPUTING CHECKED



REFERENCE CATAMARAN

THEORETICAL CATAMARAN WHICH CORRESPONDS TO THEORETICAL AREA CURVE TO 280' WL IN VERTICAL ATTITUDE. VALUES IN PARENTHESES ARE FOR BASE CATAMARAN USED IN COMPUTER MODEL




THEORETICAL AREA CURVE
ACTUAL AREA CURVE
TOTAL AREA CURVE BELOW
INTERSECT BOTTOM (LEGS)
℄ KEEL
BILGE TANGENT

B

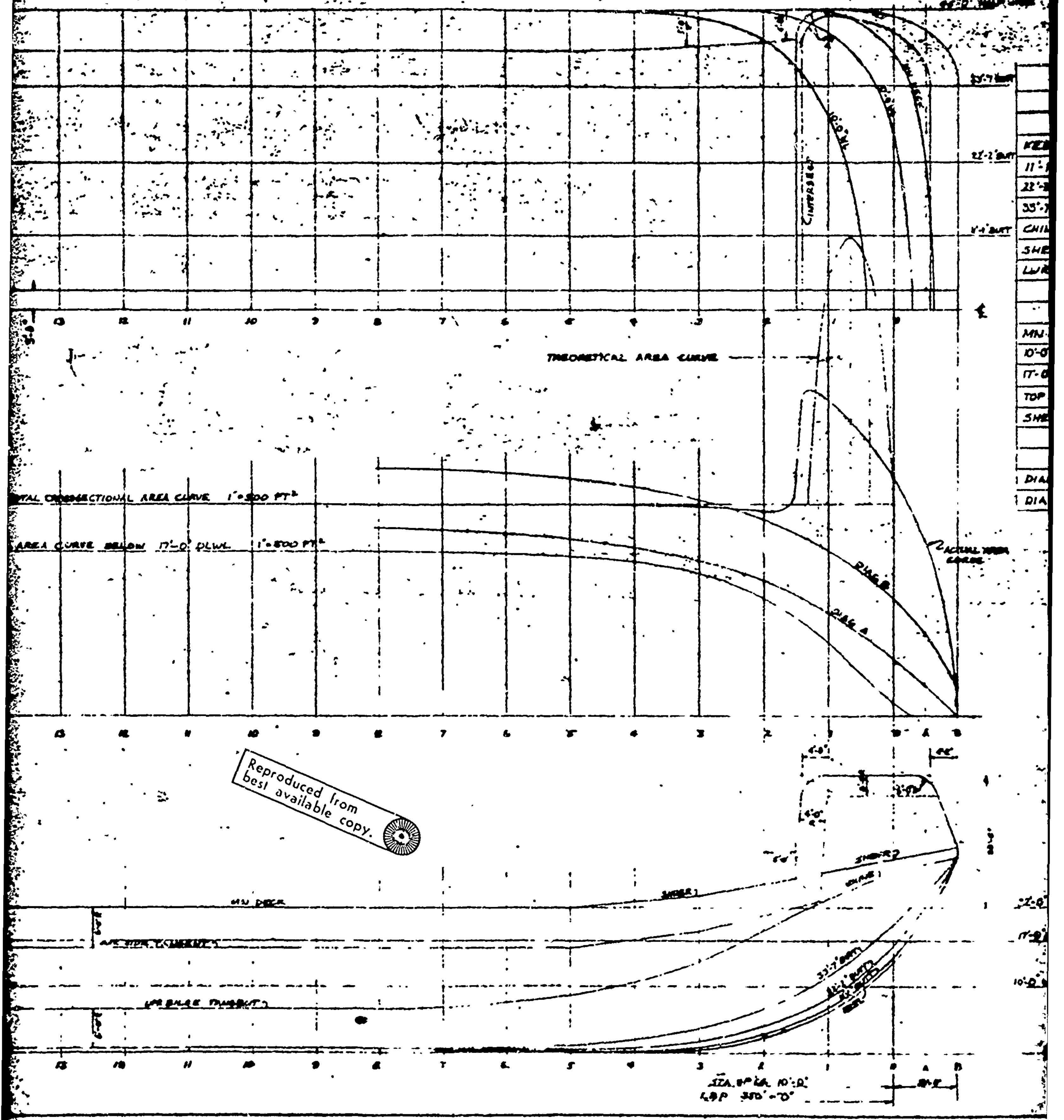
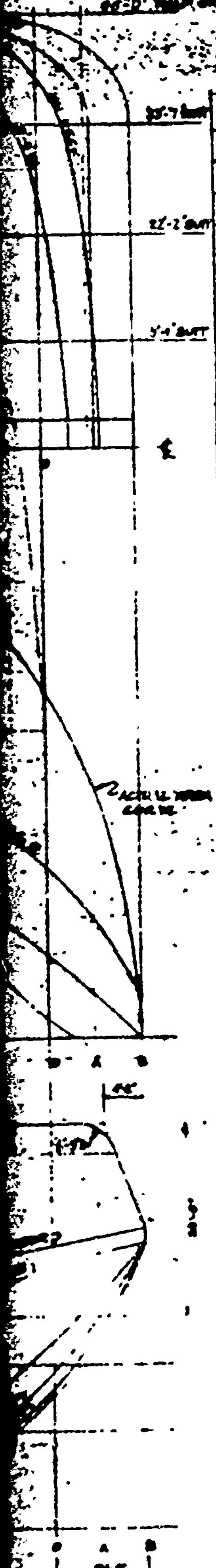
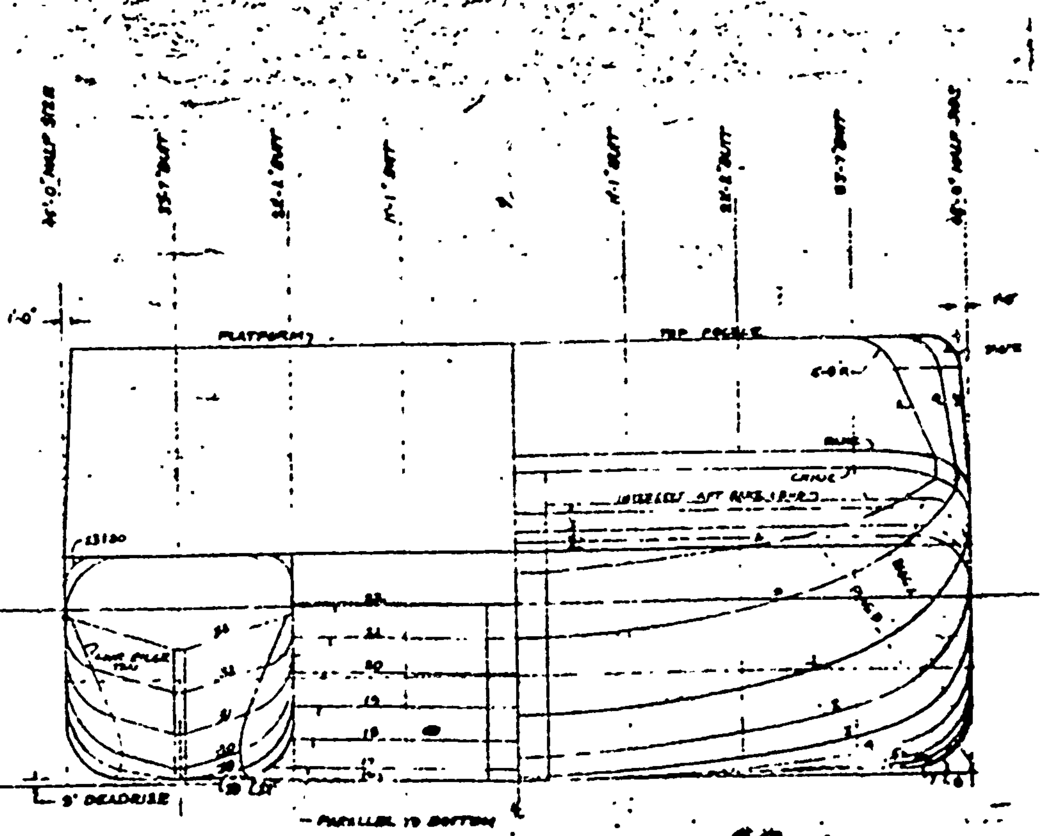

THEORETICAL AREA CURVE
TOTAL CROSSSECTIONAL AREA CURVE 1" = 500 FT²
AREA CURVE BELOW 17'-0" DLWL 1" = 500 FT²
ACTUAL AREA CURVE
DIAG B
DIAG A
UNDERSEAT
SHEER 2
SHEER 1
MN DECK
STA. SP'G. 10'-0"
LBP 350'-0"

TABLE OF OFFSETS

STATIONS	B	A	0	1	2	3	4	5	6	7	8	16	17	18	19	20	21	22	26	27	28	29	30	31	32	33
	HEIGHTS ABOVE ℄																									
KEEL	29'-6"	19'-8"	15'-9"	6'-3"	2'-5"	0'-5"	0-0	— STRAIGHT			—	0-0"	1'-5"	3'-0"	— STRAIGHT —			11'-0"								
11'-1" BUTT	29'-6"	20'-8"	14'-6"	6'-11"	2'-10"	0'-10"	0'-2"	— STRAIGHT			—	PARALLEL TO BOTTOM														
22'-2" BUTT	29'-6"	22'-1"	16'-2"	8'-4"	4'-1"	2'-9"	0'-9"	0'-4"	—	—	—	PARALLEL TO BOTTOM														
33'-7" BUTT	29'-6"	24'-2"	19'-4"	11'-8"	6'-7"	3'-9"	2'-0"	1'-1"	0'-6"	—	—	—	—	—	STRAIGHT							0'-6"	1'-7"	6'-10"	STR	13'-0"
CHINE UPR TANG.	29'-6"	28'-5"	27'-0"	23'-5"	18'-6"	13'-10"	10'-8"	8'-6"	7'-7"	6'-0"	6'-8"	—	—	—	STRAIGHT				6'-8"	6'-9"	7'-6"	8'-11"	— STRAIGHT —			11'-0"
SHEER	31'-0"	— STRAIGHT —		20'-5"	25'-5"	25'-9"	STR	22'-0"																		
LWR TANG AFT																			4'-LB TAN	0'-9"	1'-11"	4'-5"	8'-8"	— STRAIGHT —		7'-8"
	HALF BREADTHS OFF ℄																									
MN DECK		22'-5"	38'-6"	44'-8"	45'-0"																					
10'-0" WL				29'-0"	40'-7"	43'-10"	44'-9"	45'-0"																		
17'-0" WL			26'-6"	41'-7"	44'-9"	45'-0"																				
TOP FOCSLE INTR		32'-6"	41'-7"	44'-0"																						
SHEER		41'-10"	44'-0"	45'-0"																						
DIAG A	0'-0"	4'-6"	8'-7"	15'-6"	20'-5"	23'-4"	25'-5"	26'-8"	27'-5"	27'-11"	28'-5"															
DIAG B	4'-4"	12'-5"	17'-7"	24'-11"	29'-6"	32'-5"	33'-7"	35'-7"	36'-6"	37'-1"	37'-5"															

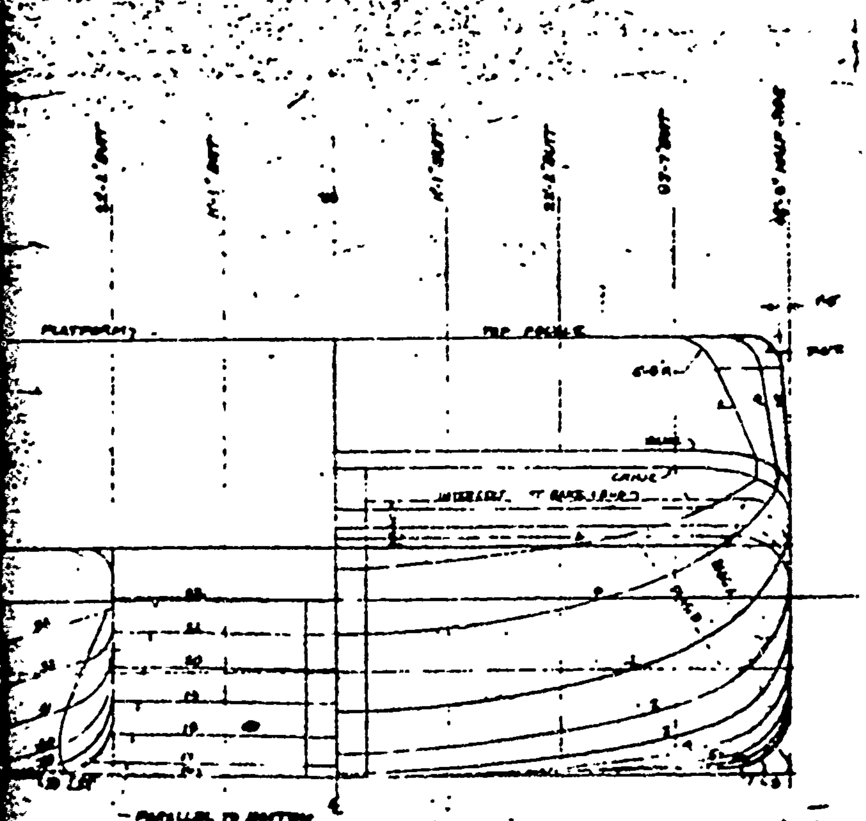




D

TABLE OF OFFSETS

	2	3	4	5	6	7	8	16	17	18	19	20	21	22	26	27	28	29	30	31	32	33
HEIGHTS ABOVE ℄																						
[illegible]	2-5	0-5	0-0	STRAIGHT				0-0	1-5	5-0	STRAIGHT			11-10								
[illegible]	2-10	0-10	0-2	STRAIGHT				PARALLEL TO BOTTOM														
[illegible]	4-1	2-9	0-9	0-4				PARALLEL TO BOTTOM														
[illegible]	6-7	3-9	2-0	1-1	0-6						STRAIGHT							0-6	1-7	6-10	STR	15-0
[illegible]	18-6	15-10	10-5	8-8	7-7	6-0	6-8				STRAIGHT				6-8	6-9	7-4	8-11	STRAIGHT			11-0
[illegible]	25-5	23-9	STR	22-0																		
															[illegible]	0-9	1-11	4-5	8-8	STRAIGHT		7-5
HALF BREADTHS OFF ℄																						
[illegible]	45-0																					
[illegible]	40-7	45-10	44-9	45-0																		
[illegible]	44-9	45-0																				
[illegible]																						
[illegible]																						
[illegible]																						
[illegible]																						
[illegible]	26-5	25-4	25-5	26-8	27-5	27-11	28-5															
[illegible]	29-6	32-5	33-7	35-7	36-6	37-1	37-5															



REFERENCES

GENERAL NOTES

PARTICULARS

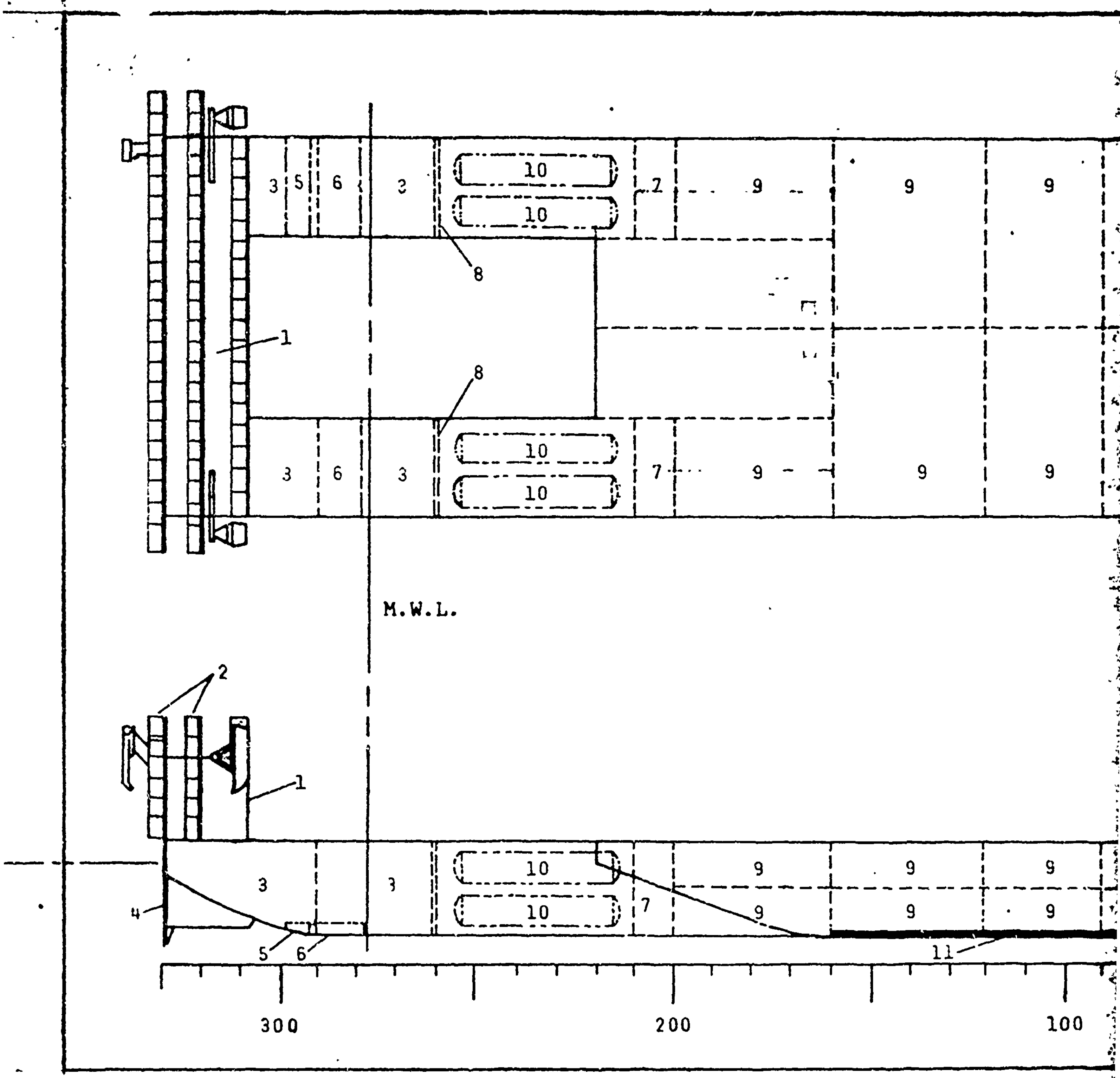
LENGTH OVERALL	360'-0"
LBP (STA 0 TO STA 33)	330'-0"
BEAM	80'-0"
BEAM UPPER HULLS	22'-10"
DEPTH	22'-0"
DRAFT-HORIZONTAL	17'-0"
DRAFT-VERT. (EQIV. CYL. DRAFT)	280'-0"
DRAFT-VERT. CLEARANCE	280'-0"
LONG LCB HORIZ (FROM STA 0)	141.59'
LONG LCB VERT (FROM STA 0)	112.0'
DISPLACEMENT VERT	13,720 LTSW
DISPLACEMENT HORIZ (17' DRAFT)	10,600 LTSW

SYM	REVISIONS	BY	DATE

SCRIPPS INSTITUTION OF OCEANOGRAPHY
LA JOLLA CALIF.

OCEAN ENGINEERING SUPPORT PLATFORM
LINES AND OFFSETS

DRAWN ALGER	DATE 7 AUG '73	SCALE	
CHECKED [illegible]	DATE 21 NOV '73	FIGURE A-1	
APPD.	DATE		



3
5
6
3
10
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7
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9
9
8
1
8
3
6
3
10
10
7
9
9
9
M.W.L.
2
1
3
4
3
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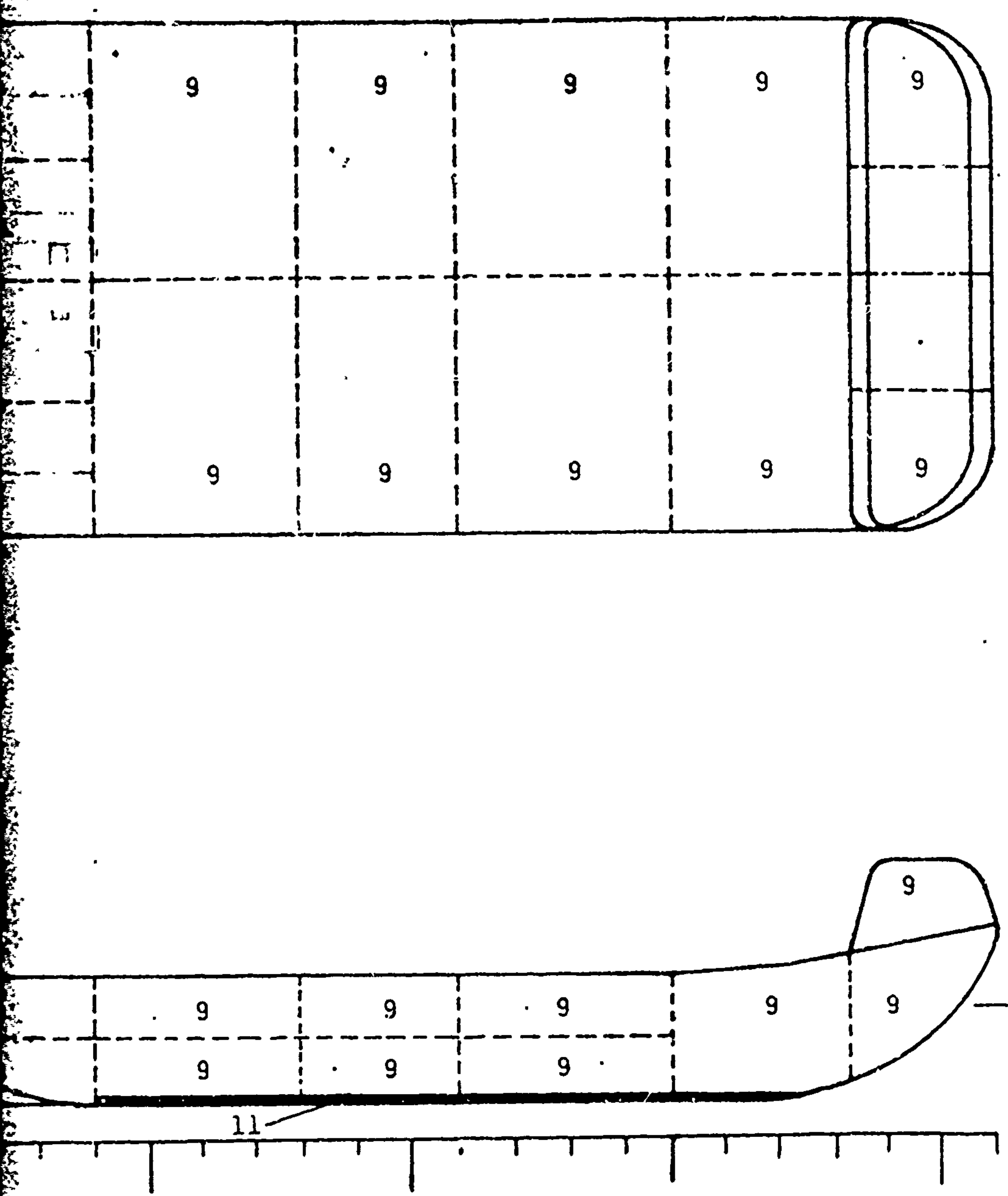
10
7
9
9
9
9
9
9
5
6
11
300
200
100

Figure A-2

A



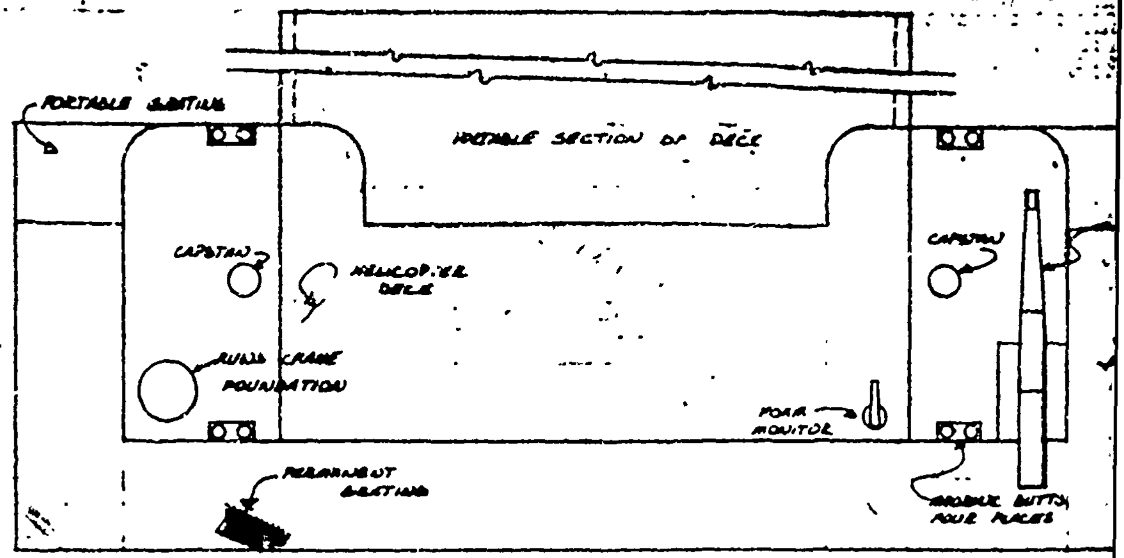
1 Superstructure--habitat, control, scientific
2 Portable walkway
3 Machinery room
4 Helicopter pad
5 Fresh water tank
6 Fuel oil day tank
7 Fuel oil tank
8 Contaminated oil
9 Salt water ballast
10 Air bottle
11 Concrete ballast

Scripps Institution of Oceanography
Drawing No. 7336-2

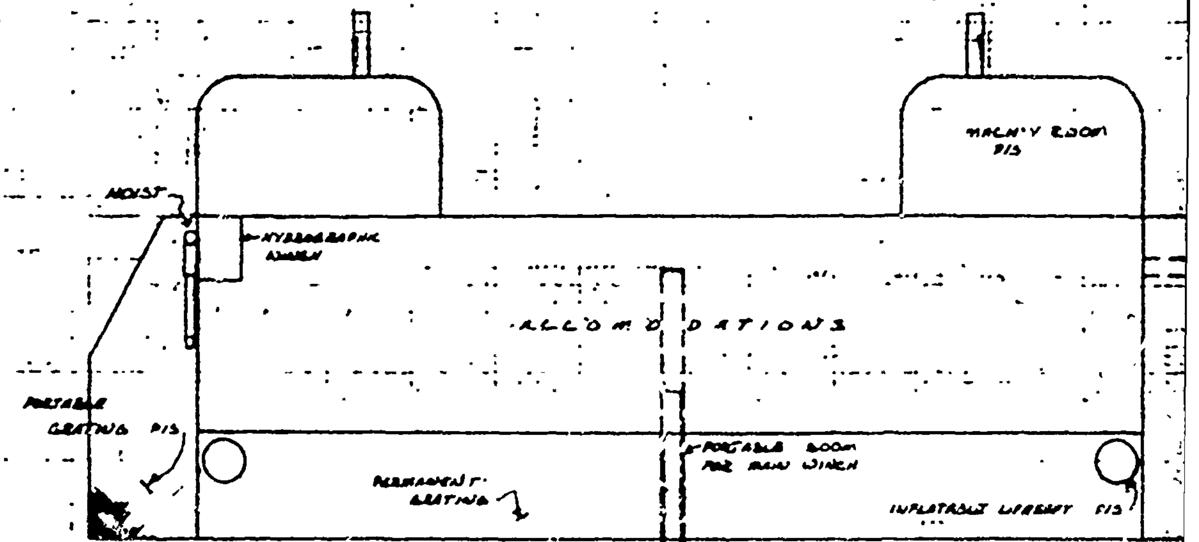
Figure A-2

B

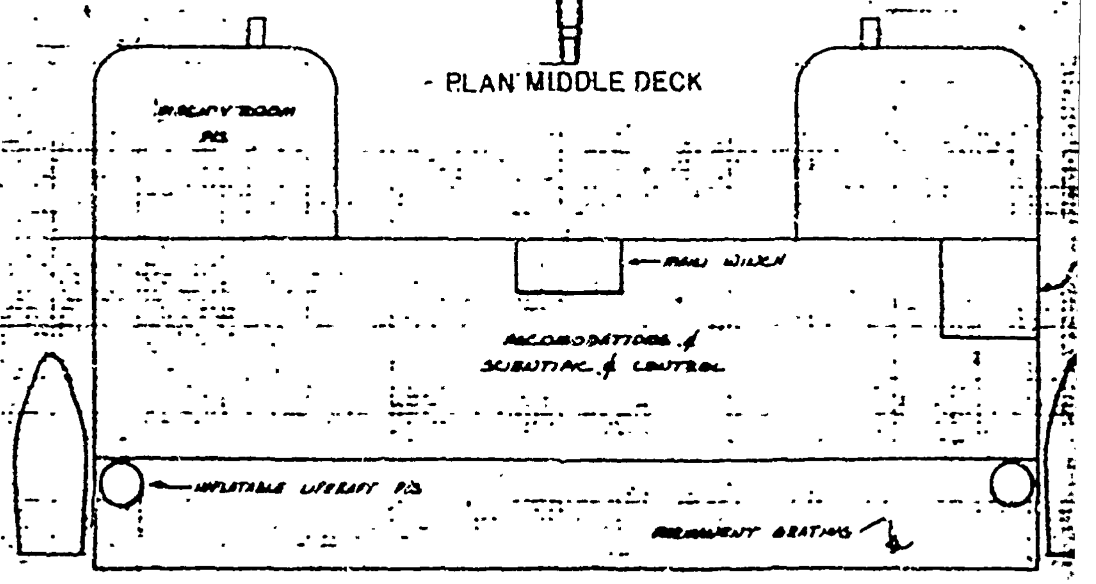
A



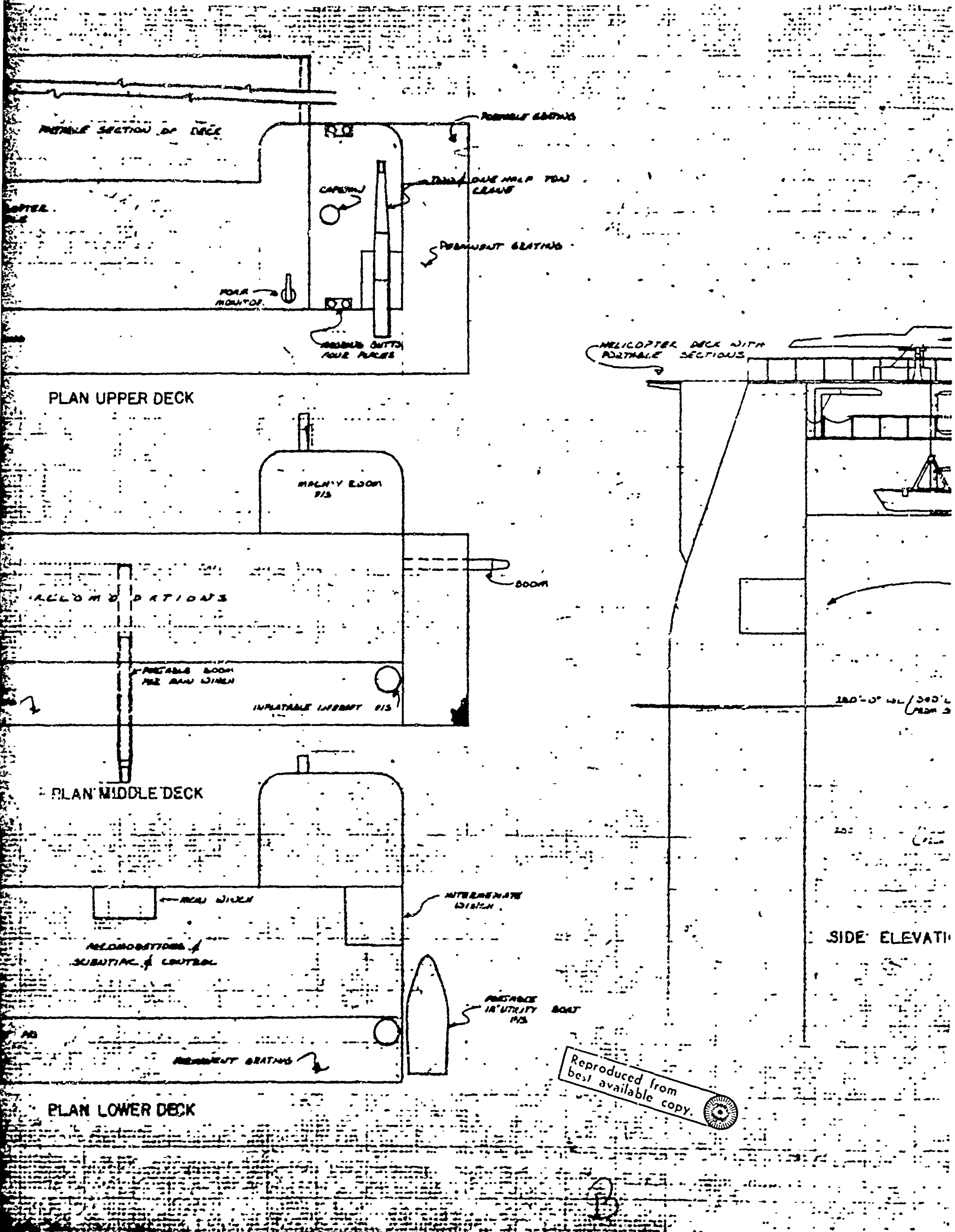
PLAN UPPER DECK



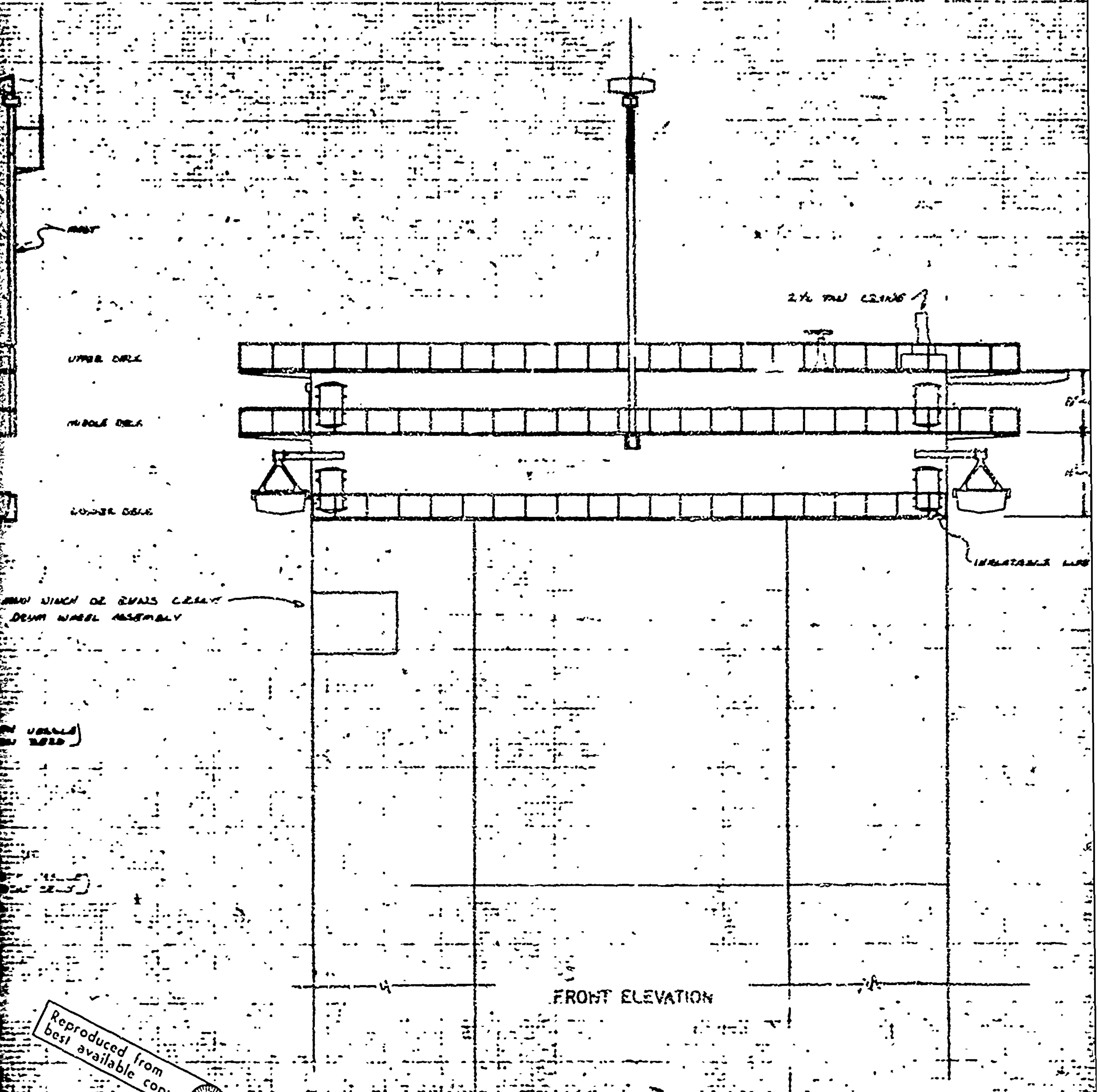
PLAN MIDDLE DECK

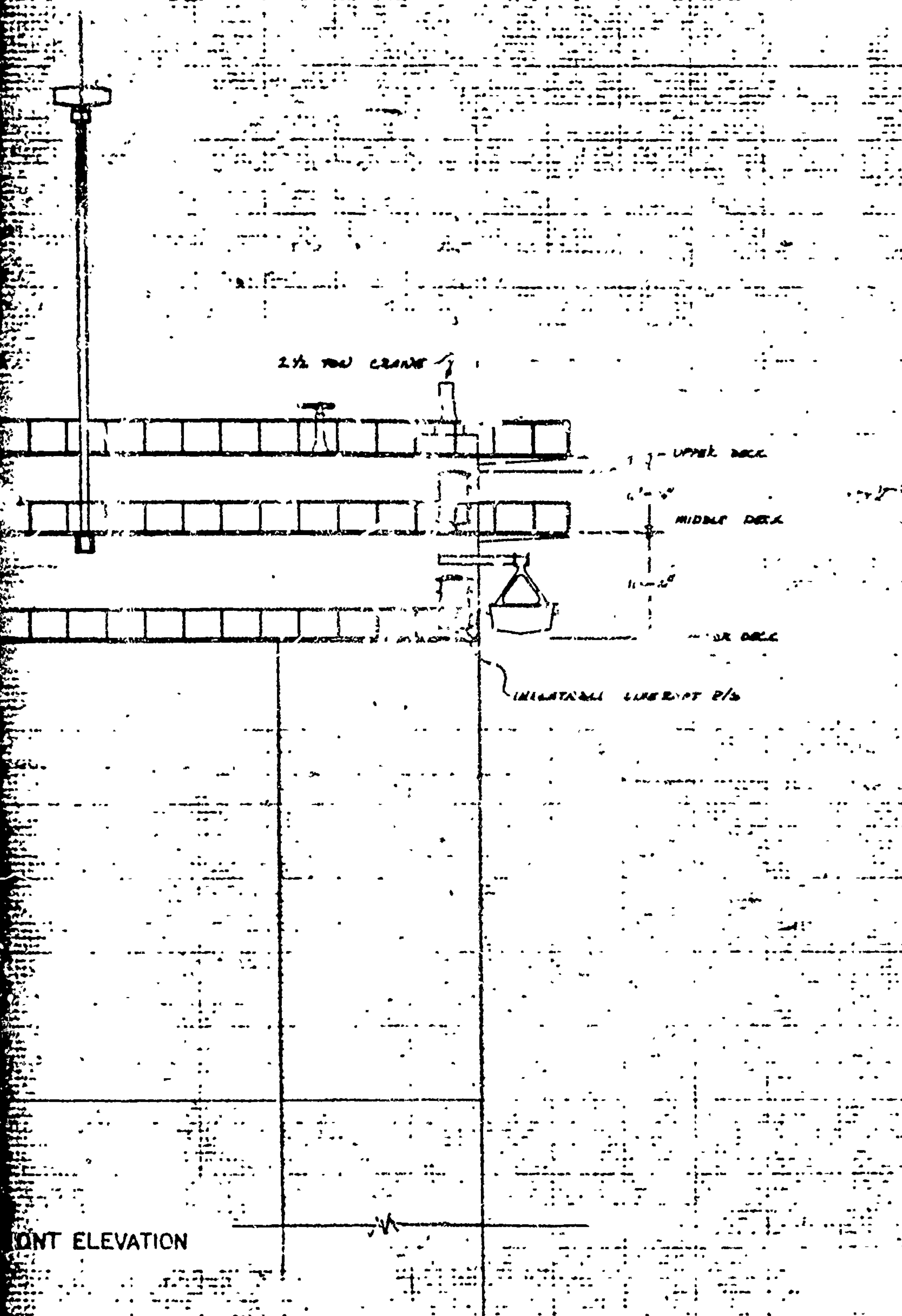


PLAN LOWER DECK



PORTABLE SECTION OF DECK
PORTABLE GRATING
CAPSTAN
CRANE
PERMANENT GRATING
PLAN UPPER DECK
ACCOMODATIONS
BOOM
INFLATABLE LIFERAFT P/S
PLAN MIDDLE DECK
MAIN WINCH
INTERMEDIATE WINCH
PLAN LOWER DECK
HELICOPTER DECK WITH PORTABLE SECTIONS
SIDE ELEVATI


UPPER DECK
MIDDLE DECK
LOWER DECK
2½ TON CRANE
FRONT ELEVATION



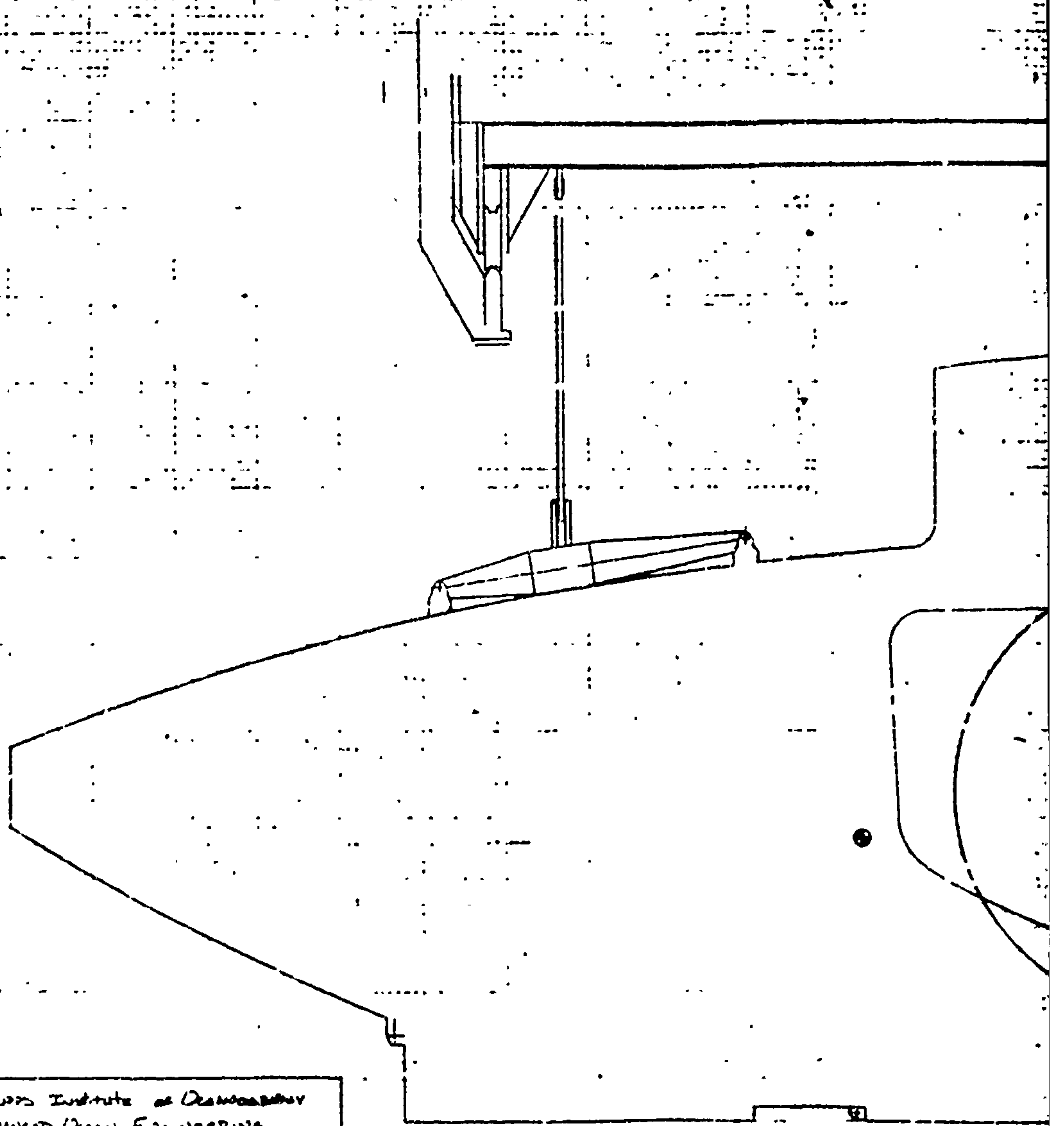
ONT ELEVATION

GENERAL NOTES

Scripps Institution of Oceanography
University of California, San Diego

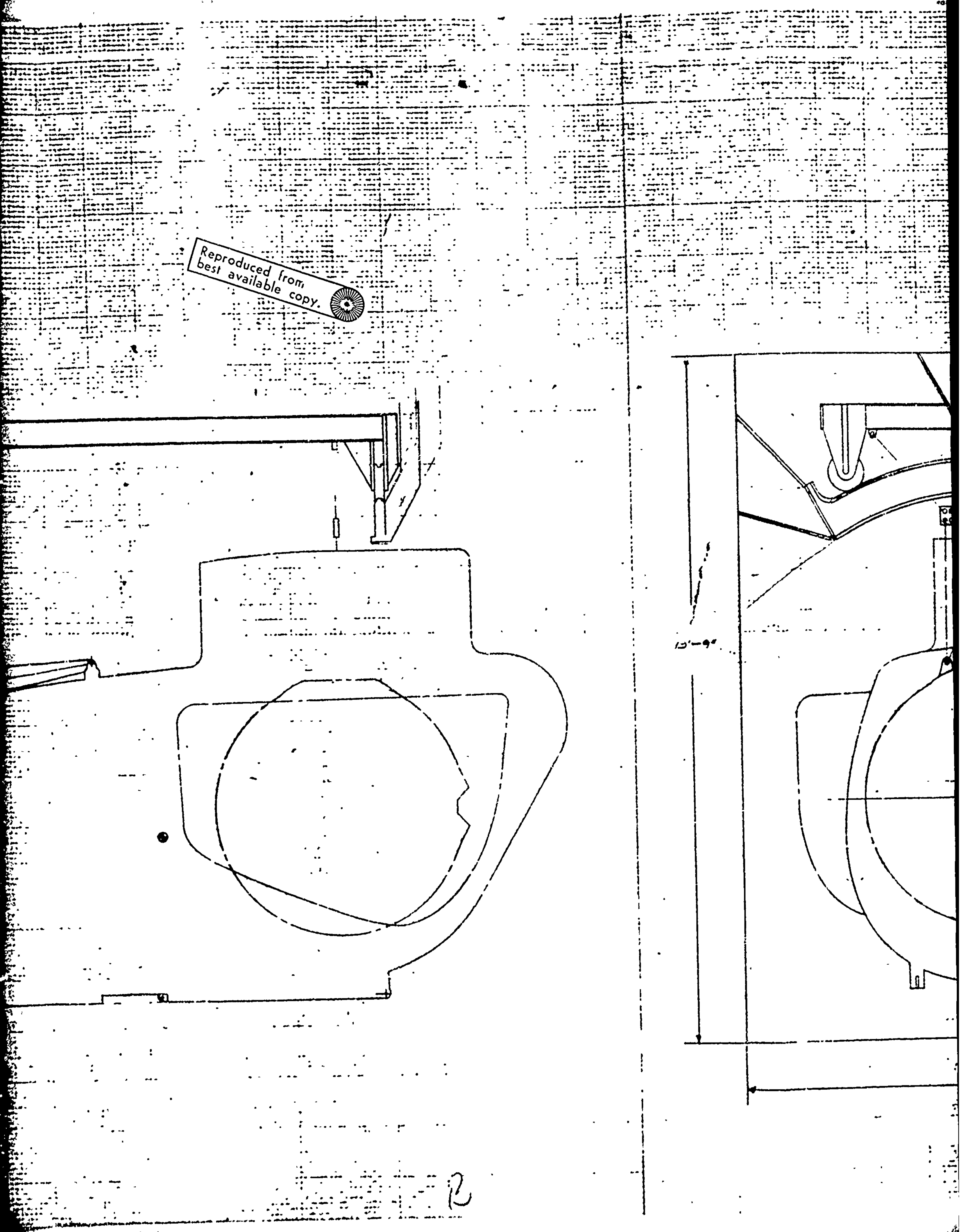
Ocean Engineering Support
Platform
Platform Arrangement

DRAWN [illegible] DATE APP'D DATE DRAWING NO. [illegible]	SCALE ⅛" = 1'

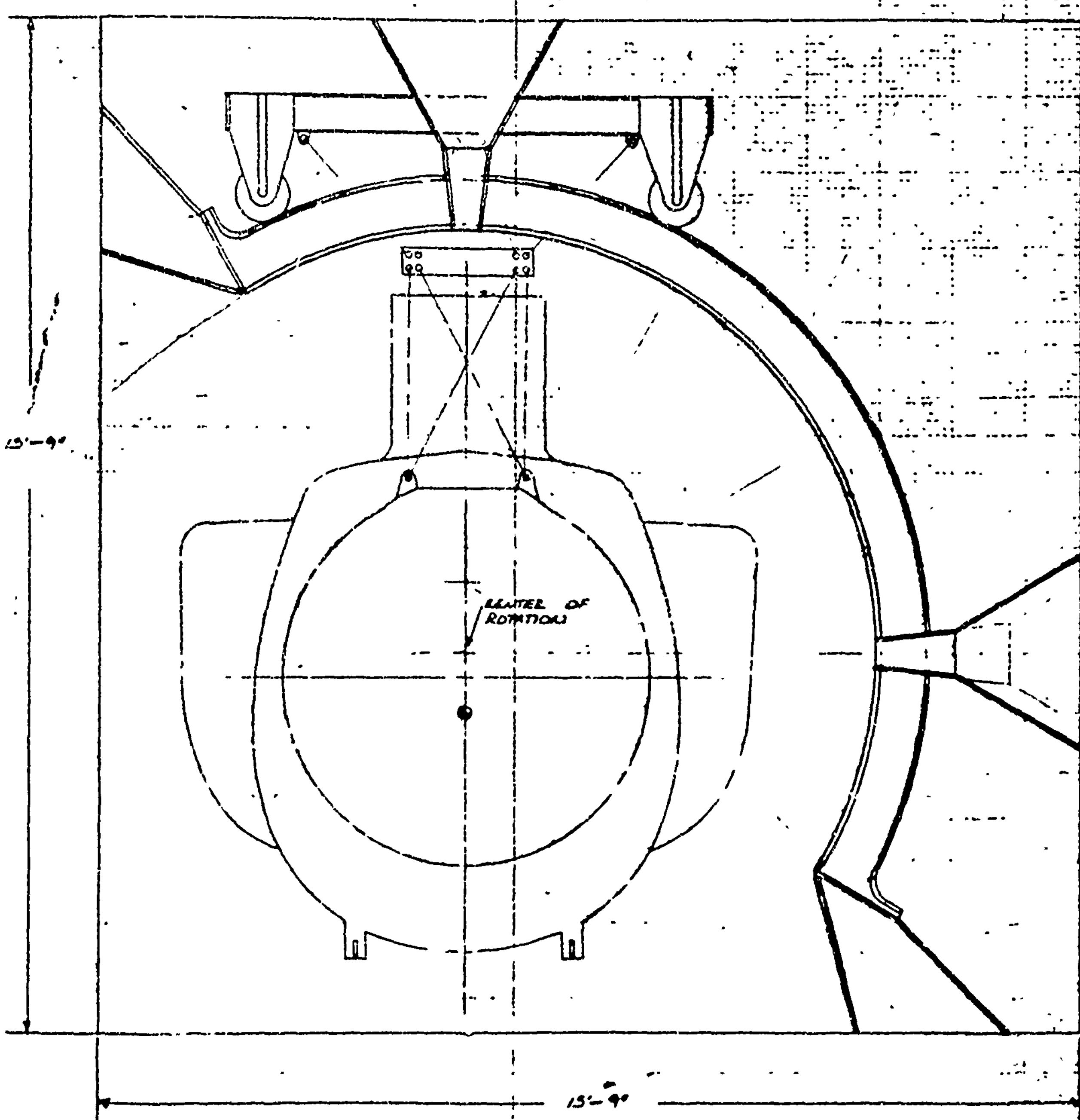


Scripps Institute of Oceanography Advanced Ocean Engineering University of California, San Diego
Submersible Gimbal Mechanism
SCALE 1/16 = 1' DWG. NO SIO 74-4-[illegible]

A



12


13'-9"
CENTER OF
ROTATION
13'-9"

APPENDIX B

DECK MACHINERY FOR OCEAN ENGINEERING SUPPORT PLATFORM

Proposed deck machinery to be installed aboard the Ocean Engineering Support Platform includes the following equipment and rated capacities:

A. Hydrographic Winch
30,000 feet of [illegible]/4" (max) center conductor cable
2000# line pull at 350 fpm (21 HP)
5000# line pull at 140 fpm

Winch and power package are integral unit with a space envelope of approximately 6' x 6' x 4'.

B. Intermediate Winch
30,000 feet of 1/2" wire rope
2500# line pull at 550 fpm (42 HP)
14,000# line pull at 100 fpm

Winch unit space envelope of approximately 9' x 9' x 5'.
Power package space envelope of approximately 5' x 3' x 3'.

C. Traction Winch
20,000 feet of 7/8" to 1-1/4" wire rope
60,000# line pull at 60 fpm (109 HP)
30,000# line pull at 120 fpm

System consists of 3 units with the approximate space envelopes:

Power unit, 10' x 4' x 4'
Traction unit, 7' x 5' x 5'
Storage drum, 9' x 8' x 7'

D. Capstans, two
2-1/2" diameter synthetic line (27 HP)
60,000# line pull at 15 fpm
10,000# line pull at 90 fpm

Capstan space envelope, 5' x 5' x 6'
Power unit space envelope, 4' x 6' x 4'
(Both capstans operate off single power unit)

E. Crane
5000# capacity with 20' articulating boom
1/2" wire rope, 4' x 7' base envelope