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Artificial Floating Islands: Cities of the Future

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ARTIFICIAL FLOATING ISLANDS

CITIES OF THE FUTURE

by

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Professor Gerald Krausse

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CONTENTS

CONTENTS

FIGURES

FIGURES

FIGURES

TABLES

INTRODUCTION

The oceans are the last frontier. They belong to no one and to everyone. All life began in them and they are our best hope for the survival of life on land.

Today many densely populated coastal areas of the world are over-congested and suffer from heavy industrial traffic and other environment-burdening activities. One solution to this enormous problem is the use of artificial floating islands. The recent utilization of small-scale floating platforms by the petroleum industry has proven that this all-weather concept is technically feasible and economically realistic.

This report will investigate the feasibility of large-scale artificial floating islands, to solve problems posed be over-population and environment-burdening activities in coastal areas. The investigation will focus on the historic, technical, utilizable and legal aspects of artificial floating islands. Although this report exemplifies artificial floating islands developed for offshore cities, electrical power generation and basing for the military, its content is applicable to any offshore floating development.

Chapter 1

HISTORICAL REVIEW OF OCEAN PLATFORMS

This brief history of ocean platforms emphasizes the factors significant to present and future applications of these platforms. The first significant development was patented in the United States on May 2, 1893 by Adoniram Fairchild. Figure (1) details Fairchild's design of a floating support for drilling devices. Adoniram Fairchild describes his tension-leg concept as follows:[1]

> This invention relates to improved means for supporting drilling apparatus used for drilling holes in rock bottoms of harbors or streams, that are to be deepened by blasting the rock and subsequently removing the debris. Where charge holes for blasting or otherwise shattering rocks at the bottom of a body of water, are to be produced from the surface of the water the operation is often rendered difficult, as the floating support for the drilling apparatus is subjected to the vertical fluctuation of water level due to swells or wave force.[2]

On March 23, 1920 Augustine Gaffney patented a semi-submersible landing-stage for vessels and land-vehicles, see Figure (2).[3]

> My invention is an improvement in landing stages for air vessels, naval vessels, merchant vessels, gasoline and electric driven cars of every character, containing power plant for propelling landing stage, for submerging the landing stage, for the hoisting of airplanes, patrol boats and cargoes, operating means for the repair of aero vessels and naval vessels, lighting, wireless telegraph, long distance telephone, search lights, winches, guns and the like.[4]

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[1] See Chapter 2 for a complete description of the tension-leg concept.

[2] Adoniram Fairchild, "Floating Support for Drilling Devices," United States Patent, No. 496,729, May 2, 1893.

[3] See Chapter 2 for a complete description of the semi-submersible concept.

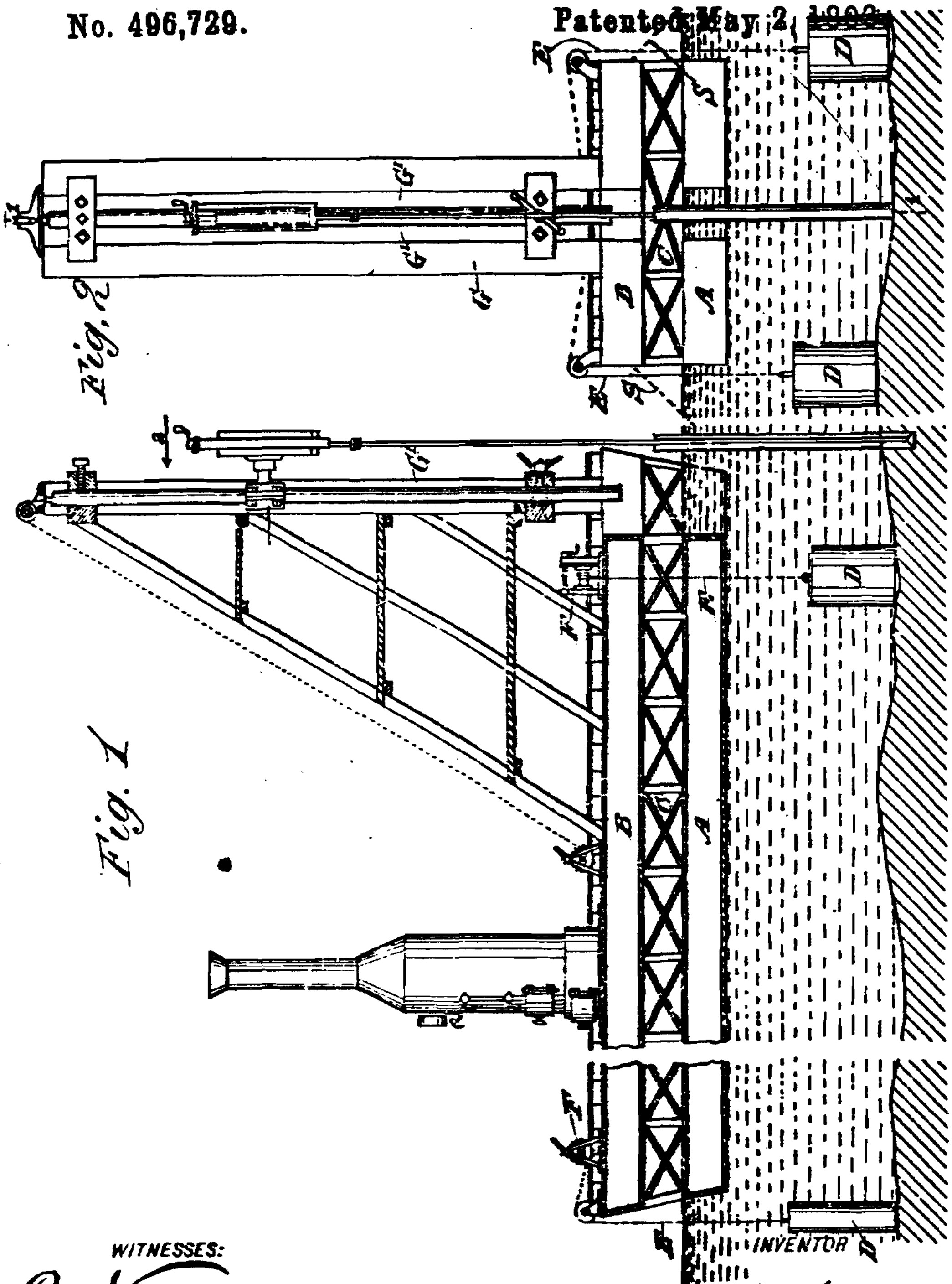
[4] Augustine Gaffney, "Landing-Stage for Vessels and Land-Vehicles," United States Patent, No. 204,977, March 23, 1920.

A. FAIRCHILD, Dec'd.

R. D. FAIRCHILD, Administrator.

FLOATING SUPPORT FOR DRILLING DEVICES.

No. 496,729. Patented May 2, 1893.



WITNESSES:

C. Nevens

E. M. Clark

INVENTOR

A. Fairchild

BY Munn & Co

ATTORNEYS.

FIGURE (1)

A. GAFFNEY.

LANDING STAGE FOR VESSELS AND LAND VEHICLES.

APPLICATION FILED DEC. 1, 1917.

1,334,445. Patented Mar. 23, 1920.

3 SHEETS—SHEET 2.

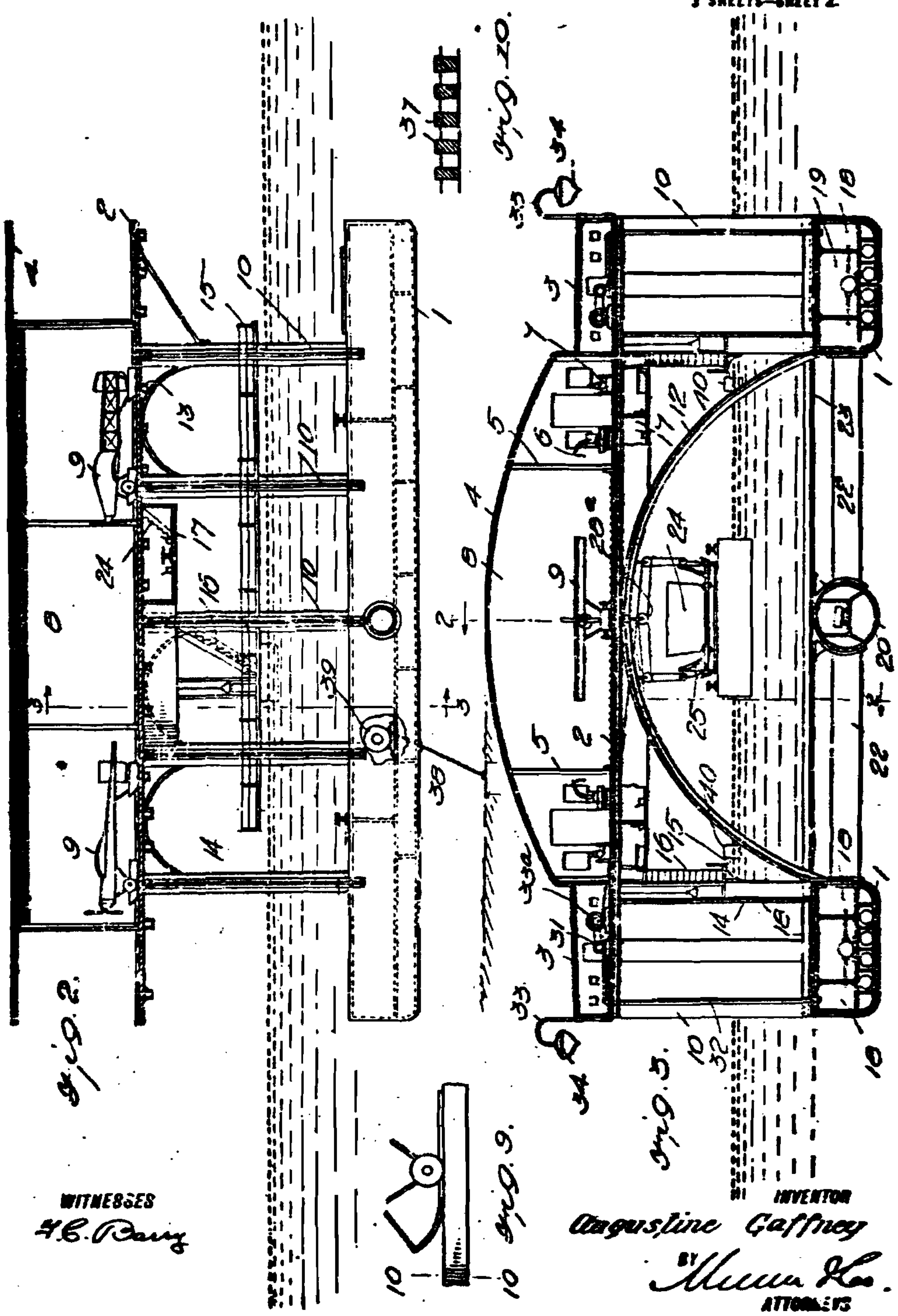


FIGURE (2)

A floating airfield or seadrome was patented by Edward R. Armstrong on October 7, 1924. This invention utilized vertically buoyant support members to stabilize the platform, see Figure (3). Armstrong stated:

> Commercial transportation by aeroplane over wide, expanses of water, such as the Atlantic Ocean between New York and London, is practical only by the use of supply stations located at desirable intervals along the route at which stations the fuel supply can be replenished and the many details of operation of such an airway properly conducted. It is the principle object of the present invention to provide for the landing on and the operation of aircraft from, such sea stations with safety under all weather conditions.[5]

Never a reality, Armstrong's concept of a deep buoyant platform was successfully proven in 1961 with FLIP (FLoating Instrument Platform) designed by Scripps Institution of Oceanography. FLIP will be discussed in detail in this chapter.

Although not a new idea, numerous floating bridges were constructed during the late 1930's and early 1940's. The most noteworthy was the Lake Washington Floating Bridge in Seattle, Washington, see Figure (4). This bridge was an important cog in the overall future of floating platforms for two reasons, (1) the use of reinforced-concrete, and (2) stability. The Lake Washington Floating Bridge was the longest continuous bridge in the world supported by 25 floating reinforced-concrete pontoons. A typical pontoon had a width of 50 feet and a length of 350 feet, almost the size of a football field.[6] Reinforced-concrete was chosen for its

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[5] Edward R. Armstrong, "Sea Station", <u>United States Patent</u>, No. 1,511,153, October 7, 1924.

[6] Charles F.A. Mann, "A Bridge That Floats", <u>Scientific American</u> (New York: Munn, February, 1940), pp. 75-7.

Oct. 7, 1924. 1,511,153

E. R. ARMSTRONG

SEA STATION

Filed Nov. 7, 1922 2 Sheets-Sheet 1

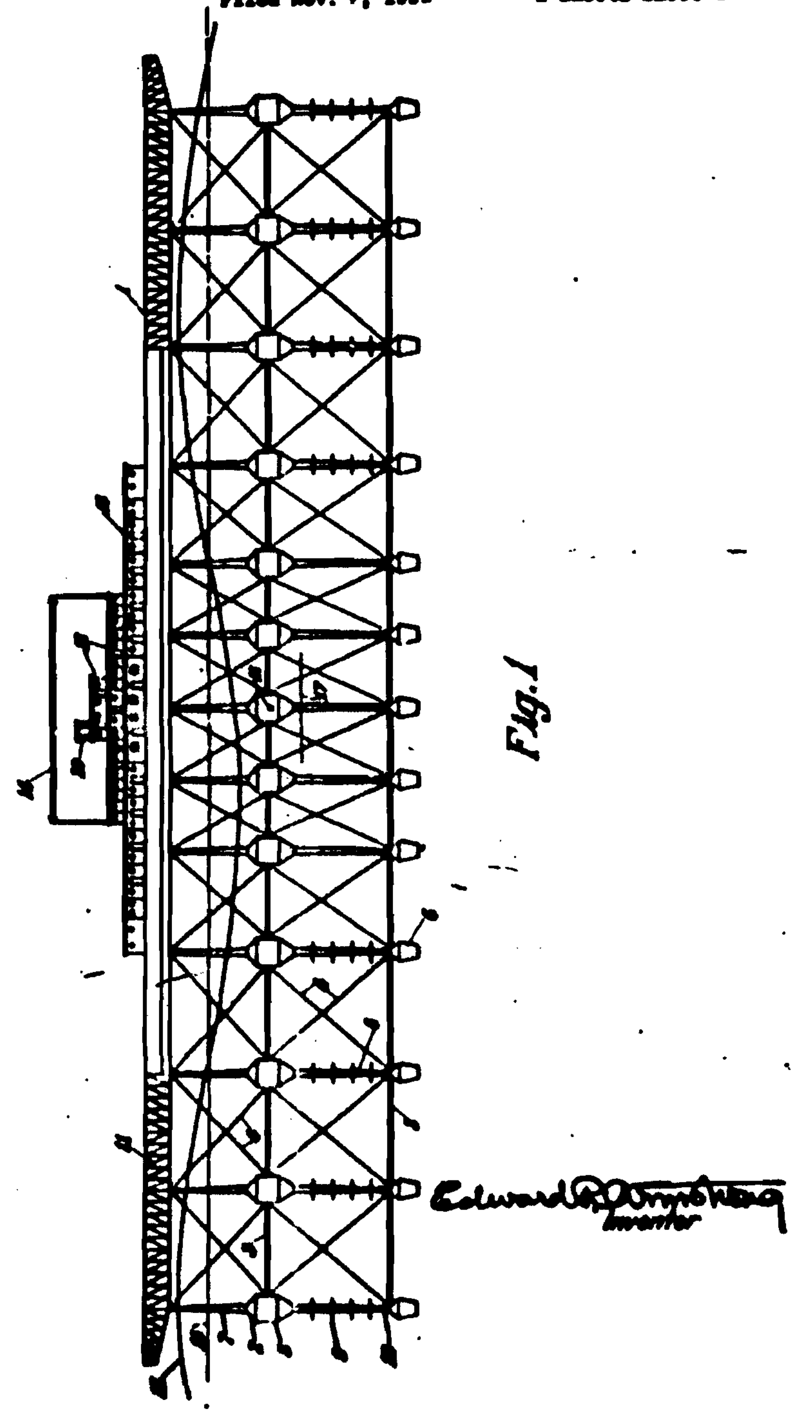

FIGURE (3)

LAKE WASHINGTON FLOATING BRIDGE near Seattle, Wash., is supported by 24 cellular reinforced concrete pontoons. Ships pass through an opening created by retracting two central sliding spans.

UNITED PRESS INTERNATIONAL

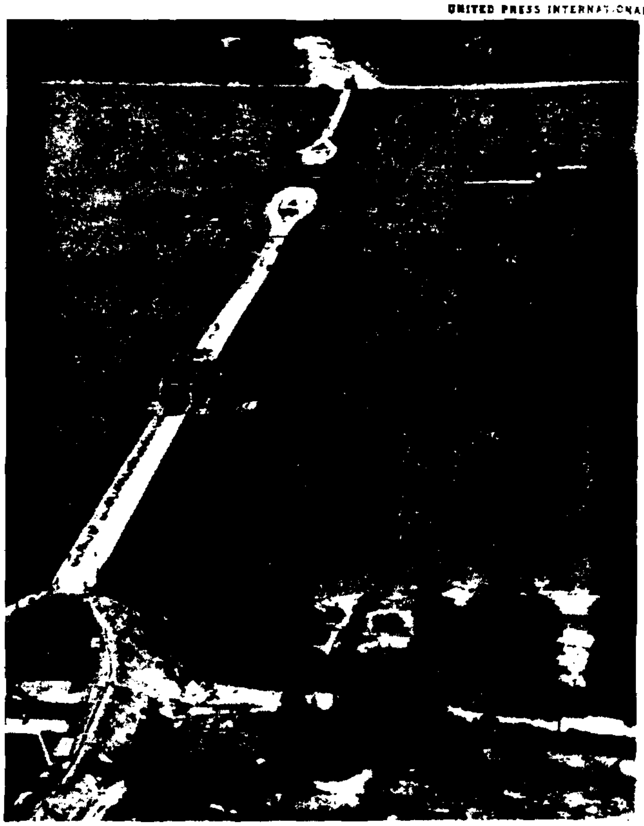

FIGURE (4)

(From: Colliers Encyclopedia, vol. 4., New York: Macmillan, 1982, pp. 547.)

continuity, freedom from joints and its great mass and dead weight.[7]

The most striking feature of this bridge was its great stability. Even though the Lake Washington Floating Bridge was continuously subjected to wind gusts of 65 miles per hour, 5 foot waves, and a tidal range of 3 feet, not the slightest movement could be felt according to Charles E. Andrew, principal engineer for the Washington Toll Bridge Authority. He furhter stated:

> The floating structure is very stable. The mass existent because of the use of concrete is a most important factor in aiding stability. Heavy trucks cause an almost imperceptible movement in the bridge and many people who ride over the bridge are not aware that it is a floating bridge. It has been subjected to a 65-mile wind with only the slightest movement resulting therefrom. In fact the structure, from all angles, has proven to be satisfactory and has fully met the expection of the engineers responsible for it.[8]

How this remarkable engineering feat paved the way for future floating platforms will be shown later.

The 1950's and early 1960's marked the renaissance for floating platforms. Initially drill rigs were placed on barges and then towed to the drill site, see Appendix (1). These barges provided high mobility but lacked the stability and station-keeping requirements for ocean drilling. What was needed was a stabilized platform that minimized the influence of wind and water action.

In 1961-1962 under the direction of the Marine Physical Laboratory

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7
A lighter floating object such as wood or steel would more readily be tossed and put in motion by waves.

8
C.E. Andrew, "problems presented by the Lake Washington Floating Bridge", American Concrete Institute, Journal Proceedings, Vol. 37, January 1941, App. 253-268; discussion, pp. 268-1 thru 268-4.

of the University of California Scripps Institution of Oceanography and funded by the United States Navy, a platform was constructed utilizing deep draft in an attempt to minimize the effects of wind and water. This Floating Instrument Platform or FLIP (see Figures 5 and 6) for short was designed as a super-stable, open-sea, free-floating platform from which to conduct research in the field of physical oceanography. The concept was taken from Armstrong's Seadrome discussed earlier.

FLIP is essentially a long, slender tubular hull 20 feet in diameter for almost half its length from the stern, and tapering to a cylinder 12½ feet in the diameter as the bow is approached.[9] Overall length is 355 feet.[10] FLIP was designed to be towed in a horizontal attitude ballasted with water. When on station, controlled flooding of tanks would cause the platform to raise her bow and drop her stern until she floats in a vertical position.

While in the vertical mode FLIP proved to be an extremely stable platform. During an operation in the Gulf of Alaska, with continuous gale force winds and seas; FLIP's vertical motion was measured at less than one-tenth wave height and heaved less than 3 inches. The experience gained from FLIP has illustrated that Armstrong's Seadrome concept, does indeed provide a stable platform.

By 1962, large semi-submersible drilling rigs had appeared, the first being Blue Water Drilling Companies Rig number 1, see Appendix

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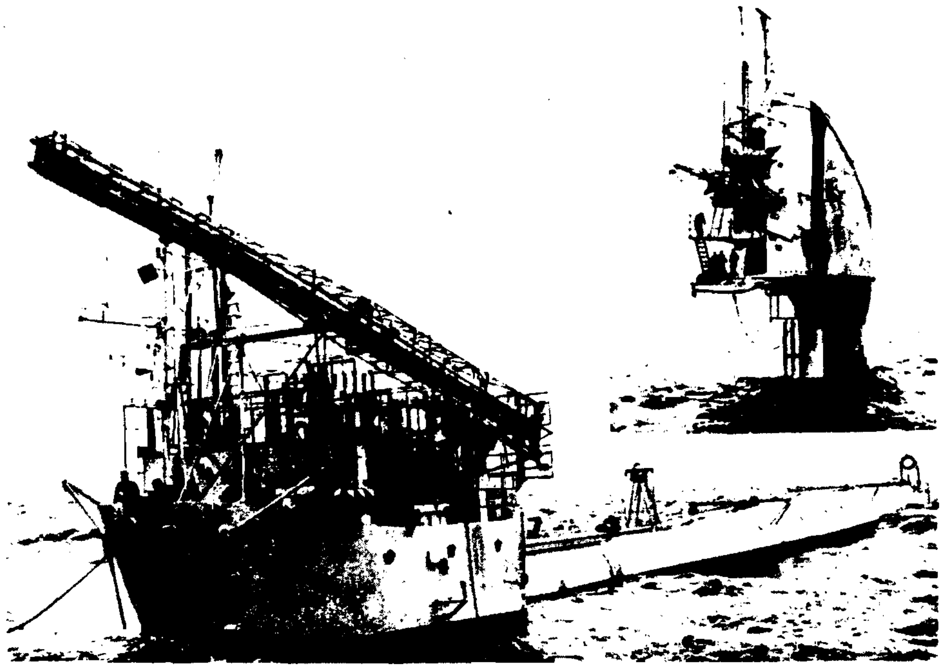
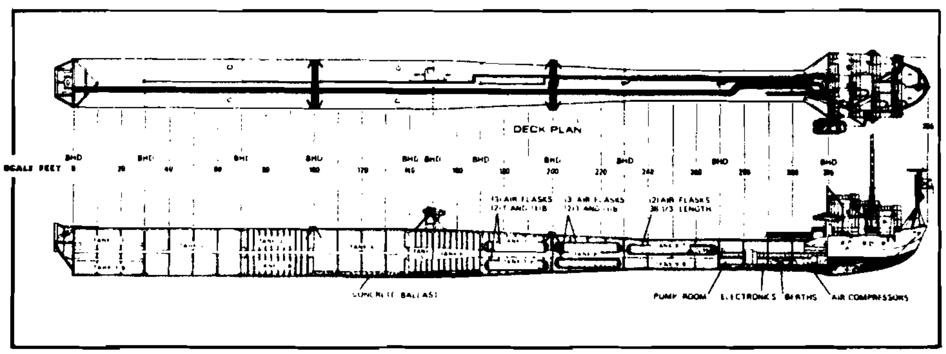
[9] Robert L. Trillo, ed., "Jane's Ocean Technology" (4th ed; New York: Franklin Watts, 1979-1980), p. 376.

[10] Ibid.



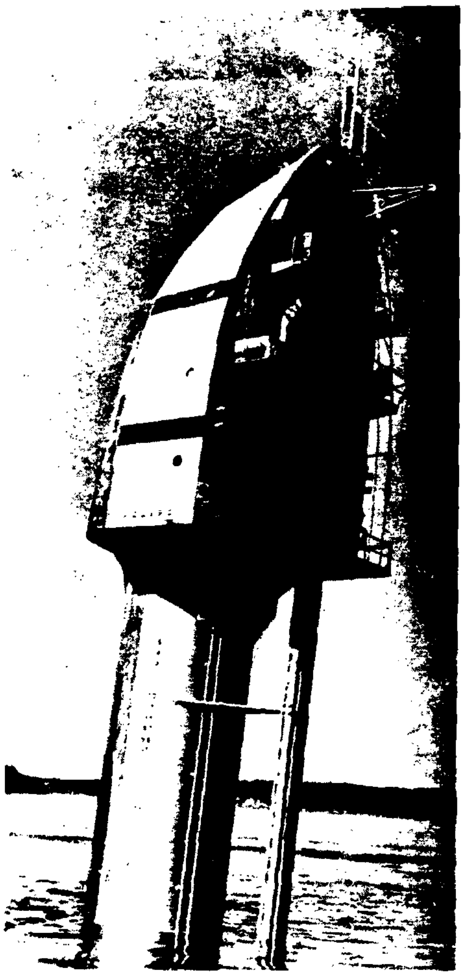
***FLIP** in its towing and vertical attitude (Scripps Institution of Oceanography)*



*Inboard profile of **FLIP** (Scripps Institution of Oceanography)*

FIGURE (5)

(From: Janes's Ocean Technology, 1979-1980, p. 376.)



FLIP (U.S. Navy)

FIGURE (6)

(From: Janes Ocean Technology, 1979-1980, p. 376.)

(1).[11] During this time the capabilities of the platforms used by the industry were mainly the result of experience. At first ocean and weather conditions were unknown, and no one theory of prediction was universally accepted. Nevertheless, platforms were designed, used and accidents occurred.[12] One of the most successful semi-submersible rigs was built by Southeast Drilling Company (SEDCO). Unlike the rectangular platform on the Blue Water rig, SEDCO utilized a triangular design. Their first rig, SEDCO-135, had successfully weathered numerous severe storms with 100-foot waves and demonstrated the inherent seaworthiness of the design, see Figure (7), so much so that SEDCO has built seven additional oil rigs of the same design from 1965-1969.

Up until the mid 1960's experience with floating platforms had been limited to the oil industry. However, one of the most ambitious drilling schemes ever undertaken outside the oil industry was Project MOHOLE. MOHOLE derived its name from the Mohorovic Discontinuity or Moho, which separates the Earth's crust from the mantle. The MOHOLE Project was a national scientific project with the broad and important objective of studying the Earth as a planet. From earlier refraction studies it was determined that the crust of Earth is thickest under the continents, averaging 21 miles, and under the deep ocean its crust is much thinner, averaging 4 miles.[13]

Since the Earth's mantle was closest to the Earth's surface in the deep ocean, drilling a hole to the mantle from a ship seemed the

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[11] See Chapter 2 for description.

[12] Blue Water Drillings Companies Rig No. 1 capsized and sunk by Hurricane Hilda in 1964. See Appendix (2).

[13] Lester Del Rey, "The Mysterious Sea", (Philadelphia: Chilton, 1968), p. 183.

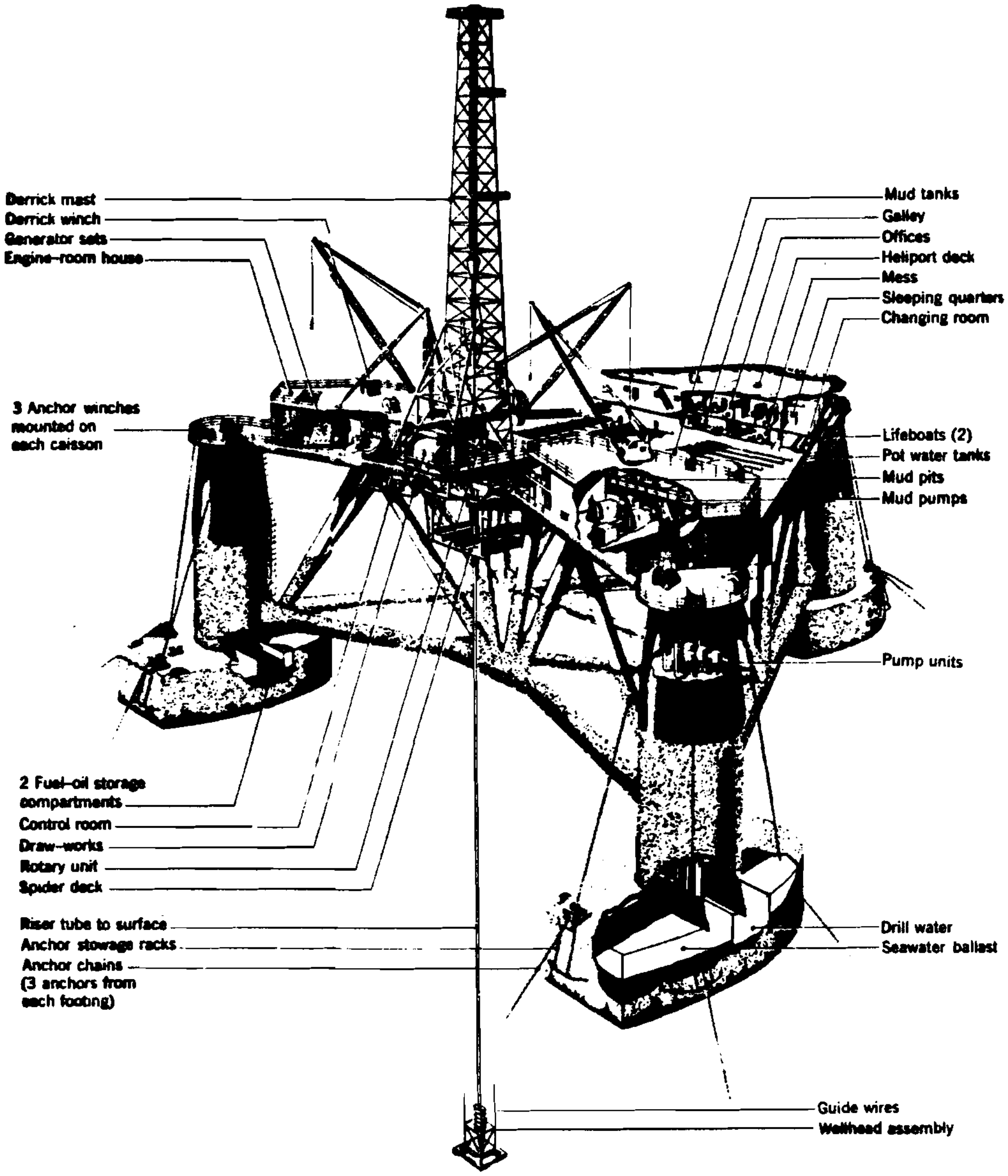

FIGURE (7): SEDCO-135

(From: John F. Brahtz, Ocean Engineering, New York: John Wiley, 1968, pp. 372.)

most logical approach to the problem. Thus, Project MOHOLE was born.

Drilling was to have been done near Hawaii, see Figure (8), in a depth of water of about 14,000 feet and to have bored through 19,000 feet of oceanic crust to reach the Moho.[14,15] For such a monumental drilling operation, stability was the key factor. The basic configuration of the MOHOLE platform is shown in Figure (9). The platform consisted of three decks, 279 feet long and 234 feet wide, floating on two submersible submarine hulls, each 390 feet long and 35 feet in diameter.[16,17] Six columns, each 88 feet long and 31 feet in diameter support the platforms on the submarine hulls creating minimal surface area for mobility. Since it was anticipated that drilling would continue for at least three years, MOHOLE's design criteria for survival were quite stringent. These criteria called for MOHOLE to survive in winds of 140 knots with 200-knot gusts and waves 100 feet high.[18]

MOHOLE was designed to be held on station by a dynamic position-keeping system. Six 750-horsepower positioning motors plus the main propulsion system were to be integrated with a sonar and a radar position-locating system to keep MOHOLE within a circle of 500-foot

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[14] Richard E. Munskem, "Progress on MOHOLE", Undersea Technology. (Arlington: Compass, December, 1963), pp. 5, 16-7.

[15] Fred N. Spiess, "Vehicle and Mobile Structures", Ocean Engineering, ed. John F. Brahtz (New York: John Wiley, 1968), pp. 373.

[16] Gordon G. Lilly, "The MOHOLE Project", The Military Engineer, (July-August, 1965), pp. 234-35.

[17] Warren E. Yasso, "Oceanography", (New York: Holt, Rinehart and Winston, 1965), pp. 70-1.

[18] Ibid.

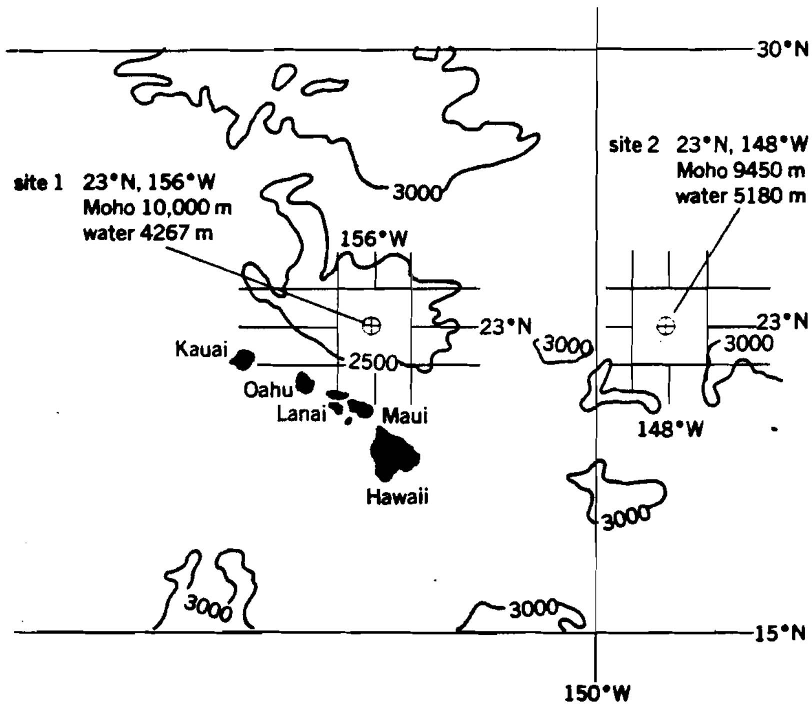

FIGURE (8): Planned core drilling sites of MOHOLE.

(From: McGraw-Hill Encyclopedia of Science and Technology, vol. 8, New York: McGraw-Hill, 1982, pp. 650.)

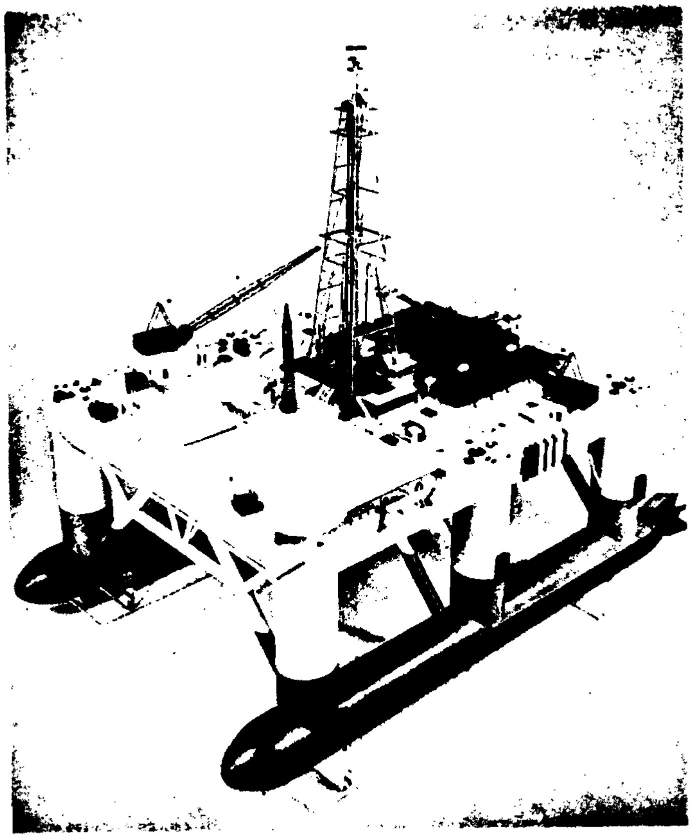

FIGURE (9): MOHOLE project.

(From: John F. Brahtz, Ocean Engineering, New York: John Wiley, 1968, pp. 373.)

radius.[19] In addition to extremely precise station-keeping ability, MOHOLE was designed to be self-propelled with a maximum speed of 10 knots, see Figure (10).

Project MOHOLE never got off the drawing board having been abandoned by Congress in 1966 for insufficient funds.[20,21] Although never a reality, all required equipment, machinery, and instrumentation had been designed, and some of it had been fabricated. Project MOHOLE was probably the single greatest achievement in stable floating platforms and a stepping stone for future platforms. "The 50,000 engineering man-hours used in developing the dynamic positioning system for Project MOHOLE were not wasted."[22] In 1967 the Western Development Laboratories division of Philco-Ford Corporation adapted the MOHOLE concept to, "design stable, station-keeping ocean platforms for use as mobile range tracking stations and other applications."[23]

The DELOS concept was a semi-submersible, column-stabilized steady ocean platform similar to MOHOLE, see Figure (11). Project manager William Richards stated:

> Ships produce at best a shaky platform for antennas. To keep from rolling, a ship must go into the wavės, often in a direction in which the way your antennas are strung out

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[19] Warren E. Yasso, "Oceanography", (New York: Holt, Rinehart and Winston, 1965), pp. 70-1.

[20] Arlen J. Large, "MOHOLE Melu", The Wall Street Journal, (January 19, 1967, pp. 12, col. 4.)

[21] "MOHOLE: The Project That Went Awry (III)", Science, vol. 143, (January 24, 1964), pp. 115-7, 334-7.

[22] Robert W. Niblock, "Oil Companies To Use MOHOLE Technology", Technology Week, (April 17, 1967), pp. 24.

[23] Robert Lindsey, "Project MOHOLE Fallout: Sea-Going Tracking Stations", Aerospace Technology, (May 6, 1965), pp. 34-5.

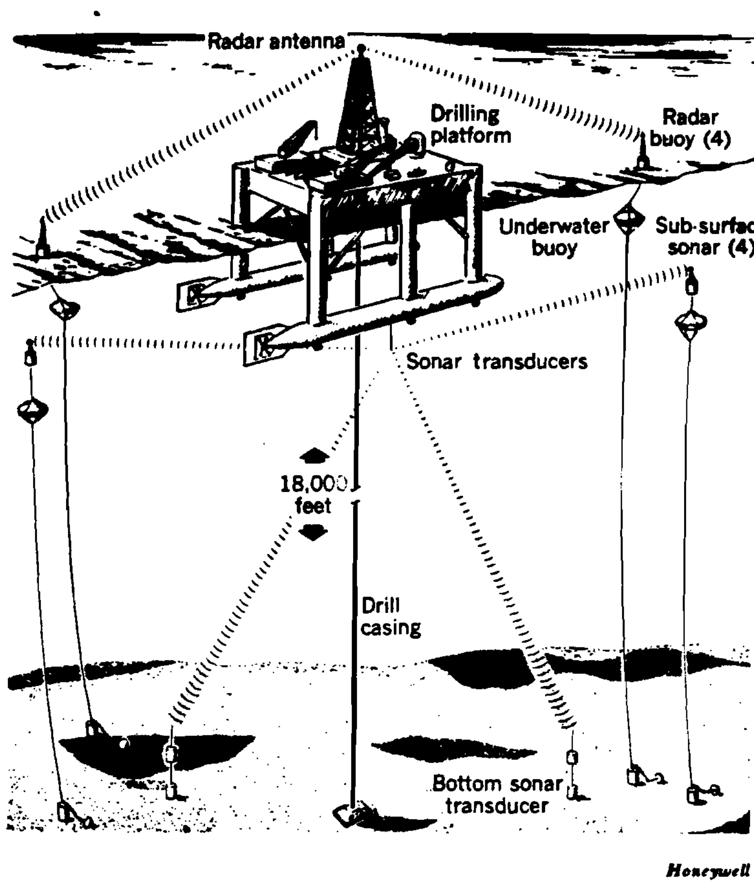
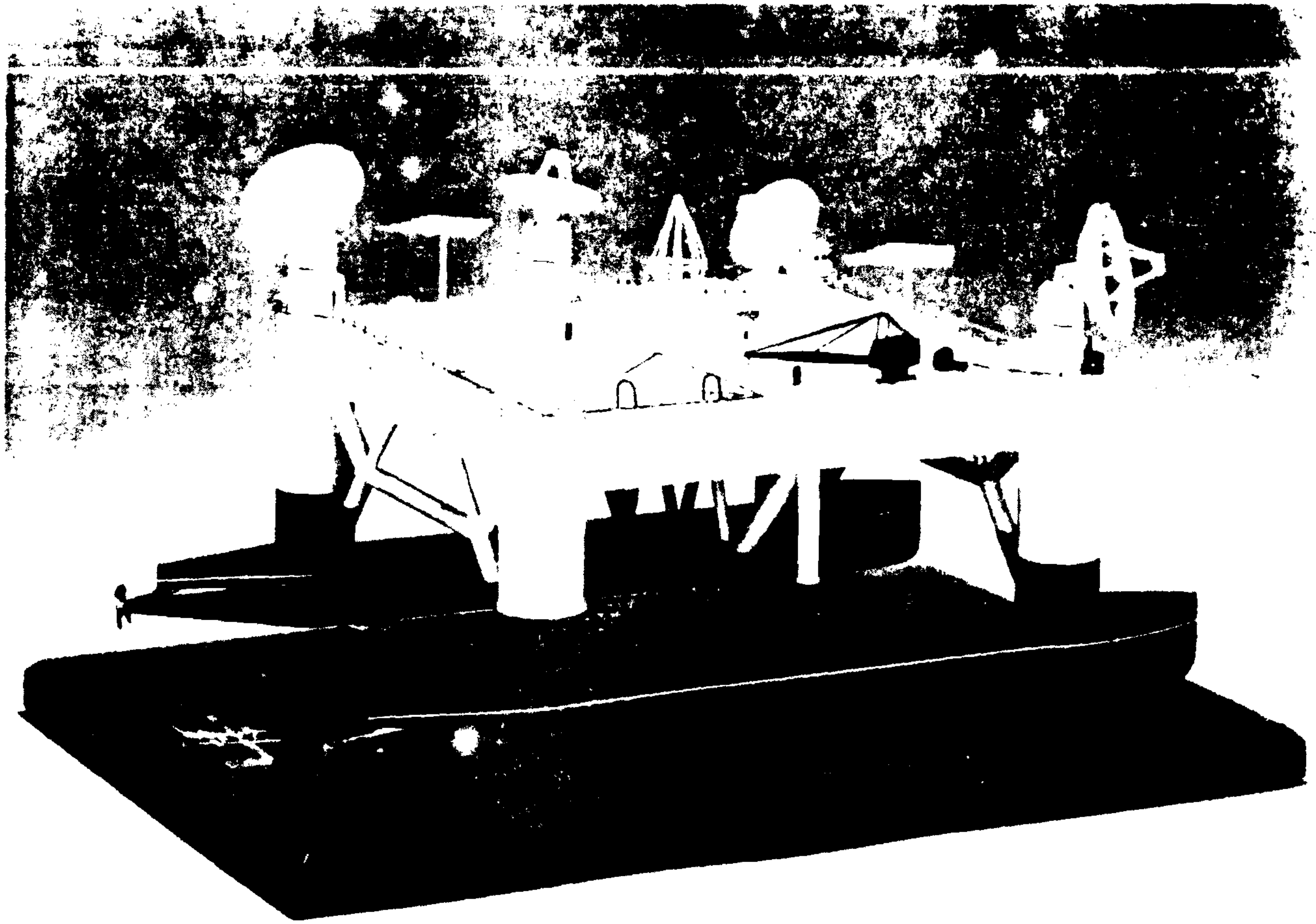


FIGURE (10): The site for Project MOHOLE lies about 100 miles north of Maui in the Hawaiian Islands; an area where explosion soundings have shown that the mantle rises to within three miles of the ocean floor, beneath two and a half miles of water.

(From: Warren E. Yasso, Oceanography, New York: Holt, Rinehart and Winston, 1965, pp. 71.)



DELOS Stable Ocean Platform

An advanced generation of a sea-mobile support platform. In transit, DELOS operates as a catamaran; on station, the twin hulls are submerged to provide inherent steadiness even in high seas. Shown here DELOS is configured as a steady sea-born tracking station designed to support missile and space programs.

<u>FIGURE (11)</u>

(From: Stewart B. Nelson, Oceanographic Ships, Washington: U.S. Government Printing Office, 1971, pp. 219.)

is not optimum. Even with inertial navigation and ship stabilizing devices, you don't have satisfactory navigation accuracy and you still have a lot of pitch and roll, causing the problem called "smear", degraded resolution of position-fixing instrumentation. Recalling that a stable platform had been developed in the abortive Project MOHOLE the effort to drill deep into the Earth's mantle, we wondered if it might provide the "floating island" technique we wanted.[24]

DELOS was designed to survive winds up to 150 miles per hour and waves towering to 100 feet, and, have the accuracy required to track space objects to within 200 feet.[25]

Several major oil companies, the United States Air Force and Navy, invisioned numerous applications of the DELOS concept to include:

(1) Offshore oil work; it can provide guidance for re-entering the riser into the top of the blow-out preventer stack, or

(2) For re-entering the blow-out preventer into the connector on the main base.[26]

(3) A platform for read-out stations of the Air Force global Satellite Control Facility. Advantages include improved reception of some kinds of data: wide ranging oceanic mobility to meet certain mission requirements; and the prospect of locating read-out stations in areas where political conditions do not permit land stations or where, perhaps in the future, a political situation forces closing of stations on foreign soil.

(4) High speed mobility of the "floating island" has a potential role in certain U.S. intelligence efforts. During Soviet ICBM tests, for example, a DELOS-like platform could be moved to almost any area where over-ocean flight tests

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24 Robert Lindsey, "Project MOHOLE Fallout: Sea-Going Tracking Stations", Aerospace Technology, (May 6, 1965), pp. 34-5.

25 "DELOS Mobile Instrumental Steady Sea Station", Undersea Technology, (July, 1968), pp. 16.

26 Robert W. Niblock, "Oil Companies To Use MOHOLE Technology", Technology Week, (April 17, 1967), pp. 24.

were to be conducted. Signature data and performance of Soviet re-entry vehicle technology could be collected virtually anywhere in the oceans.

(5) Other applications include use as a base for anti-submarine warfare operations; monitoring of ocean-bottom seismic and nuclear test observation and missile impact location sensors; as a "mother ship" during recovery attempts of objects lost in the oceans; as a platform for launching weapons; and a variety of proposed industrial and scientific maritime operations.[27]

Project MOHOLE and DELOS were indeed very similar. So much so that, DELOS was also abandoned for insufficient funds in 1968.

This has been a brief history of the early beginnings of artificial floating islands. Although the future of these platforms may not appear promising, much has indeed been accomplished. The technology has been refined over the last 100 years and it's only a matter of time before artificial floating islands will arrive. Before looking into some future applications of artificial floating islands, lets examine the different types of structures presently available for artificial floating islands.

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27 Robert Lindsey, "Project MOHOLE Fallout: Sea-Going Tracking Stations", Aerospace Technology, (May 6, 1965), pp. 35.

CHAPTER 2

TYPES OF STRUCTURES

Before discussing the possible applications of artificial floating islands, a review of various platform concepts is required.

The primary factors one has to deal with in the design of marine structures are those associated with winds, waves, tides, and currents. In addition, biological activities such as fouling and boring organisms must be considered for certain structures, as must certain chemical (corrosion), electrolytes, and thermal (ice expansion) phenomena.[28]

The effects of wind, waves, tides and current will be discussed here and the effects of biological chemical and other activities will be dealt with later.

Wind and waves are directly related and therefore will be deliberated together. Waves on the surface of the sea are caused principally by wind. In fact, wind speed at sea can be estimated from wave conditions, see Table (1).

The amount of energy in even a moderate wave is overwhelming. A four-foot wave striking a coast expends more than 35,000 horsepower per mile of beach, and for each 56 miles of coast, the energy expended equals the power generated at Hoover Dam.[29] Keeping this in mind, the effect of wind and waves can have disastrous effects on floating platforms. For the North Sea oil rigs to frequently experience 30-50 foot seas and 100 mile per hour winds is not uncommon. In the overall

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[28] Robert L. Wiegel, Oceanographical Engineering, (Englewood Cliffs: Prentice-Hall, 1964), pp. 442.

[29] Nathaniel Bowditch, American Practical Navigation, (Washington: Defense Mapping Agency Hydrographic Center, 1977), pp. 791.

BEAUFORT NUMBER*	WIND SPEED (kilometers per hour)	SEAMAN'S TERM	EFFECTS OBSERVED AT SEA
0	under 1	Calm	Sea like a mirror
1	1–5	Light air	Ripples with appearance of scales; no foam crests
2	6–11	Light breeze	Small wavelets; crests of glassy appearance, not breaking
3	12–19	Gentle breeze	Large wavelets; crests begin to break; scattered whitecaps
4	20–28	Moderate breeze	Small waves, becoming longer; numerous whitecaps
5	29–38	Fresh breeze	Moderate waves, taking longer form; many whitecaps; some spray
6	39–49	Strong breeze	Larger waves forming; whitecaps everywhere; more spray
7	50–61	Moderate gale	Sea heaps up; white foam from breaking waves begins to be blown in streaks
8	62–74	Fresh gale	Moderately high waves of greater length; edges of crests begin to break into spindrift; foam is blown in well-marked streaks
9	75–88	Strong gale	High waves; sea begins to roll; dense streaks of foam; spray may reduce visibility
10	89–102	Whole gale	Very high waves with overhanging crests; sea takes white appearance as foam is blown in very dense streaks; rolling is heavy and visibility reduced
11	103–117	Storm	Exceptionally high waves; sea covered with white-foam patches; visibility still more reduced
12	118–133	Hurricane	Air filled with foam; sea completely white with driving spray; visibility greatly reduced
13	134–149		
14	150–166		
15	167–183		
16	184–201		
17	202–220		

**Beaufort numbers*, still used to indicate approximate wind speed, were devised in 1806 by the English admiral Sir Francis Beaufort, based on the amount of sail a fully rigged warship of his day could carry in a wind of a given strength. Modified from U.S. Naval Oceanographic Office, 1958. *American Practical Navigator* (Bowditch), rev. ed., H.O. Publ. No. 9, Washington, D.C., p. 1069.

Table (1): Appearance of the Sea at Various Wind Speeds.

design of floating platforms, it is therefore imperative that the effects of wind and waves be considered. If not, disastrous results have and will occur, see Appendix (2).

The tidal phenomenon is the periodic motion of the waters of the sea due to differences in the attractive forces of various celestial bodies. The effect of tides can be extremely important to floating platforms, specifically to the mooring systems employed by these floating structures located near coastal waters. The reason being, the range of tide can be quite dramatic is some parts of the world. For example, the tidal range in some parts of the Bay of Fundy can change as much as 40 feet in a period of six hours. This could obviously create problems if consideration had not been given to the effect of tides in the overall design of floating platforms located in these areas.

Finally, the effects of current must be considered in the design of floating structures. There are several main types of currents in the ocean: the general oceanic currents, the tidal currents, and the wind-induced surface currents. Current velocities vary from place to place. Measurements range from zero to over 10 knots depending on location and time of year. No matter what the type of current, their effects must be considered in the design of floating platforms. Specifically, mooring and position-keeping systems, to be effective, must be designed to compensate for the effects of current.

Platforms can be divided into four different types: columnar or elevated, semi-submersible, barge and tension-leg. Each concept will be discussed in length as well as their advantages/disadvantages, and operational/constructional deficiencies.

COLUMNAR OR ELEVATED PLATFORMS

This concept is an extension to large platforms of the proven principles embodied in the very successful ocean platform FLIP. This idea is not new. Thinking back to Chapter 1, Armstrong patented the concept for a floating airport in 1924. Columnar platforms are designed to employ many vertical buoyant elements to support the work surface, see Figure (12). These vertical elements or columns reach far down into deep water for buoyant support and exceptional stability.

The columnar platform concept has three major variations. In the first, small platform or deck modules (about 50-60 feet square), and column sections (20-30 feet in diameter and 50 feet long), are towed to the operating site. Once on location, the deck and column modules are jointed together to form the complete platform, see Figure (13). The objective of this design is to keep the elements small enough so that they can be fabricated at a comparatively small industrial establishment, instead of depending on large shipyard facilities.

The second variation is basically identical to the first, except on a larger scale. The deck sections are now about 200 feet square, and, the column sections are 300 feet long. The columnar sections are placed only at the corner of each deck section, and, where two or four sections come together, they share the support of a single column at that point. The idea behind this variation is to reduce the number of module connection points, and hopefully lessen assembly time.

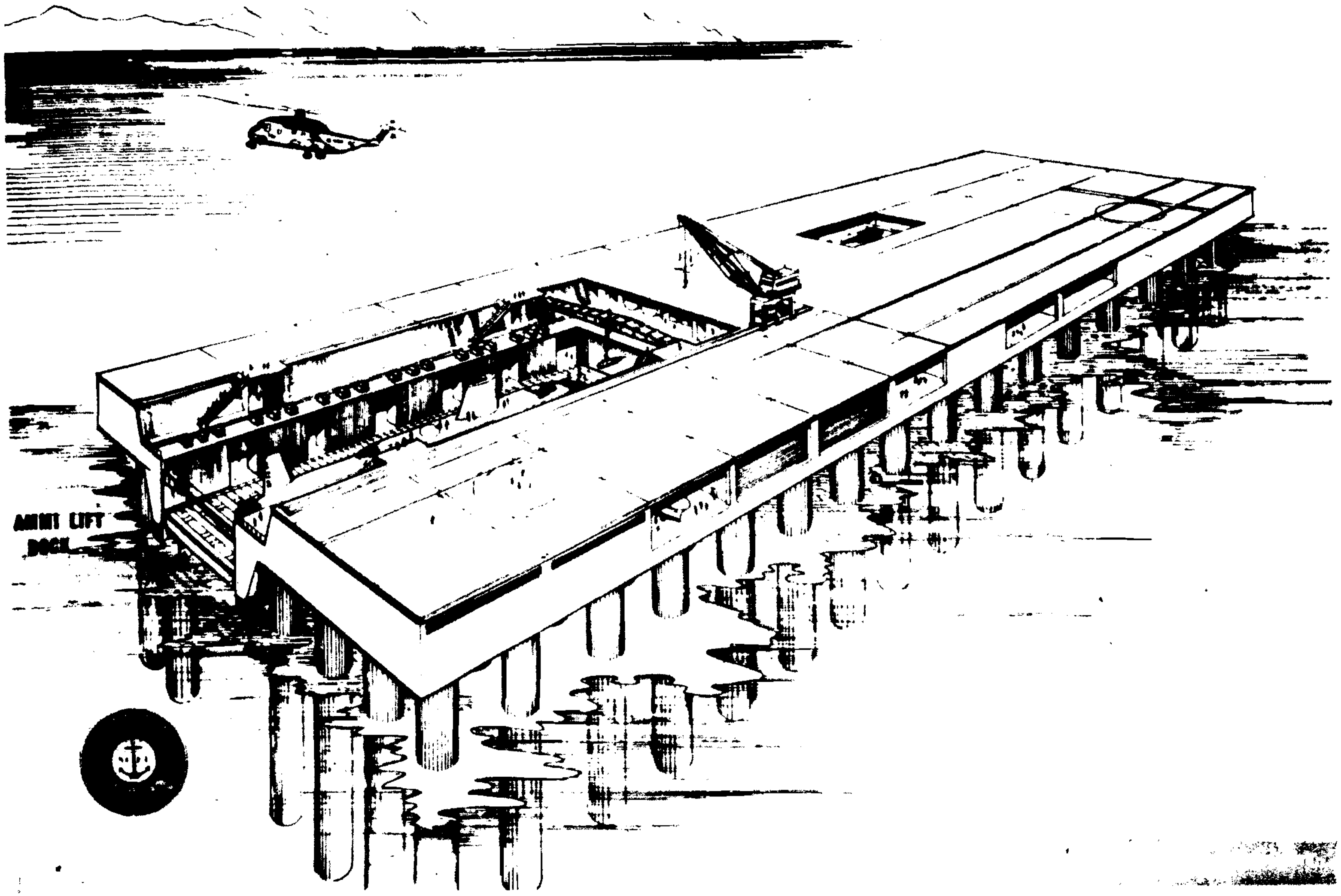
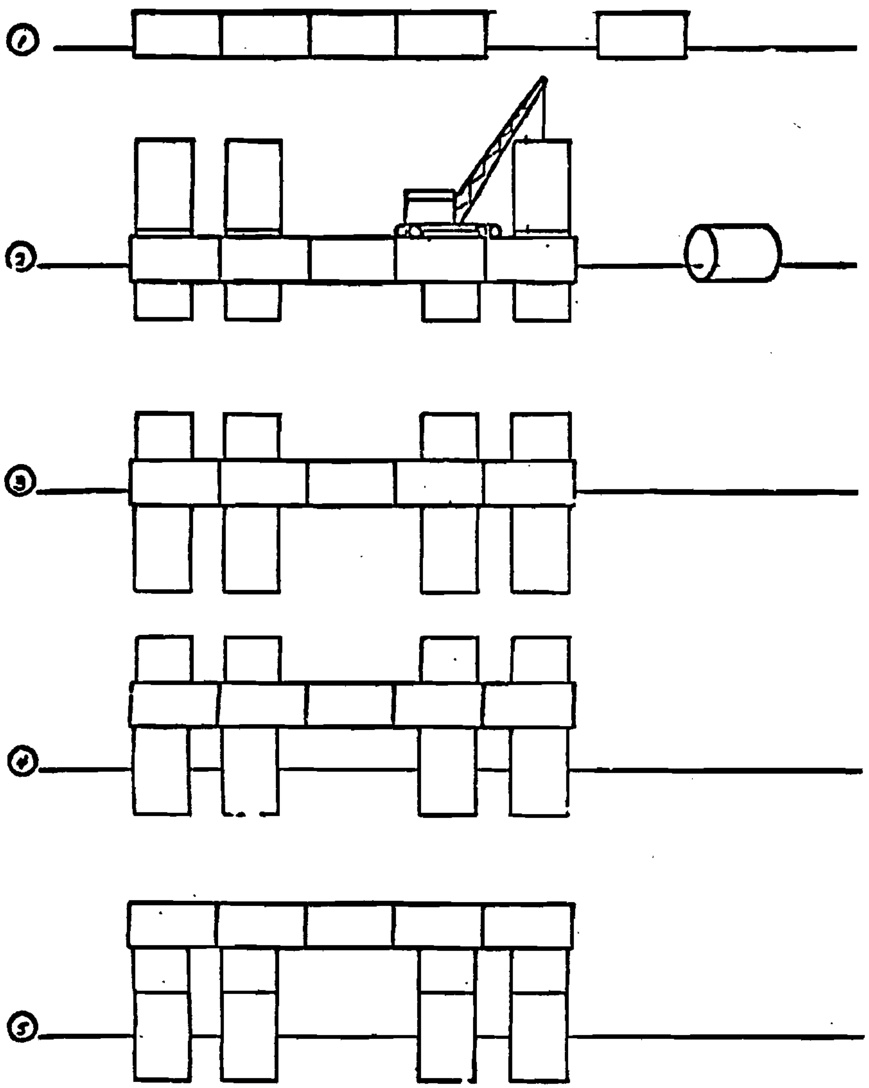


FIGURE (12): Elevated platform with circular cylindrical legs.

(From: Naval Civil Engineering Laboratory
Port Hueneme, California)



I. Join sections, while floating.
   A. Winch together.
   B. Quick connect.
   C. Pin, bolt or weld.

II. Install leg sections.

III. Flood legs, lower, secure.

IV. Ballast-up rig by pumping.

V. Repeat 3 & 4 to give final configuration.

FIGURE (13): ARPA-Floating Platform (Assembly Procedure)

The last configuration of columnar platform utilizes bottle-shaped floating elements, see Figure (14). In this design, the neck of the bottle provides a smaller surface area in contact with surface water. This reduced surface area lessens the effects of wave and current action and increases the overall stability of the platform.

Advantages

The advantages of a hydro-dynamically stable columnar platform are many. Probably the most important advantage is stability. A columnar platform can be designed to have a minimum heave, pitch, and roll response for practically any sea condition. Pilot tests conducted in a wave tank indicate that a 1000 foot by 4000 foot columnar platform would provide sufficient stability for handling large, heavily laden cargo aircraft, such as the C-130, see Figure (15). Another advantage of a columnar platform is its apparently favorable drift response. By using the bottle-leg configuration and limiting the deck thickness, wave tank studies have revealed that this type of platform may actually remain stationary under moderate sea conditions.[30] Finally, the versatility of the columnar platform is enormous. Its inherent stability makes this platform ideal for airports, urban expansion, industrial facilities or power generation.

Disadvantages

The columnar platform design has two basic disadvantages. First, since its stability is depended on long-buoyant vertical legs, the platform has an average draft of 300-400 feet. This places a restriction

[30] Moderate sea conditions being 3-4 foot seas and 10-15 mph winds.

FIGURE (14): Bottle-shaped element

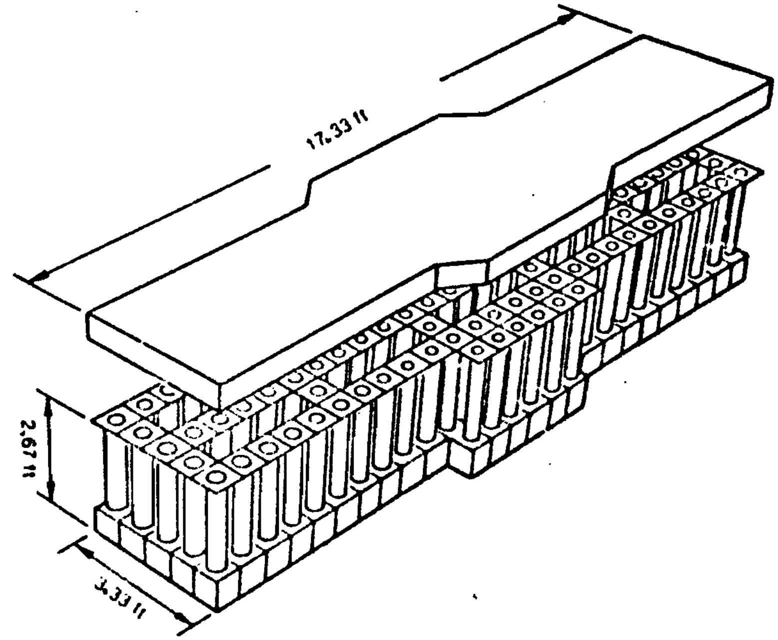


FIGURE (15): Wave tank test model for columnar platform.

on columnar platforms in that they must be located at sites having a water depth greater than 300-400 feet. The second disadvantage is high-towing drag and lack of mobility. The design of columnar or elevated platforms does not include the use of internal main propulsion and, if these platforms are to be moved, they must be towed by external means. Preliminary calculations have indicated that the force required to move a 1000 foot by 4000 foot platform with a 300 foot draft is enormous. Therefore, site selection is extremely important. A permanent location must be chosen, with the idea in mind, that once these platforms are constructed they are not going to be moved great distances unless disassembled.

SEMI-SUBMERSIBLE PLATFORMS

The second contender for future artificial floating islands is the semi-submersible concept. Early examples of this concept, were the landing stage for vessels and land vehicles patented by Augustine Gaffney and Projects MOHOLE and DELOS.[31] A semi-submersible is a buoyant platform with most of the buoyancy coming from the submerged hulls. The basic configuration consists of a lower hull formed of tubular members for buoyancy, vertical support columns attached to the lower hull and the deck, see Figure (16).

Mobility and stability are inversely proportional on semi-submersible platforms. To achieve mobility the self-propelled platform rides high out of the water in a shallow draft condition, thus, reducing hydrodynamic

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31 See Chapter 1.

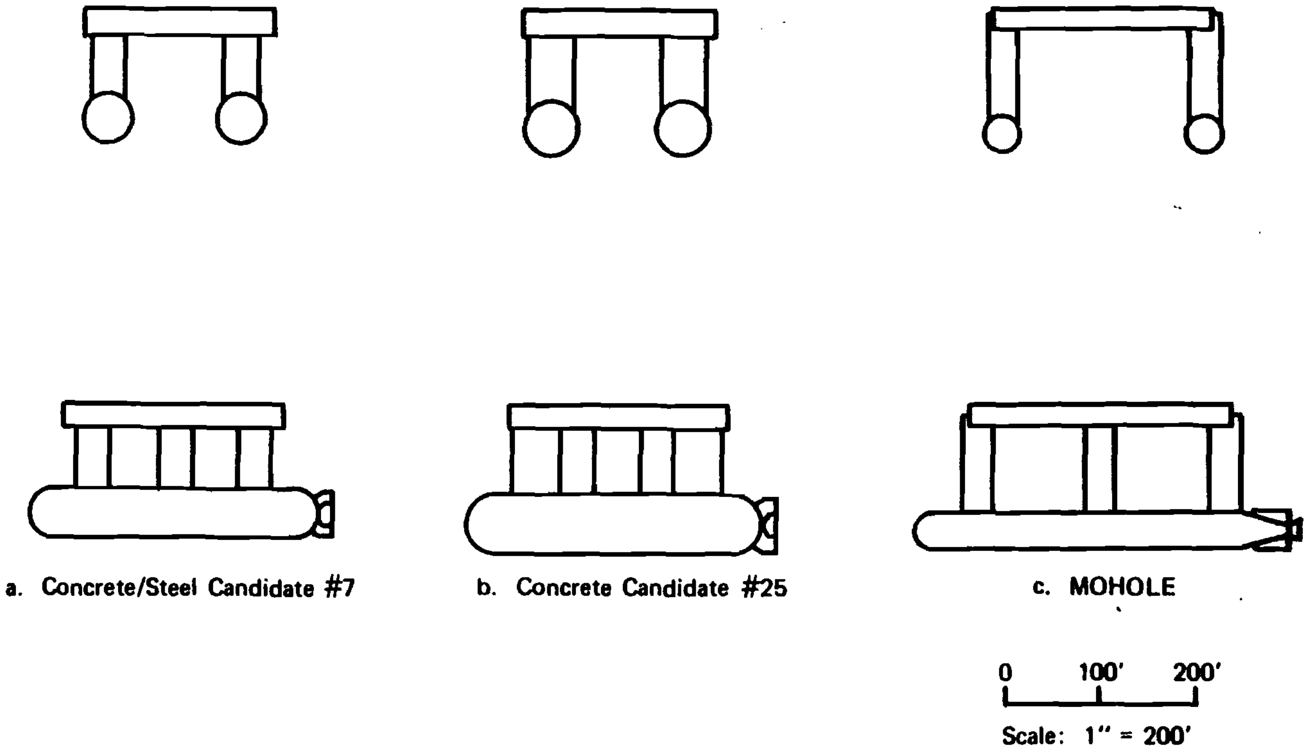

FIGURE (16): Semi-submersible configurations.

(From: Naval Civil Engineering Laboratory,
Port Hueneme, California)

drag to a minimum. In this shallow draft condition, stability is at a minimum, being greatly influenced by the effects of wave and wind action. Once on station however, increased stability is obtained by ballasting to a deep-draft mode, sacrificing mobility.

A one-tenth scale twin-hull semi-submersible platform was designed by the Naval Civil Engineering Laboratory in 1973 to evaluate stability and construction techniques, see Figures (17) and (18). After nine months of submergence and vigorous testing, the test model was evaluated as a complete success. D.A. Davis a technical engineer for the project stated:

> (1) A preliminary analysis of a mobile, semi-submersible platform indicates that the concept is feasible, provided that:
>
> a. A comparatively lightweight deck is used.
> b. An underneath deck clearance of 30 to 40 feet above mean water surface is acceptable.
> c. Large diameter columns and hulls (up to 60 feet in outside diameter) having a wall thickness not exceeding 2 feet are acceptable from considerations of formability and strength.
>
> (2) It is feasible to construct a full-scale platform using precast concrete elements and post-tension techniques.
>
> (3) Power required for propulsion at 15 knots, for all configurations studied lies in the range of 8,700 to 12,700 shp.
>
> (4) Cost for an acceptable, all-concrete platform having deck plan dimensions of 200 feet by 230 feet is estimated to be around 15 million dollars.[32]

Advantages and Disadvantages

The primary advantage of the semi-submersible concept is that it's

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32
D.A. Davis, The Concrete Semi-Submersible Platform, (Port Hueneme: Naval Civil Engineering Laboratory, 1973), pp. 32.

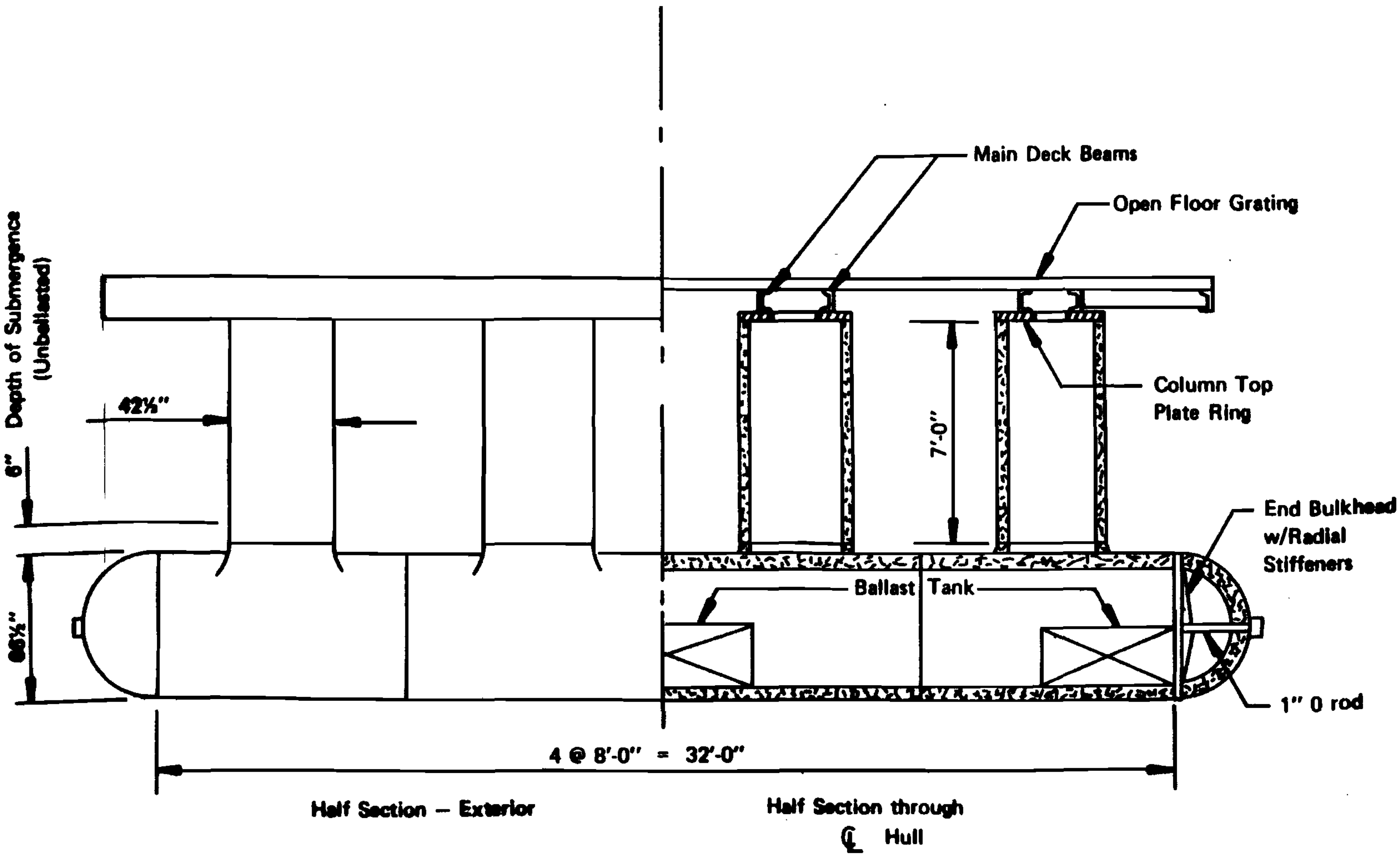


FIGURE (17): 1/10 scale semi-submersible test model.

(From: Naval Civil Engineering Laboratory,
Port Hueneme, California)

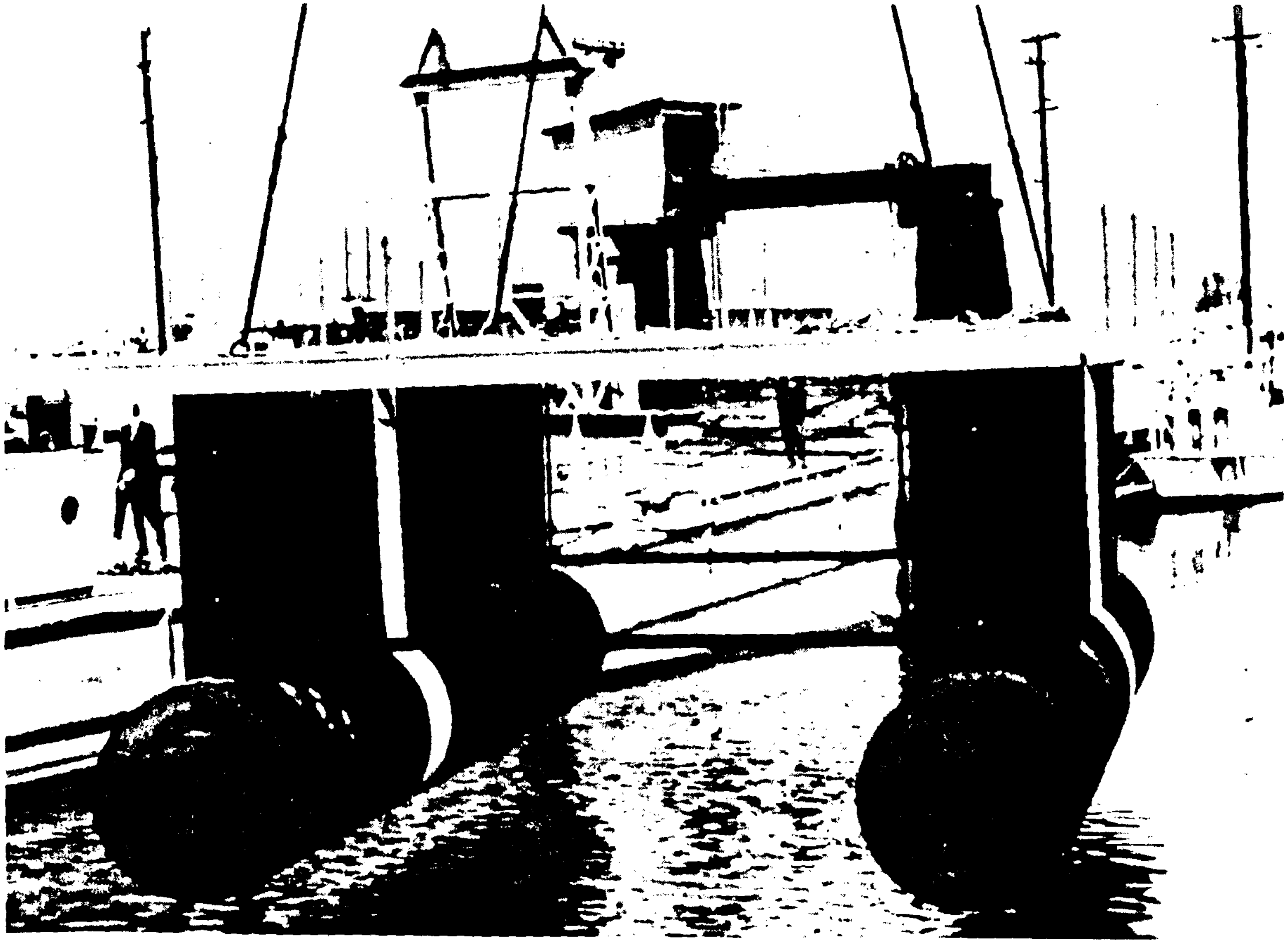


FIGURE (18): 1/10 scale semi-submersible test model.

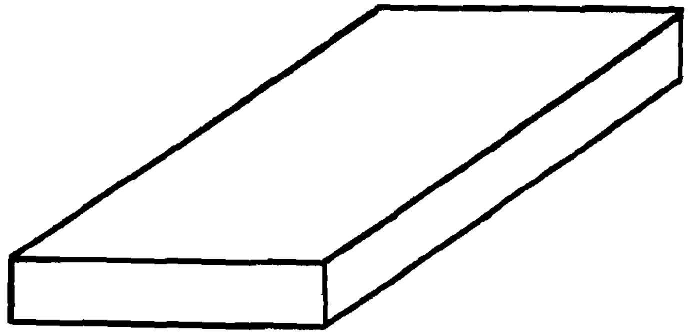
(From: Naval Civil Engineering Laboratory,
Port Hueneme, California)

more than an idea or model, it is a reality. Medium size semi-submersible platforms have been utilized by the offshore oil industry as exploration, development, and work platforms for the past 15 years. The design has been refined along the way and its enormous success is a matter of record. Unlike the columnar platform designed strictly for maximum stability, the semi-submersible platform is a compromise. Semi-submersibles are inherently less stable than deep buoyant platforms but, more so than conventional ships. On the other hand, they have greater mobility when compared to elevated platforms but, less than conventional ships. Because of this compromise, the applications for a semi-submersible platform are on a smaller scale in relation to columnar platforms. Applications include, (1) VSTOL and helicopter basing for the military or coastal urban areas, (2) oceanographic research, (3) petroleum tank storage and, (4) submarine rescue/recovery.

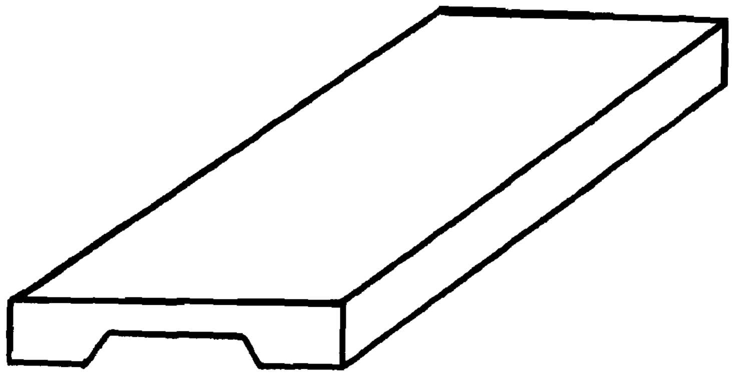
BARGE PLATFORMS

The barge probability dates back to prehistoric times when man lashed logs together and floated down a waterway. Several thousand years later, the barge is now being considered for large offshore floating platforms. Figure (19) illustrates four possible barge configurations.

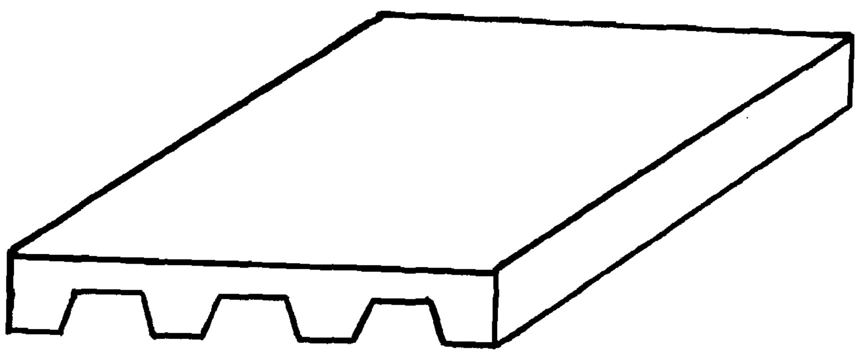
The first, oldest and simplest configuration geometrically is a flat-sided, flat-bottom hull having the distinction of offering the lowest draft to displacement ratio, see Figure (20). An offspring of the first, the catamaran and trimaran hulls offer greater structural resistance to sagging and hogging stresses, but do have a greater



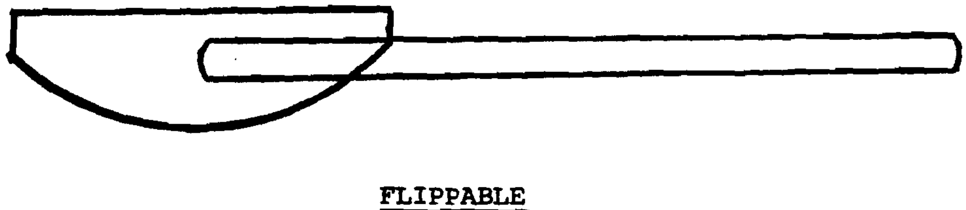
FLAT HULL



CATAMARAN



TRIMARAN



FLIPPABLE

FIGURE (19): Four possible barge configurations.

FIGURE (20): Flat Barge Configuration.

(From: Naval Facilities Engineering Command,
Alexandria, Virginia)

draft than a flat hull configuration, see Figure (21). Probably the most innovative and versatile design is the flippable-barge concept.

The concept utilizes a major module of the sort shown in Figures (22) and (23). The craft can operate in either a horizontal or vertical mode, and can carry a deck load consisting of a number of FLIP-like columns which would be the large platform supporting elements. These would be loaded on deck in port, and the entire rig (looking like a conventional large seagoing barge with deckload) would be towed to the assembly area. Once on station, the major module would flip with its deck load still attached and then, once in the vertical, would release the individual columns to be pulled away one by one. The legs and the major module would be coupled into a single rigid structure which would then be mated to other similar subgroups to form the entire platform, see Figure (24).

An offspring of the flippable-barge just described was designed by Advanced Research Projects Agency (ARPA) and Scripps Institute of Oceanography in 1970. The Scripps-ARPA design comprised a floating platform made up at sea from two-legged modules. Each module consisted of a pair of FLIP-like legs rigidly connected to each other and supporting a superstructure platform on a trunnion so that it remains essentially level as the legs are changed from the horizontal to the vertical attitude, see Figure (25). The major difference between the original flippable-barge design and the Scripps-ARPA design, was reduced surface area in the later design. This reduced surface area would reduce the effects of wind and wave action, and therefore, increase

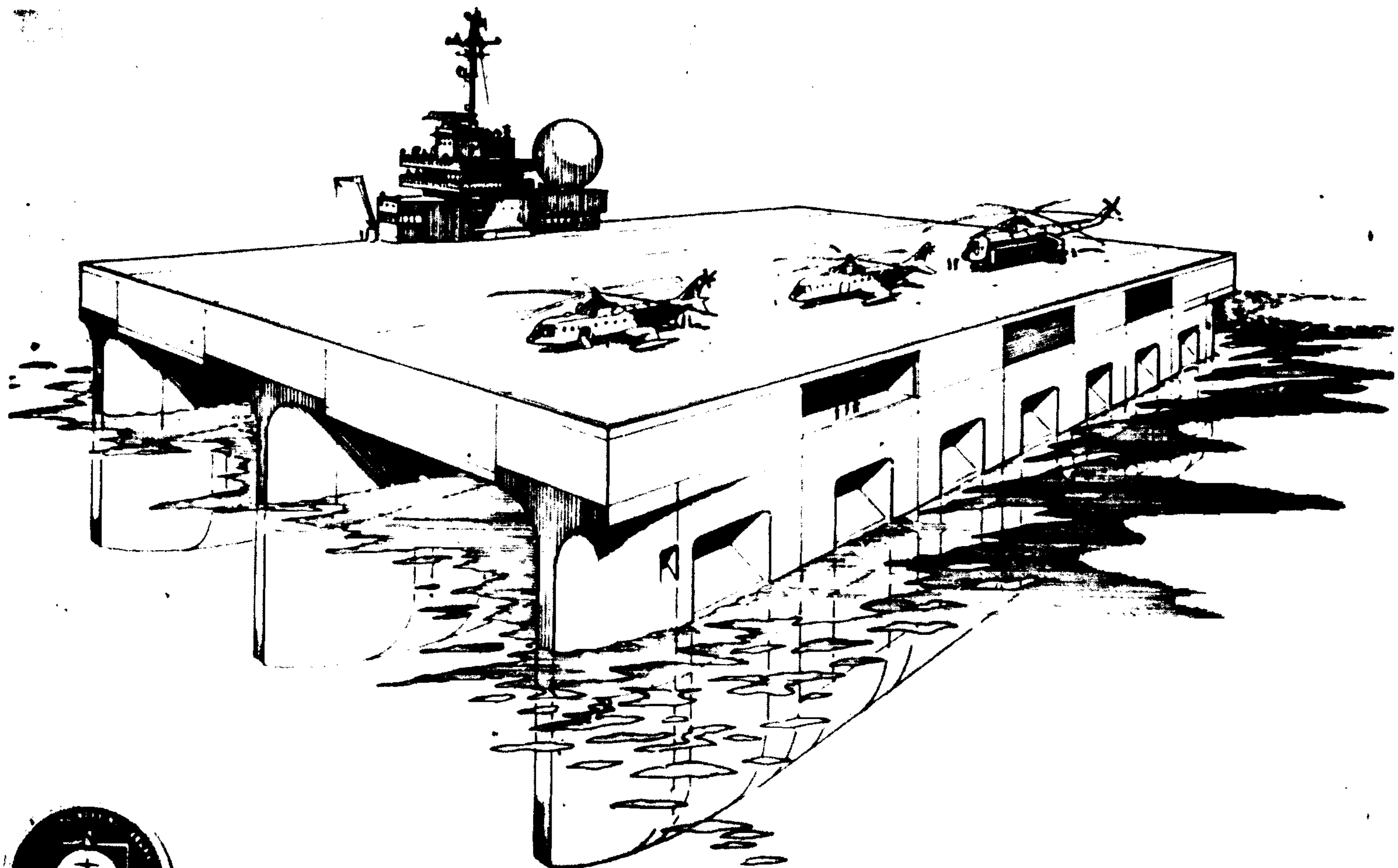
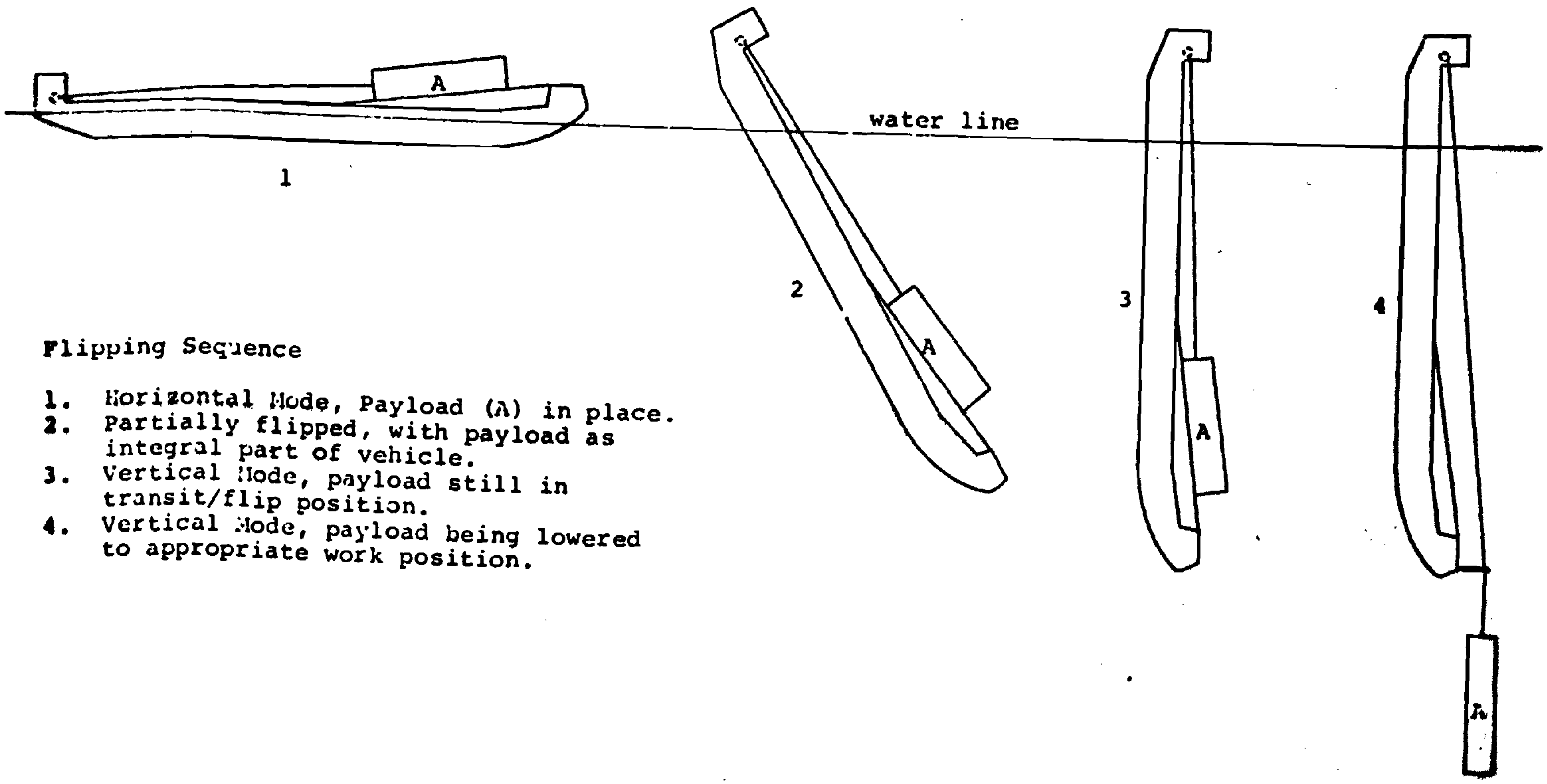


FIGURE (21): Trimaran Barge Platform.

(From: Naval Civil Engineering Laboratory,
Port Hueneme, California)



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 (22): Flippable Barge.

(From: Naval Civil ENgineering Laboratory, Port Hueneme, California)

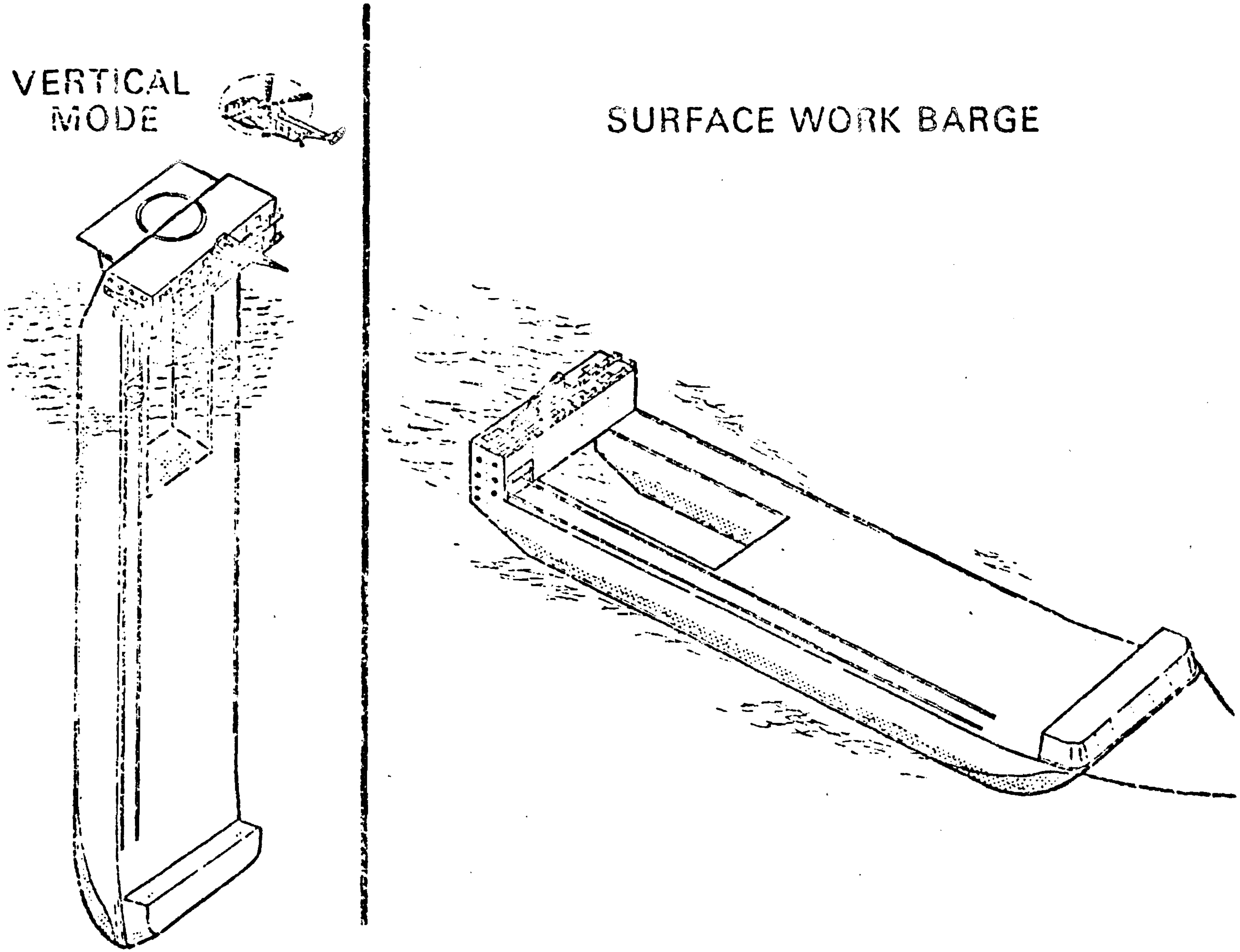


FIGURE (23): Flippable Barge.

(From: Naval Civil Engineering Laboratory,
Port Hueneme, California)

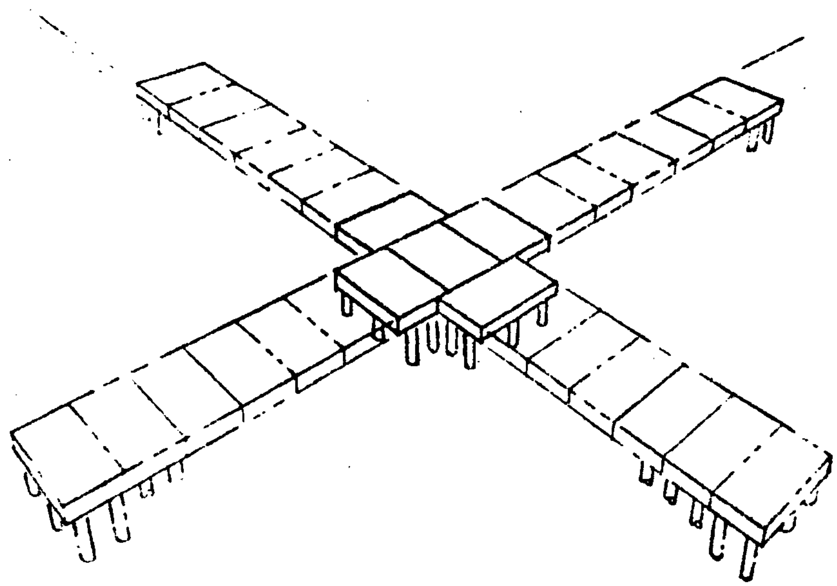


FIGURE (24): Example of Possible Large Platform Configuration for **flippable barge.**

(From: Naval Civil Engineering Laboratory,
Port Hueneme, California)

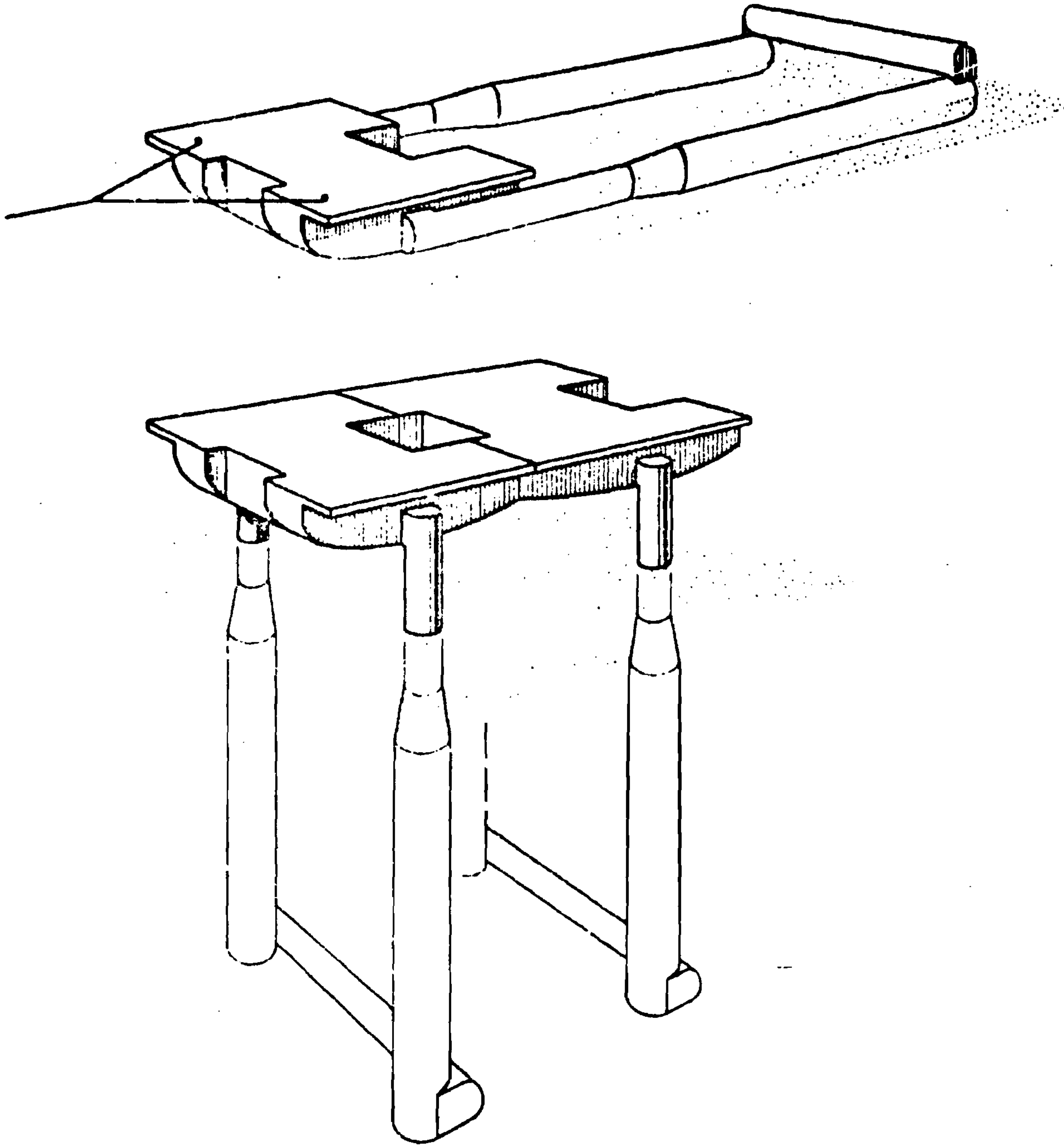


FIGURE (25): Scripps-ARPA Flippable Barge Concept.

(From: Naval Civil Engineering Laboratory,
Port Hueneme, California)

the overall stability of the platform.

Advantages

Like the semi-submersible platform, there is a long and successful record established in the construction of ocean going barges. By present engineering standards a 1000 foot by 4000 foot barge is feasible. As opposed to elevated and semi-submersible platforms, barge platforms have a shallow draft. This reduced draft enhances utilization of the barge platform in coastal areas for urban expansion or floating airports. The hydrodynamic drag is also comparatively low. Reduction in drag is extremely important if the platform must be moved rapidly, or for long distances, and for this reason the United States Navy is considering the use of barge trains for an advanced base battle group logistic support unit, see Figures (26) and (27). Finally, the barge hull can be used for storing and housing personnel and equipment, including power plants and propulsion systems.

Disadvantages

Shallow draft, in addition to being an advantage is also a disadvantage. With the exception of the flippable-barge, all other configurations have their buoyant support at or near the water surface. Keeping this in mind, barge platforms are more susceptible to wave induced motion than elevated or semi-submersible platforms. Generally, catamaran or trimaran type barges have greater stability when compared to flat barges, due to their greater draft and decreased water plane area. The flippable-barge configuration unquestionably

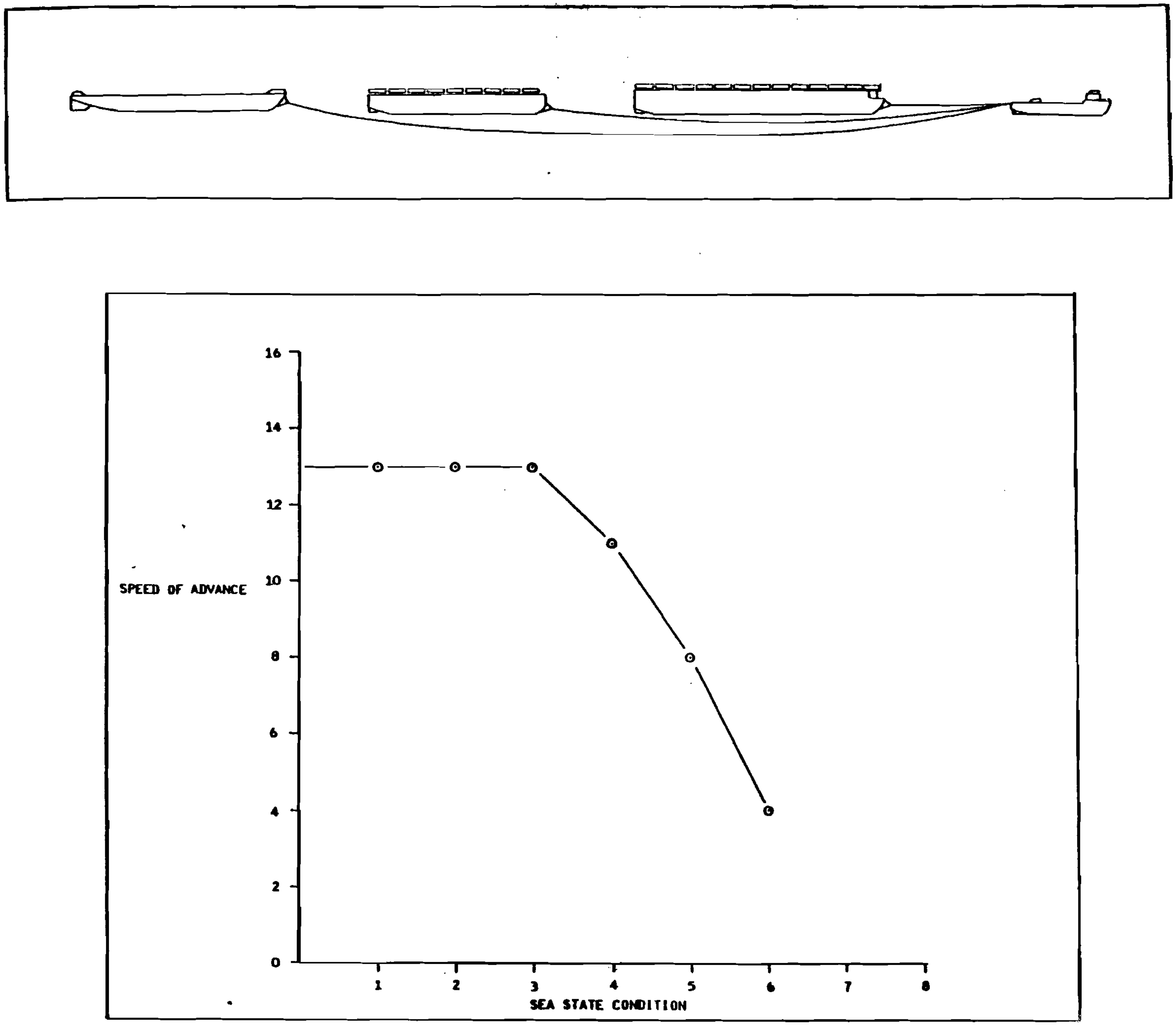


FIGURE (26): Barge Train Speed of Advance vs Sea State Condition.

(From: Science, Engineering and Analysis, Inc., Oxnard, California)

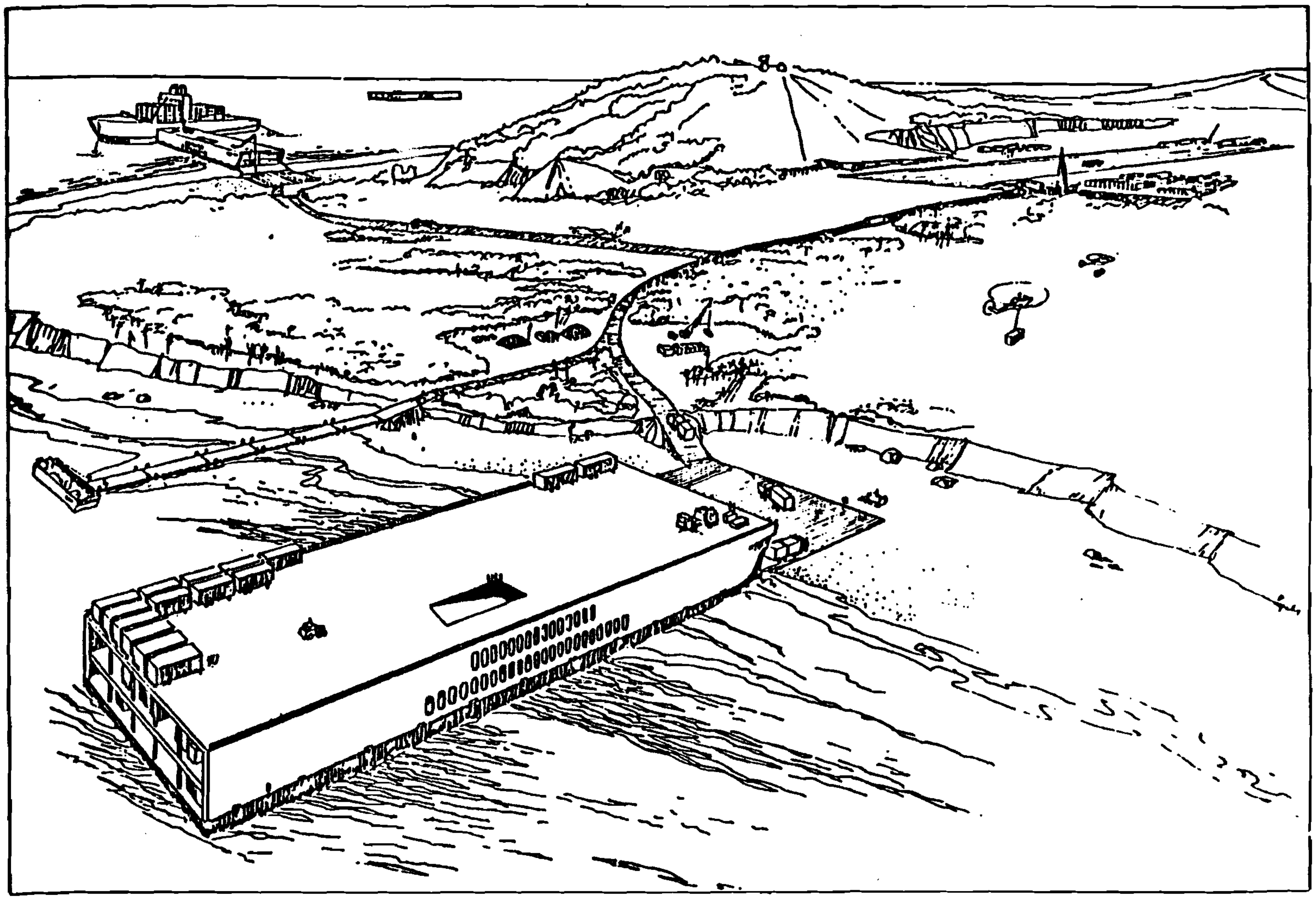


FIGURE (27): Barge Concept for Advanced Base Battle Group Logistics Support.

(From: Science, Engineering and Analysis, Inc., Oxnard, California) has the greatest stability, but like the semi-submersible, mobility is reduced due to greater draft.

TENSION-LEG PLATFORM

This concept is a variation of the semi-submersible platform. It utilizes the principle of tensioning a buoyant platform into the water with anchors and cables (patented by A. Fairchild in 1893, see Chapter 1).

> Tension-leg platforms have two main structural elements: a floating hull similar to a semi-submersible drilling rig but much larger and an array of highly tensioned vertical tethers at each corner. The tethers fashioned out of high-tensile-strength steel tubes, pull the floating hull down so far that they never go slack even in the trough of the maximum wave estimated to come once every 100 years. Although the tether system allows a degree of lateral motion, it prevents the heave, or vertical motion, associated with free-floating craft such as drilling vessels.[33]

Figure (28) illustrates the tension-leg platform. The superior stability of this platform is due to several factors. These include:

(1). Reduction of the waterplane area.

(2). Buoyant pontoons beneath the water surface.

(3). Tension anchor lines.[34]

"The Hutton platform, being developed and built by Conocco, Inc., for the British sector of the North Sea, is the first commercial tension-leg platform."[35] Figure (29) details the method of construction

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33 Fred S. Ellers, "Advanced Offshore Oil Platforms", Scientific American, vol. 246, April 1982, pp. 43.

34 Robert R. Nunn, "New Concepts for Deep Water Production", Ocean Industry, vol. 3, no. 9, September 1968, pp. 50.

35 Fred S. Ellers, "Advanced Offshore Oil Platforms", Scientific American, vol. 246, April 1982, pp. 46.

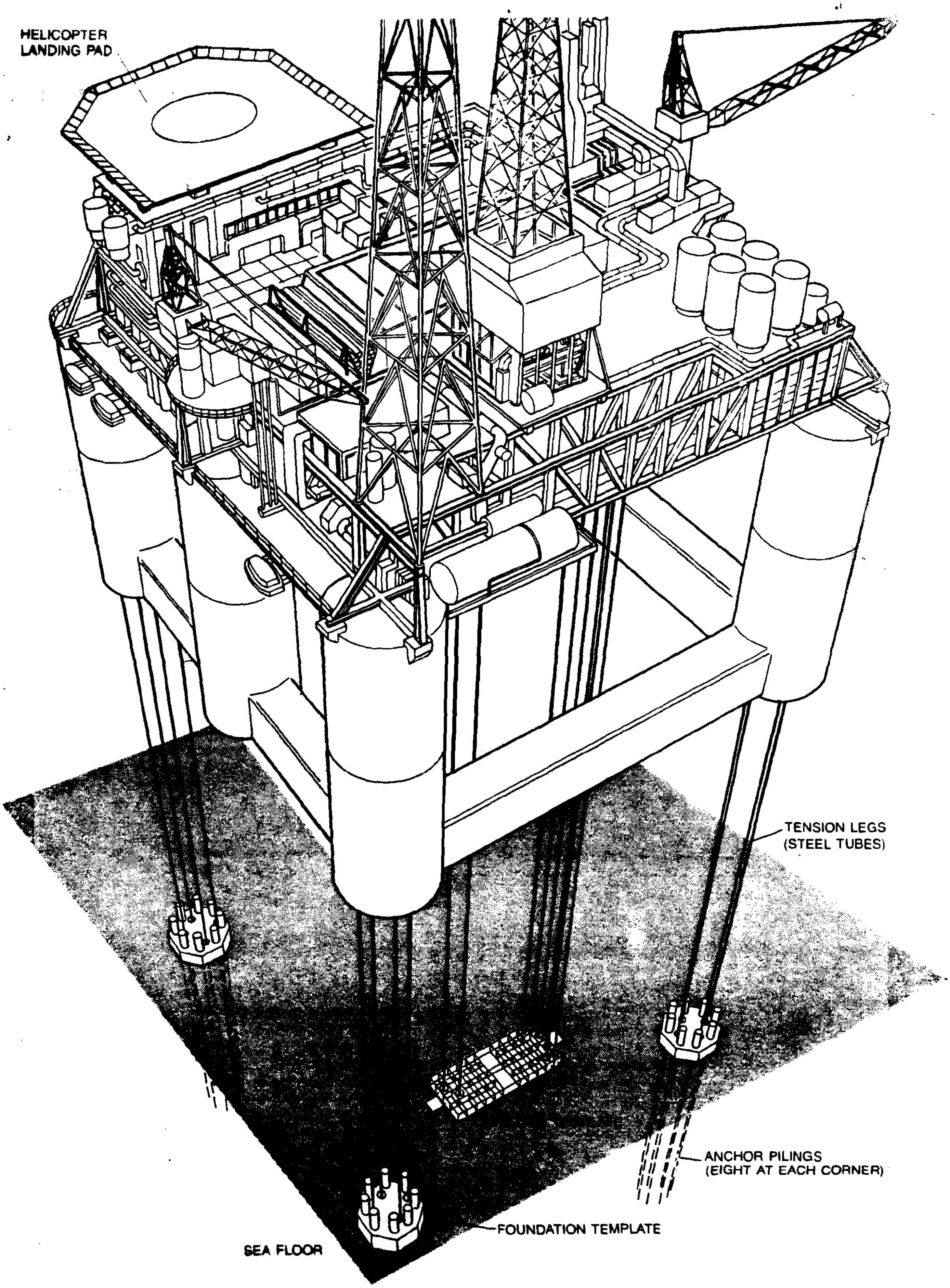

FIGURE (28): Tension-Leg Platform Design.

(From: Scientific American, April 1982, pp. 44)

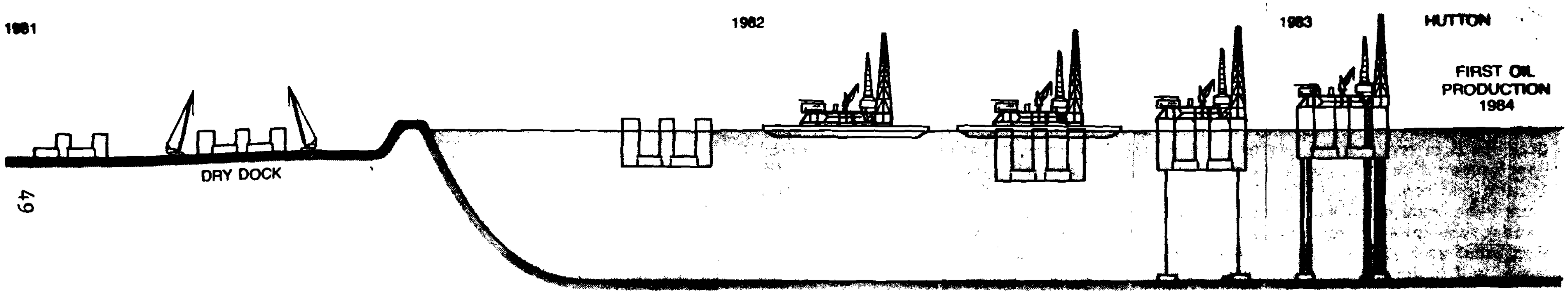

FIGURE (29): Method of Construction for the Hutton Tension-Leg Platform.

(From: Scientific American, April 1982, pp. 44) and emplacement for the Hutton platform. Very simply, the hull is constructed in a drydock and floated into deep water. After being partially submerged, the superstructure will be towed overhead and attached to the hull. Finally, the complete platform will be towed to the selected site and tethered to its prepared foundations. Initial oil production for the Hutton platform is scheduled for early 1984.

Advantages and Disadvantages

The tension-leg platform has several noteworthy advantages. Foremost is its ability to remain on station. The tensioned vertical tether will keep the platform inside a circle with a radius of 10% of the water depth even when subjected to a combination of 85 mph winds and 2 knot currents.[36] This concept also has the distinct capability of being insensitive to water depth. In other words, as water depth increases, the tethers need only be lengthened while the basic configuration remains unchanged. From an economic perspective the tension-leg platform is advantageous. Since one basic design can be utilized over a wide range of water depths, it seems to hold great promise for standardization.[37]

Disadvantages of the tension-leg platform are twofold. First construction and maintenance costs are extremely high. The tension-leg platform design is inherently complex and capital intensive. In addition, a requirement for periodic maintenance and inspection of the

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[36] Robert R. Nunn, "New Concepts for Deep Water Production", Ocean Industry, vol. 3, no. 9, September 1968, pp. 50.

[37] Fred S. Ellers, "Advanced Offshore Oil Platforms", Scientific American, vol. 246, April 1982, pp. 49.

anchoring system increases the overall operating cost. The second drawback of the tension-leg platform is its having to be buoyant under all weather conditions. This stipulation limits the maximum deck-load capacity of the platform.

DETERIORATION PREVENTION AND CONSTRUCTION MATERIALS FOR ARTIFICIAL FLOATING ISLANDS

The ocean environment presents a unique challenge to the marine engineer in terms of proper selection of materials for a given floating structure. The effects of winds, waves, tides and currents on marine structures were discussed at the beginning of this chapter. This section will continue that discussion dealing specifically with fouling, corrosion, and the effects of ice, and how these factors determine the construction materials required for marine structures.

FOULING

Fouling refers to the accumulation of various plant growths and animal organisms on any solid object in the water. The process begins when immersed or partially immersed surfaces become coated with a film of organic matter containing bacterial microcolonies and their metabolic products. Many organisms colonize where this film has accumulated; some seeking a firm surface on which to attach themselves and, still others live by consuming the film. Depending upon the construction materials and location chosen for a floating platform, the effects of fouling could be catastrophic if not considered in design, see Figure (30). In some parts of the world, fouling may be a foot or more thick causing severe structural deterioration of ocean platforms. Numerous studies conducted on North Sea oil rigs have revealed that a 2-inch thickness of fouling led to an overall load increase of 5.5% on the typical platform.[38] In addition to load increase, fouling can can cause the following effects on floating platforms:

(1) Increased drag and corrosion rates.

(2) The abrasion and possible severance of mooring lines and cables.

(3) Reduction in overall stability and mobility.

(4) Direct deterioration of structural components.

(5) Degradation of periodic inspections and maintenance.

Finally, the process of fouling is almost impossible to completely arrest. The effects can, however, be minimized by the following: selection of construction materials that exhibit a natural resistance to fouling; utilizing anti-fouling paints and inhibitors; periodic cleaning and inspection; and, probably the most important, considering these effects in the overall design.

CORROSION

Corrosion is due to an electrochemical process that occurs when two dissimilar metals are present in an electrolytic medium.

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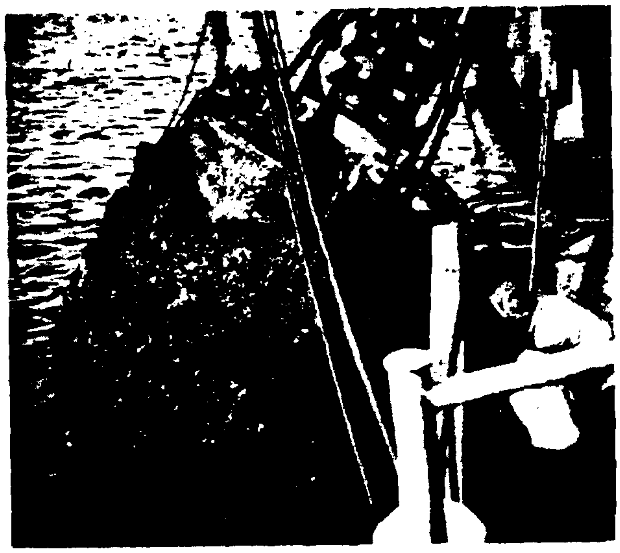
38 John Gaythwaite, "The Marine Environment and Structural Design", (New York: Van Nostrand Reinhold, 1981), pp. 276.



Navigation buoy heavily fouled with mussels.

Section of pipe laid open to show a plug of mussels.

Figure (30): Examples of excessive fouling.

(From: "Marine Fouling and its Prevention," Woods Hole Oceanographic Institution, Annapolis: United States Naval Institute, 1952.)

Sea water is an efficient electrolyte. Very simply, metals in contact with sea water lose electrons or rust and become positively charged. Thus, an electrical current is formed and the process continues, see Figure (31). After a period of time, scaling or pitting of the surface of the metal will occur. Eventually if corrosion is allowed to continue, the metal will completely deteriorate and dissolve.

Like fouling, the process of corrosion can never be completely eliminated. It can, however, be minimized and controlled. Careful consideration by the structural engineer, in the overall functional design and selection of materials can reduce the effects of corrosion on floating structures. In addition, Figures (32-34) illustrate protective coatings, claddings, rust inhibitors and cathodic-protection that are available to the engineer to combat the effects of corrosion.

ICE

Finally, the effects of ice, must be taken into account in the design of floating structures. Figure (35) summarizes the numerous forces that ice can exert. The structural engineer has many options and alternatives in designing floating platforms to reduce the impact of ice, see Table (2). The critical factor is that these structural design alternatives are applied to all structures located in areas where ice is present.

CONSTRUCTION MATERIALS

Presently there are two choices of construction materials for artificial floating islands, steel and concrete. Steel has been the traditional building material for marine vessels and platforms.

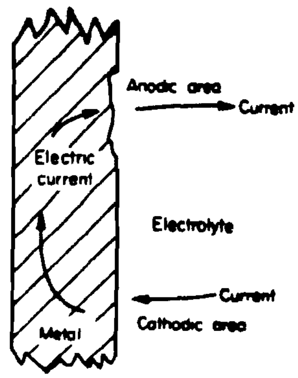


Figure (31): Electrolytic Corrosion.

(From: K.J. Rawson and E.C. Tupper, Basic Ship Theory, (New York: Longman, 1977), pp. 546.)

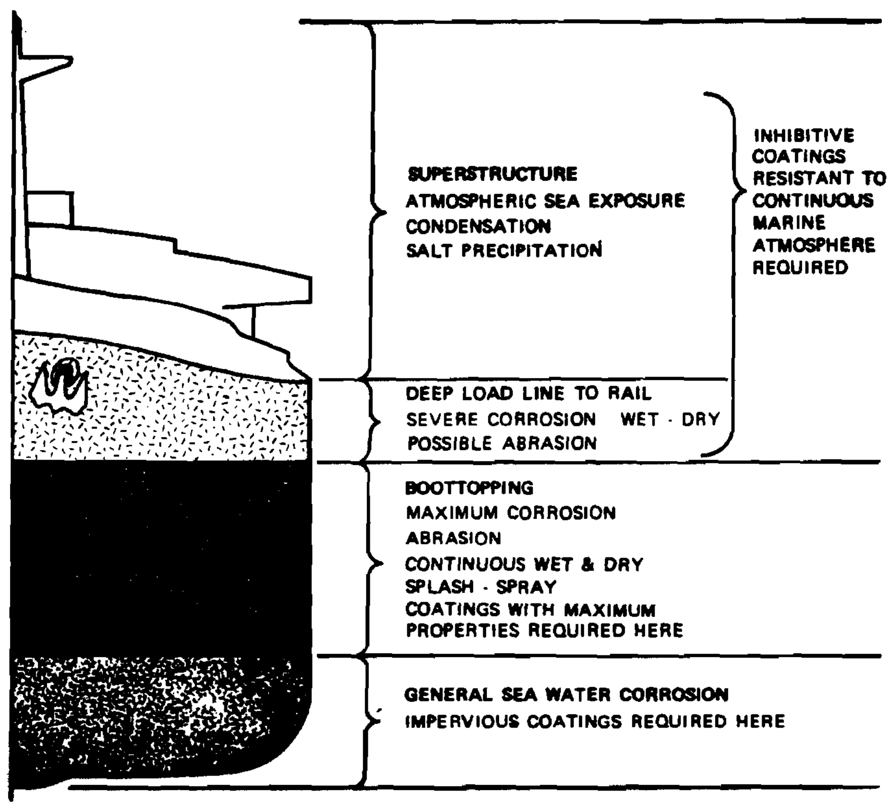


Figure (32): Choice of coatings for different zones of off shore structures

(From: Francis L. Laque, Marine Corrosion: Causes and Prevention, (New York: John Wiley, 1975), pp. 298.)

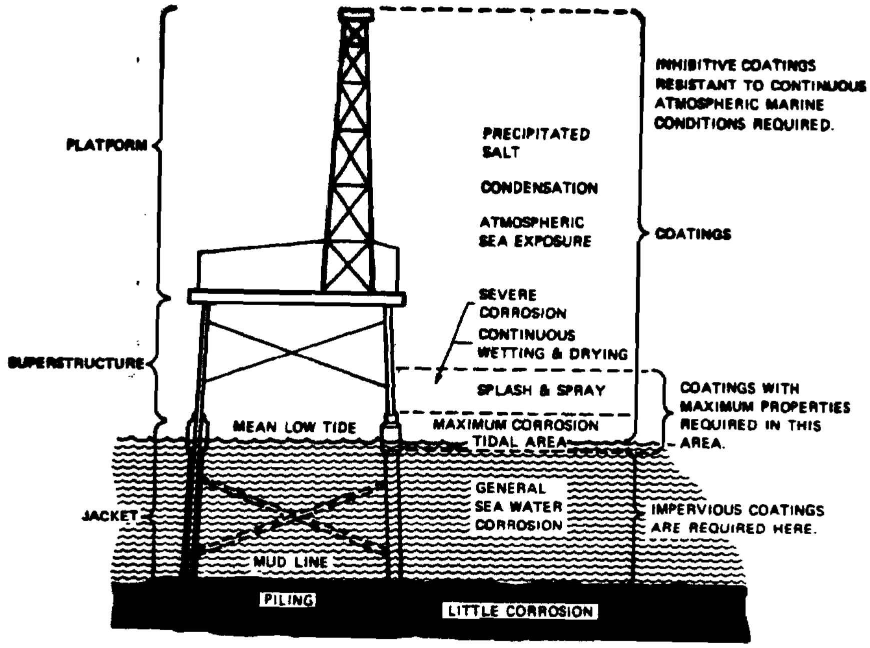


Figure (33): Various zones on marine structures where coatings are used as the primary means of protection.

(From: Francis L. Laque, Marine Corrosion: Causes and Prevention, (New York: John Wiley, 1975), pp. 299.)
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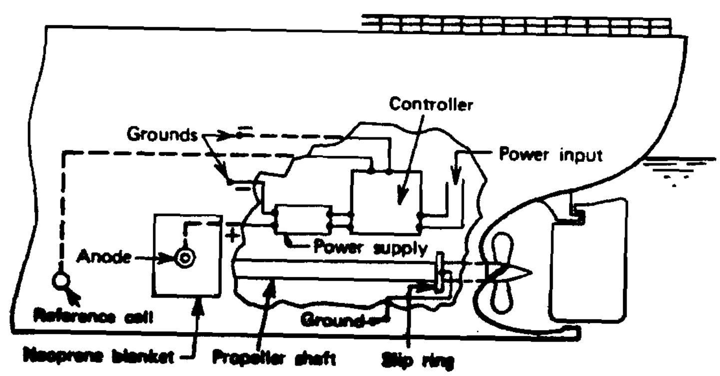
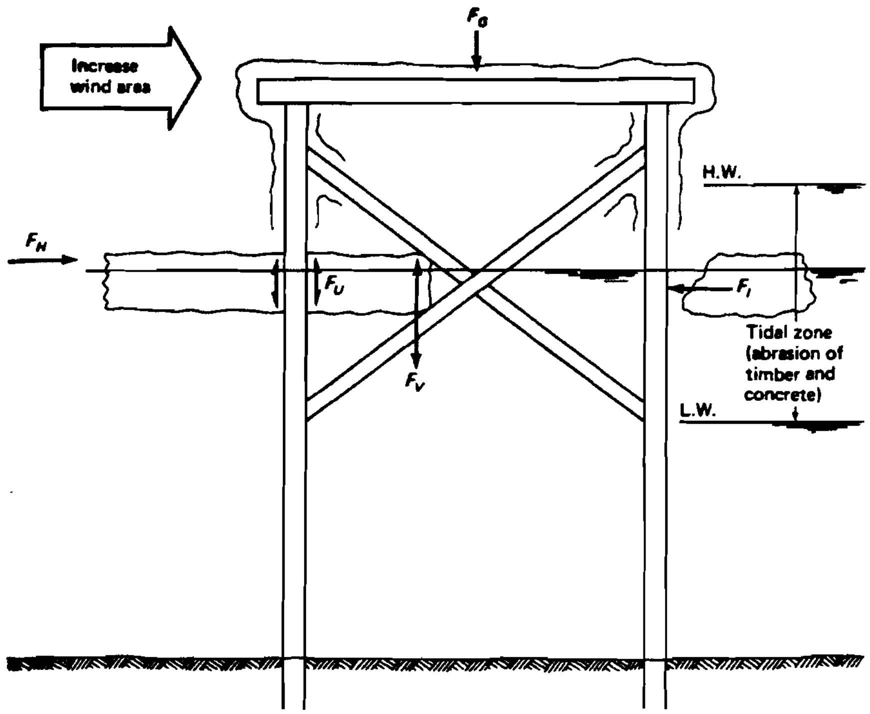


Figure (34): Diagram of automated cathodic protection control system.

(From: Francis L. Laque, Marine Corrosion: Causes and Prevention, (New York: John Wiley, 1975), pp. 176.)



Composite diagram of ice forces. Abbreviations: F_e = expansion of captive ice freezing in pockets (not shown); F_G = increase gravity load due to accumulation of ice and frozen spray; F_H = horizontal thrust due to pressure of ice sheet moved by wind or current stress or due to expansion of ice with rising temperature in enclosed area; F_I = impact of iceburgs and bits driven by wind or current (or vessels); F_U = uplift on piles due to adhesion of ice and rising water level; F_V = vertical force due to buoyancy of ice caught beneath X-bracing or batter piles and downward due to weight of trapped ice sheet. Note: F_H and F_I do not act simultaneously.

Figure (35): Composite diagram of ice forces.

(From: John Gaythwaite, The Marine Environment and Structural Design, (New York: Van Nostrand Reinhold, 1981), pp. 247.)

Effect of ice	Effect on structural design	Effect on functional design	Operational considerations
Thrust	Design for maximum expected thrust with regard to: ice thickness, temperature rise, degree of restraint, etc.	Avoid exposure to thrust if possible (i.e., moor floats with anchors vs. piles); use alternate structure, (i.e., cells vs. pier); use proper configuration.	Prevent freezing at structure, bubblers, heaters, etc.; if feasible, caution in use of ice breakers in confined areas.
Uplift (jacking)	Design for maximum expected uplift with regard to ice thickness, tide range, etc.	Minimize use and/or number of piles; design pile to resist uplift; use massive structure; minimize x-bracing; use proper shapes.	Use bubblers, moor floats in winter season; do not leave fixed to anchor piles.
Impact	Design for probable ice loads with regard to mass, velocity, and direction.	Avoid exposed sites.	Use camels or other protective devices.
Expansion	–	Avoid designing pockets and areas that can trap freezing water.	–
Gravity	Design for additional weight of ice with regard to expected accumulation.	Slope decks for drainage; use proper configuration.	Prevent ice from freezing on decks (i.e., heaters, salts?).
Buoyancy	Design for uplift as required.	Provide "air gap" above highest expected tide level; avoid x-bracing; design to prevent ice from getting under decks.	–
Accretion	Consider increased projected areas in wind and current force calculations; gravity loads as above.	Design with adequate drainage to prevent ice build-up.	Keep decks clear.
Abrasion	Consider effects of reduced section properties in design.	Use cladding, impervious materials; chamfer all sharp edges on concrete; avoid projections; protect exposed timber in tide zone.	–
Freeze-thaw (concrete)	Specify dense and durable concrete mix (i.e., low W/C ratio, type II cement); use air-entraining admixture.	Avoid immersion in tide zone (i.e., exposure to alternate wetting and drying).	–

Table (2): Effects of Ice on Design of Offshore Structures.

(From: John Gaythwaite, The Marine Environment and Structural Design, (New York: Van Nostrand Reinhold, 1981), pp. 248.)

Steel is a homogeneous material with excellent strength characteristics; it may be cast, forged, or worked in plate form. It is susceptible to various welding processes and the weldments are uniform and reliable. The primary disadvantage of steel for shipbuilding use is its lack of resistance to corrosion. It is exceptionally vulnerable to corrosion in the presence of sea water, and this characteristic, therefore, demands careful attention to painting and constant vigilance in maintenance.

The second construction material under consideration for artificial floating islands is concrete.

> It is reported that on the day in 1862 set for the launching of Merchant, the first iron steamer on the Great Lakes, one of her owners went off to his summer home, ostensibly (and probably actually) because he did not wish the doubtful pleasure of seeing his ship disappear beneath the waves. How much more would these people have distrusted a ship built of stone! Yet this is essentially what a concrete steamer is, and the reinforced concrete vessels built in the United States at the time of the First and Second World War proved themselves entirely seaworthy and practicable from an engineering point of view.[39]

Concrete has many advantages over steel. They include:

(1) Much more durable material in a marine environment than steel.

(2) Can be made impervious to sea water, corrosion and resistant to abrasion.

(3) Resistant to the build-up of marine organisms.

(4) Repairable on site; above or below the water line.

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39 Jean Haviland, "American Concrete Steamers of the First and Second World Wars", American Neptune, vol. 22, no. 3, 1962, pp. 157.

(5) Readily available material.

(6) Workable into any shape.

(7) Has excellent compression strength.

(8) Is highly resistant to fire damage.

(9) Has toughness and high resistance to brittle fracture.

(10) When continually submerged will gain strength with the passage of time.

In 1971 an attempt was made to prove that concrete was an excellent material for ocean structures by the Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California. The NCEL deployed 18 hollow concrete spheres in water depths of 2000-4000 feet. Each sphere, 66-feet in diameter with 4-inch thick walls, was anchored to the seafloor by the 2600 pound weight of a 2 1/4 inch anchor chain 53 feet long.[40]

> Examination of one of these spheres, recovered after 10 years at a depth of 1800 feet, revealed no visible corrosion to the steel reinforcement bars although in some areas of the model the steel had less than one inch of concrete cover. Nor was there visible deterioration of the concrete material itself in any of the five spheres and blocks retrieved to date.[41]

The study conducted by the NCEL firmly supports the hypothesis that concrete is a viable construction material for ocean structures.

On the other hand, concrete has only three limiting factors when compared to steel; (1) limited tensile strength, (2) low strength-to-weight ratio, and (3) progressive deterioration when subjected

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40 "Concrete Sphere Survives 10 Years at Depths of 975 Meters", Sea Technology, October, 1982, pp. 52.

41 Ibid.

to alternate freezing and thawing. Simply stated, a concrete platform requires larger structural members and will weigh more than a steel platform of the same size and design. This in turn means that a concrete platform will have a greater drag and would correspondingly increase the mooring and/or station-keeping power requirements for such a platform. Now let's briefly look at the historical beginnings of concrete as a construction material for vessels and platforms.

The concept of using concrete for vessels was developed in 1848 by J.L. Lambot in France when he built 10-foot long reinforced mortar rowboats. By the late 1800's and early 1900's numerous countries had applied Lambot's principles for building ocean-going concrete barges in expectation that these could be built and maintained more cheaply than steel ships and barges. With the entrance of the United States into the First and Second World Wars, concrete vessels provided a means to compliment a war-torn merchant fleet and at the same time reduce a serious steel shortage.[42] During the early 1940's, for example, 100 concrete hulls were built, some being self-propelled dry cargo ships in excess of 300 feet long, see Table (3).[43]

From an engineering point of view, concrete vessels were a complete success:

> There was general agreement that (concrete vessels) were entirely seaworthy and that they handled well. A particular merit was that in them there was no condensation as in steel ships and, as a consequence, their cargo kept

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[42] Jean Haviland, "American Concrete Steamers of the First and Second World Wars", American Neptune, vol. 22, no. 3, 1962, pp. 158.

[43] Ibid, pp. 182.

Name	*Tonnage*		*Hull*		*Engine*	
	Gross	*Net*	*Builder*	*Dimensions (feet)*	*Builder*	*Dimension*
Atlantus	2481	1502	Liberty	249.3 x 43.5 x 22.5	Worthington, Buffalo	19", 32", 56" x 36"
Cape Fear	2795	1693	Liberty	266.6 x 46.0 x 24.8	Worthington	19", 32", 56" x 36"
Cuyamaca	6486	4082	Pacific	420.7 x 54.0 x 34.3	Llewellyn	24½", 41½", 72" x 48"
Darlington	1433	1332	MacDonald	290.2 x 33.9 x 22.0	Bolinders	
Dinsmore	6144	3696	Bently	420.0 x 54.0 x 35.0	Hooven	24½", 41½", 72" x 48"
Durham	1433	1332	MacDonald	290.2 x 33.9 x 22.0	Bolinders	
Faith	3427	2071	San Francisco	320.0 x 44.5 x 27.7	Bethlehem, Alameda	24", 39", 65" x 42"
Latham	6287	3893	Ley	420.7 x 54.0 x 34.4	Hooven	24½", 41½", 72" x 48"
McKittrick (ex. *Tanker* No. 1)	2702	1528	Newport	300.1 x 44.0 x 24.0	Nordberg	19", 32", 56" x 36"
Moffitt	6144	3696	Bently	420.0 x 54.0 x 35.0	Hooven	24½", 41½", 72" x 48"
Palo Alto	6144	3696	San Francisco	420.0 x 54.0 x 35.0	Llewellyn	24½", 41½", 72" x 48"
Peralta	6149	3701	San Francisco	420.0 x 54.0 x 35.0	Llewellyn	24½", 41½", 72" x 48"
Polias	2564		Fougner	267.3 x 46.0 x 23.4	Worthington, Ampere	19", 32", 56" x 36"
San Pasqual	6486	4082	Pacific	420.7 x 54.0 x 34.3	Llewellyn	24½", 41½", 72" x 48"
Sapona	2795	1693	Liberty	266.6 x 46.0 x 24.8	Worthington	19", 32", 56" x 36"

Table (3): Examples of Concrete Vessels Built in the United States.

(From: Jean Haviland, "American Concrete Steamers of the First and Second World Wars", American Neptune, vol. 22, no. 3, 1962, pp. 181.)

> particularly well. One master complained that the crew's quarters were unbearably hot in warm weather, but otherwise he was much pleased with his concrete ship and definitely preferred her to a Liberty ship.[44]

Unfortunately, concrete vessels were not successful from an economic perspective. "While mass production could doubtlessly have lowered costs, there is nothing in the United States to suggest a realization of the early hope that concrete vessels could be constructed more cheaply than those of steel."[45]

Today the "cards" have changed. During the past ten years, steel prices have sky-rocketed to the point where concrete is relatively inexpensive when compared to steel. So much so that, when cost is added to the list of advantages over steel, it is easy to understand why concrete is being considered for the majority of all future artificial islands.

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44 Ibid, pp. 181.

45 Ibid.

Chapter 3

APPLICATIONS OF ARTIFICIAL FLOATING ISLANDS

"Now is the hour of the genesis of floating architecture."[46] Previous chapters discussed the earliest stages in the development of floating platforms, dealing with their history and design. Lets examine closely into the crystal-ball and perceive with our minds the future uses for artificial floating islands. Explicitly this discussion will focus on three relevant applications:

(1) Urban expansion.

(2) Electric power generation.

(3) Mid-ocean basing for the military.

CITIES OF THE FUTURE

Heavily populated regions of the world, particularly near the coast, are experiencing a major dilemma, limited land. Man is continuously in search of sites for housing, industry, and public recreation. In attempting to accomplish this insurmountable task, he (man) is confronted with a land resource that is overpopulated, overpolluted and undersupplied with natural resources. One possible solution to this dilemma is to build on water. The concept is not new. The entire city of Venice, Italy was built on pilings in the fifth century. During the thirteenth century, the Netherlands began reclaiming the watery deltas of the Rhine, Maas and Scheldt

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[46] Jurgen Claus, Planet Meer, (Cologne: Verlag M. der Mont Schauberg, 1972).

rivers using poldering.[47] More recent examples in the nineteenth century include the coastal cities of Boston, Massachusetts and New Orleans, Louisiana. "Almost 60 percent of the old city of Boston was once under water, including the entire Back Bay district; 95 percent of New Orleans is still below water level, protected by levees."[48] Prior to the late 1950's urban expansion of coastal cities on water fell into the three patterns mentioned above; piling, land-filling, and poldering, see Figure (36). During the early 1960's however, a fourth and futuristic approach to urban expansion on water emerged. The floating city. The first attempt to design such a city was in 1961 by architect Buckminster Fuller, who was commissioned by a Japanese businessman to design a tetrahedronal floating city for Tokyo Bay.

A native New Englander, Richard Buckminster Fuller spent his summers as a boy among Maine fishermen. During that time he became fascinated with net weaving, tieing, splicing, and discovered that a fishermen's net gained strength from tensioning the lines. Ironically, one of the oldest occupations in the world lead him to design revolutionary architectural structures. One of Fuller's criteria in design was maximum performance per pound of metal invested. He employed conventional materials, steel, but shifted their orientation to utilize them the strong way rather than the weak, lengthwise instead of edgewise, to benefit from the pull rather than take a chance on

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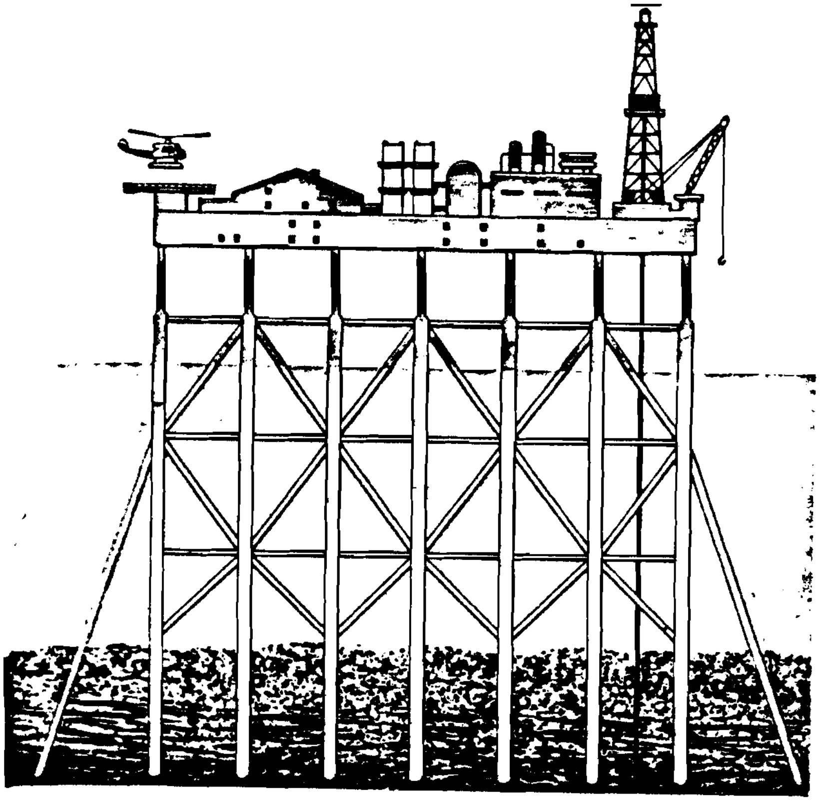
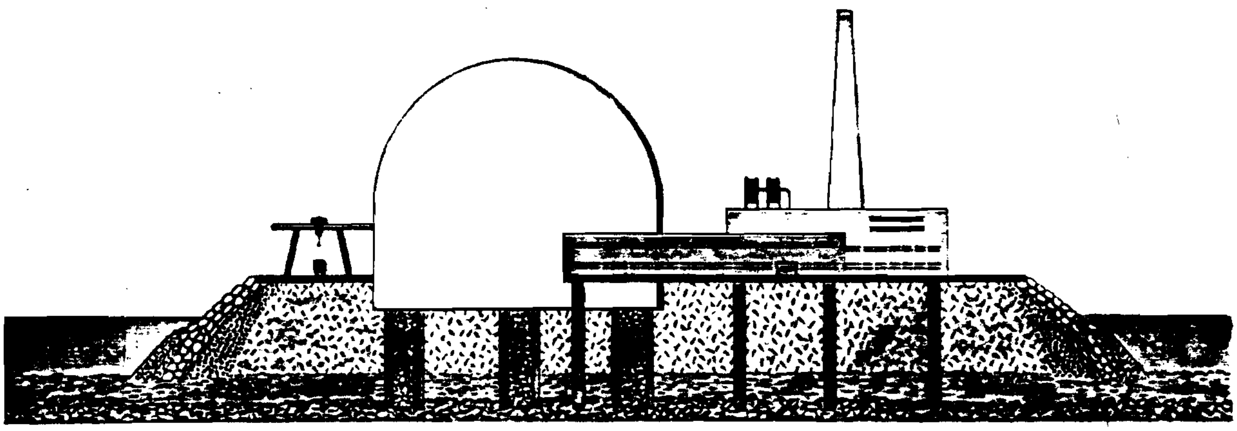
47 Walter McQuade, "Urban Expansion Takes to the Water," Fortune. September 1969, pp. 131.

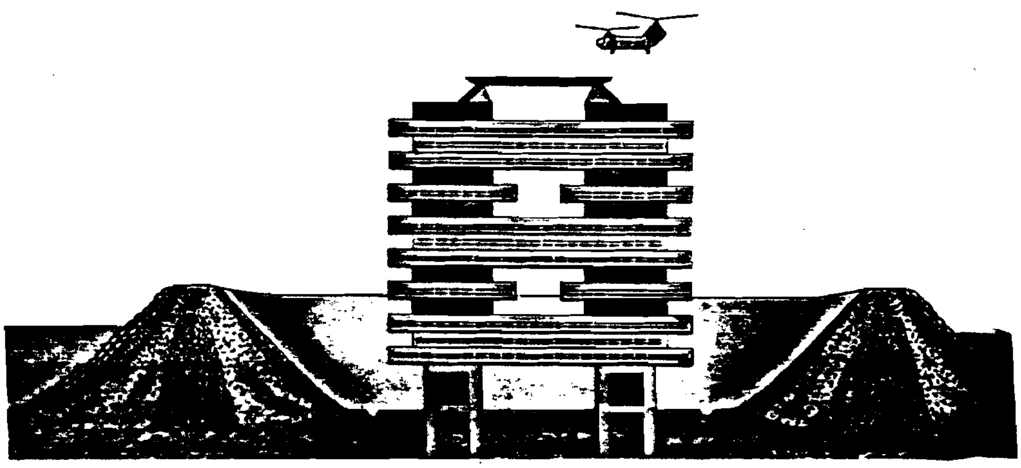
48 Ibid.



PILING



LAND-FILL



POLDERING

Figure (36): Three traditional methods of building on water.

(From: Walter McQuade, "Urban Expansion Takes To The Water," Fortune, September 1969, pp. 132-33.)

the break. Very simply, try to break a pencil in two; it is easy. Try to pull it in two; not so easy. Buckminster Fuller's most noteworthy achievement was the geodesic dome, see Figure (37).

> It is a regular polyhedron of any size which can be erected with a minimum of on-site labor. Perhaps his best known dome was that built for the United States pavilion at the Montreal Expo, 1967, which was 250 feet in diameter and stood 200 feet high. The basic unit was a hexahedron of steel tubing, glazed with gray-tinted plastic acrylic panels which were graduated from clear at the bottom to the darkest at the top.[49]

Finally, Fuller had invisioned a two mile-wide dome to seal off mid-town New York. This coverall would save, he argued, the incalculable expenses of air conditioning, street cleaning, snow removal, head colds, umbrellas, rubbers, and so on, see Figure (38). As mentioned earlier, Fuller was tasked to design a floating city for Tokyo Bay. His design, dubbed "Triton City", utilized a tetrahedron shape, see Figures (39) and (40). His reasoning was based on the fact that the tetrahedron has the most surface with the least volume of all polyhedrons. Fuller stated:

> The tetrahedron provides the most possible "outside" living. Its sloping external surface is adequate for all its occupants to enjoy their own private, outside, tiered, terracing, garden homes. These are most economically serviced from the common nearest possible center of volume of all polyhedrons. All the mechanical organics of the floating city are situated low in its hull for maximum stability. All the shopping centers and other commercial service facilities are inside the structure; tennis courts and other facilities are on the top deck.[50]

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49 Leland M. Roth, <u>A Concise History of American Architecture</u>, (New York: Harper & Row, 1979), pp. 322.

50 Richard B. Fuller, "Floating Cities," <u>World</u>. December 19, 1972, pp. 40.

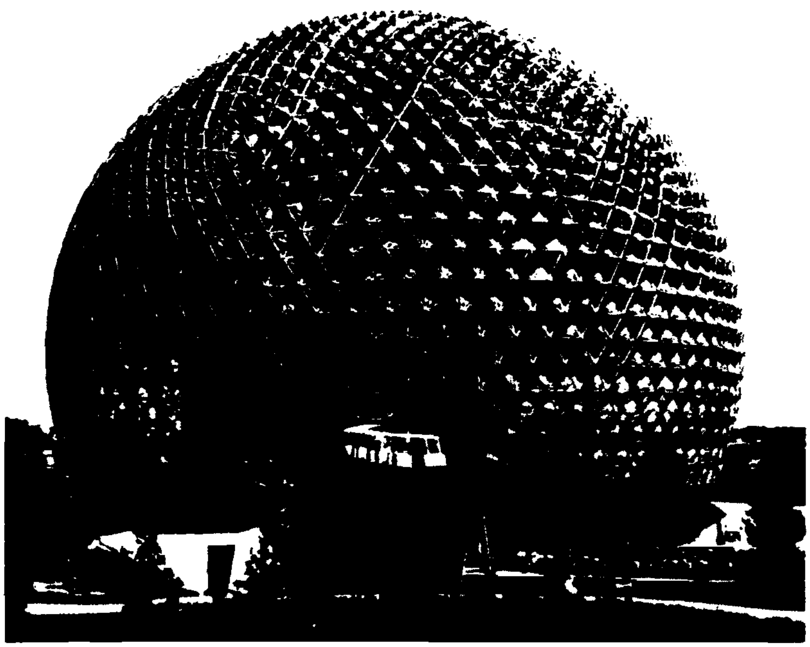

Figure (37): R. Buckminster Fuller, U.S. Pavilion, Montreal Expo, Montreal, Quebec, Canada, 1967.

(From: Leland M. Roth, A Concise History of American Architecture, (New York: Harper & Row, 1979), pp. 323.)

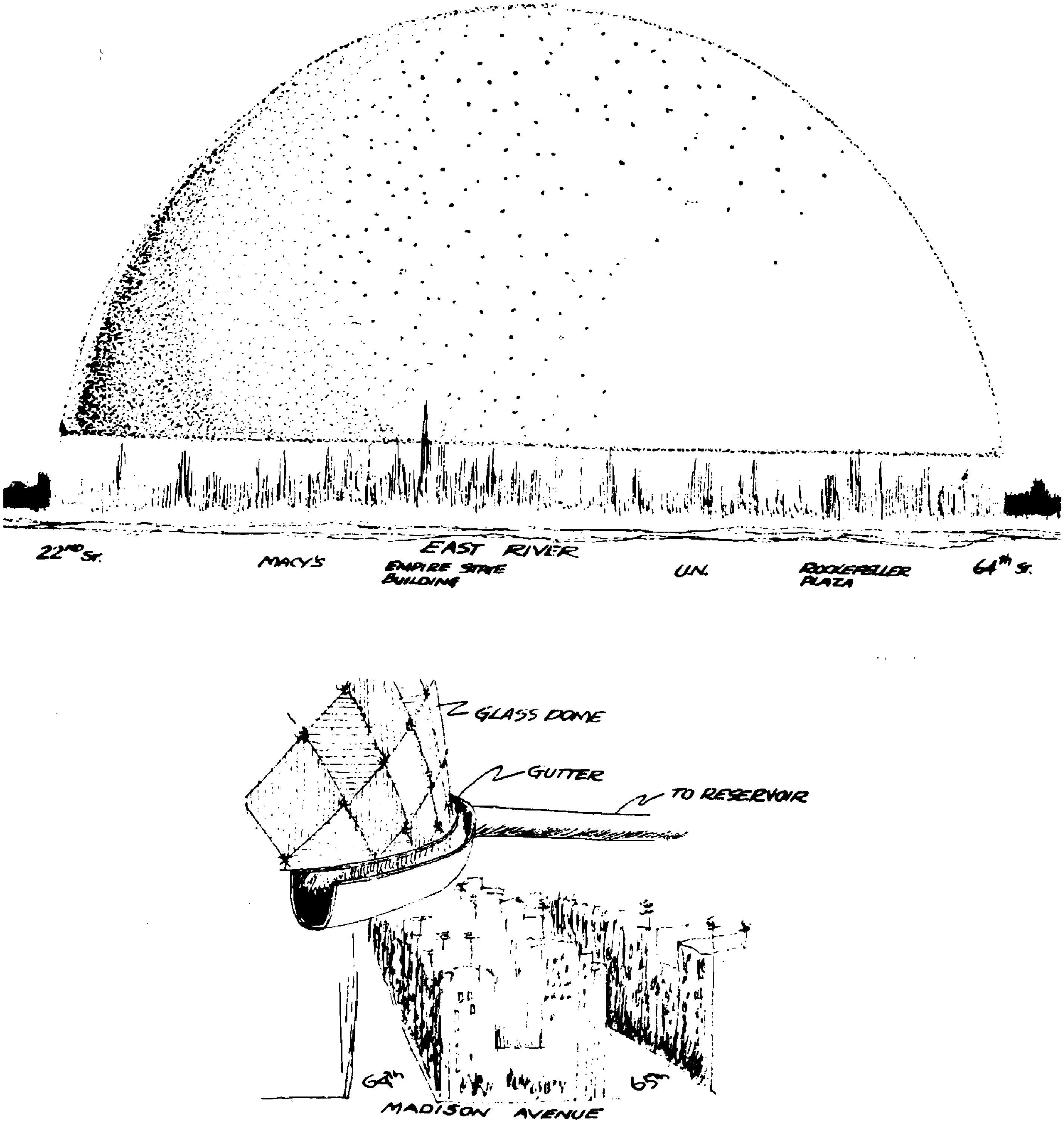

Figure (38): Buckminster Fuller's geodesic dome concept over New York City.

(From: R. Buckminster Fuller, "Why Not Roofs Over Our Cities?" Think, January-February 1968, pp. 8-9.)

<u>Figure (39)</u>: **Buckminster Fuller shows** his floating **city** to U.S. housing **officials.**

(From: R. Buckminster Fuller, "Why Not Roofs Over Our Cities?" *Think*, January-February 1968, pp. 8-9.)

A fully developed floating city for 100,000 inhabitants where residences and urban units combine.

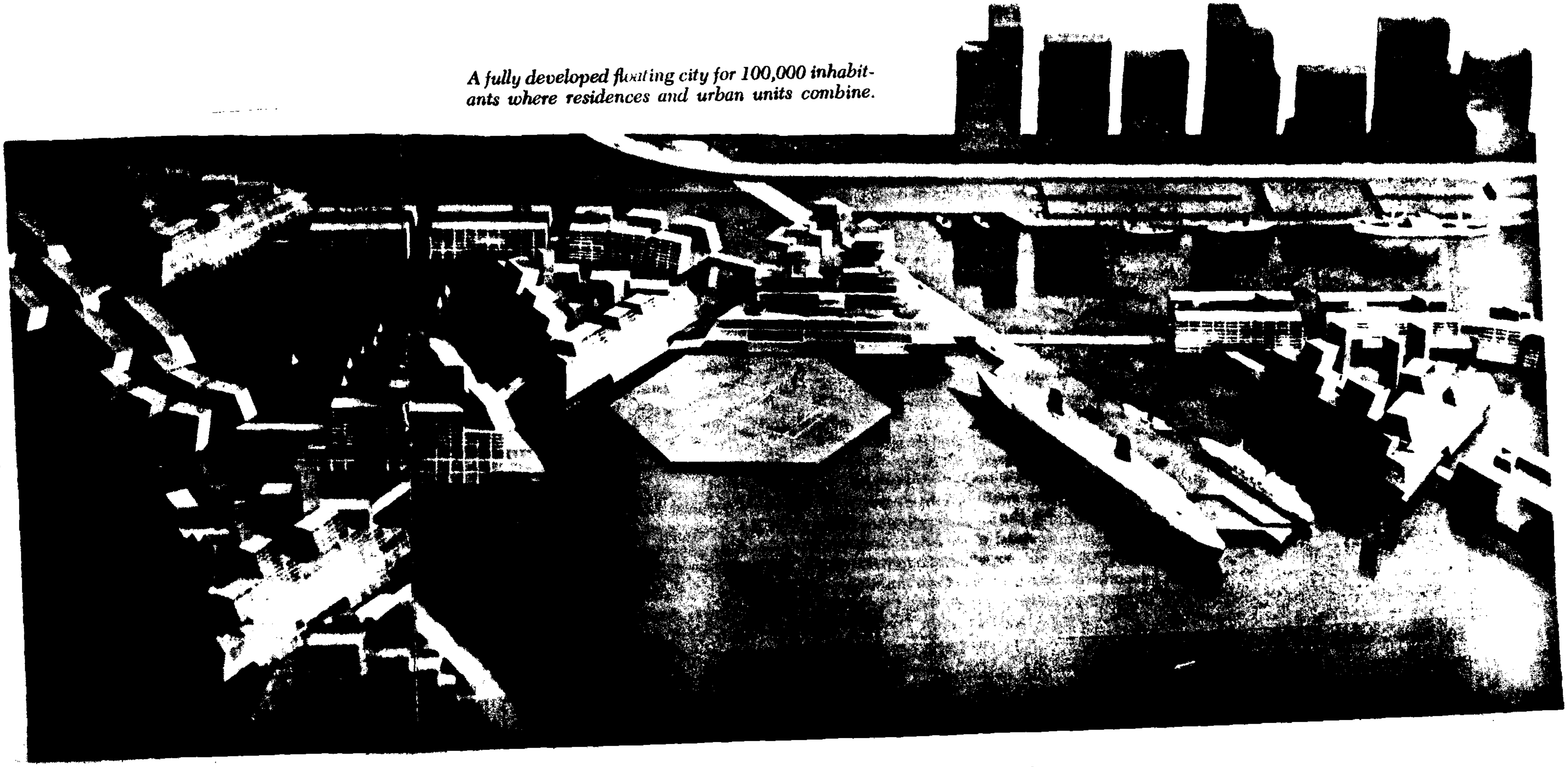

Figure (40): Buckminster Fuller's Floating City.

(From: R. Ruckminster Fuller, "Floating Cities," World, December 19, 1972, pp. 40-1.)

In 1966, after the design was near completion, the Japanese client passed away and the project was abandoned. But, all was not lost.

The United States Office of Housing and Urban Development (HUD), under the Johnson Administration, commissioned Fuller to continue his work on the floating city under a HUD grant. The idea was to investigate the technical and economic feasibility of locating "Triton Cities" adjacent to major coastal cities.

> The basic unit of the "Triton City" plan is a neighborhood-sized floating community that would accommodate 3,500 to 6,500 people. There are two kinds of neighborhood modules designed for the city. One is composed of a string of four to six small platforms, each holding about 1000 people, the other is a larger, triangular platform which would be of high density and have capacity for as many as 6,500. Three to six of these neighborhoods, with a total population of 15,000 to 30,000, would form a town. At this point, a new town platform including a high school, more commercial, recreational and civic facilities, and possibly some light industry, could be added. When the community has reached the level of three to seven towns (90,000-125,000 population), it would become a full-scale city and would then add a center module containing governmental offices, medical facilities, a shopping center, and possibly some form of special city-based activity like a community college or specialized industry.[51]

Fuller designed "Triton City" to be flexible to location. In coastal areas and sheltered harbors the barge concept discussed in Chapter 2 is employed; for deep-sea installations, large semi-submersible platforms are utilized.

Having completed the design, Fuller sent his device to the United States Navy's Bureau of Yards and Docks. "The Bureau of ships verified

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51 Shoji Sadao, "Buckminster Fuller's Floating City," The Futurist. February 1969.

all calculations and found the design to be practical and "seaworthy", and the cost was within 10 percent of projected cost which bore out its occupiability at rental just above poverty-level income."[52]

Inauspeciously, when the Nixon Administration entered office, Fuller's research grant was terminated and the "Triton City" project deteriorated. Once again history repeats itself; "Triton City" had pursued the footsteps of artificial floating platforms.[53] The future of artificial floating islands appears grim. But, there is still hope. In 1971, Dr. John Craven, Dean of Marine Programs, University of Hawaii, and Japanese architect Kiyonori Kikutake had been involved in the conceptual development and engineering design of a large floating platform, known as "Floating City".

Craven and Kikutake designed "Floating City" from a unique perspective. They initially examined the minimum requirements necessary for an urban society. These include:

(1) An economic supply of water, food, clothing, and shelter for all inhabitants.

(2) Non-polluting, rapid, comfortable, flexible, and immediate transportation for people who may be carrying from 40 to 80 pounds of goods.

(3) Non-polluting and non-obstructive transportation of goods in quantities in excess of 80 pounds.

(4) Telephone, radio, television, printed media, mail, accounting and computational communications.

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52 Richard B. Fuller, "Floating Cities," World. December 19, 1972, pp. 40.

53 See Chapter 1; Projects MOHOLE and DELOS.

(8) Opportunities for experiencing variety and the freedom to select or alter ones' local environment.

(9) Preservation of similar opportunity for posterity.[56]

With these factors implanted in their minds, Craven and Kikutake began to design the "ideal" Floating City.

Their "Floating City" design utilizes the beehive concept developed by idealist/architect Paolo Soleri, see Figure (41). Living spaces are located around the periphery to afford maximum privacy and unobstructed view of the natural seascape. Proceeding inward, population density increases toward shopping areas and community services. Finally, population density is maximum at the core, where entertainment and religious facilities are located. Industrial activities, utilities and transportation systems are located beneath the beehive equidistant from all other points. This allows maximum utilization and distribution of services to the populas, and, eliminates the congestion and unpleasantness often associated with the like.

During the summer of 1972 the University of Hawaii and the Naval Undersea Center evaluated a 50-ton, 1:20 scale steel model of "Floating City", illustrated in Figure (42):

> The test model employs 30 bottle-shaped cylindrical legs mounted on 10 triad modules; each triad contains three legs that are joined rigidly. The modules are hinged together at the deck and bolted at the upper and lower horizontal connections. Within each module are three upper and three lower struts, welded to form an integral portion of the module. The lower struts

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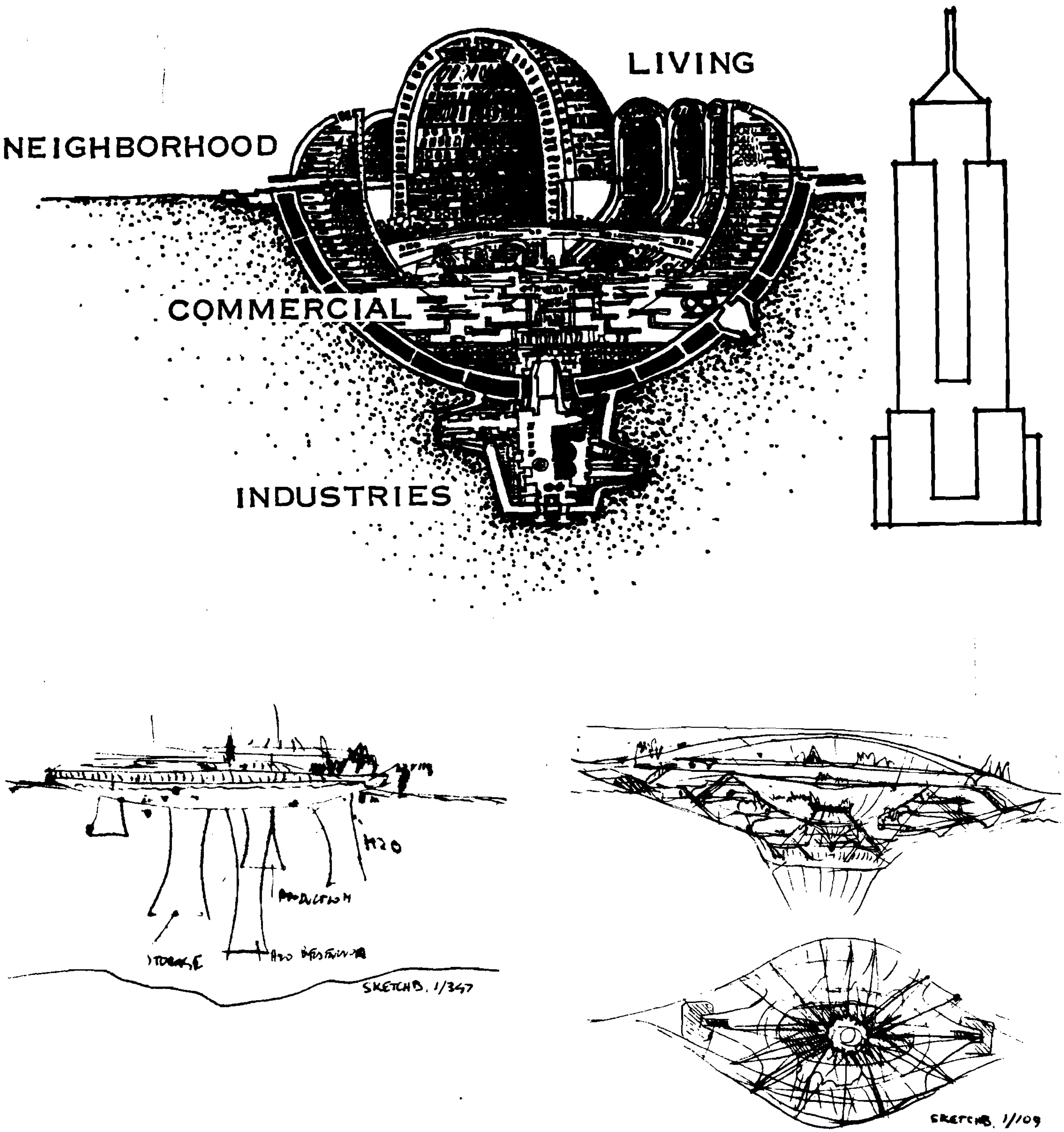
[56] John P. Craven, "Cities of the Future: The Maritime Dimension," American Association for the Advancement of Science, 1980, pp. 182-183.



<u>Figure (41)</u>: Paola Soleri's beehive concept for a floating city.

(From: Paolo Soleri, <u>Arcology: The City in the Image of Man</u>, (Cambridge: MIT Press, 1969), pp. 15.)

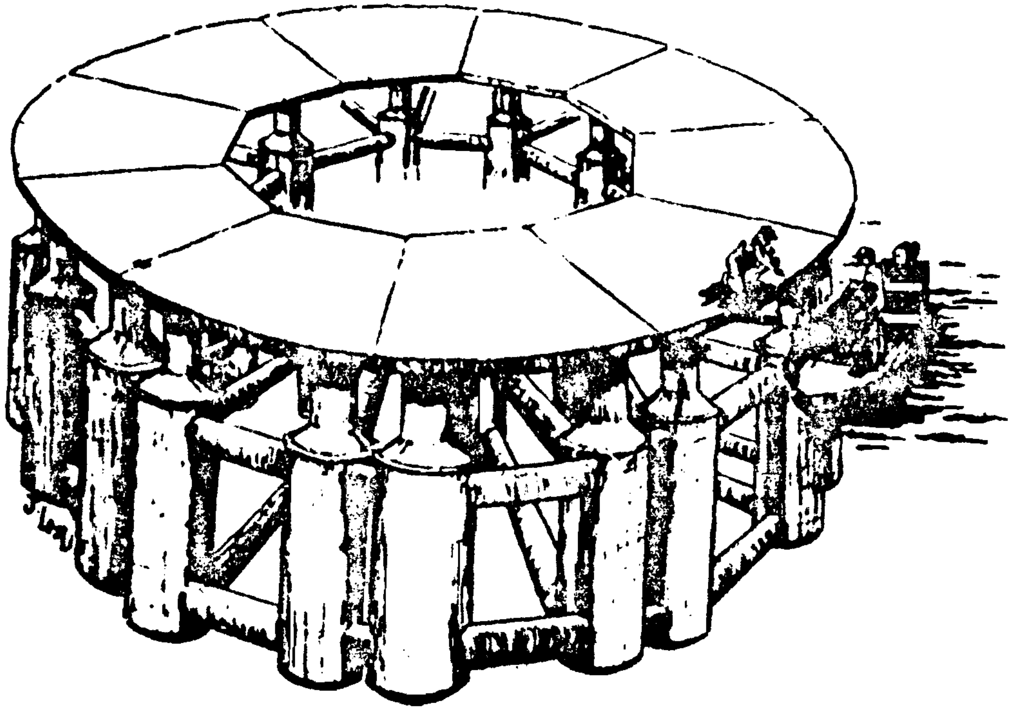


Figure (42): 1/20 scale model of the Craven & Kikutake Floating City project. Model diameter is 50 feet.

(From: Naval Civil Engineering Laboratory, Port Hueneme, California)

> are flooded to bring the center of gravity as low as possible but the upper struts serve as watertight, buoyancy chambers.[57]

Testing was completed in March 1973. The results verified the theoretical predictions of Craven and Kikutake that, within today's technology, a floating city can be built and safely operated.

The Craven and Kikutake design was so successful that the Japanese Ministry of International Trade and Industry decided to display "Aquapolis", a floating city, as a symbol of the International Ocean Exposition, Okinawa Japan, see Figure (43). Time precluded the construction of a vertical column platform, therefore a semi-submersible structure was designed. Construction began in January 1974 by Mitsubishi Heavy Industries and was completed one year later, see Figure (44).

"Aquapolis" is a welded cubic semi-submersible structure similar to Project MOHOLE. The supporting structure consists of 16 columns standing on four lower hulls, see Figure (45) and Table (4). On the columns there stands an upper structure consisting of the main deck, the middle and the upper deck. A brief description of the decks follows:

> On the main deck there are the Aqua Hall, display space, machine room, Aqua port, dining room, kitchen and clerical office. The Aqua Hall accomodates the Aqua screen, temporary stage for entertainment and assemblies, and Marineorama. There are also city facilities like the "rest corner', "telephone corner", "information corner" and the Aqua post office from which visitors can

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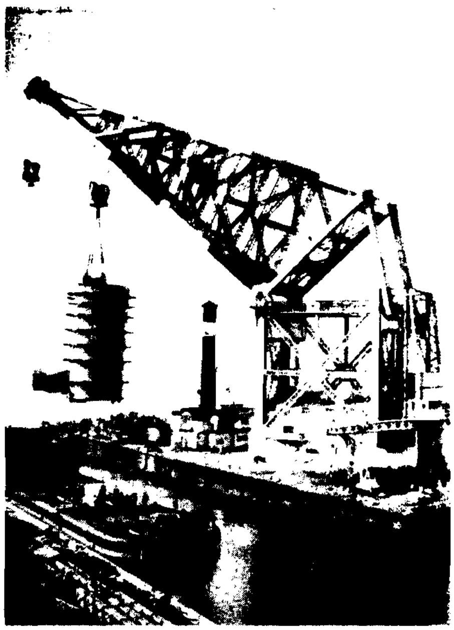
57 "Stationary Floating Ocean Platforms," Ocean Engineering, (Washington: National Technical Information Service, January 1975), pp. 86-87.

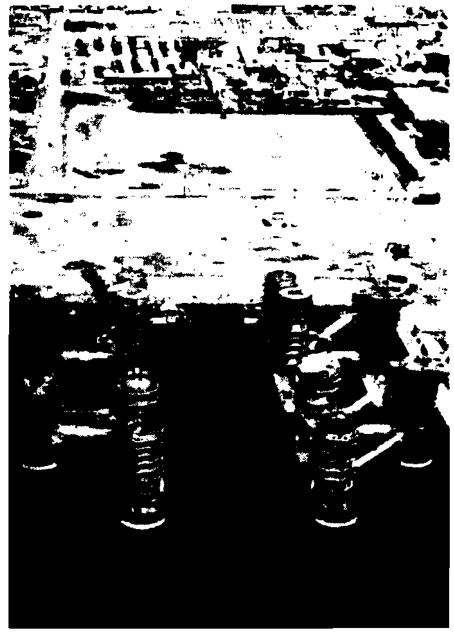
Figure (43): AQUAPOLIS: Floating Pavilion of the Government of Japan, International Ocean Exposition, Okinawa, Japan.

● Completed four lower hulls (January 1974)



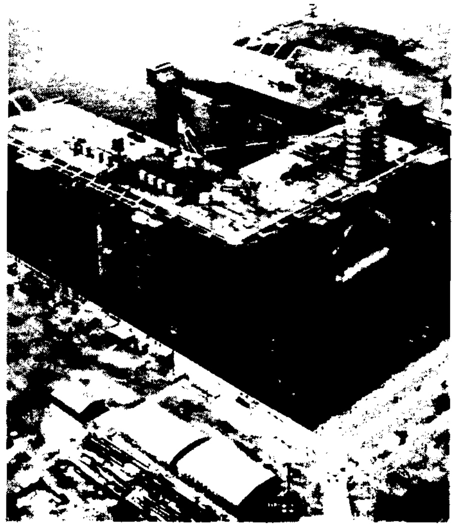
1. Assembly of a column (February 1974)

2. Assembly of the columns completed (April 1974)

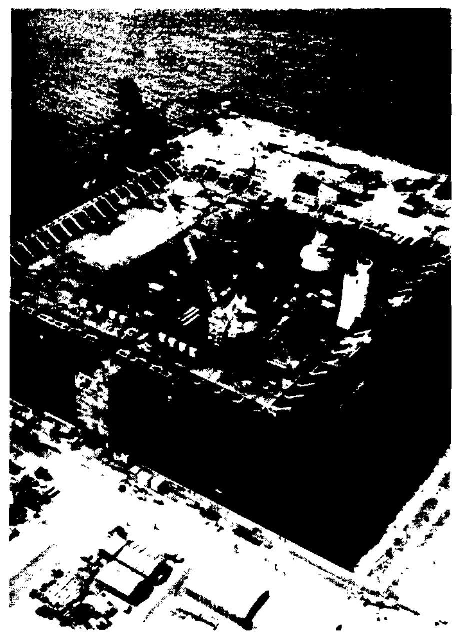


3. Assembly of the main deck started (April 1974)

4. Assembly of both sides and assembly of the main decks completed (May. 1974)



5. Assembly of the upper deck and the central part of the main deck (June 1974)



6. Assembly of the upper deck completed (October 1974)

Figure (44): Construction sequence of Aquapolis.

(From: Japan Association for the International Ocean Exposition, Okinawa. The Aquapolis Project Department)

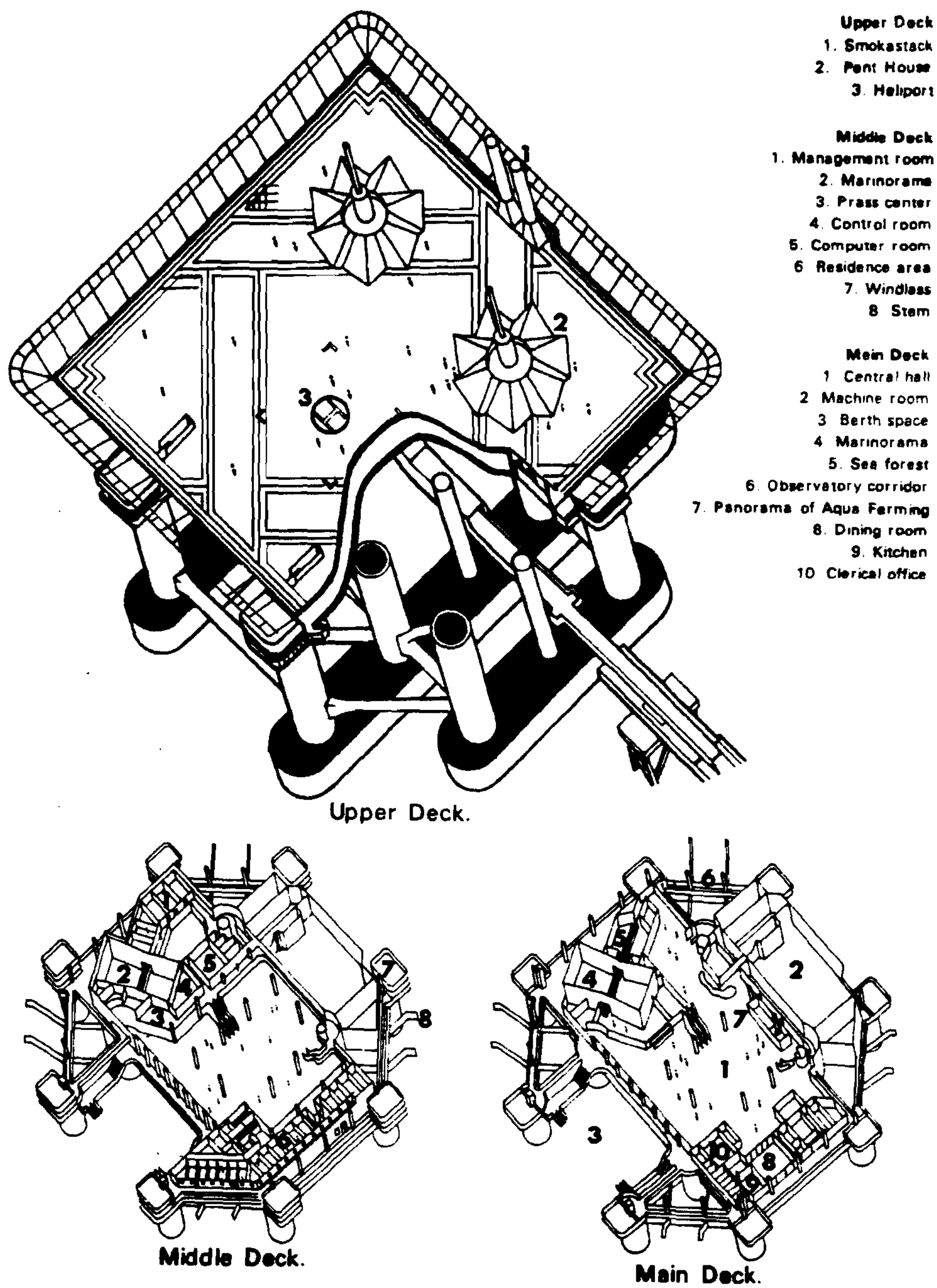


Figure (45): Basic layout of Aquapolis.

(From: Japan Association for the International Ocean Exposition, Okinawa. The Aquapolis Project Department)

Dimensions

1) Overall structure
   - Length 104.0 m
   - Width 100.0 m
   - Height (from the base of the lower hull to the main deck) 26.0 m
   - (from the base of the lower hull to the upper deck) 32.0 m

2) Lower hull
   - a) Small (outside) lower hulls (2)
     - Length 56.0 m
     - Width 10.0 m
     - Depth 6.0 m
   - b) Large (inside) lower hulls (2)
     - Length 104.0 m
     - Width 10.0 m
     - Depth 6.0 m

3) Column
   - a) Large columns (12) 7.5 m. dia.
   - b) Small columns (4) 3.0 m. dia.

4) Area of the Upper Deck (including a surrounding peripheral corridor) 10,000 m^2

5) Total weight
   - 15.647 tons (lightly loaded)
   - 28.070 tons (fully loaded)

Table (4): Design parameters for Aquapolis.

(From: Japan Association for the International Ocean Exposition, Okinawa. The Aquapolis Project Department)

send letters to their home directly from the first floating city built in the world.

The middle deck contains rooms for visting VIPs and staff officials, the central control room, utility control room, computer room and the residence area for about 40 employees. The central room receives information from the computer room, utility control room, ballast control room and the Aqua Hall, and using TV sets for observation set up at many places it carries out unitary management of the Aquapolis.

The upper deck has the Aqua Plaza, where visitors can take a rest and see pavilions on the Expo site. The penthouse, lawns, and heliport are located on the Aqua Plaza, which in future floating cities will be the place where collectors of natural energy, such as solar and wind energy, are set up.[58]

As a complete urban environment, "Aquapolis" was designed to fulfill the functions of a city to include:

(1) The generation of electrical power. The electrical power plant is composed of two 1,200 kW main generators, one 250 kW emergency generator, and one 24 V 400 AH battery which may be used as an emergency source of electricity.

(2) The supply of water. Fresh water required by the floating city is obtained through the distallation of ocean water. "Aquapolis" has the capability to distill 66 tons of water per day.

(3) Sewage treatment. The treatment facility has a capacity of 90 tons of waste per day, or can accommodate approximately 3000 persons. Sludge, the by-product of sewage treatment is burned in a spray-combustion incinerator.

(4) Waste Disposal. All wastes including paper, vegetable waste, and plastic are burned in a two-phase incinerator. It is then discharged as a smokeless, odorless and harmless gas.

(5) Disaster Prevention. Aquapolis provides a complete fire and flooding alert and prevention system.

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58 "Aquapolis," Japan Association for the International Ocean Exposition, Okinawa. The Aquapolis Project Department, 1975.

It also provides sophisticated lifesaving equipment.[59]

Figures (46 and 47) illustrate schematic diagrams of the services provided by "Aquapolis".

Japan's "Aquapolis" and Hawaii's "Floating City" have demonstrated positively that it is now technically feasible to evolve or develop a floating urban community. Before discussing the future of floating platforms, lets look at other possible applications.

POWER GENERATION

Competitive land and water uses in densely populated coastal areas of the world, and, the recent drive to preserve and improve the environment, have placed heavy industry and other environment-burdening activities in a unique situation; where to locate their facilities. One possible solution to this dilemma is to locate these facilities on artificial floating islands. Although there are numerous environment-burdening activities that could utilize the floating platform concept, this section will specifically look at the feasibility of floating coal-fired and nuclear power generating plants.

Floating Coal-Fired Power Plant

Since the Arab oil embargo and until just recently, the United States has promoted the use of energy alternatives to reduce our dependence on foreign oil. One such alternative was the substitution

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59 Ibid.

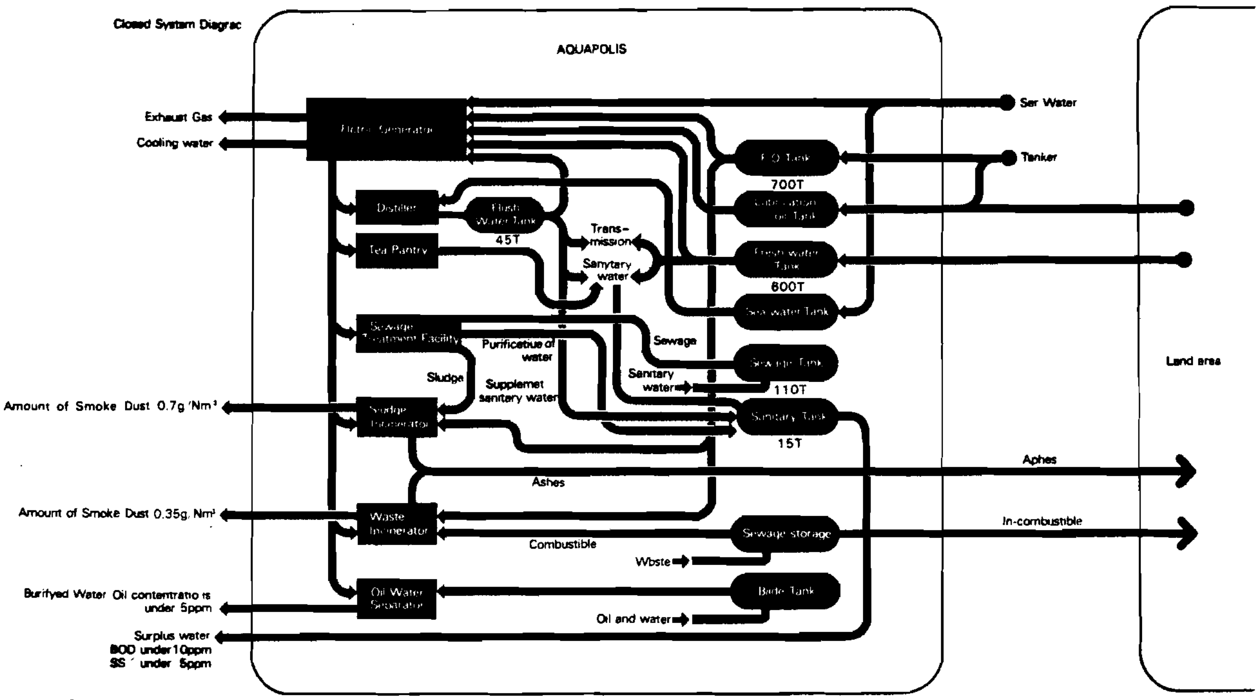
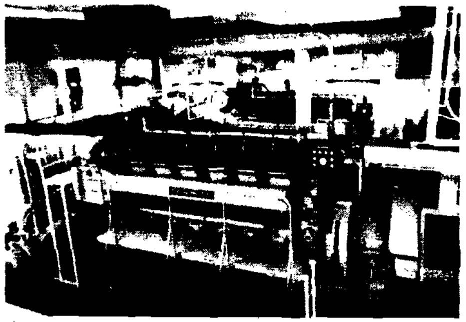


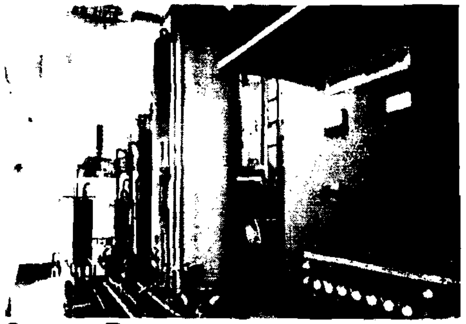
Figure (46): Flow diagram of services provided by Aquapolis.

(From: Japan Association for the International Ocean Exposition, Okinawa. The Aquapolis Project Department)



Generator

Utility Control Room



Sewage Treatment

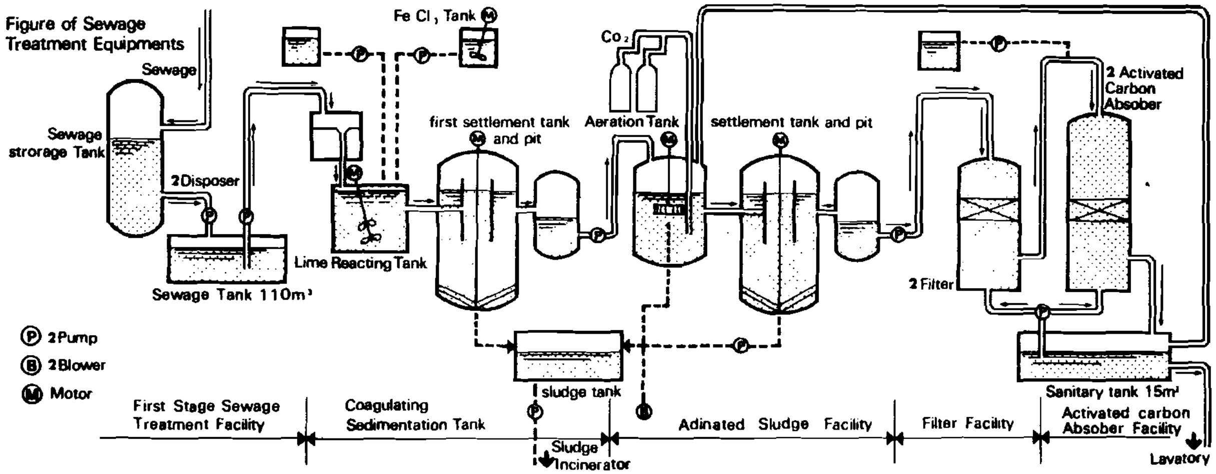


Figure (47): Sewage treatment facilities for Aquapolis.

(From: Japan Association for the International Ocean Exposition, Okinawa. The Aquapolis Project Department)

of coal for oil in the generation of electrical power. The only major drawback associated with coal-fired power generation was air pollution. Coal-fired power plants generate more air pollution than oil-fired power plants, therefore, in order to meet stringent air quality standards, land-based coal-fired power plants were required to install capital intensive pollution abatement systems, a Catch 22. The solution, construct a floating coal-fired power plant.

During the mid 1970's the Ocean Engineering Systems department at the University of Hawaii under the direction of Dr. John P. Craven, investigated the feasibility of a floating coal-fired power plant. Their objective goal was:

> The design, construction, and deployment of an offshore energy conversion system that is capable of operating at a location at sea near a point on shore utilizing the energy derived via marine space and converting this energy into 100MW of electric power with pollutant emissions which insure maintenance of established environmental standards on shore, and having the capability to be expanded at some future date to produce an additional 50MW of packaged energy, and that this system will successfully perform 95% of the time with a conditional probability of 95% that the average yearly outage will be less than or equal to 8 hours and have a demonstrated reliability of 95%. Inherent in this objective goal is the value judgement that mass-produced coal power plant systems will be more saleable in 100 MW units as prime power for small island nations and communities and as supplemental power for major installations during growth or transition periods.[60]

A semi-submersible hull (similar to Project MOHOLE) was chosen for the buoyant support. Consideration had been given to the barge concept

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60 John P. Craven, "Some Economic and Engineering Considerations For a Floating, Coal-Fired 100mW Power Plant," Ocean 75, 1975, pp. 272.

due to its lower construction costs, Figure (48). The primary reason for this decision was stability. The semi-submersible platform with its greater stability over the barge, permitted the use of standard land, lower cost, based systems and components rather than expensive, marine systems. The overall dimensions of the floating power plant are: (1) a platform above the ocean interface which is 390 feet long by 340 feet wide and (2) three main hulls which occupy a volume of 390 feet wide by 750 feet long by 90 feet deep.[61]

The environmental impact of a floating coal-fired power plant, versus a land-based plant was given serious investigation. Certainly the idea behind locating environment-burdening activities offshore was not out-of-sight, or, out-of-mind. By locating coal-fired power plants offshore, advantages accrue from distance and diffusion. Although particulate emission control systems are still required, they are simpler in design and lower in cost when compared to land-based systems. Finally, Tables (5-9) summarize the conclusions of Dr. Craven's analysis.

Floating Nuclear Power Plant

The Arab oil embargo of 1973 also sparked a greater interest in nuclear power. Unfortunately, the land-based nuclear power industry was confronted with numerous setbacks during this time, to include:

(1) In densely populated or rapidly growing regions the

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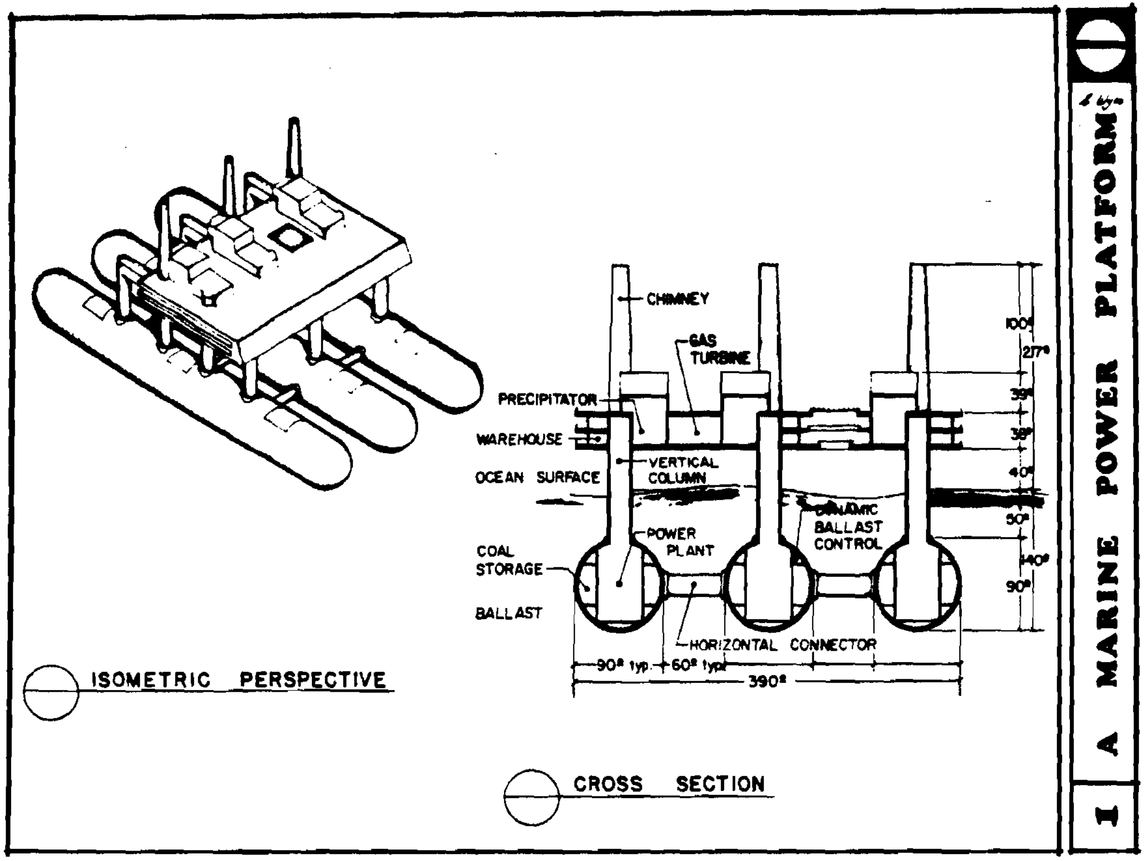
[61] Ibid, pp. 273.



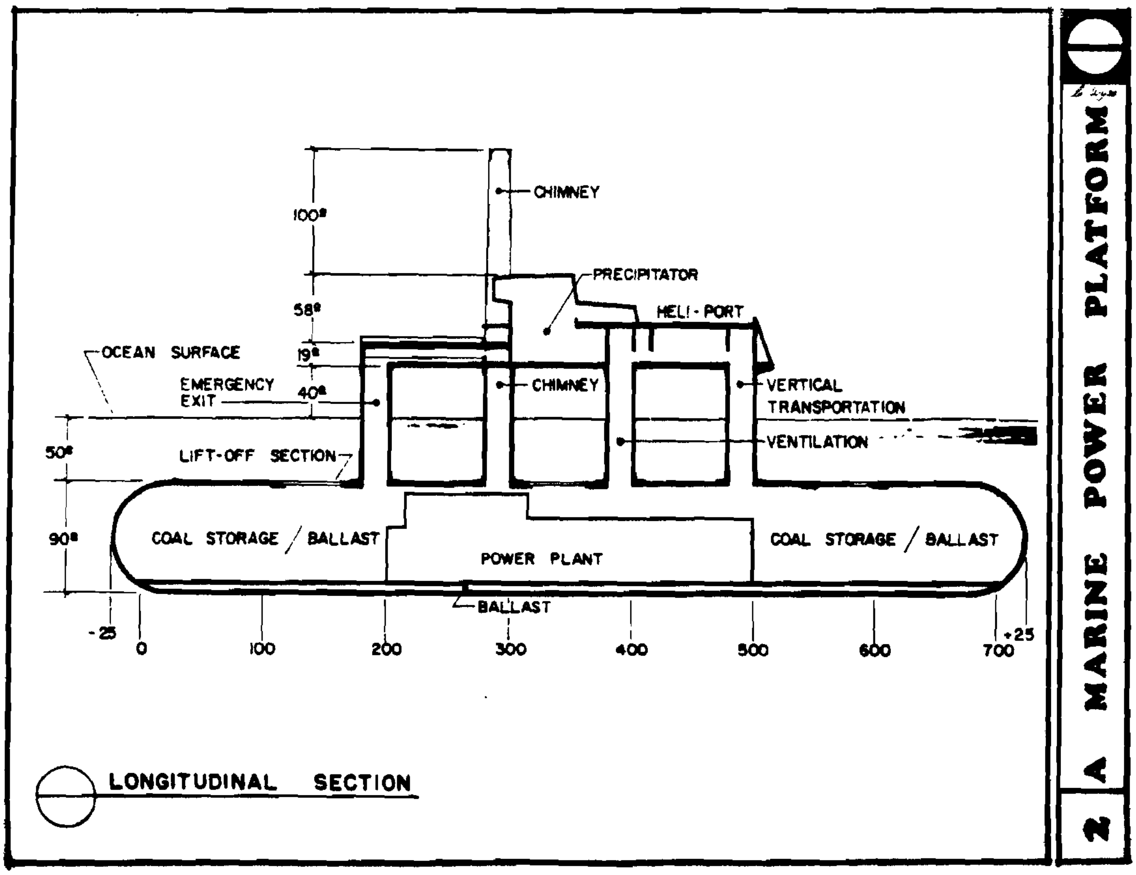


Figure (48): Design configuration for a floating, coal-fired power plant.

(From: John P. Craven, "Some Economic and Engineering Considerations For a Floating, Coal-Fired 100mW Power Plant," Ocean 75, 1975, pp. 276.)

ESTIMATED DELIVERED COAL COSTS

cost/ton	Heating Value 8,500 BTU/lb low range	Heating Value 8,500 BTU/lb high range	Heating Value 10,000 BTU/lb low range	Heating Value 10,000 BTU/lb high range
Coal Cost at Mine	$2.00	$ 3.00	$ 3.00	$ 4.50
Overland Shipment	4.05	4.95	4.05	4.95
Terminal Charge	.60	.90	.60	.90
Ocean Shipment	3.15	6.60	3.15	6.60
Total Cost per Ton	$9.80	$15.45	$10.80	$16.95
Cost per 10^6 BTU	.57	.90	.51	.80

Table (5)

FIXED COST DIFFERENCES OF SEA AND LAND POWER PLANTS

Item	Land	Sea
1. Site	High cost landsite	No landsite costs
2. Site development and structure	Conventional on-site construction	Integral structure in platform construction. Construction in shipyard.
3. Equipment	Conventional plus increment for freight and on-site installation	Conventional - installed simultaneous with platform construction
4. Fuel storage	Site and facilities, tanks for oil	None--free storage available in hull--coal used as ballast
5. Electrical transmission	To load center	To load center plus undersea transmission
6. Stacks	Standard	Lower--reduced cost
7. Mooring and installation	None	Mooring and installation required
8. Engineering costs	Conventional	Higher cost
9. Air pollution equipment	Extensive high cost pollution controlments	Simple low cost units
10. Cooling equipment	Conventional once through piped sea water with thermal pollution controls	Simpler cooling system
11. Insurance	Standard	Higher
12. Property taxes	Standard	Unknown--probably lower

Table (6)

(From: John P. Craven, "Some Economic and Engineering Considerations For a Floating, Coal-Fired 100mW Power Plant," Ocean 75, 1975, pp. 277.)

Table (7)

OPERATING COST DIFFERENCES, EXCLUDING FUEL, OF SEA AND LAND POWER PLANTS

Item	Land	Sea
1. Personnel	Standard	Higher--additional transport costs
2. Plant maintenance and repairs	Standard	Probably higher due to lessened accessibility and additional transport costs
3. Pollution control	Substantial costs for operation of equipment and disposal of liquid and solid wastes produced	Simpler equipment, lower costs
4. Ash disposal	Standard	Less if ocean dumping is feasible, more if land fill disposal
5. Fuel transfer costs (port to plant)	Standard	Not required. Direct discharge into plant.

(From: John P. Craven, "Some Economic and Engineering Considerations For a Floating, Coal-Fired 100mW Power Plant," Ocean 75, 1975, pp. 278.)

Table (8)

CAPITAL COSTS PER KW

	Land	Sea
Basic Plant Equipment*	$ 136	$ 125
Land and Structure	35	---
Platform and Structure	---	58
Mooring and Connection	---	11
Undersea Cable	---	5
Delivery and Installation	---	3
SO_2 Pollution Control Equipment	25	---
Cooling System	4	3
Extra Engineering Costs	---	7
TOTAL COST PER KW	$ 200	$ 212
Total Plant Cost - 175 MW say:	$35,000,000	$37,100,000
Annual Capital Cost @ 12% say:**	$ 4,200,000	$ 4,460,000
Annual Capital Cost mills/KWH	3.4	3.6

*Excludes land, structures, cooling system, SO_2 control system.
**80% operating factor.

Table (9)

TOTAL COSTS OF POWER GENERATION, EXCLUDING FUEL, IN MILLS/KWH

	Land	Sea
Capital Costs	3.4 mills/KWH	3.6 mills/KWH
Other Fixed Costs	1.3	1.3
Operating Costs, Excluding Fuel	2	2
Total Costs, Except Fuel	6.7 mills/KWH	6.9 mills/KWH

(From: John P. Craven, "Some Economic and Engineering Considerations For a Floating, Coal-Fired 100mW Power Plant," Ocean 75, 1975, pp. 279) land available for nuclear plants is scarce or nonexistent. Even in more remote and less populous areas where land is more plentiful, power plants of any kind are rarely welcome.

(2) The delays encountered during on-site construction of typical nuclear plants have led to cost overruns of many millions of dollars.

(3) The licensing and review process for individual plants has dragged and been extended to the point that years of delay have been added to many plant schedules. Each new delay adds additional millions of dollars to the final cost of an operating nuclear plant.[62]

Offshore Power Systems (OPS), an enterprise of Westinghouse Electric Corporation had the perfect solution, a Floating Nuclear Plant (FNP).

The FNP concept utilizes a conventional Westinghouse turbine-generator and pressurized water reactor. The plant's 1150-megawatt electrical outpϷt is enough to supply a city of 600,000 people. The primary steam loop is located in a reinforced-concrete containment building. In the unlikely event of a loss-of-coolant accident, "China Syndrome", the FNP incorporates emergency power and cooling systems designed to operate under severe conditions. The containment building, turbine hall and electrical substation, control room, auxiliary buildings and administrative and service areas are situated on a barge-type floating platform, see Figure (49).

> The hull is approximately 400 feet square and forty-four feet deep. It is composed of watertight bulkheads and ballast tanks inside a welded steel shell. The platform has been designed to satisfy or surpass the applicable standards of seaworthiness and safety set by the American

62 Offshore Power Systems, Jacksonville, Florida.

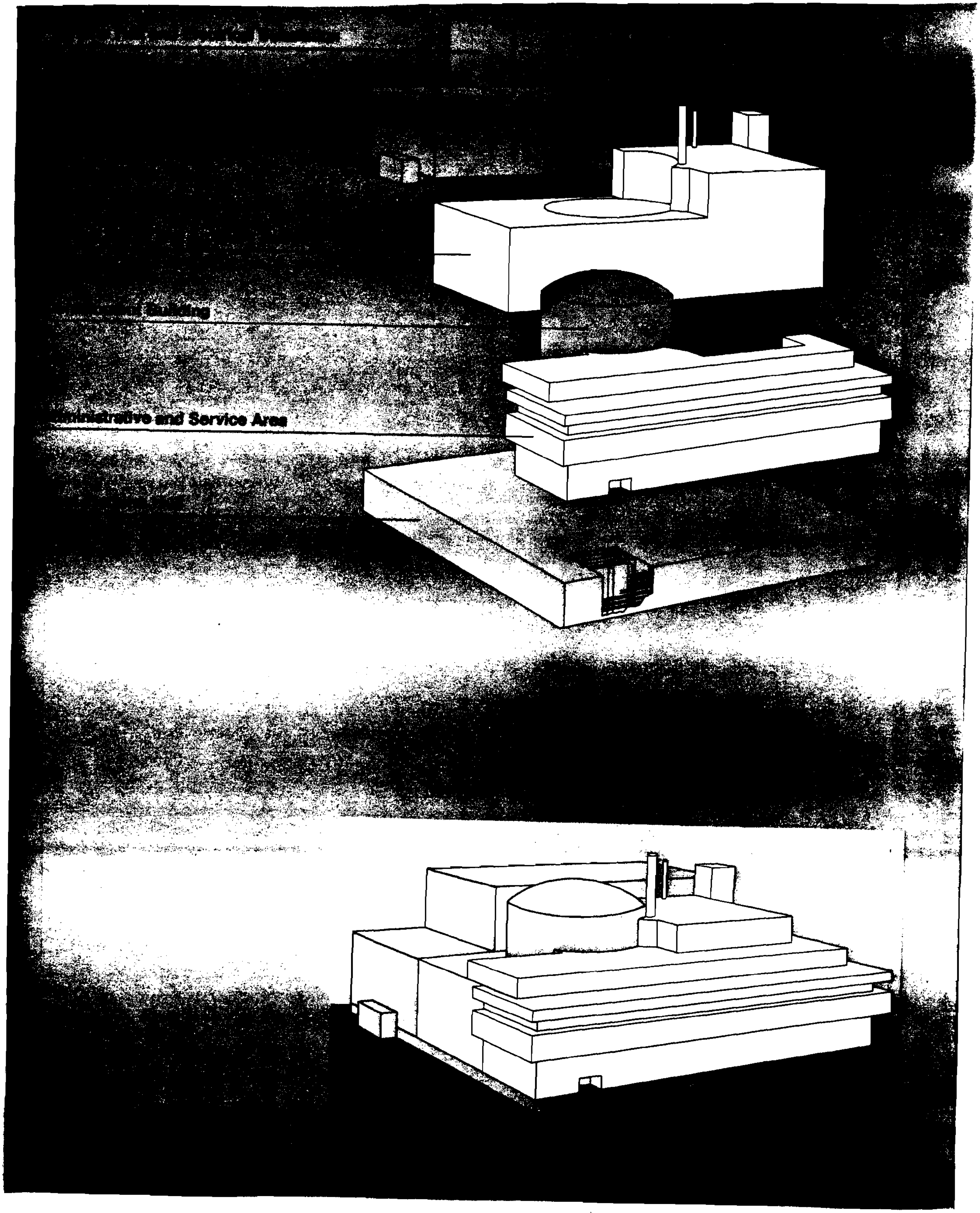


Figure (49): Basic layout for a Floating Nuclear Plant.

(From: Offshore Power Systems, Jacksonville, Florida)

Bureau of Shipping and the United States Coast Guard.[63]

The FNP furnishes the electric utility and the consumer with numerous key advantages over land-based systems. These advantages include:

(1) Siting flexibility: FNP's will not be sited on land, but on water--in rivers, estuaries, inlets or in the open ocean, see Figures (50-52). Regardless of the location, the FNP is identical for each site. The FNP is simply towed to a selected location and "pluged-in"; the only variable is the breakwater configuration. If site parameters change, the FNP can easily be towed to a different location.

(2) Minimized environmental impact. FNP's are designed to minimize adverse impacts on the environment. Their impact will be no greater, and in many cases actually less, than the impact of a land-based nuclear plant. Thermal effects are drastically reduced by utilizing the dissipating action of the ocean. The resultant plume of discharge water is focused in one direction via a high flow circulating water system which minimizes cooling water temperature. Equally important, critical freshwater supplies, less and less available on land, are not used for this cooling process. The combination of warm discharge water and surrounding breakwater serves as an artificial reef and allows ocean plants and animals to flourish. Finally, FNP's conserve valuable land. A two plant FNP site will occupy only about 100 acres; a similar land-based site requires 500-5,000 acres depending on cooling water systems, site layout, marshalling area, accessibility, etc.[64]

(3) Simplified licensing procedure: All nuclear power plants must be licensed by the Nuclear Regulatory Commission (NRC), the FNP is no exception. Initially, the NRC queried Offshore Power Systems idea to mass produce FNP's. After reviewing their (OPS) design, the NRC amended its licensing regulations in 1973 and created a new type of license called a "License to Manufacture." This novel license would allow OPS to build a series of identical FNPs without specific consideration of the

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63 Offshore Power Systems, Jacksonville, Florida.

64 Ibid.

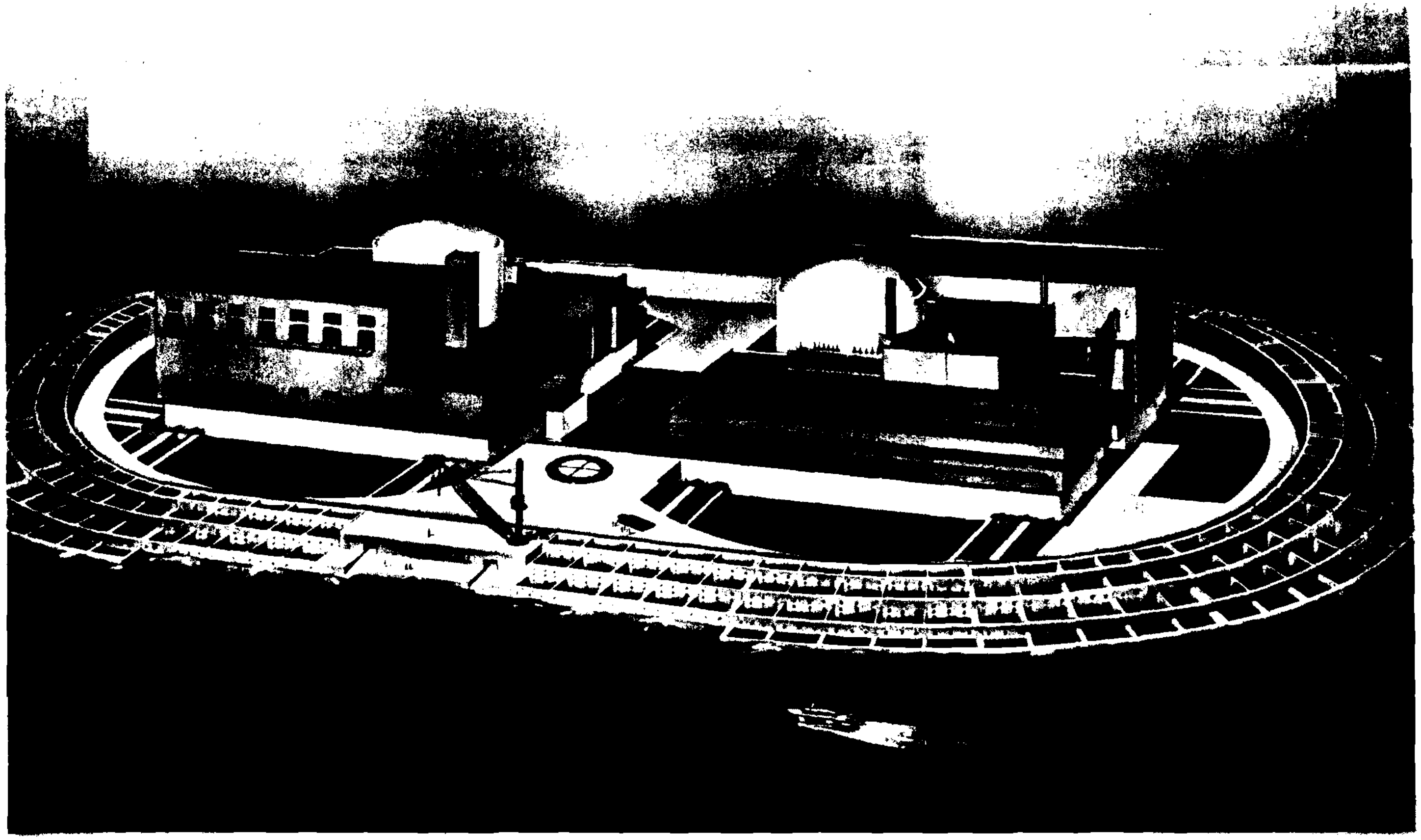

Figure (50): Floating Nuclear Plant sited offshore.

(From: Offshore Power Systems, Jacksonville, Florida)

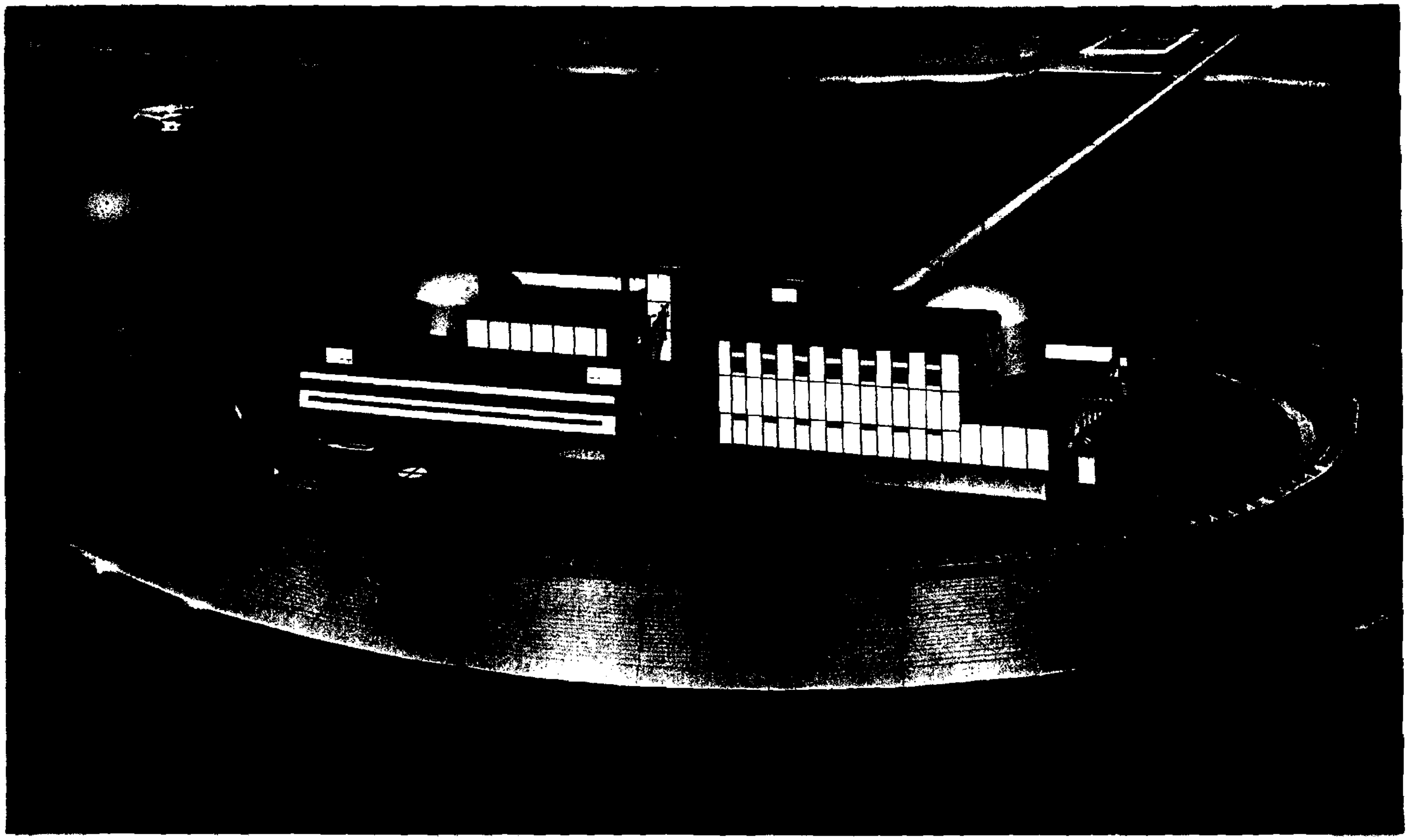

Figure (51): Floating Nuclear Plant sited nearshore.

(From: Offshore Power Systems, Jacksonville, Florida)

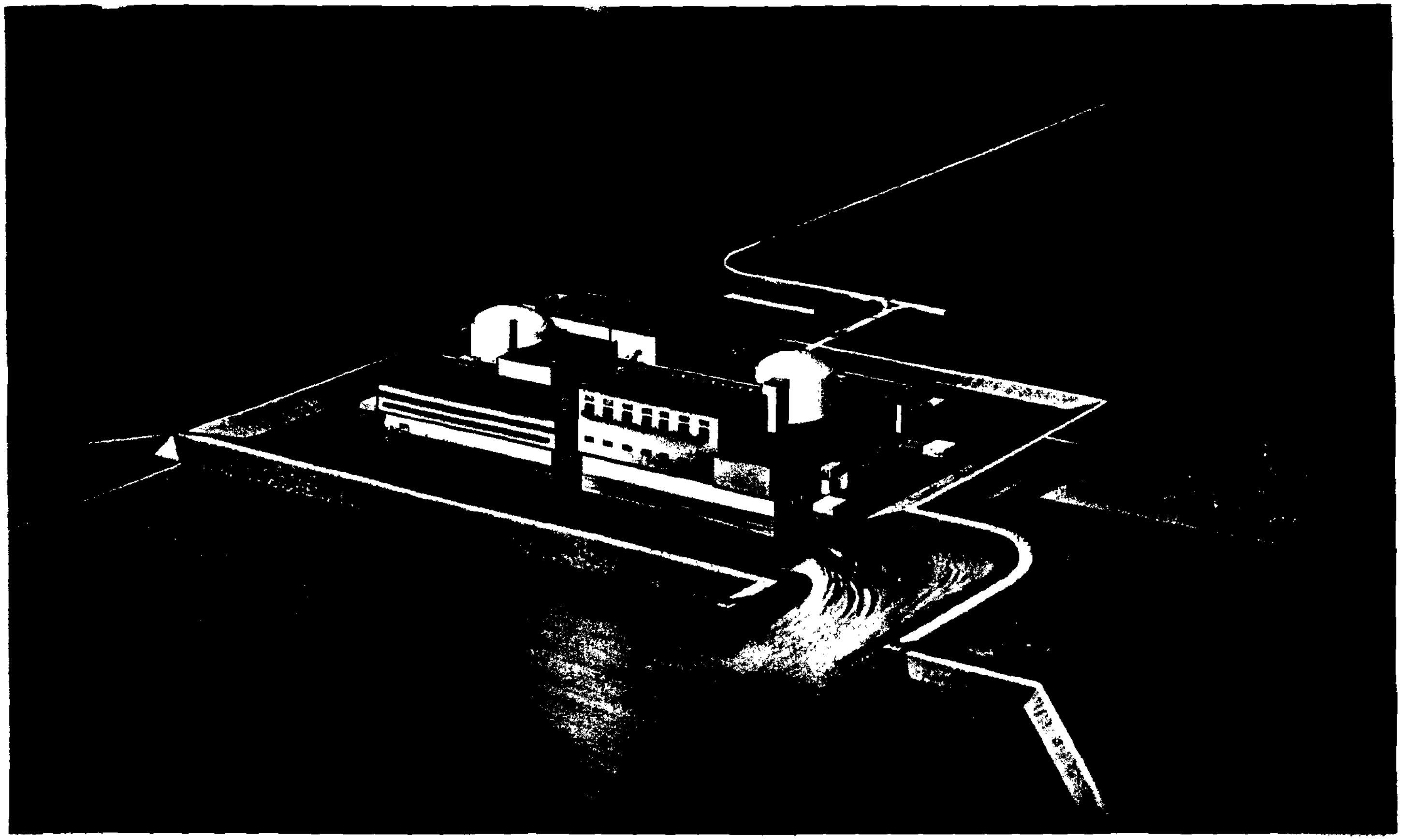

Figure (52): Floating Nuclear Plant sited in riverine.

(From: Offshore Power Systems, Jacksonville, Florida)

individual sites at which the plants will utimately be installed and operated. The manufacturing license would also meet over 80% of the regulatory requirements encountered by custom-built onshore plants. The buying utility would only have to meet specific plant/site interface parameters, see Appendix (3), where the floating plant would be anchored. Table (10) illustrates the plant lead time reduction a FNP has, versus a land-based nuclear plant.[65]

(4) Standardized design: The majority of land-based nuclear power plants are one-of-a-kind. This adds tremendously to capital cost, which, is ultimately passed on to the consumer. OPS concept for FNPs employs standardization. This approach promises to minimize capital costs by reducing both design expenses and the amount of time required to bring a nuclear plant into operation.[66]

In 1973 OPS began to fabricate one of the world's largest graving dock and slipway facilities, located on 875 acres of Blount Island in the St. Johns River in Jacksonville, Florida, see Figure (53). At about the same time, Public Service Electric and Gas Company of New Jersey ordered four twin reactor units that were to be located off the New Jersey coast. At $1.5 billion, this was the largest order in the history of the electric utility industry. For the next 5 years everything ran smoothly, the graving dock and slipway had been dredged; a welding engineering laboratory; manufacturing office and laboratory, maintenance building, and warehouse complex were built. In addition, Figure (54) illustrates a 900-ton gantry crane was installed. Shockingly, the bottom dropped out of the gallows in 1978.

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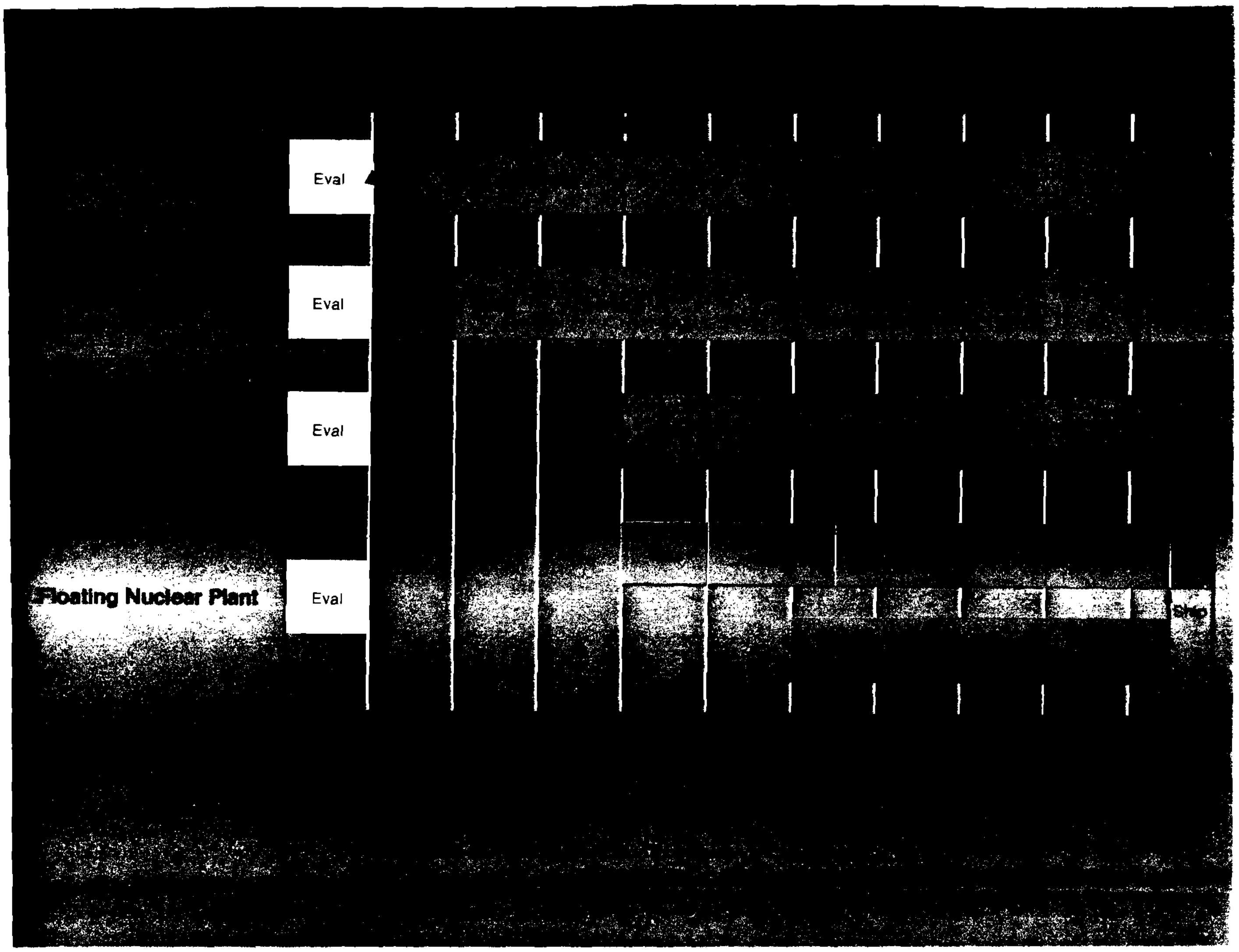
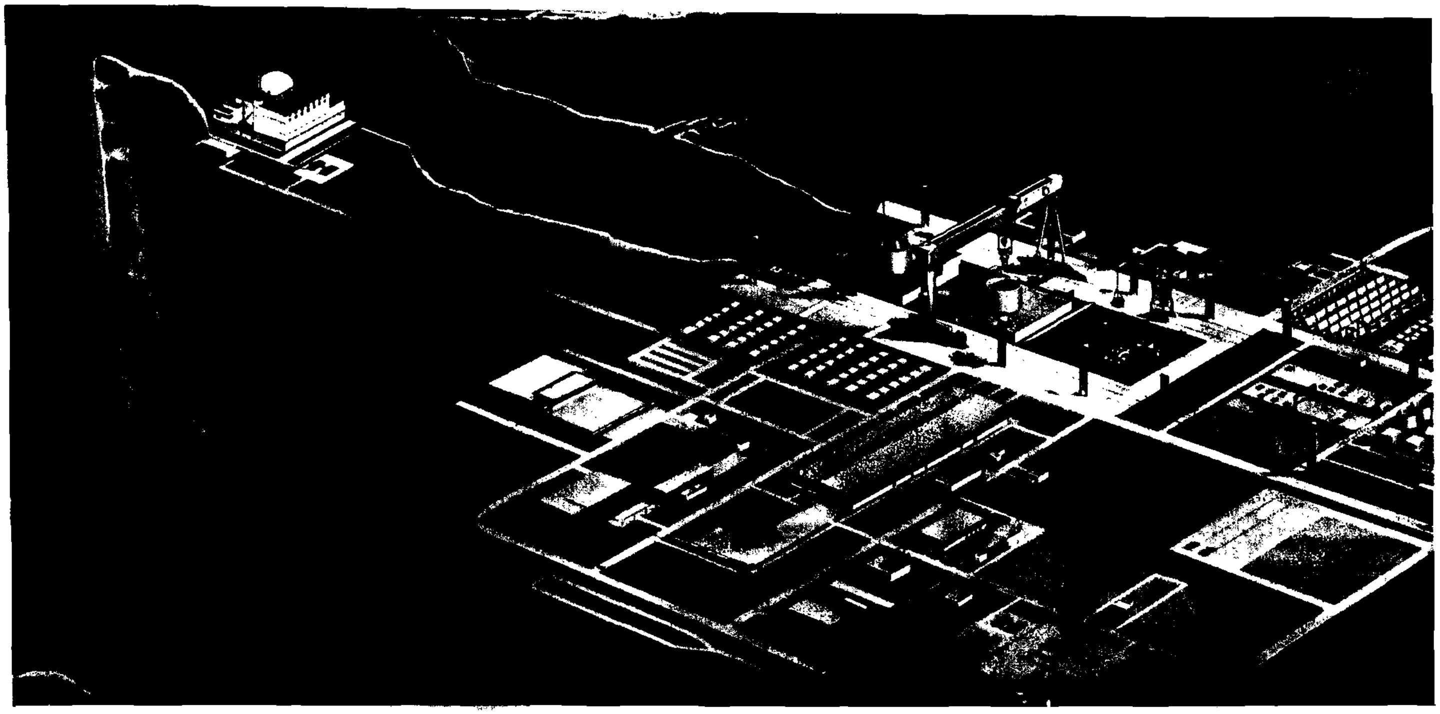
65 Offshore Power Systems, Jacksonville, Florida.

66 Ibid.

Table (10): Comparison of Generating Plant Lead Times.



(From: Offshore Power Systems, Jacksonville, Florida)



<u>Figure (53)</u>: The Blount Island Manufacturing Facility as it will appear when producing one FNP per year.

(From: Offshore Power Systems, Jacksonville, Florida)

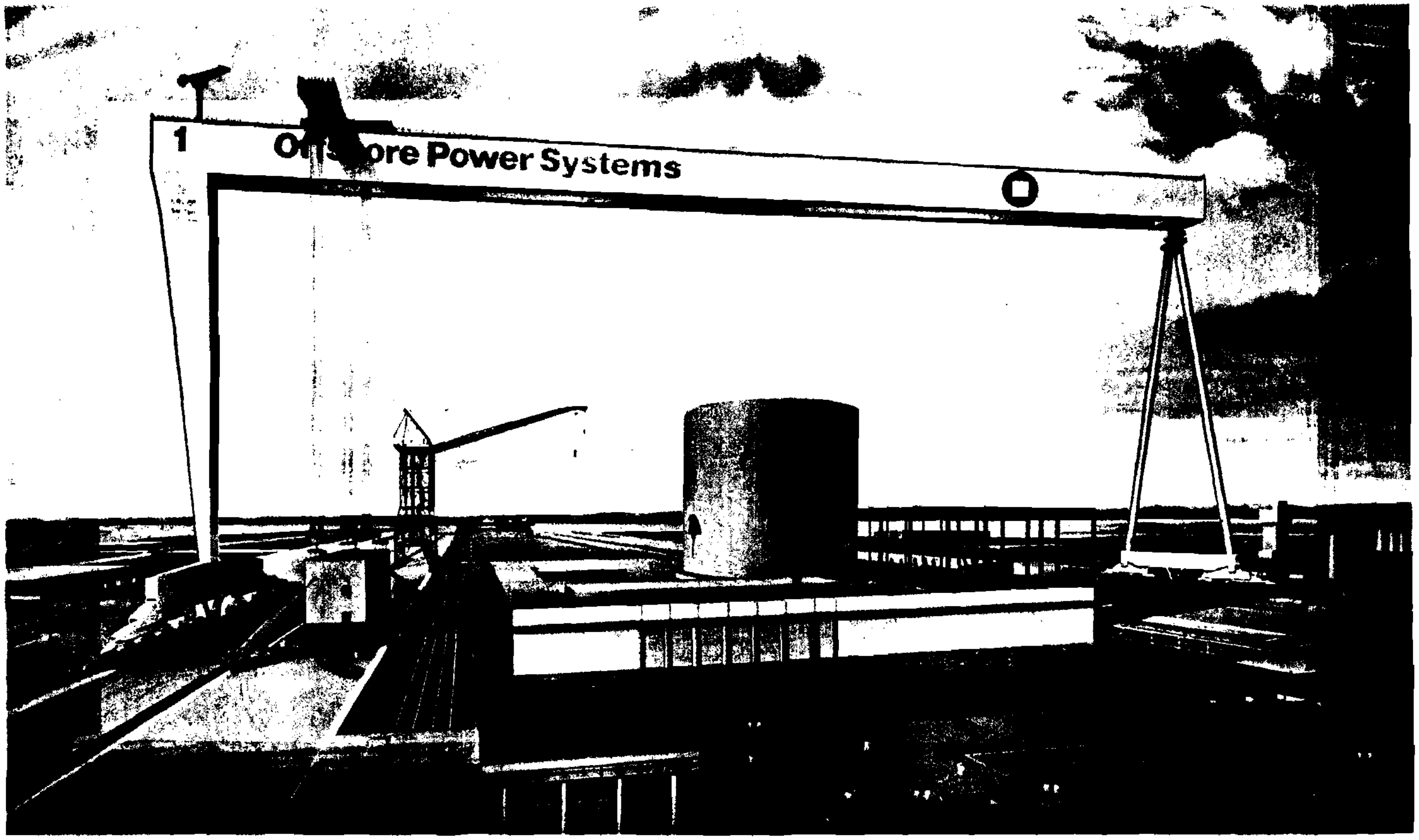


Figure (54): Offshore Power Systems 900-ton gantry crane.

(From: Offshore Power Systems, Jacksonville, Florida)

Public Service Electric and Gas Company of New Jersey canceled its whole order and has no intention of reentering the market.

> The radical design of the floating plants drew stiff opposition from environmental groups, which caused numerous delays in the licensing process. And public consumption of electricity did not grow at the expected pace.
>
> "It's just one of those unfortunate circumstances that there has been a dramatic change in the growth in the demand for electricity," Westinghouse spokesman John Burke said. "The growth prior to the oil embargo was about 7 percent. Now its 1 to 2 percent. And because of that, the market for floating power plants has just not developed."[67]

Recently, OPS has made plans to sell Blount Island. The facilities are now being considered to construct oil rigs or repair supertankers. Ironically, OPS received their "License to Manufacture" from the NRC on June 30, 1982.

The last application for artificial floating islands to be discussed, is that of Mid-Ocean Basing for the military.

MID-OCEAN BASING SYSTEMS

Now more than ever, United States presence overseas is essential. During the 1960's and 1970's numerous hostile outbreaks occurred around the world where quick United States military response was required. The Cuban missile crisis, the Vietnam War and the Iranian hostage incident were just a few examples. " In conventional terms the most practical way of keeping strong military forces readily available is to use an overseas base."[68] In recent years however, there

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67 Norm Going, "Westinghouse to Sell OPS Land on Blount Island," Times-Union, Jacksonville, Florida, December 1982.

68 Gordon J.F. MacDonald, Uses of the Seas, (Englewood Cliffs: Prentice-Hall, 1968), pp. 175.

has been strong political opposition, from Greece and Japan for example, to the existence of United States military installations on foreign soil. How then could the United States continue to excercise her military strength overseas?

> The ultimate solution to overseas bases may lie in the construction of giant floating platforms that could be stationed against wind and current. A global array of such sites would protect areas of strategic interest, and would not be subject to the political uncertainties of land bases, which often are an international irritant.[69]

These giant floating platforms or Mid-Ocean Basing Systems (MOBS) were investigated by the Defense Advanced Research Programs Agency (ARPA) from 1968 through 1975 at a cost of $4 million. ARPA established general requirements that a MOBS must satisfy. These are:

(1) It can maintain position for periods of the order of a year in mid-ocean.

(2) It can be self-sufficient for several months.

(3) It can be safe from the onslaught of the most severe oceanic conditions expected.

(4) It can continue to fulfill its particular role under all but the most extreme conditions for some applications.

(5) It can be mobile.[70]

The optimal choice was a deep buoyant structure.[71] Included in ARPA's

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69 Ibid, pp. 176.

70 "ARPA Stable Floating Platform," <u>Scripps Institution of Oceanography</u>, May 5, 1969, pp. 1-2.

71 See Chapter 2 for complete description of deep buoyant structures.

investigations were the experimental verification of selected theoretical analyses, and the experimental design and costing of an airfield 500 feet wide and 6,000 feet long suitable for the operational support of C-130 aircraft, naval forces and ground forces. Figures (55-58) illustrate possible MOBS configurations.

Presently, the majority of technological problems associated with MOBS and artificial floating islands in general have been solved. Unfortunately, the political and legal ramifications for their emplacement are yet unsolved.

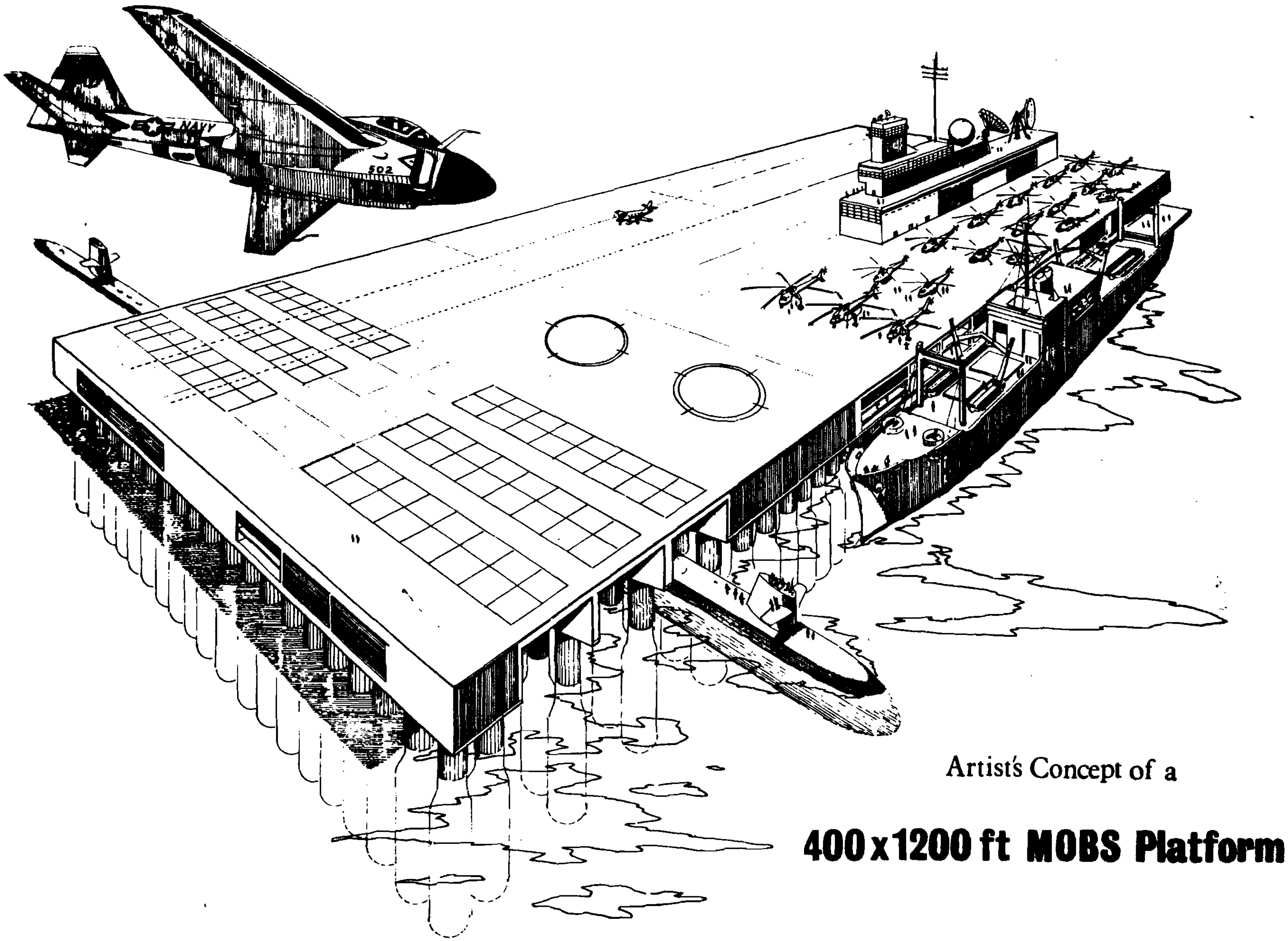

Figure (55)

(From: Naval Civil Engineering Laboratory, Port Hueneme, California)

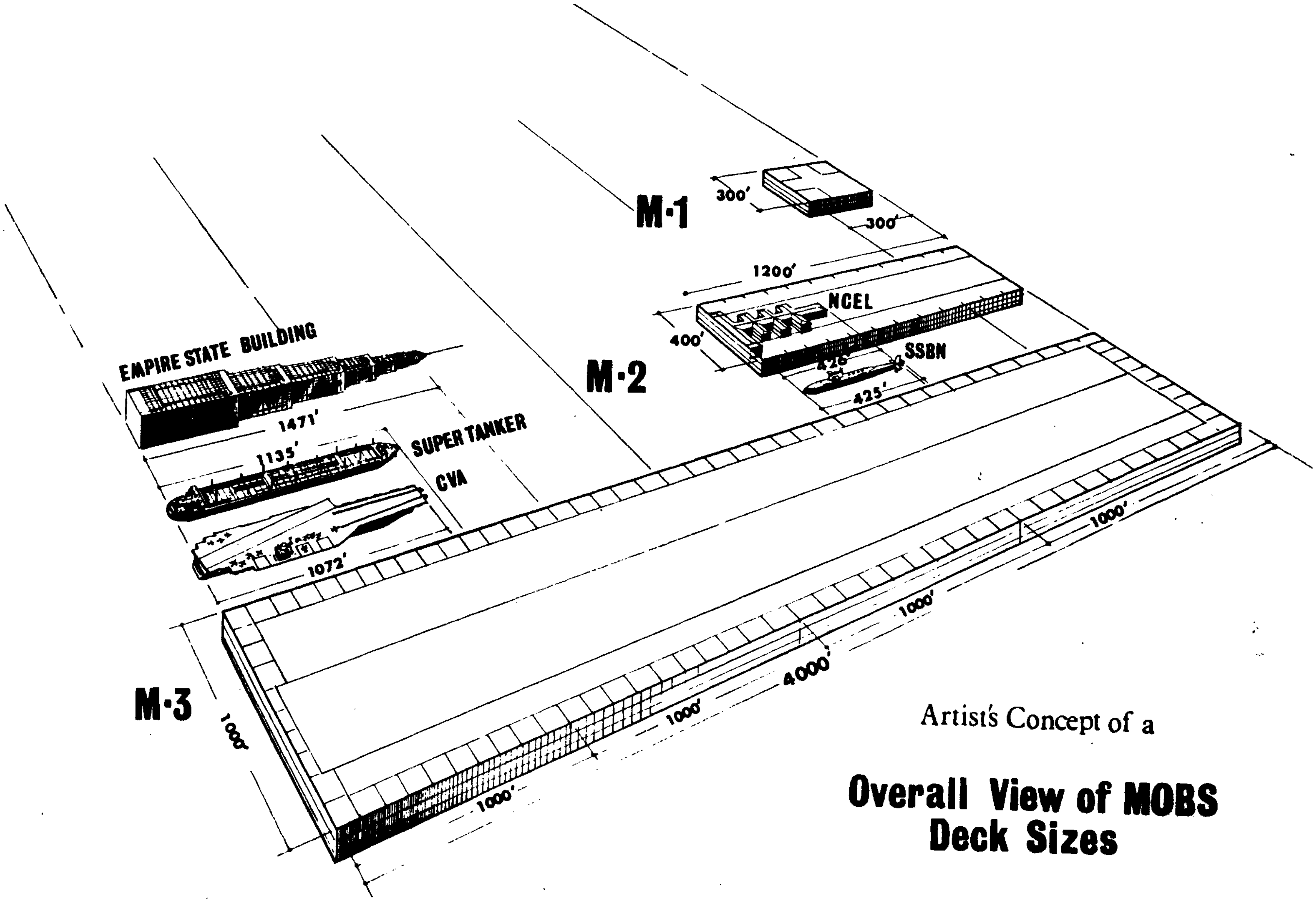

Figure (56)

(From: Naval Civil Engineering Laboratory, Port Hueneme, California)

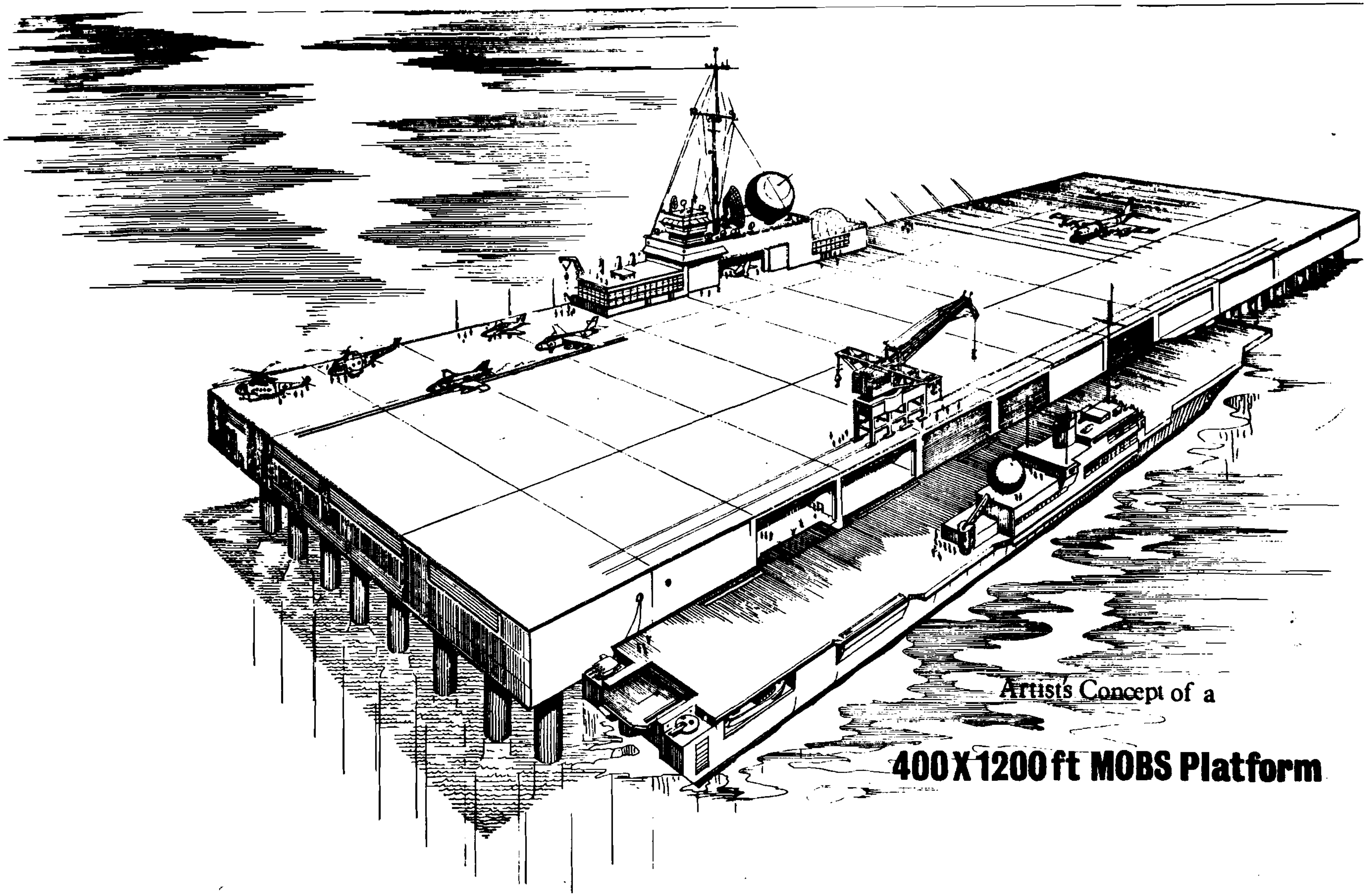

Figure (57)

(From: Naval Civil Engineering Laboratory, Port Hueneme, California)

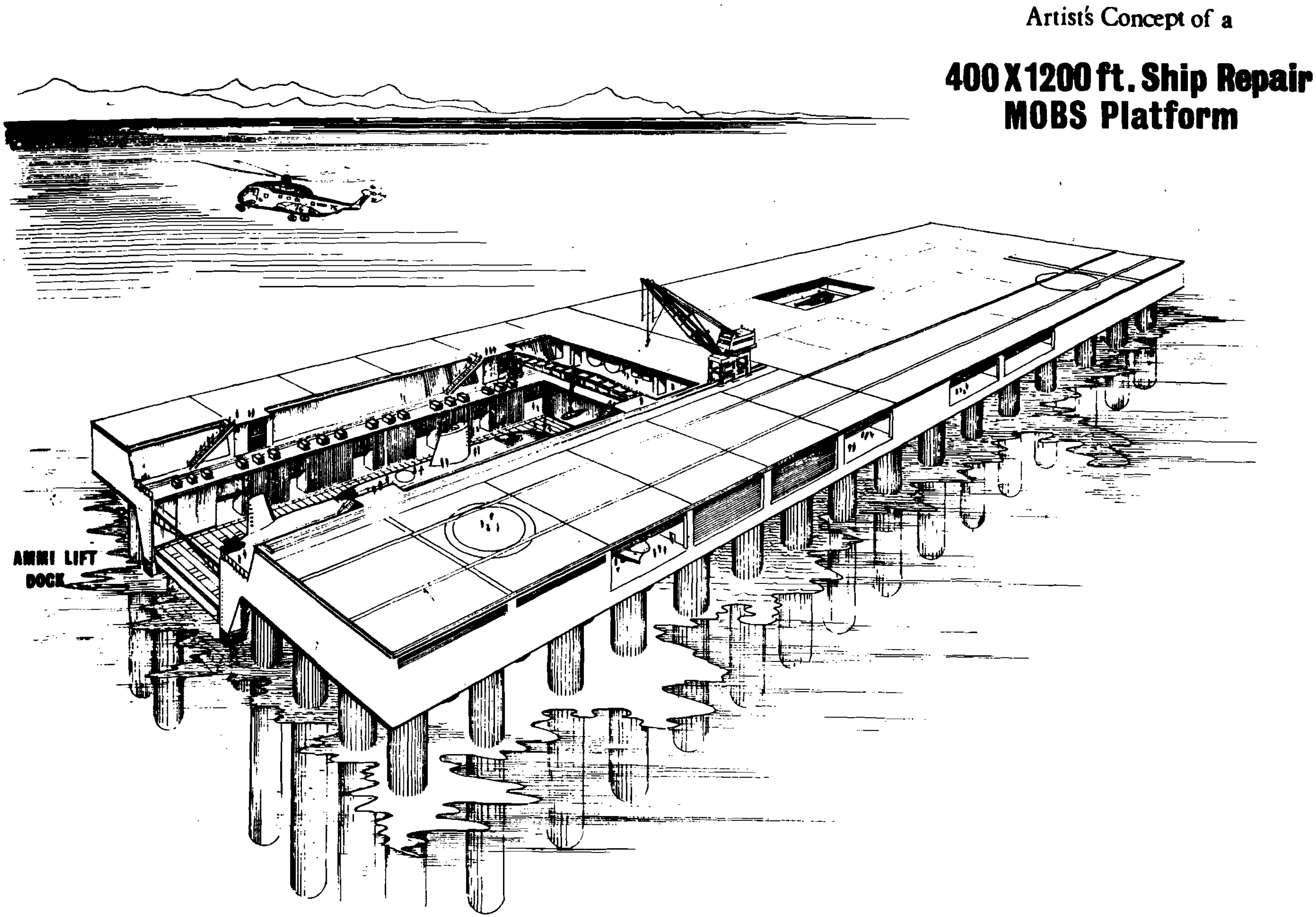

Figure (58)

(From: Naval Civil Engineering Laboratory, Port Hueneme, California)

Chapter 4

ARTIFICIAL FLOATING ISLANDS AND INTERNATIONAL LAW

Solving the technical problems associated with artificial floating islands appears to be only the tip of the iceberg. The legal and political characterization of floating platforms may very well determine their final outcome. This issue was first discussed in 1934 by Roberto Sandiford. He posed the following legal questions concerning floating airports or seadromes on the open ocean:

> (1) What is the nature of these "floating islands?" Should they be regarded as artificial islands or as vessels?
>
> (2) As they are destined to occupy permanently a definite space of the high sea, can their establishment be regarded as lawful and compatible with the principle of the freedom of the seas and of navigation?
>
> (3) If it is admitted that the establishment of such floating islands is lawful, must they be placed under the jurisdiction of any one State?
>
> (4) If it is admitted that such floating islands must be placed under the jurisdiction of any one State, is it necessary that this State possess a sea-border?
>
> (5) At any rate what is the legal regime to which such floating islands will be or ought to be subjected?
>
> (6) In order to assure the liberty of aerial navigation and of the high seas, is it necessary that such islands be placed under an international regime in peace time and under a regime of neutralization in war time?
>
> (7) Does the establishment of such floating islands carry with it sovereignty over the adjacent sea space?[71]

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[71] Roberto Sandiford, "Aerodromes on the Open Seas," Air Law Review, 1934, pp. 11.

Presently, some fifty years later these questions have yet to be completely answered. The final answer to these questions will depend on the legal characterization of artificial floating islands. Are they vessels? Are they structures? Or are they states?

Artificial Floating Islands as Ships or Vessels

The term vessel or ship has had numerous definitions in admiralty law through the years. In Cope v Vallette Dry-Dock Co. (1887) the Supreme Court of the United States held that a floating dry-dock was not a vessel. This was a libel for salvage by the owners of a steam-tug against the Vallette Dry-Dock Company, to recover salvage for salving the company's dry-dock from sinking.

> The libel alleges that the Vallette Dry-Dock is a large floating vessel and water-craft and artificial contrivance, used and capable of being used as a means of transportation in water.[72]

The Supreme Court stated:

> A fixed structure, such as this dry-dock is, not used for the purpose of navigation, is not a subject of salvage service, any more than is a wharf or a warehouse when projecting into or upon the water. The fact that it floats on the water does not make it a ship or vessel, and no structure that is not a ship or vessel is a subject of salvage. A ship or vessel, used for navigation and commerce, though lying at a wharf, and temporarily made fast are capable of receiving salvage service.[73]

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72 Nicholas J. Healy and David J. Sharpe, Cases and Materials on Admiralty (St. Paul: West Publishing Co., 1974), pp. 224.

73 Ibid, pp. 225.

In this case the key words used to define a vessel were, devoted to the purpose of transportation, commerce and navigation.

During the 1940's through 1960's there was a rapid growth in offshore fixed and floating platforms for oil exploration and drilling. Along with this rapid growth came a change in the courts definition of vessels and ships. In Offshore Co. v Robinson the court stated that an oil rig meet the requirements as a vessel even though it was not devoted to the purpose of navigation, transportation or commerce. It had no engines, navigational equipment and was fixed to the ocean floor while performing its primary task.

> There is an evidentiary basis for a Jones Act[74] case to go to the jury: (1) it there is evidence that the injured workman was assigned permanently to a vessel (including special purpose structures not usually employed as a means of transport by water but designed to float on water) or performed a substantial part of his work on the vessel......Expansion of the terms "seaman" and "vessel" is consistent with the liberal construction of the Act that has characterized it from the beginning and is consistent with its purposes. The absence of any legislative restriction has enabled the law to develop naturally along with the development of unconventional vessels, such as the strange-looking specialized watercraft designed for oil operations offshore and in the shallow coastal waters of the Gulf of Mexico.[75]

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[74] 46 USC Section 688. The Jones Act applies to seamen injured or killed in the cause of employment. It was passed to provide seamen with the same rights to recover for negligence as they would have had if they had not been seamen.

[75] Nicholas J. Healy and David J. Sharpe, Cases and Materials on Admiralty (St. Paul: West Publishing Co., 1974), pp. 334.

With this dramatic change in the definitional test for a ship or vessel under United States case law, it is conceivable that artificial floating islands be classified as vessels or ships. This being the case, artificial floating islands as vessels or ships are subject to international regulation depending on their location; (1) territorial sea, (2) contiguous zone, (3) exclusive economic zone (EEZ), or (4) high seas.

The principle text regulating vessels in the territorial sea and contiguous zone of a coastal State is the Convention on the Territorial Sea and the Contiguous Zone which came into force on September 10, 1964. Although Article 1 states, "The sovereignty of a State extends beyond its land territory and its internal waters, to a belt of sea adjacent to its coast, described as the territorial sea," it does not grant the coastal State total sovereignty over foreign vessels within its territorial sea. Specifically, the following Articles would apply to artificial floating islands, should they be classified as vessels or ships:

> <u>Article 14</u>
>
> 1. Subject to the provisions of these articles, ships of all States, whether coastal or not, shall enjoy the right of innocent passage through the territorial sea.
>
> 2. Passage means navigation through the territorial sea for the purpose either of traversing that sea without entering internal waters, or of proceeding to internal waters, or of making for the high seas from internal waters.
>
> 3. Passage includes stopping and anchoring, but only in so far as the same are incidental to ordinary navigation or are rendered necessary by "force majeure" or by distress.

4. Passage is innocent so long as it is not prejudicial to the peace, good order or security of the coastal State........[76]

Article 15

1. The coastal State must not hamper innocent passage through the territorial sea.

2. The coastal State is required to give appropriate publicity to any dangers to navigation, of which it has knowledge, within its territorial sea.[77]

Article 16

1. The coastal State may take the necessary steps in its territorial sea to prevent passage which is not innocent....

2. The coastal State may, without discrimination amongst foreign ships, suspend temporarily in specific areas of its territorial sea the innocent passage of foreign ships if such suspension is essential for the protection of its security. Such suspension shall take effect only after having been duly published.[78]

Article 19

1. The criminal jurisdiction of the coastal State should not be exercised on board a foreign ship passing through the territorial sea to arrest any person or to conduct any investigation in connection with any crime committed on board the ship during its passage, save only in the following cases:

   (a) If the consequences of the crime extend to the coastal State; or

   (b) If the crime is of a kind to disturb the peace of the country or the good order of the territorial sea; or

   (c) If the assistance of the local authorities has been requested by the captain of the ship or by the consul of the country whose flag the ship flies; or

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[76] Convention on the Territorial Sea and Contiguous Zone, 29 April 1958, 2 UST 1606, TIAS No 5639, 516 UNTS 205.

[77] Ibid.

[78] Ibid.

(d) If it is necessary for the suppression of illicit traffic in narcotic drugs.[79]

Article 20

1. The coastal State should not stop or divert a foreign ship passing through the territorial sea for the purpose of exercising civil jurisdiction in relation to a person on board the ship.

2. The coastal State may not levy execution against or arrest the ship for the purpose of any civil proceedings, save only in respect of obligations or liabilities assumed or incurred by the ship itself in the course or for the purpose of its voyage through the waters of the coastal State.[80]

If artificial floating islands are classified as vessels the preceeding Articles would apply. Briefly stated, artificial floating islands would be granted the right of innocent passage through the territorial sea of a coastal State with certain minimum restrictions. Finally, with regards to the "contiguous zone",[81] Article 24 states:

> In a zone of the high seas contiguous to its territorial sea, the coastal State may exercise the control necessary to:
>
> (a) Prevent infringement of its customs, fiscal, immigration or sanitary regulations within its territory or territorial sea;
>
> (b) Punish infringement of the above regulations committed within its territory or territorial sea.[82]

Continuing with the assumption that artificial floating islands are classified as vessels, the primary source for their

---

[79] Ibid.

[80] Ibid.

[81] The contiguous zone is a zone which by the terms of the Convention on the Territorial Sea and Contiguous Zone may not extend beyond 12 miles from the baselines drawn along the coast to define the territorial sea.

[82] Convention on the Territorial Sea and Contiguous Zone, 29 April 1958, 2 UST 1606, TIAS No 5639, 516 UNTS 205.

regulation on the high seas is the Convention on the High Seas. Article 2 states:

> The high seas being open to all nations, no State may validly purport to subject any part of them to its sovereignty. Freedom of the high seas is exercised under the conditions laid down by these Articles and by the rules of international law. It comprises, inter alia, both for coastal and non-coastal States:
>
> (1) Freedom of navigation;
> (2) Freedom of fishing;
> (3) Freedom to lay submarine cables and pipelines;
> (4) Freedom to fly over the high seas.......[83]

As vessels, artificial floating islands would be required to sail under the flag and registry of one State and, for all intent and purpose, be subject to its exclusive jurisdiction on the high seas. Essentially this means an artificial floating island is an extension of the flag State on the high seas and free to operate without regulation from other than the flag-State. Furthermore, depending on the specific function of the artificial floating island it might seek the laxity of regulation provided by a "flag-of-convenience" or "flag-of-necessity". Registered under a flag-of-convenience, an artificial floating island could minimize restrictions on its operation by heading for the high seas and escape any further regulation.

The most recent transnational attempt to comprehensively regulate the sea is the Third United Nations Conference on the Law of the Sea (UNCLOS III). Presently awaiting ratification, the draft treaty makes

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[83] Convention on the High Seas, 29 April 1958, 2 UST 2312, TIAS No 5200, 450 UNTS 82.

several small changes with regard to the regulation of vessels or, artificial floating islands under the current assumption. The treaty extends the territorial sea and contiguous zone and also gives each coastal State a 200-mile EEZ. The right of innocent passage is still however guaranteed within the territorial waters of a coastal State. To reemphasize, innocent passage is defined as the continuous and expeditious navigation through the territorial sea. Article 19 of the draft treaty further defines the meaning of innocent passage:

> 1. Passage is innocent so long as it is not prejudicial to the peace, good order or security of the coastal State. Such passage shall take place in conformity with this Convention and with other rules of international law.
>
> 2. Passage of a foreign ship shall be considered to be prejudicial to the peace, good order or security of the coastal State, if in the territorial sea it engages in any of the following activities:
>
> (a) Any threat or use of force against the sovereignty, territorial integrity or political independence of the coastal State, or in any other manner in violation of the principles of international law embodied in the Charter of the United Nations;
>
> (b) Any exercise or practice with weapons of any kind;
>
> (c) Any act aimed at collecting information to the prejudice of the defense or security of the coastal State;
>
> (d) Any act of propaganda aimed at collecting information to the prejudice of the defense or security of the coastal State;
>
> (e) The launching, landing or taking on board of any aircraft;
>
> (f) The launching, landing or taking on board or any military device;

(g) The embarking or disembarking of any commodity, currency or person contrary to the customs, fiscal, immigration or sanitary regulations of the coastal State;

(h) Any act of willful and serious pollution, contrary to this Convention;

(i) Any fishing activities;

(j) The carrying out of research or survey activities;

(k) Any act aimed at interfering with any systems of communication or any other facilities or installations of the coastal State;

(l) Any other activity not having a direct bearing on passage.[84]

This again would not pose a restriction on the operation of vessels and artificial floating islands utilizing the territorial sea of a coastal State for transit so long as the provisions in Article 19 were not violated.

Artificial Floating Islands as Structures

The Outer Continental Shelf Lands Act of 1960 states that the Constitution, laws and civil and political jurisdiction of the United States are extended to the subsoil and seabed of the outer continental shelf and to all artificial islands and fixed structures erected thereon to the same extent as if the outer continental shelf were an area of exclusive federal jurisdiction within a state. In 1969 the Supreme Court of the United States in Rodrique v Aetna Casualty & Surety Co. supported the Outer Continental Shelf Lands Act.

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84 Draft Convention of the Law of the Sea (Informal Text) 28 July-29 August 1980.

The case involved a wrongful death of a worker on a drilling rig located on the outer continental shelf off the coast of Louisiana. The court stated:

> The Outer Continental Shelf Lands Act makes it clear that federal law, supplemented by state law of the adjacent State, is to be applied to these artificial islands as though they were federal enclaves in an upland State.......
>
> Congress decided that these artificial islands, though surrounded by the high seas, were not themselves to be considered within maritime jurisdiction. Thus the admiralty action under the Death on the High Seas Act no more applies to these accidents actually occurring on the islands than it would to accidents occurring in an upland federal enclave or on a natural island to which admiralty jurisdiction had not been specifically extended.[85]

The preceeding court decision dealt specifically with structures in contact with the ocean floor. However, if an artificial floating island were permanently moored to the ocean floor, it might be classified as a structure.

In Cope v Vallette Dry-Dock Co. discussed earlier the Supreme Court stated, "The fact that it floats on the water does not make it a ship or vessel......We think no case can be found which would construe the terms (ship or vessel) to include a dry-dock, a floating bridge, or meeting house, permanently moored or attached to a wharf."[86] This also indicates that artificial floating islands permanently moored would be classified as structures. The primary distinction between vessels and structures is their function:

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85 Rodrique v Aetna Cas. & Sur. Co., 395 U.S. 352, 89 S. Ct. 1835, 23 L. Ed. 2d 360 (1969).

86 Cope v Vallette Dry-Dock Co., 119 U.S. 625, 7 S. Ct. 336, 30 L. Ed. 501 (1887).

> The word 'structure' has arisen most often in the law of the sea in regard to oil towers or rigs which rest on the ocean floor and are not mobile. A floating-city ship built on a free-floating platform would be distinguishable from such towers and rigs. However, if the floating city was stabilized for long periods of time in the same location, it would not generally be involved in navigation or transportation as a ship, and the argument could be made that it was for all intents and purposes an installation or structure. Its function would be that of a structure, and that fact might be persuasive in court. Again, these definitional distinctions under US law are not determinative of international law, but indicative of the direction in which international law may evolve.[87]

The UNCLOS III drafty treaty, for the first time in history in a law of the sea treaty, addresses the question of the regulation of structures and artificial islands. Although not specifically mentioning artificial floating islands, the following provisions could be extended to include artificial floating islands that were dynamically stabilized or permanently moored for long periods of time:

> <u>Article 56</u>
>
> In the EEZ, the coastal State has jurisdiction as provided for in the relevant provisions of this Convention with regard to the establishment and use of artificial islands, installations and structures.[88]
>
> <u>Article 60</u>
>
> In the EEZ, the coastal State shall have the exclusive right to construct and to authorize and regulate the construction, operation and use of artificial islands......
>
> The coastal State shall have exclusive jurisdiction over such artificial islands, installations and structures, including jurisdiction with regard to customs, fiscal health, safety and immigration regulations.[89]

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87 Kent Keith, "Floating Cities," Marine Policy, July 1977, pp. 196.

88 Draft Convention on the Law of the Sea (Informal Text) 28 July-29 August 1980.

89 Ibid.

Article 80

Article 60 applies mutatis mutandis to artificial islands, installations and structures on the continental shelf.[90]

Article 87

The high seas are open to all States, whether coastal or land-locked. Freedom of the high seas is exercised under the conditions laid down by this convention and by other rules of international law. It comprises inter alia, both for coastal and land-locked States; Freedom to construct artificial islands and other installations......[91]

Should artificial floating islands be classified as structures their operation under the UNCLOS III convention would be closely regulated within a coastal State's territorial sea and EEZ. In the case of a totally self-sufficient floating city employing mariculture activities for its food supply for example, it is likely that it will want to spend long periods of time in a resource-rich EEZ of a coastal State. Therefore, under the present UNCLOS III draft treaty, that floating city must comply with the regulations determined by the coastal State; design standards, construction techniques, pollution abatement and safety standards are just a few examples.

Finally artificial floating islands might be classified as new states.

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[90] Ibid.

[91] Ibid.

Artificial Floating Islands as New States

A State has been defined as ".....an entity that has a defined territory and population under the control of a government and that engages in foreign relations."[92] Lets assume that a floating city permanently moored on the high seas had a population of twenty thousand, an organized government, and engaged in foreign relations. Would it not qualify as a new State? Article 12 of the Statute of the International Court of Justice states:

> The political existence of the State is independent of recognition by other States. Even before being recognized, the State has the right to defend its integrity and independence, to provide for its preservation and prosperity, and consequently to organize itself as it sees fit, to legislate concerning its interests, to administer its services, and to determine the jurisdiction and competence of its courts. The exersise of these rights is limited only by the exercise of the rights of other States in accordance with international law.[93]

In addition, Article 4 of the Charter of the United Nations states:

> Membership in the United Nations is open to all other peace-loving states which accept the obligations contained in the present Charter and, in the judgement of the Organization, are able and willing to carry out these obligations.

It may be argued that an artificial floating island permanently moored on the high seas does not meet the factual criteria to support a finding of statehood by lacking actual land territory.

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92 Noyes E. Leech, Covey T. Oliver, and Joseph Modeste Sweeney, Cases and Materials on The International Legal System, (Mineola: The Foundation Press, 1973), pp. 726.

93 2 U.S.T. 2394, 119 U.N.T.S. 3, as amended February 27, 1967, 21 U.S.T. 607.

This argument is indeed valid. However, there have been numerous cases in international law where the factual criteria for statehood were compromised.

> For example, as a result of political compromise it was agreed at the founding of the United Nations that two of the federal states of the Union of Soviet Socialist Republics would be admitted to the United Nations as members: Byelorussian Soviet Socialist Republic and Ukranian Soviet Socialist Republic. This compromise was agreed to by the founders of the United Nations even though these units of the USSR did not freely engage in international relations with the rest of the world.[94]

If in the past, compromises were made dealing with the factual criteria for statehood, could it not be possible that permanently moored artificial floating islands having a population under the control of a government and that engage in foreign relations be accepted as new States with international recognition.

Conclusion

Are artificial floating islands vessels, structures, or are they States? The key to the problem and its appropriate response is to be found in the nature of artificial floating islands themselves. They don't completely fulfill the criteria for vessels, structures or States under the current international legal system. Artificial floating islands are indeed a new breed; a breed whose characterization and strength will be evaluated in the years to come. For now, the international legal response is one of "wait and see", awaiting the first operational, full-scale artificial floating island.

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94 Noyes E. Leech, Covey T. Oliver, and Joseph Modeste Sweeney, Cases and Materials on The International Legal System, (Mineola: The Foundation Press, 1973), pp. 731.

SUMMARY

Numerous coastal areas of the world are over-populated and suffer from industrial pollution. Artificial floating islands appear to be an answer to these, and a wide range of other issues. Ocean floating-platform technology now makes it possible to live and work on the surface of the ocean. Floating cities, electrical power generation stations and mid-ocean basing for the military are just a few of the possibilities for artificial floating islands. By virtue of their great size, stability, storage capacity, and long endurance station keeping capability, artificial floating islands will be a mid-ocean facility of great military, commercial, and scientific significance. Why then have they not received the recognition they rightfully deserve?

The answer is no different than with any new, futuristic technology. Within human nature there's always a bit of skepticism and resistance to change. The age of artificial floating islands is only now beginning. The opportunities derived from artificial floating islands in the future are limitless. Time is indeed the answer for ocean-floating platform technology. As the concept gains regulatory and socio-economic acceptance, artificial floating islands will indeed develope for the betterment of mankind.

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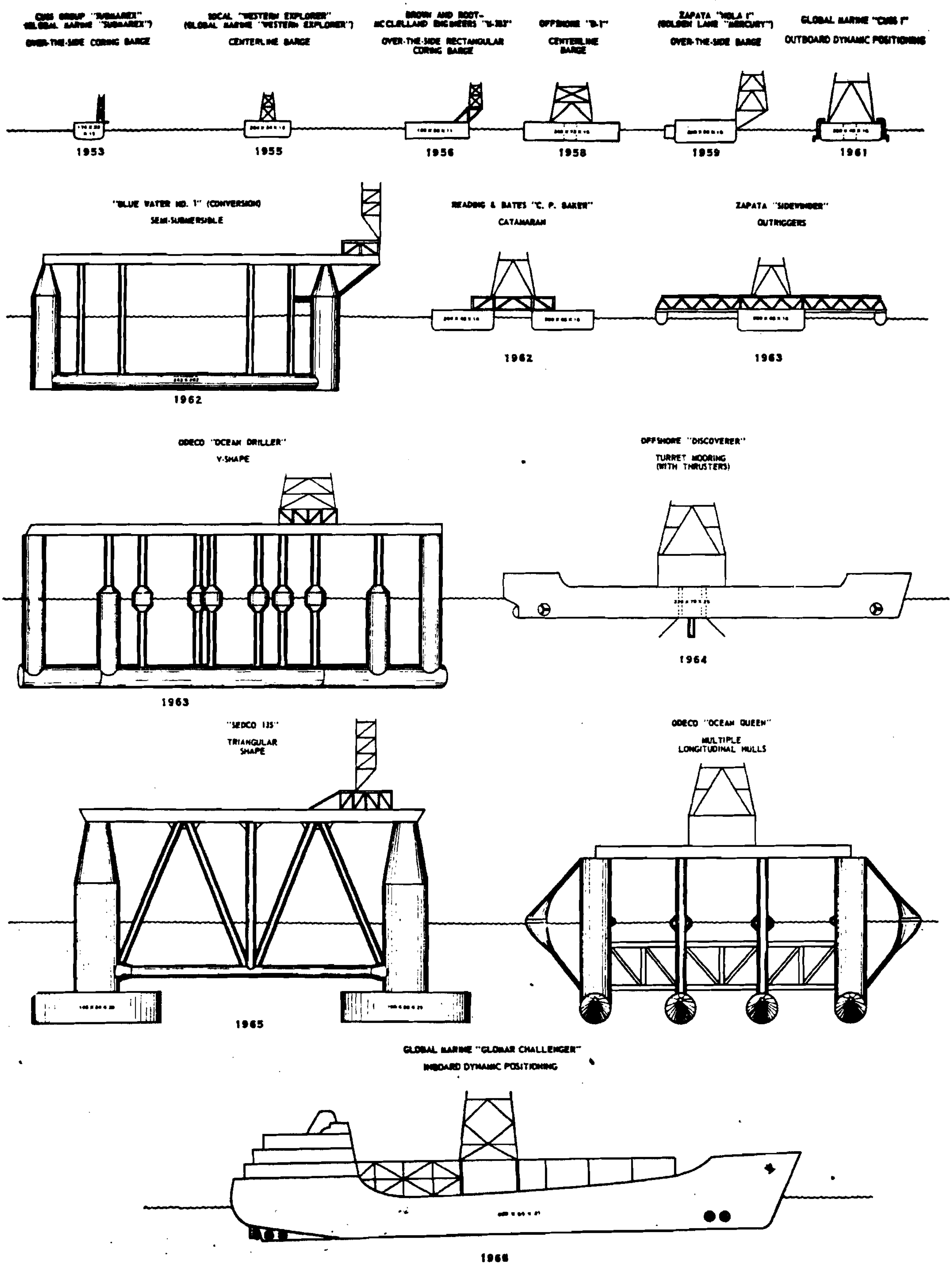
CHRONOLOGY OF FLOATING RIGS, 1953–1968



APPENDIX (2)

MAJOR RIG MISHAPS

Year	Rig	Type Of Rig	Type Of Mishap
1955	Calco "S-44"	Submersible—recessed pontoons	Damaged by blowout and fire in Gulf of Mexico—repaired and put back into service.
1955	American Tidelands "101"	Submersible—hinged pontoons	Capsized while moving off a location in Gulf of Mexico—righted and put back into service.
1956	SEDCO "Rig 22"	Submersible—recessed pontoons	Capsized at shipyard—righted and put into service.
1957	Royal/Dutch Shell "Qatar Rig No. 1"	Jack-up—square legs (barges for transport)	Broken up by a sudden storm while preparing to move in Persian Gulf—not salvaged.
1957	Glasscock Drilling Co. "Mr. Gus I"	Jack-up—mat + cylindrical legs	Tipped over while preparing to move in Gulf of Mexico—lower hull salvaged.
1957	Deepwater "No. 2"	Jack-up—triangular legs	Collapsed while drilling in Gulf of Mexico—salvaged but not returned to service.
1957	John W. Mecom "Ed Malloy"	Submersible—drydock	Drill barge destroyed by Hurricane Audrey. Drydock salvaged but not returned to service.
1958	Underwater Gas Developers "Translake No. 3"	Jack-up—mat	Capsized while being towed to first location in Lake Erie—not salvaged.
1959	Trans-Gulf "No. 10"	Jack-up—cylindrical legs	Tipped over while preparing to move in Gulf of Mexico—not salvaged.
1959	Reading and Bates "C. E. Thornton"	Jack-up—triangular legs	Damaged by blowout and fire in Persian Gulf—repaired and returned to service.
1960	Zapata Off-Shore "Nola 2"	Barge (YF)	Beached during storm in Bay of Campeche while moving to new location—not salvaged.
1961	Offshore Co. "No. 55"	Jack-up—square legs	Beached in British Honduras during Hurricane Hattie while being towed from Trinidad to U.S.—repaired and returned to service.
1961	Louisiana Delta "Delta"	Submersible—bottles	Damaged by hurricane in Gulf of Mexico—repaired and returned to service.
1962	Global Marine "SM-1"	Barge (LSM)	Sunk by storm while on location off Santa Barbara, Calif.—not salvaged.
1964	Reading and Bates "C. P. Baker"	Barge (catamaran-type)	Turned over end-for-end during blowout and fire in Gulf of Mexico—not salvaged.
1964	Blue Water "Rig No. 1"	Semi-submersible	Capsized and sank in Hurricane Hilda—not salvaged.
1965	Penrod "Rig 52"	Jack-up—mat	Capsized while moving on location in Gulf of Mexico—broken up during Hurricane Betsy—not salvaged.
1965	Royal/Dutch Shell "Orient Explorer"	Jack-up—cylindrical legs	Damaged in Mediterranean Sea while under tow from Borneo to England—repaired and returned to service.
1965	SNAM-SAIPEM "Paguro"	Jack-up—triangular legs	Destroyed by blowout and fire in Adriatic Sea—not salvaged.
1965	Marlin Drilling Co. "Marlin No. 3"	Jack-up—mat	Partially submerged while moving to location in Gulf of Mexico—repaired and returned to service.
1965	Zapata Off-Shore "Maverick I"	Jack-up—triangular legs	Lost in Hurricane Betsy—not salvaged.
1965	Royal/Dutch Shell "Triton"	Jack-up—cylindrical legs	Destroyed by blowout and fire in Nigeria—not salvaged.
1965	Royal/Dutch Shell "Bruyard"	Semi-submersible	Broke up in South China Sea while under tow—not salvaged.
1965	Compagnie General D'Equipments "Sea Gem"	Jack-up—cylindrical legs	Collapsed in North Sea while preparing to move—not salvaged.
1966	CEP "Roger Butin"	Jack-up—cylindrical legs	Tipped over after moving on location off Cameroun—not salvaged.
1966	Golden Lane "Mercury"	Barge (YF)	Capsized and sank during storm off Tuxpan, Mexico—not salvaged.
1968	Zapata Off-Shore "Chaparral"	Jack-up—triangular legs	Lost three legs during storm in Gulf of Mexico while under tow to Italy—repaired and returned to service.
1968	ODECO "Ocean Prince"	Semi-submersible	Destroyed while sitting on bottom in North Sea—not salvaged.
1968	Dixilyn "Julie Ann"	Jack-up—triangular legs	Sank while under tow during storm in Gulf of Mexico—not salvaged.
1968	Dresser Offshore "Dresser II"	Jack-up—cylindrical legs	Tipped over on location—not salvaged.

APPENDIX (3)

Summary of Plant/Site Interface Parameters

for Floating Nuclear Plants

Site Envelope

The Site Envelope is a group of limits and conditions that any and all potential FNP sites must meet. If the potential site does not meet, or cannot feasibly and economically be altered to meet the envelope requirements, then it is not suitable for FNP siting.

Plant Environmental Conditions

The envelope specifies limiting environmental conditions in which the FNP can be located. Included in this category are:

Maximum and Minimum Water Depth
Maximum and Minimum Water Temperature
Minimum Air Temperature
Minimum Sea Bottom Bearing Strength
Maximum Seismic Motion
Maximum Wave Induced Plant Motion
Maximum Rainfall Rate
Maximum Winds (Operating and Design Basis)
Atmospheric Diffusion Conditions
Meteorological Monitoring Programs
Combinations of Conditions

Site Hazards

The envelope specifies that potential FNP sites should be selected so that potential hazards to the plant are minimized. The hazards may be minimized by engineered means or by sufficient reduction of the probability of a given hazard's occurrence, or by a combination of both.

The hazards considered under the envelope include:

Aircraft Crash
Explosion in the Vicinity of the Plant
Release of Cloud of Flammable Vapor in the Vicinity of the Plants
Release of Cloud of Toxic Vapor in the Vicinity of the Plants

The last three of the above are assumed to be from a ship collision in the vicinity of the site. For riverine or onshore sites, the probabilities of land transportation accidents should be considered in addition to or in lieu of ship collisions.

Structures

The envelope requires that the design of site structures (the breakwater or other protective works, the mooring system, the circulating water catchment and outfall, and the electrical transmission structures) be such that the plant will not exceed any design basis parameters during its lifetime.

The structures serve to protect the plants from hazards such as wave damage, excessive accelerations and angular displacements, and ship collision.

The structures position the plant, provide a means of discharging heated water away from the plants, and a means of transmitting the electrical energy generated.

1. The Breakwater (protective structures)

   The breakwater must reduce wave motion inside the basin to a level such that design basis plant accelerations and angular displacements are not exceeded. It must protect the plant from ship collision, prevent the entry of floating petroleum, chemicals, bulk cargo or debris into the basin, restrict access of unauthorized personnel and vessels, and provide a path for unrestricted water flow to plant intakes, and at the same time prevent fish entrapment.

2. Mooring System

   The mooring system requirements include:

   Restricting plant horizontal motion to prevent plant contact with catchment basin and breakwater, and to ensure transmission line integrity.

   Reducing the horizontal seismic acceleration at the plant to acceptable values.

   Allowing vertical plant motion to accommodate basin water depth changes associated with tides, storm surges waves and tsunami.

Other Interface Requirements

Other requirements that are imposed upon the site structures designers, by the FNP design include the following:

1. Circulating Water Catchment and Discharge Piping

   Circulating water is discharged from the plant to a concrete catchment mounted on the basin bottom via inverted "L" shaped discharge pipes. The clearances between the plant, the discharge piping, and the catchment is designated in this interface requirement.
2. Electrical Connection to the Transmission System

   This requirement specifies the requirements for connections between the FNP and the transmission system including voltage, power transmitted, number of circuits, spares, and AEC Design Criteria to be followed in the design.

3. Miscellaneous Interface Requirements include those concerning:

   Cathodic Protection
   Plant Access
   Communications
   Security
   Emergency Plans
   Technical Specifications