SITING CONSIDERATIONS FOR FUTURE OFFSHORE
NUCLEAR ENERGY STATIONS*

by

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Introduction

Questions concerning environmental quality, priority of land uses, and public safety have created and will continue to create difficulties in finding acceptable sites for nuclear power stations. This situation has stimulated interest in nonconventional siting possibilities. Among the more attractive of these is the offshore station. Since most of the major energy consuming centers in the United States are in states adjoining either the oceans or the Great Lakes, offshore siting has broad appeal. This new concept presents opportunities for reducing environmental impacts, improving safety, and reducing construction time, resulting possibly in extensive use of the oceans to dissipate waste heat and to provide space for an expanding energy industry.

The purpose of this study¹ was to investigate the availability and characteristics of offshore sites that may be suitable for meeting future needs. A further objective was to explore directions of technological change in offshore power plants which will be necessary to match future site availability.

Investigations of offshore nuclear plants were begun in the mid-sixties and numerous offshore plant concepts have been proposed since that time. These include: floating platforms with and without bottom-supported breakwaters,²⁻⁵ bottom-seated platforms,⁶⁻⁸ artificial islands,^{9,10} and various forms of submerged plants.^{11,12} The present state of the art is defined by the concept being offered commercially by Offshore Power Systems (OPS), a joint venture by Westinghouse and Tenneco. The OPS plant, the first of which is scheduled for commercial introduction by 1980, consists of a conventional PWR mounted on a 380 by 400 ft steel

barge of shallow draft (~30 ft). The power plant is to be constructed in a shipyard-like facility and towed to the final site for emplacement inside a bottom-supported breakwater.

Offshore nuclear plants will be first applied on the East Coast of the U.S. where the water is relatively shallow and the nuclear plant siting problems are currently most severe; the OPS concept appears to be especially tailored to this application. Nevertheless, the basic concept embodies fundamental elements, especially the shallow draft floating platform that can be factory constructed, that are essential for a successful offshore plant. Thus, it is believed that advanced offshore concepts will evolve from the present basic design.

Site Availability

General Considerations

With increasing population and per capita consumption of all industrial products, suitable land for industrial sites, including nuclear sites, is dwindling and the price is increasing. A major advantage of offshore siting is that new "land" would be created. The necessity for competing with other uses for real estate would be reduced, and this could be an important factor in gaining public acceptance. To gain some perspective of the magnitude of the offshore site resource relative to the potential site demand, estimates were made of average spacing between hypothetical offshore plants for two regions - California and the Northeast - assuming that all new capacity for these regions would be located off the coast associated with each region. Future electrical generating

requirements were based on forecasts by the California Region Framework Study Committee¹³ and by the Federal Power Commission.¹⁴ The average spacing between hypothetical 1000-MW(e) blocks of capacity placed on a line parallel to the coast, shown in Fig. 1, provides a measure of potential demand for offshore sites. As indicated by Fig. 1, the average spacing along the California coast in the year 2000 would be six miles per 1000 MW(e) of new capacity if the energy demands were met under the postulated conditions. Along the U.S. Northeast Coast, the average spacing by the year 2000 would be even closer.

It is emphasized that the above examination is not intended as a realistic assessment of actual offshore siting needs or practices but is merely a device to gain general insight into the magnitude of potential site requirements. In actuality, not all incremental capacity would consist of offshore power reactors, but this is offset somewhat by the fact that part of the coastal region will not be available for reactor siting because of conflicting use requirements. It is apparent, however, that offshore reactor sites are not an inexhaustible resource and that careful planning will be required if this approach to nuclear siting is to play a major role in meeting the nation's long-term energy needs. In particular, this planning must consider the necessity of placing the required capacity in a few very large multiunit stations so as to avoid the clutter that would result from using small dispersed plants.

Furthermore, it may be necessary to locate these large stations much farther offshore than is presently envisioned to reduce visual and environmental impacts.

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Fig. 1. Offshore siting requirements to meet future power demands.

Site Availability for Offshore Plants Based on Present Technology

A survey was made to determine the approximate size and location of zones off the U.S. coast that may be suitable for siting offshore nuclear plants based on present technology. As noted previously, present technology is defined by the OPS concept which consists of a shallow draft floating platform protected by a bottom-supported breakwater. Three major factors that restrict offshore siting were investigated: the requirement for adequate remoteness from populated areas, water depths, and the separation distance from shore needed to reduce the visual and aesthetic impact of the station.

Proximity to People. The criterion used to establish the necessary separation distance between a reactor site and the population was that the cumulative population vs distance should not exceed current practice¹⁵ as represented by presently approved U.S. power reactors. The site survey was performed by considering arrays of possible offshore sites along all coasts of the conterminous United States and then calculating the associated population vs distance relationships. Locations with population curves that lay consistently at or below the envelope defined by current practice were considered suitable with respect to remoteness. The population data were based on the 1970 census; transient people were not accounted for. Typical results are shown in Fig. 2, Criterion A, for Southern California. (Criterion B, also shown in Fig. 2, is not germane to this article.) It must be recognized that the criterion used to determine acceptability of the population-distance relationship for offshore sites is quite crude; however, it is a useful tool for surveying large areas and for identifying local areas that should be investigated in more detail.

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Fig. 2. Offshore reactor siting survey, Southern California.

Offshore Reactor Siting Survey, Southern California.

Water-Depth Limitations. It is an established fact that the construction cost of offshore structures increases with water depth - therefore it appears that economics rather than engineering feasibility will determine the maximum practical depth for a plant protected by a bottom-supported breakwater. Only limited cost information is available for such plants, and therefore the following simple rationale for predicting the maximum practical water depth was applied to breakwater protected designs where some of the site related costs could be estimated. A limitation on breakwater cost of \$75/kW(e) was assumed since the alternative of building plants inland with cooling towers might entail a penalty of about this amount. For costing purposes, the breakwater was assumed to be constructed of filler rock with precast reinforced concrete tribar wave protection. The sides of the breakwater were assumed to slope 45° from the vertical, both on the exterior and interior faces, with a free-board of 40 ft. Thus the breakwater formed a protective rectangular lagoon for the platform. For a single unit the lagoon dimensions were 1100 by 1100 ft, ranging to 1600 by 1600 ft for the four-unit station. The resulting approximate costs, Fig. 3, indicate a maximum acceptable water depth of 100 ft for a four-unit [4000 MW(e)] station.

Aesthetics

The intrusion on the landscape of large shining domes, rectilinear sheet-metal buildings, cyclone fences, brick stacks, and other appurtenances of power stations are quite objectionable to many people, especially when these structures appear in a naturally scenic setting. Off-shore stations could probably be seen from a longer distance and by more people than shore-based plants. On the other hand, the impact of the

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Fig. 3. Cost of bottom-supported breakwater
as a function of water depth.

Cost of Bottom-Supported Break-water as a Function of Water Depth.

visual impression would probably be diminished because the station would have its own setting, distinctly apart from other activities. The distance offshore is an important variable with respect to aesthetics. This is illustrated in Fig. 4 which shows a true perspective of three four-unit floating power stations [4000 MW(e) capacity] located 1/2 mile, 3 miles, and 10 miles offshore. For this size station, the ten-mile plant would be almost unnoticeable; three miles offshore would probably be acceptable, and this latter distance was selected as the minimum acceptable from an aesthetic viewpoint.

Potential Sites for Bottom-Seated Breakwater Plants

Typical results of the siting survey made within the previously discussed constraints on population distribution, water depth, and aesthetics are shown in Table 1 which lists potential sites off the New Jersey and California coasts. The results shown for New Jersey are generally representative of the East Coast. Potential sites were found available continuously from Cape May, New Jersey, up to Fire Island, New York, except for a nine-mile-long stretch off Asbury Park. The distance from land, however, is considerable in some instances, reaching 15 miles near New York City.

It was concluded that most of the East Coast has an adequate number of potential shallow water sites (< 100 ft), some at considerable distance from land, to accommodate near-term requirements. As discussed earlier, far-term needs will require efficient use of available sites. Multiple unit stations producing several thousand megawatts appear advantageous near large load centers, such as the East Coast population centers. Off-shore plants deployed in arrays extending in the seaward direction may be

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Fig. 4.

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Table 1. Potential Sites Off New Jersey and California For Shallow Water Concepts

<u>General Location</u>	<u>Latitude</u>		<u>Length</u>	<u>Min. Dist.</u>	<u>Water</u>
<u>New Jersey</u>	<u>From</u>	<u>To</u>	<u>(Miles)</u>	<u>From Shore</u>	<u>Depth</u>
				<u>(Miles)</u>	<u>(Ft.)</u>
S. of Atlantic City	38°-56'	39°-17'	26	3	20-100
Atlantic City	39°-17'	39°-21'	12	3-7	20-100
N. of Atlantic City	39°-21'	39°-52'	35	3	25-100
Near Seaside Park	39°-52'	40°-8'	21	3-12	50-100
N. of Asbury Park	40°-17'	40°-36'	29	3-15	60-100
<u>California</u>					
Near San Onofre	33°-18'	33°-20'	1	3	100
Near Pt. Hueneme	34°-7'	34°-17'	10	3-9	60-100
Near Pt. Sal	34°-50'	34°-51'	1	3-5	90-100
Near Oceano	35°-5'	35°-6'	1	3-4	90-100
Near Santa Cruz	36°-53'	36°-56'	3	3-6	72-100
Near Pt. Delgada	39°-55'	39°-58'	3	3-5	72-100
S. of Eureka	40°-39'	40°-42'	3	3-4	100
S. of Trinidad Hd.	40°-59'	41°-1'	2	3-5	75-100
S. of Requa	41°-21'	41°-33'	12	3-4	80-100
S. of Crescent City	41°-41'	41°-42'	1	3-4	60-100
N. of Crescent City	41°-48'	41°-59'	11	3-5	80-100

required to limit visual impact and to afford sufficient separation between individual units.

In comparison to conditions off the East Coast, shallow water sites are very scarce off the California coast; only 11 siting areas were found with a total shoreline length of about 48 miles. Along the fast growing Southern California Coast between San Diego and Santa Barbara, only two potential sites were located. The large population and relatively deep water of the region contributed to this scarcity. Similar results were found for Florida south of West Palm Beach.

It should be noted here that some sections of coastline judged suitable for plants on the basis of aesthetics, water depth, and population distribution may not be suitable when other factors are considered.

Important additional considerations not included in this study are:

- (1) type, quantity, and importance of marine life along each section of coastline;
 - (2) proximity to load centers and transmission corridors;
 - (3) relationship to shipping lanes;
 - (4) stability of the ocean floor;
 - (5) existence of active faults; and
 - (6) compatibility with other planned uses for the coastal zone.
- These factors, which require detailed examination on a site-by-site basis, would further reduce the number of potential sites suitable for offshore plants supported by the ocean bottom.

Thus there is a need for deep-water plant concepts to meet future power requirements on the West Coast and also on part of the Florida coast. The deep-water plant would also be applicable to the East Coast, especially at such time when suitable near-shore sites become unavailable. A further incentive for the development of these new plant designs not supported on the ocean bottom is their resistance to earthquakes, perhaps allowing the introduction of nuclear reactors into regions with potentially strong seismic motions.

Problems Associated with Deep Water Concepts

The development of plants for deep-water applications requires the resolution of several fundamental issues. The feasibility of developing platforms and mooring systems to accommodate maximum sea conditions is an important question: Thomas et al.,¹⁶ have conducted exploratory investigations in this area. Other considerations include protection from ship collision and safeguards against platform sinking.

On the positive side, environmental impacts may be reduced, and there is also the possibility that for deep-water sites it may become feasible to utilize the heat sink capability and the hydrostatic pressure of the ocean in improved engineered safeguards.

Protection from Ship Collision

One safety-related question that will be of significant importance for deep-water applications of offshore nuclear plants is the consequences of ship collision. There are two kinds of damage that might be sustained by an unprotected offshore plant as a result of ship collision: (1) direct damage resulting from impact and (2) indirect damage from fire and explosion. As an example of the former, ramming by a high-speed warship might result in significant penetration because of the ship's speed, hull strength, and bow sharpness. The worst case of indirect damage might result from the full-speed impact of a tanker or ammunition ship, destruction of the ship, and burning or explosion of its cargo.

Based on studies made for the Nuclear Ship Savannah,¹⁷ it appears altogether practicable to incorporate sufficient collision protection in the platform structure to assure that essential safety functions would not be impaired by impact and penetration. It appears, however, that the

consequences of fire and explosion would be of the greatest significance relative to safety and would be much harder to deal with exclusively by platform design features. A collision preventive system would, therefore, seem to be required.

Ship Arresting System. A collision preventive system would probably include active devices, which require human reactions, such as horns, lights, and radar. But active systems would probably not be sufficient as evidenced by the fact that even with such systems collisions at sea are not rare. Thus, it would appear that a ship arresting system, which operates directly on the hull of the vessel, would be highly desirable. The system should meet the following requirements:

1. It should be essentially passive in nature so that a minimum of human or machine reactions are required.
2. It should stop or deflect a ship without serious damage to the ship. In other words, the protective system should not create the potential for fire or explosion.
3. It should be small enough so that it will not significantly interfere with coastal marine traffic.
4. It should be effective on all ships that could create sufficient damage to endanger the nuclear safety systems.
5. The cost should be reasonable — probably on the order of \$10/kW.

Hammond¹⁸ has suggested a ship arresting system which, if developed, might satisfy most of the requirements listed above. This system, shown schematically in Fig. 5, uses an arresting cable or series of cables which surround the nuclear power plant. The arresting cables are kept on or near the surface by buoys and are attached to drag anchors. When

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Fig. 5. Schematic diagram of ship-arresting system.

Schematic Diagram of Ship-Arresting System.

a ship strikes the arresting gear, it is decelerated, and eventually stopped, by the drags.

Ship Energetics. A key element in the design of an arresting system is the energy that must be dissipated by the system. The most energetic ships in the world's merchant fleet are the supertankers and high-speed container ships. Of the naval vessels, nuclear-powered aircraft carriers potentially possess the most kinetic energy. All of these ship types might be found in U.S. coastal waters. The size of tankers using waters near the U.S. coast is currently limited by the capacity of U.S. harbors. The Maritime Administration reports¹⁹ that there are no U.S. ports that can accommodate tankers of more than 80,000 dwt (~100,000 tons displacement). However, this situation is likely to change within the next decade or so. For example, the Port of Long Beach is being expanded²⁰ to accommodate tankers of about 200,000 ton displacement. The Maritime Administration has proposed¹⁹ a deep-water terminal off the Atlantic Coast which would accommodate tankers of 350,000 dwt capacity (~400,000 ton displacement). It is reasonable to assume, therefore, that within the planning horizon for offshore nuclear power plants, tankers of up to 400,000 ton displacement will be using U.S. coastal waters.

Some examples of ships with high kinetic energy that may be using U.S. waters in the future are shown in Table 2. Nuclear aircraft carriers of the Nimitz class would possess the most kinetic energy of any of the ships considered.

Table 2. Examples of Ships with High Kinetic Energy

Ship Type	Draft (ft) .	Displacement (long tons)	Speed (knots)	Kinetic Energy (ft-lbs)
Nuclear Aircraft Carrier (<u>Nimitz</u>)	~30	95,100	~40	15×10^9
Tanker (<u>Universe Ireland</u>)	81	375,811	~18	12.1×10^9
Tanker (<u>Kaimon Maru</u>)	59	205,096	~18	6.6×10^9
Container Ships				
Present	34	50,200	31	4.8×10^9
Planned	39	~75,000	35	9.1×10^9

Stopping Forces. If the ships listed in Table 2 were subjected to uniform retarding forces by the arresting system, the stopping distance would be approximately as shown in Fig. 6. In calculating the data of Fig. 6, hull drag and propulsion forces were ignored. For stopping distances of one mile or less, both of these forces are negligible relative to the forces exerted by the arresting system.

As an illustration of the forces required, the most energetic ship, a nuclear aircraft carrier, could be stopped from 40 knots in about 3/4 of a mile with a constant force of 1900 tons. An arresting system with a force capability of this amount would, of course, stop other ships in lesser distances, e.g., a 200,000 ton (displacement) tanker in about 1/3 of a mile.

Structural wire rope, sheathed with polyethylene or polyurethane for corrosion protection, would probably be a good candidate for the arresting system. Wire rope and structural strand are currently

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Fig. 6. Distance required to stop ships as a function of applied restraining force.

Distance Required to Stop Ships as a Function of Applied Restraining Force.

produced²¹ in sizes up to 4 in. in diameter with breaking strengths to 925 tons. As few as three cables might therefore suffice to arrest a large carrier. Actually, a larger number of smaller cables would probably be desirable from the standpoint of reliability.

General Plausibility. It appears that a positive ship collision preventive system would be highly desirable for offshore nuclear plants located in deep water. Although research and development would be required to demonstrate feasibility, a cable arresting system appears plausible based on present information.

Platform Sinking

The potential causes of platform sinking include ship collision, fire, explosion, and stranding. With proper attention to design details, the likelihood of sinking from these causes can undoubtedly be made very small; however, it may be difficult to demonstrate this capability convincingly, and it would therefore be only prudent to examine the consequences of sinking and to develop design features to keep the plant in a safe shutdown condition even after sinking.

In the instance of nuclear offshore stations floating in shallow water, the act of sinking may submerge the platform by only a small amount and thus the operating environment of the plant would be relatively unaffected, and adequate decay heat removal and other safety functions can probably be assured.

The potential hazards from sinking will depend in part on the depth of water, the rate of sinking, and the attitude of the platform. At intermediate water depths where platform capsize can be ruled out, it

may be possible to provide emergency power sources, a manned control station, and other prerequisites for decay heat removal, on a tall structure designed to remain above water following sinking.

In very deep water where the entire platform can become submerged, possibly overturning on the way down, the situation becomes more difficult. Plant components designed for a dry environment may become immersed in seawater and thus fail. Also, the communication links between the operator and the plant may be severed, or the emergency power supplies might become disabled, placing safe reactor shutdown in question. For these sites it may become necessary to develop a truly unsinkable hull, perhaps a platform incorporating flotation compartments filled with a low density material.

It appears therefore that the development of floating stations for deployment in deep water will require investigation of the following problem areas: (1) integrity of the reactor containment after sinking, (2) the effect of sinking on the emergency core cooling system and the power supplies essential to remove decay heat, (3) the effect of immersion on the reactor system, including consideration of thermal shocks, and (4) development of unsinkable floating platforms for sites with very deep water.

Mooring Reliability

Waves in open water may exert large forces on structures exposed to them, imposing mooring loads considerably larger than those experienced by breakwater-protected platforms. Deep-water platforms and their mooring system must be designed to cope with these forces and the resulting motions, or a shelter such as a floating wave damper must be provided to limit wave effects.

A mooring system may fail only partially, allowing the platform to move from its design position slowly, or the failure might be complete resulting in the platform becoming adrift. In either case, safe reactor shutdown can probably be assured as long as the platform is in sufficiently deep water; however, if it should run aground on a hard shoal and become immobilized during heavy weather, platform breakup becomes conceivable. Decay heat removal and other safety related functions under this circumstance would be questionable, clearly an unacceptable situation. Thus, since the mooring system forms a critical part of reactor safety, it is concluded that the system must have unusually high functional reliability so that the deep-water plants may match the safety performance² projected for land-based plants. The required reliability is probably greater than that demonstrated so far with open-water mooring systems — the practical difficulty may lie not so much in devising an adequate system but rather in demonstrating reliability convincingly. A ship arresting system of the type described in a preceding section could possibly also serve as a mooring system back-up for a deep-water plant.

Conclusions

It is evident that offshore nuclear power plants will be first applied on the East Coast of the U.S. where the water is relatively shallow and the nuclear plant siting problems are currently most severe. If present plans are implemented, the first plant should be operational by 1980. This plant will be a barge-mounted unit protected by a bottom-supported breakwater. Unless unforeseen difficulties are encountered,

rapid proliferation of offshore plants can be expected on the East Coast during the 1980's. By 1985 it is not unreasonable to expect an operational offshore plant on the West Coast. Early West Coast plants may use the breakwater technology as applied to the shallow-water, seismically inactive regions of the Eastern U.S. Widespread application to the West Coast will, however, require the development of plants suitable for deep water. In the long-term such deep-water plants are also expected to be needed for other coastal areas since suitable sites within say three miles of shore may become scarce. If so, it may be necessary to site plants much farther offshore and, consequently, in deeper water than is presently envisioned.

Several fundamental problems must be resolved in the development of offshore plants for deep-water applications; these include: (1) developing platforms and mooring systems to accommodate maximum sea conditions, (2) providing protection from ship collision, and (3) providing safeguards against platform sinking. Although some of these questions will be difficult to resolve, they do not appear intractable. Certainly the long-term benefits associated with expanding the scope of applicability of offshore siting would appear to justify the development effort required.

References

1. O. H. Klepper and T. D. Anderson, Future Siting Requirements for Offshore Nuclear Energy Stations, Transactions of the American Nuclear Society, Vol. 16, Suppl. 1, April 1973.
2. Offshore Nuclear Generating Station - Preliminary Description of a Pressurized Water Reactor, Westinghouse Electric Corporation Report prepared for Public Service Electric and Gas Company, October 1971.
3. Offshore Nuclear Generating Station - Preliminary Description of a Boiling Water Reactor, General Electric Company Report prepared for Public Service Electric and Gas Company, October 1971.
4. A Floating Earthquake-Resistant Nuclear Power Station; Daniel, Mann, Johnson, and Mendenhall Report No. 182-1-1 prepared for the Oak Ridge National Laboratory, April 1968.
5. H. G. Arnold, W. R. Gall, and G. Morris, Feasibility of Offshore Dual-Purpose Nuclear Power and Desalination Plants, ORNL-TM-1329, January 1966.
6. Offshore Nuclear Generating Station - Preliminary Concept and Site Description, Volume I, Public Service Electric and Gas Company, October 1971.
7. Power Generation Siting Study, Bechtel Report prepared for Consolidated Edison, December 1970.
8. Power, Pollution, and Public Policy - Issues in Electric Power Production, Shoreline Recreation, and Air and Water Pollution Facing New England and the Nation, MIT Report COM-72-10398, June 1971.
9. Bechtel Corporation, Engineering and Economic Feasibility Study Phases I, II, III for a Combination Nuclear Power and Desalting Plant, USAEC Report TID-22330, Vols. 1 and 2, December 1965.
10. O. H. Klepper and C. G. Bell, Underwater Caisson Containment for Power Reactors, Nucl. Eng. Design, 7: 262-278 (1968).
11. Offshore Submerged Nuclear Power Generating Station - A Preliminary Technical and Economic Evaluation, General Dynamics (Electric Boat Division) Report IRAD No. P400-452-70, July 1970.
12. Burlie A. Brunson et al., A Conceptual Design for a Semisubmerged Offshore Nuclear Generating Station, Oregon State University, October 1971.
13. Comprehensive Framework Study, California Region, Appendix XIV, Electric Power, prepared by the California Region Framework Study Committee for Pacific Southwest Inter-Agency Committee, Water Resources Council, June 1971.

14. The Federal Power Commission, The 1970 National Power Survey, Part II.
15. H. B. Piper and G. L. West, The Siting of Nuclear Reactors as Related to Urban Heat Supply, ORNL-HUD-11, August 1970.
16. D. G. Thomas, J. D. Sheppard, and R. P. Hammond, Exploratory Model Studies of Reactor Platform Motions, Transactions of the American Nuclear Society, Vol. 16, Suppl. 1, April 1973.
17. Nuclear Ship Savannah Safety Assessment, Vol. 4, Babcock and Wilcox report prepared for Marad and AEC, November 1960.
18. R. Philip Hammond, Protecting Offshore Plants from Ship Collision, Transactions of the American Nuclear Society, Vol. 16, Suppl. 1, April 1973.
19. "North Atlantic Deepwater Terminal," Ocean Industry, p. 19, October 1972.
20. The Port of Long Beach, California, Fiscal Year Report 1970.
21. "USS Tiger Brand Wire Rope," a United States Steel Catalog.