TECHNICAL REPORT NO. 1691

ORI

AN ASSESSMENT OF U.S. SHIPBUILDING CURRENT CAPABILITY TO BUILD A COMMERCIAL OTEC PLATFORM AND A COLD WATER PIPE

MARCH 1980

EDITED BY:
M. C. KOMELASKY

PREPARED FOR:
NOAA OFFICE OF OCEAN ENGINEERING
AS TASK ORDER 1.3
UNDER DEPARTMENT OF COMMERCE CONTRACT
NO. MO-A01-78-00-4137

DOE/NOAA/OTEC-26

AN ASSESSMENT OF U. S. SHIPBUILDING CURRENT CAPABILITY TO BUILD A COMMERCIAL OTEC PLATFORM AND A COLD WATER PIPE

March 1980

Work Performed Under Contract No. EG-77-A-29-1078

ORI, Inc.
Silver Spring, Maryland

U.S. Department of Energy

Solar Energy

TABLE OF CONTENTS

1.0 INTRODUCTION

As the OTEC Program proceeds towards commercialization, the emphasis is changing from the analytical to the experimental stage. Along with a multitude of tests both in the laboratory and at sea, is the initial assessment of the requirements which will be needed to construct and deploy a commercial size OTEC plant. As a part of this assessment, Lowry & Hoffmann Associates Inc. (LHA) performed for ORI an analysis of the shipbuilding requirements for constructing an OTEC plant, and the available shipyard assets which could fulfill these requirements. In addition, several shipyards were queried concerning their attitudes towards OTEC. The results of this shipbuilding study were presented in a Lowry & Hoffmann Associates Inc. report[1] to ORI.* This analysis was based on LHA's extensive experience, including a recent Maritime Administration (MarAd) study of shipyards.[2]

In assessing the shipbuilding requirements for an OTEC plant, four different platform configurations were studied and four different designs of the cold water pipe (CWP) were examined. The platforms were: a concrete ship design proposed by Lockheed[3]; concrete spar designs with internal heat exchangers (IHE) (Rosenblatt[4]) and external heat exchangers (XHE) (Lockheed[3]); and a steel ship design proposed by Gibbs & Cox[5]. The types of materials examined for CWP construction were:[6,7] steel, fiber reinforced plastic (FRP), elastomer, and concrete.

This technical report provides all the information developed from the LHA study but deletes the platform and CWP design descriptions which may be obtained from the pertinent references. The report is organized into three major discussion areas. In Section 2.0, all the construction requirements are synthesized for the four platforms and CWPs, and general comments are made concerning their availability in the U.S. Specific shipbuilders facilities are reviewed in Section 3.0 for their applicability to building an OTEC plant. In Section 4.0, an assessment of the shipyards general interest in the OTEC program is presented providing an insight into their nearterm commercial

*All references including those which define the platform and CWP designs, are listed at the end of this report.

outlook. The method of determining this interest will depend largely on a risk analysis of the OTEC system. Also included in this section are factors which may comprise this analysis, and a methodology to ascertain the risk. In the appendices, various shipyard specifications are presented (A), shipyard assessment matrices are given (B) graphs of various shipyard economic outlooks are provided (C) and definitions of the risk factors are listed (D).

2.0 SHIPYARD REQUIREMENTS

In this section, the four platform and CWP construction requirements will be identified, indicating those aspects that will require new or unique capabilities.

2.1 Platforms

The platform types are; a concrete ship with external heat exchangers (XHE), concrete spar designs with internal heat exchangers (IHE) and with external heat exchangers (XHE), and a steel ship with either IHE or XHE.

2.1.1 Concrete Ship

In the discussion of the construction requirements for the concrete ship, two types of concrete and two different construction techniques were assessed. The types of concrete were light weight concrete (lwc: 1.88 Mg/m^3 - 115 lbs/ft^3) and normal weight concrete (nwc: 2.55 Mg/m^3 - 156 lbs/ft^3). The construction techniques were: Method 1, to build the ship from the keel to the main deck, upright, and Method 2, to build the ship upside down, starting with the main deck. Method 2 would require a deep water site to turn the ship over prior to construction of the superstructure, but would reduce the depth requirement for the graving dock and access channels. Regardless of the type of concrete or construction method, working with concrete on a commercial size OTEC ship (displacement-258,000 MT) has never been attempted and no U.S. shipbuilding facility can construct this platform without modifying its present facilities. The construction requirements are tabulated in Table 2.1.

TABLE 2.1

CONCRETE SHIP XHE CONSTRUCTION REQUIREMENTS

Items		Method 1 (built upright) nwc(*)	lwc (**)	Method 2 (built upside down) nwc (*)	lwc(**)
(1) Graving dock	Length	250m (820')	Same	Same	Same
	Width	88m (289')	Same	Same	Same
	Depth	21.5m (71')	16m (53')	15m (49')	9m (30')
(2) Access channel	Width	88m (289')	Same	Same	Same
	Depth	21.5m (71')	16m (53')	15m (49')	9m (30')
(3) Shallow water site (for finish outfitting)	Depth	28.5m (93')	27m (89')	28.5m (93')	27m (89')
(4) Deep water site (for turnover)	Depth	NA	NA	36.6m	Same
(5) Concrete		46,000m^3	Same	Same	Same
(6) Flotation barges		4-20mx20m	4-20mx15m	4 with 600m^2 water-plane area	
(7) See additional requirements in text					

* nwc - normal weight concrete

** lwc - light weight concrete

The following items refer to locations identified in Table 2.1. In reference to item 1, not only is the graving dock not available in any U.S. shipyard, but in the case of normal weight concrete (nwc) ships, the required water depths are also not available. To satisfy this latter condition would probably necessitate obtaining numerous environmental and building permits which might be a very difficult process. Access channels (item 2) exist at some U.S. shipyards to a depth of 13.5m which will permit the construction of a lwc ship using Method 2. Only in the Long Beach and Puget Sound areas (16 to 21.5m depth) can a nwc ship be built, again using Method 2. Planned channel depths at Corpus Christi could apparently accommodate the nwc ship and existing depths at Long Beach and San Francisco plus planned increases at Hampton Roads and Galveston could accommodate the lwc ship. However, reliance on planned channel deepening such as in Corpus Christi, Galveston, Hampton Roads, and other areas is conjectural and should be considered only as a long range possibility.

No U.S. shipbuilder has pier depths adequate to meet the shallow water site (item 3) requirement. Only Puget Sound has reasonably sheltered conditions with these depths. Thus, other yards would be required to complete construction in open waters, increasing the risk of completing the platform. It should be noted that the installation of the warm and cold water pumps, warm and cold water discharge pipes, and the cold water intake pipe require a much greater depth and will probably be installed at the final deployment site. The last area, the deep water site, item 4 is required only for Method 2. These depths are no closer than 50 kilometers to any shipyard site which would require a long transit to the deep site and back to the shallow water site for completing the internal installation of equipment. Handling problems may arise while towing the structure to and from the site due to platform stability and flooding uncertainties. Also, the turnover process which must be performed at this deep water site has never been demonstrated on a concrete structure of this magnitude.

Items 5 through 7 of Table 2.1 cover material and equipment considerations for the concrete ship. The use of concrete for ocean structures has been very limited in the past. Most shipyards have very limited experience with lwc. Although most yards are inexperienced, the concrete technology to build a concrete structure of this size is within the state-of-the-art (SOA) for large contractors. The barges needed for an operation of this size presently exist and other equipment such as tugs, winches, and heavy lift cranes may only need minimal modification. The technical requirements (item 7) vary from plugs in the seawater system, to towing considerations of the platform and CWP. Large plugs must be manufactured for the warm and cold water plenums which must be water-tight and safe, but easily removed. The distances which must be travelled to the two proposed operating sites (Florida) for the concrete ship from the East Coast and Gulf Coast are feasible, however a new construction site on Hawaii may be preferrable to a tow from the West Coast.

2.1.2 Concrete Spar

The concrete spar platform of the commercial size OTEC plant will be a first of its kind. Both types of concrete (lwc and nwc) are being considered for the spar and two designs with internal and external heat exchangers are being examined. With a draft of nearly 130m, the use of lwc under these pressures has yet to be proven and the spar design with internal heat exchangers (IHE) would be the largest OTEC platform. Because of its size, the IHE is also considered the most difficult to build. No U.S. shipbuilder has facilities large enough to build any concrete spar, and the water depths near the shipyards are insufficient, with the exception of some areas in Puget Sound. As with the concrete ship, two construction methods are being considered. Method 1 involves building the main body of the spar as one unit. In Method 2 the body is built in two sections, upper and lower. The construction requirements for the concrete spar are tabulated for the IHE and XHE designs in Table 2.2 and 2.3 respectively.

The first four items of these tables cover construction site requirements. No existing graving dock meets the requirements of item 1 and the depths of the U.S. facilities is also a problem. For both the graving dock and the access channel (item 2), only the depth requirement for the lwc spar, using construction Method 2, can be fulfilled by most shipyards. The depth of some areas of Puget Sound meet the requirements for the lwc spar using construction Method 1, and either type of concrete spar using Method 2.

TABLE 2.2

CONCRETE SPAR XHE CONSTRUCTION REQUIREMENTS

Items			Method 1		Method 2	
			nwc	lwc	nwc	lwc
(1)	Graving dock	Length	100m (328')	Same	185m (607')(*)	Same
		Width	100m (328')	Same	Same	Same
		Depth	25m (82')	19.2m (63')	16m (53')	12.5m (41')
(2)	Access channel	Width	100m (328')	Same	Same	Same
		Depth	25m (82')	19.2m (63')	16m (53')	12.5m (41')
(3)	Shallow water site	Depth	NA	NA	36m (118')	34m (112')
(4)	Deep water site	Depth	90m (295')	70m (230')	90m (295')	70m (230')
(5)	Concrete		37,262m^3	Same	Same	Same

(6) Additional construction requirements in text

* NOTE: Both halves of spar poured at same time, therefore a single graving dock of 185m or 2-100m docks would be necessary.

TABLE 2.3

CONCRETE SPAR IHE CONSTRUCTION REQUIREMENTS

	Items		nwc	lwc
(1)	Graving dock	Length	100m (328')	Same
		Width	100m (328')	Same
		Depth	24m (79')	20.4m (67')
(2)	Access channel	Width	100m (328')	Same
		Depth	24m (79')	20.4m (67')
(3)	Shallow water site	Depth	NA	Na
(4)	Deep water site	Depth	230m (755')	180m (590')
(5)	Concrete		219,092m^3	Same

(6) Additional construction required in text.

It is noted that Det Norske Veritas (DNV) has offered an alternate scheme for spar construction; however, insufficient details are available to evaluate this suggestion. The problem with Method 2 is the need for a shallow water site (item 3) to assemble the two sections. It's depth is equivalent to the deep water site, 36.6m for the concrete ship, and these areas are more than 50 kilometers from any facility except the Puget Sound area. At the deep water site, the same type of completion work as the concrete ship must be accomplished, in addition to a significant amount of concrete pouring. The depth required for this site (item 4) is more than twice the shallow water site requirement for the XHE designed spar, and more than four times the depth for the IHE design. Most probably, the completion work on both spars will be accomplished at the operating location.

Items 5 and 6 of both tables address material and equipment requirements. The same comments on concrete problems and experience, which are presented for the concrete ship apply as well to the concrete spar. In addition for the IHE design, approximately 10% of the concrete platform is poured in the graving dock and the rest at an open water site. The XHE design has a similar problem with 30% of the concrete construction required to be completed at the deep water site. Involved in item 6 are two major engineering development problems. Plugs and valves must be designed for the seawater system. A 30m diameter plug is need for the cold water pipe plenum and 8-15m and 8-6m plugs are needed for the warm water system and seawater discharge openings. These plugs must not leak during the platform construction, must withstand a seawater pressure head greater than 50m, but must be safely removed when the warm water, cold water and seawater discharge pipes are ready to be attached. The flow valves in the warm water and sea-water discharge pipes (8-6m and 8-15m butterfly or gate valves) have similar problems. The manufacturing capability does exist, however it has never been built. The water tightness, reliability and safety of the valves are a necessity since they will be fully closed when maintenance is needed on the system. As with the plugs, the valves will also need to withstand a 50m head of water.

2.1.3 Steel Ship

The OTEC steel ship platform is of similar design to conventional commercial steel ships. There are two design options for the steel ship; with internal heat exchangers (IHE) and with external heat exchangers (XHE). There are also a variety of construction methods which increase the complexity of the operation but decrease the channel depth requirement. The easiest construction method (and the method usually used in shipbuilding) is to build the ship in a single unit, however this requires a dock larger than existing shipyard facilities. If the construction is performed segmented, then the sections can be joined either above water on barges (as large as 103m x 40m x 12m) or underwater using cofferdams. It is doubtful that floatation barges equipped with ballast tanks, pumps, etc., of the size indicated actually exist. Hence, these must be constructed and are stated to cost in excess of $40M. Their special design makes future general commercial use impractical. If the steel ship has XHEs and an installed seawater system then the barge assembly is required. IHE design steel ships do not need barges. Any of the construction methods are within an acceptable level of risk with respect to feasibility, cost and schedules.

The construction requirements are tabulated in Table 2.4. In addition to the five construction scenarios which were assessed, Lowry and Hoffmann Associates Inc. proposed an alternate method to Method 2. The existing Method 2 proposes that two longitudinal ship halves be constructed simultaneously in tandem within a proposed new 385m x 52m dock. The suggested alternate, Method 2a, would permit building each half individually in any existing dock about 195m x 52m. Each half would be separately launched, with both being welded together after the launching of the second half. This increases the total construction time, but really is not different than Method 3 or 4, where two launchings are required for the 3+1 and 2+2 ship quadrants. In reference to item 1, a dock size of 195m x 95m is required, however the largest dock available is 490m x 75m (Newport News). This is the reason for the segmented construction plans which will permit construction using existing facilities. The access channel (item 2) depth varies very little whether an IHE or XHE design is constructed and the existing channel widths and depths at most shipyards can accommodate this platform. The assembly site (item 3)

TABLE 2.4

STEEL SHIP XHE AND IHE CONSTRUCTION REQUIREMENTS

Construction Methods / Items	1 One Unit	2 Half & Half(P&S)	2a Half & Half (P&S)	3 Quadrants 3+1 (*)	4 Quadrants 2+2(*)	5 7 Lateral Sections
			Segmented Consruction			
(1) Graving Dock (for external heat exhangers; see discussion for internal heat exhanger configuration)						
Length	195m (640')	385m (1263')	195m (640')	290m (950')	195m (640')	95m (312')
Width	95m (312')	52m (170')	52m 170')	52m 170')	52m 170')	38m (125')
Depth(++)	5m(**) (16.4') 8.5m(***) (28')	Same	Same	Same	Same	Same
Lift	65,000MT	65,000MT	32,500MT	48,750MT	32,500MT	12,000MT
(2) Access Channel (for external heat exchangers)						
Width	200m	Same	Same	Same	Same	Same
Depth(+)	9m (30')	Same	Same	Same	Same	Same
(3) Assembly Site						
Width	107m (350')	Same	Same	Same	Same	Same
Draft	30.4m (100')	Same	Same	Same	Same	Same

NOTES:

- * Indicates number of quadrants or segments to be constructed
- ** Sea water pump system not installed
- *** Sea water pump system is installed
- \+ 14m (45.9') for ship with internal heat exchangers
- ++ These are depths required for barge float-off; however after ship is floated off, the total draft of ship with sea water pumps installed, may preclude return of ship for final completion. Thus, maximum outfitting should be performed during ship/barge phase.

in reality has three sites, the first to join the platform sections; the second for float-off of the completed platform; and the third for installing the cold and warm water discharge pipes, which may be done at the platform deployment site.

2.2 Cold Water Pipes (CWP)

This section covers the construction requirements for the four cold water pipe (CWP) concepts. The CWP systems will be considered from the point of being constructed by or near the shipbuilding industry. The construction concepts are:

Steel - shell and tee steel, and bottom mounted
Fiberglass Reinforced Plastic (FRP)
Elastomer
Concrete

These special pipes have not been constructed, nor does design information exist, for a 30.5m diameter size pipe which is contemplated for a commercial size OTEC plants, or in the lengths (approximately 900m) necessary to serve the cold water system. While steel pipe is well within the SOA,, the use of FRP, elastomer and concrete pipe material is not entirely within the SOA and has not been demonstrated. Before a commercial size CWP becomes a reality, the research and development effort must be completed and a small demonstration plant size CWP must be built and operated. Studies have proposed both sectional and continuous length cold water pipe construction methods. In all cases, it will be necessary to provide specialized equipment, such as cranes and barges to transport and deploy a CWP.

Since waterborne transport of the CWP is required, then the CWP construction facility should have access to the sea. Shipyards have proven experience in constructing seaworthy vessels and are a logical choice for a CWP construction facility. However, other non-shipbuilding heavy industrial plants adjacent to the water may also be able to satisfy the CWP construction facility requirements.

The ultimate manufacture of the various CWP types can be undertaken in many diverse areas of the U.S. coastline. The selected manufacturing site should be correlated with the deployment site of the OTEC platform considering the cost, risk and time of transporting the CWP. The availability of barges and certain heavy lift gear should be no problem, although some special barge types will require special construction. Shipyards can competitively produce these under separate contracts.

2.2.1 Steel CWP

There are two steel CWP construction concepts. One is the shell and tee design supported from a platform and the other is a heavier steel, bottom mounted pipe without stiffners. Under both designs, the construction concept is to build prefabricated sections ashore or on a barge alongside a pier with the sections being joined on a special barge at the final CWP deployment site. The construction requirements are presented in Table 2.5.

It is proposed to barge sections of pipe to the deployment site and to join the sections vertically on a special construction-deployment barge using a separate 1000 MT floating crane barge to handle the prefabricated CWP sections. The size of barges, tugs and cranes are indicated in Table 2.5. The weather must be reasonably calm for this operation for extended periods of time. Provision must be made to make erection site facilities seaworthy in bad weather when CWP is under construction and assembly.

Another steel CWP concept is to fabricate the entire assembly ashore and tow the entire length to the deployment site. The manufacturing and erection processes have not yet been finalized.

Steel pipe fabrication is considered within the SOA and poses no real manufacturing problem other than size and weight. The sections may be constructed in a dedicated location of the yard, either lifted (1500MT) or skidded on the transport barge and finally welded together at sea. The difficulty arises when a continuous steel pipe is being manufactured which

TABLE 2.5

STEEL CWP CONSTRUCTION REQUIREMENTS

Construction Requirements	Steel Shell and Tee	Steel Bottom Mounted
Construction Site		
Piers		
Length	185m (607')	185m (607')
Width	46m (150')	46m (150')
Depth water alongside	6m (20')	7.6m (25')
Equipment		
Barges with fitted tracks	Four (4) 122mx30.5mx6.1 DWT Cap-12, 454MT(1)	Four (4) 122mx30.5mx7.6m DWT Cap-17, 544MT(1)
Cranes	750MT at 23m	900MT at 23m
Automatic weld equipment	--	--
Rolling Mill	--	--
Tugs	Two 3.7MW (5000 H.P.)	Two 3.7MW (5000 H.P.)
Spider Stiffeners	4 per 30.5m pipe	
Special Construction Deployment barge	--	--

NOTE: (1) Barges are in current U.S. inventory.

requires some type of launching and floating storage area. Many yards or manufacturers could find floating storage logistically difficult, depending upon their locations.

The installation of a bottom mounted steel CWP is indicated for Puerto Rico. Accordingly, a manufacturing facility in Puerto Rico could be considered. If Puerto Rico proves impractical, a long tow of pipe sections will be required from the Atlantic or Gulf Coast. These comments apply to any platform location site which differs from the manufacturing location of the CWP.

2.2.2 FRP Sandwich CWP

There are two methods of fabrication of an FRP pipe. The pipe is constructed horizontally in one 900m (3000') long pipe and towed to an OTEC platform, or it is constructed vertically in short sections, and joined on site through an erection barge moon pool. The construction requirements are presented in Table 2.6.

The manufacturing facility for this work would in all probability have to be laid out specifically for the type of CWP with special forming, building, material handling arrangement, and ancillary services and equipment. A plant similar in some respects is the General Dynamics, LNG sphere manufacturing facility in Charleston, S.C.

The transport of the horizontal CWP (30.5m x 900m) from shore to the deep water upending site will require reasonably calm seas and winds for the entire operation. These same conditions apply also to the vertically fabricated sections which are barged and joined at the site.

The installation of the FRP CWP is considered for locations in Florida, Hawaii and Puerto Rico. Manufacturing facilities for the horizontal CWP, which is towed as a 900m unit, should be as close to those locations as practical. However, the vertical segmented CWP may be barged to the platform development site for installation.

TABLE 2.6

FRP SANDWICH CWP CONSTRUCTION REQUIREMENTS

Construction Site	Method No. 1 Horizontal	Method No. 2 Vertical segmented
Construction Channel		
Length	900m (3000')	--
Width	35m (225')	--
Depth of water	5m (16')	--
Access Channel		
Width	300m (984')	--
Depth of water	10m (35')	--
Dock		
Length	--	100m (328')
Depth of water	--	5m (16')
Equipment		
Core assembly unit FRP wrapping machine	Horizontal access	Vertical access
Crane	50MT (49LT)	500MT (490LT)

2.2.3 Elastomer CWP

The elastomer CWP concept proposes a series of collapsible fabric type pipe sections supported and joined at the ends by 1.5m wide steel or concrete rings 30.5m in diameter. Each section would measure 28.6m long with the fabric expanded. Seven of these sections would be joined ashore to make a 200m (656') expanded unit for deployment at the erection site through a special moon pool construction-deployment barge. The construction requirements are stated in Table 2.7.

The facility for fabricating sections of the CWP in 200m units will require a dedicated area for this specific purpose with suitable storage space and job designed material handling equipment. Environmental problems may also be significant.

Special jigs and automatic welding stations will be required to fabricate the steel rings. Concrete ring fabrication will require dedicated facilities consisting of heavy lift cranes and concrete mixing and pouring facilities.

The pipe transfer from transportation barge to deployment barge and for assembly requires reasonably calm seas and good weather for an extended period of time. The TRW study indicates a 71-day time span[6].

Since elastomer CWP is recommended for location off Hawaii and Puerto Rico, the manufacture of the pipe closest to these sites or other finally selected sites is preferable; however, barging is manageable.

2.2.4 Lightweight Concrete CWP

This pipe is made of lightweight concrete with a density of 17.5 Mg/m^3 with a submerged weight of 39.3 MT per linear meter and dry weight of 82 MT per meter. It would be constructed in approximately 15m (50') vertical sections. Buoyancy tanks will be provided to reduce the total submerged

TABLE 2.7

ELASTOMER CWP CONSTRUCTION REQUIREMENTS

- 30.5m (100 ft) diameter mandrel
- Calendar based on 10m (32.8 ft) wide conveyor belting
- 28.6m (94 ft) pipe section lengths constructed by vulcanizing belts longitudinally
- Steel fabricating shop or concrete plant facility to fabricate the rings
- Construction site to assemble 28.6m (94 ft) sections into 200m (656 ft) lengths onshore or direct onto the barges
- Onshore crane with a lifting capacity of 1,500 MT

weight and thus reduce the forces transmitted through the section connections. The construction requirements are tabulated in Table 2.8.

This concrete pipe fabricating plant will be a dedicated area for the CWP construction with suitable storage and material handling equipment.

The 15m lwc pipe sections will be transported by oceangoing barges having suitable ballast tanks and pumps to adjust for loading conditions. A large number of these barges are currently available for sale or rent.

In addition, a special deployment barge of adequate size equipped with four hydraulic jacks and a 36m diameter moon pool is required for assembling the various pipe sections. This type barge can be constructed. The first pipe section is picked up from the transport barge with the help of a 2000 MT derrick barge crane and lowered onto the deployment barge. This capacity derrick barge is currently in existence.

As is similar in the installation of all types of CWP, the concrete pipe also requires reasonably calm seas and good weather for extended periods of time.

The lwc pipe construction is possible through most of the U.S., although there is a cost and time advantage in utilizing facilities that may now exist. The pipe could be manufactured either in or away from a shipyard. However, the manufacturing site should be reasonably close to the pipes' deployment site since more than 60 - 15m long sections are required and the transportation time and cost become factors. The pipe could also possibly be built in more than one facility.

3.0 SHIPYARD ASSESSMENT

3.1 Capability of the U.S. Shipbuilding Industry

The structure of the shipyard industry is defined by the U.S. Department of Labor's Standard Industrial Classification Manual, (SIC) Code

TABLE 2.8

LIGHTWEIGHT CONCRETE CWP CONSTRUCTION REQUIREMENTS

Concrete Plant

- Reinforcing bar shop
- Prestressing shop
- Concrete casting area
- Warehouse and storage area
- Batching plant with aggregate and cement storage
- Steel fabrication shop for buoyancy tanks
- Pier facilities for unloading and loading
- Laboratory

Transport of sections within facility - either 2000 MT gantry crane, rollers or walkers.

Materials - 45,000 m^3 lwc
6,000 MT rebar

3731, as that industry which covers shipbuilding and repairs. It consists of approximately 140 commercial facilities. The total employment has increased gradually from 114,000 in 1961, up to a peak of about 175,000 in 1977. As of November 1979, it employed a total of 170,300.

The industry is diversified and is engaged in the construction of both large and complex Navy vessels and merchant ships, with a present emphasis on Navy vessels in many of the major yards. The geographical distribution of the major yards in the industry is indicated in Figure 3-1. The industry depends to a large extent on Government funding, either direct support for the Navy and other federally owned ships, or indirect support by subsidies, tax benefits, etc., for privately owned merchant ships, tankers, barges and tugs. Appropriations for FY 79 totalled $7,934 million to cover these programs, a significant portion of which purchased sophisticated equipment to be installed by the yards in the ships. It is estimated that the industry's value of work done was about $7,581 million in 1979 for both Government and privately sponsored work.

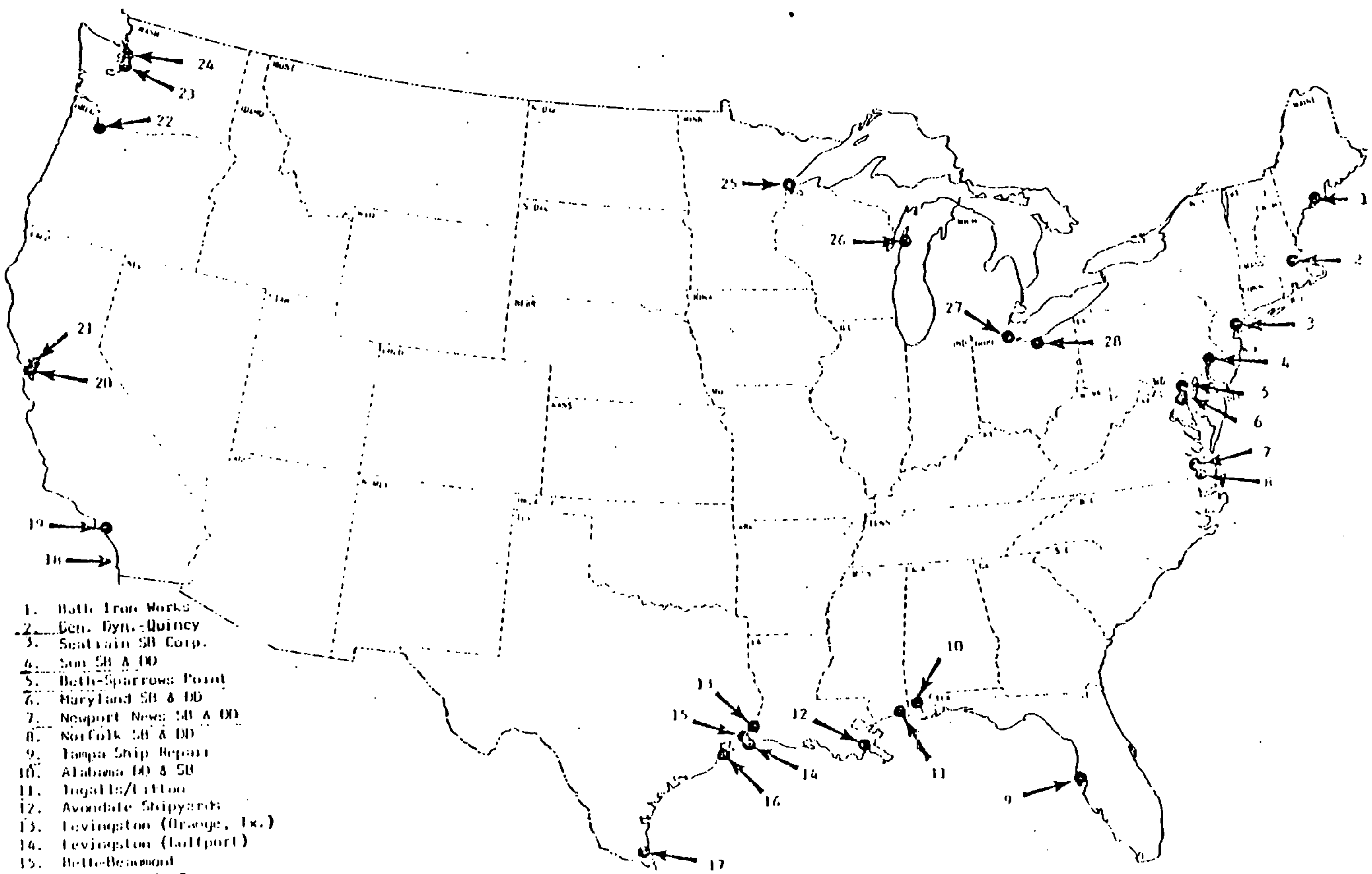
3.2 Shipyard Selection

3.2.1 Criteria for Selecting Shipyards

An overall analysis of the U.S. shipbuilding industry, and the special requirements for constructing OTEC platforms and cold water pipes (CWP), indicates that some of the shipbuilding and/or repair yards should not be seriously considered for many reasons. For example, a repair yard with a large construction dock would be expected to dedicate the use of the dock to its primary interest, namely repair work. In addition, many repair yards are rarely, or only sporadically engaged in major construction, and as a result lack the engineering, management, labor force, facilities, etc., to construct any complex platforms. They may, however, have an interest in dedicating a portion of their facilities to the exclusive use of CWP construction. In addition, non-shipyard waterfront facilities can be readily adapted for CWP construction. The selection of the construction location is heavily dependent upon the deployment site of the platform, which affects the transportation problems and costs.

Figure 3-1

SHIPBUILDING INDUSTRY IN THE UNITED STATES



1. Bath Iron Works
2. Gen. Dyn.-Quincy
3. Seatrain SB Corp.
4. Sun SB & DD
5. Beth-Sparrows Point
6. Maryland SB & DD
7. Newport News SB & DD
8. Norfolk SB & DD
9. Tampa Ship Repair
10. Alabama DD & SB
11. Ingalls/Litton
12. Avondale Shipyards
13. Levingston (Orange, Tx.)
14. Levingston (Gulfport)
15. Beth-Beaumont
16. Galveston SB Co.
17. Marathon LeTourneau
18. NASSCO
19. Todd-Los Angeles
20. Beth-San Francisco
21. Triple "A"
22. FMC Corporation
23. Lockheed SB
24. Todd Seattle
25. Fraser Shipyards
26. Bay SB Corporation
27. American SB Co., Lorain
28. American SB Co., Toledo

MAJOR AMERICAN SHIPYARDS
BUILDING CAPACITY - SHIPS 475 FEET IN LENGTH OR OVER

The shipyard assessment indicates that the CWP may be manufactured in many shipyards and other facilities throughout the U.S. Thus, transportation of the pipe becomes manageable to any of the proposed platform deployment sites, providing the pipe is built in bargeable sections. Whole pipe lengths of about 900m, require towing which may prove difficult, even over reasonable distances. However, it can be accomplished.

Table 3-1, Proposed Location of Platforms Versus Possible Construction Sites, lists the types of platforms, types of CWP and the tentatively selected platform deployment sites. Analysis of various shipyard capabilities derived in this study indicates that there are no construction sites available for spars on the Gulf or East Coasts, unless new construction methods are developed. Additionally, towing of these spars from the West Coast is unmanageable. It is therefore believed that spars as described in this report cannot be used at Puerto Rico or Florida sites. From the viewpoint of construction and platform development sites, the concrete and steel ship platforms show distinct advantages.

TABLE 3-1

PROPOSED LOCATION OF PLATFORMS VERSUS POSSIBLE CONSTRUCTION SITES

Type Platform	CWP Type (1)	Platform Development Sites	Suggested Platform Construction Site
Concrete Ship	FRP	Florida	Gulf or East Coast
Concrete Ship	Elastomer	Hawaii	West Coast or Hawaii (2)
Concrete Spar XHE	FRP	Hawaii	Puget Sound or Hawaii (3)
Steel Ship	FRP	Hawaii	Preferably West Coast, could build Gulf or East Coast
Steel ship	Elastomer	Puerto Rico	East or Gulf Coast
Concrete Spar IHE	FRP	Florida	No available site (4)
Concrete Spar IHE	Elastomer	Puerto Rico	No available site (4)

(1) CWP may be manufactured in any area of continental U.S.; however, consideration must be given to whether the pipe is built in bargeable sections or as a whole unit which requires towing.

(2) Hawaii construction is considered difficult, but not impossible.

(3) Hawaii offshore construction is hazardous, also towing from Puget Sound is difficult but possible.

(4) Primary problem is the long tow distance from Puget Sound and lack of suitable water depths in Gulf and East Coast for construction.

3.2.2 Selection Process

An analysis of the 28 major U.S. shipyards shown in Figure 3-1 shows the following:

- Shipyards capable of constructing one or more versions of an OTEC platform:

  General Dynamics - Quincy
  Sun Shipbuilding
  Bethlehem - Sparrows Point
  Newport News S. B.
  Tampa Ship Repair Yard
  Ingalls - Litton
  Avondale
  National Steel and S. B.
  Bethlehem - San Francisco Repair Yard
  Triple A Repair Yard
  Lockheed S. B.

- Facility capabilities for these shipyards are given in Appendix A.

- Shipyards no longer in operation:

  Seatrain S. B.

- Shipyards located in the Great Lakes where access to the Atlantic Ocean is limited to the 75 foot beam in the St. Lawrence Seaway locks:

  Fraser Shipyards
  Bay S. B.
  American S. B. - Lorain
  American S. B. - Toledo

- Shipbuilding and repair yards not considered suitable as OTEC construction candidates, and who lack many requirements, chief of which are suitable building ways or docks, supplemented by lack of one or more additional capabilities, such as, necessary access channels, deep water sites, engineering, adequate skilled work force, complex construction experience, and/or financial capability:

  Bath Iron Works
  Maryland S. B. & D. D.
  Norfolk S. B. & D. D.
  Alabama D. D. & S. B.
  Levingston (Orange)
  Levingston (Gulfport)
  Bethlehem - Beaumong
  Galveston S. B.
  Marathon Le Tourneau
  Todd - Los Angeles
  FMC Corp.
  Todd - Seattle

The selection of shipyards is based on analyzing each yard's capability of constructing at least one version of an OTEC platform. The minimum denominator is the size of the construction dock, after which consideration must be given to many other factors necessary to complete the structure ready for sea. As presented on the previous page, only seven of the major U.S. shipyards qualify, to which number has been added three repair yards which have the physical capability and one yard which does not presently have facilities, but must be considered a good prospect. The selected yards are distributed throughout the East, Gulf and West Coasts, which have the advantage of relating the platform construction site with its ultimate deployment location.

Appendix A cover the facility capabilities for each of the 11 yards. Indicated are data on number and size of construction docks, shipways, water depths over dock sill, principal crane capacities and nearest floatation site necessary to complete construction. There is also a diagram showing the plant layout for each yard. It should be noted that not all yards use graving docks, rather some like Sun, Avondale, and Ingalls-Litton have building sites from which the ships are launched via a floating dock. Information on the shipyards has been developed from MarAd, the Navy and private sources. Table 3-2 summarizes and highlights the selected shipyard characteristics and also makes reference to access channel depths.

In assessing the capability of shipyards, consideration is given to constructing all four platforms and four CWP configurations. While the yards will lack some of the required facilities to construct the concrete ship or spars; nevertheless, some yards may have sufficient capabilities in non-concrete areas that may possibly influence them to consider providing additional facilities, including a new graving dock, or joining a consortium to construct the concrete ship or spar.

As was previously discussed, the steel ship is the platform most suitable for construction in several U.S. yards throughout the country. The concrete ship with XHE, the concrete spar with XHE and the concrete spar with IHE, will be increasingly difficult to construct, in the order listed.

The variety of construction methods provides steel ship construction opportunities to many yards. The alternate Method 2a, would add Bethlehem Sparrows Point, Ingalls, Avondale, National Steel, and Sun to Newport News who already meet Method 2 requirements. It should be noted that Sun and Avondale could build each half simultaneously in separate docks, and Ingalls would build both sections on shore and launch sideways onto its floating dock. The lift capacities of the floating drydocks would dictate the amount of construction and outfitting performed before launching and what would be accomplished after launching. A summary of shipyard capability by coastal

Table 3-2

SUMMARY OF BASIC SHIPYARD CHARACTERISTICS AND CAPABILITIES

Shipyard	Facility No. & Type	Maximum Ship Size LOA Beam	Depth Over Sill	Access Channel Depth	Shipyard Capability to Construct Steel Ship Platform (1) 1	2	2a	3	4	5
General Dynamics Quincy, Mass. (2)	BD	936' x 143'	28'	35'	0	0	0		0	X
	2 BD	860' x 123'	28'	35'						
	2 BD	860' x 144'	22'	35'						
Sun S.B. & D.D. Chester, Pa.	2 Slabs	700' x 195'	-	40'	0	0	X(9)	X	X	X
	2 SW	745' x 129'	-							
	2 FD	350' x 195' (3)	28'	40'						
Bethlehem Steel Sparrows Point, Md.	GD	1200' x 192'	29'	30'	0	0	X	X	X	X
Newport News S.B. Newport News, Va.	GD	1600' x 240'	32'	40'	0	X	X	X	X	X
	GD	1100' x 136'	40'	45'						
	GD	960' x 124'	35'	45'						
Tampa	GD	896' x 146' (4)	36'	25'	0	0	0	0	0	X
Ingalls S.B. (West Bank) Pascagoula, Miss.	FD	896' x 176' (5)(6)	41'	40'	0	0	X(9)	X	X	X
Avondale Shipyard New Orleans, La.	Slab	1020' x 174' (5)(6)	-	-	0	0	X(9)	X	X	X
	SW	1200' x 126' (6)	-	40'						
	FD	1000' x 216'	37'	45'						
National Steel & S.B.	GD	980' x 170' (7)	16'	23'	0	0	X	X	X	X
Bethlehem Steel San Francisco, Calif.	FD	950' x 144'	37.6'	39'	0	0	0	0	0	X
Triple A Machine Works San Francisco, Calif.	GD	1088' x 136' (8)	47'	37'	0	0	0	0	0	X
Lockheed S.B. Seattle, Wash.	2 SW	600' x 95'	35'	60 +	0	0	0	0	0	0
	1 SW	690' x 90'	35'	60 +						
Total Number of Shipyards Capable of Building Steel Ship Platforms					0	1	6	6	6	10

X = Has capability; 0 - Lacks capability.

TABLE 3-2 (continued)

NOTES:

(1) Based on six suggested alternate construction methods.

(2) Fore River Bridge width limit is 175'.

(3) FD used for launching and joining ship halves up to 700' x 195' to make maximum length of 1400'.

(4) Under construction.

(5) FD used for launching ships constructed on-shore.

(6) Can construct several ships in parallel and simultaneously on each shipway.

(7) Launching draft would require close control.

(8) Former Navy Yard facility leased to Triple A.

(9) Two longitudinal halves may be built simultaneously and then launched.

BD - Building Dock

Slab - Level building area

FD - Floating Dock

GD - Graving Dock

SW - Shipway

X - Yard has capability to construct

O - Yard does not have capability to construct area utilizing the various steel ship construction methods discussed is as follows:

Number of Yards Capable of Constructing Steel Platform

Method	East Coast	Gulf	West Coast	Total Yards
1	0	0	0	0
2	1	0	0	1
2a	3	2	1	6
3	3	2	1	6
4	3	2	1	6
5	4	3	3	10

The construction methods of the steel platform should not preclude the possibility of either end or side launching by yards other than Ingalls and Avondale. It is impossible to predict what methods the interested yards would undertake and finance, or what yards that do not have adequate construction docks, such as Lockheed in Seattle, would undertake in modifying sliding ways to accommodate the ship. There are many variables and the assessments are based only on existing facilities. Table 3-2 summarizes the physical capability assessment for shipyard construction of the steel ship platform.

Based on the criteria for selecting shipyards, a list of U.S. shipyard candidates has evolved. These are considered among the most qualified to construct the steel ship platforms. Using these yards as a base, their qualifications for constructing the concrete ship and concrete spars have also been evaluated. This selection does not preclude the possibility of future shipyard changes and interests, or major construction companies teaming with a smaller shipbuilder or repair yard.

3.3 Capability Assessment of Selected Yards

It is clear that while the U.S. shipbuilding industry is able to construct the steel ship platform, it has significantly less capability in the construction of the concrete structures without major investments and considerable ingenuity. The industry's ultimate interest in OTEC will be greatly influenced by the lack of normal shipbuilding work, the future and magnitude of OTEC programs, the facility and financial requirements, the risks of the project, and the prospect for financial gain.

In this section, a summary analysis is made for each of the selected yards considering overall capability, available facilities, anticipated workload, and possible interest. Comparative assessments have been made on each yard, based on requirements for each different platform type and the methods of construction, to which the following comparative rates have been applied:

Rating Level	
3	Full capability
2	Good, requiring some upgrading
1	Limited, requiring considerable upgrading
0	No existing capability

Ratings are applied to both steel and concrete construction, even though the yard may not have a dock in which the platform would be built. For example, the yard may have a #2 rating for engineering necessary to construct a concrete ship, indicating that concrete designers would be required. If a #1 rating is applied, it implies a serious deficiency in meeting the requirements. Similarly, a #3 rating indicates full potential capability in those areas so rated, even though the yard has never constructed a concrete structure. The individual shipyard assessments are presented as Appendix B.

The following is a brief overview of how future workload would affect the selected shipyards:

3.3.1 General Dynamics, Quincy:

The shipyard has delivered 12 highly successful Liquified Natural Gas (LNG) ships with spherical LNG tanks. Due to its success in this field, it is expected the yard would obtain significant portions of this work if it becomes available. This yard is also capable and has built complex combat and auxiliary Navy ships. It is believed that G.D. would give preference to LNG and Navy contracts, if available, but might do OTEC (steel construction) if construction dock space were available.

The only permissible steel construction would be by using Method 5 or the seven lateral sections. Since the Fore River Bridge, which is the access to Quincy Harbor, has a width of only 150 feet, it will be necessary to connect the ship sections outside of the yard in addition to considerable outfitting, not possible during the section construction. This yard is fully qualified to undertake this work; however, it would require a new facility to build a concrete ship platform or spar. It is questionable whether the commercial shipbuilding segment of the corporation would invest in a new facility. G.D.'s Charleston, S.C. LNG plant has only a 20 foot water depth.

3.3.2 Sun S. B. & D. D. Co.

Sun is primarily a commercial shipyard undertaking very little Navy work up to this time. The yard will continue to be a strong competitor for all merchant ship construction. Sun has a proven record of successfully managing complicated projects, i.e., Manhattan Arctic conversion and the Glomar Explorer.

There has been a recent management change which has resulted in great interest in construction of Navy auxiliaries. It is possible that Sun might be active in offshore oil drilling ship/rig construction if this market becomes more active for East Coast drilling.

OTEC construction appears to be the type of work Sun is qualified to undertake, and would tend to receive special consideration. The yard's new facility has the space and flexibility to accommodate the steel ship platform and possibly any of the four types of CWP. Whether it would participate in concrete construction is questionable due to water depths and new dock site requirements.

Sun may encounter special problems of building the steel platform on barges and moving the barge/ship units onto the floating drydock for launching.

3.3.3 Bethlehem, Sparrows Point

Like Sun, Bethlehem is a commercial yard which in recent years has specialized in tankers and cargo ships with no Navy work in the last ten years. Bethlehem will be a strong contender for tanker construction in the 1980's and in LHA's opinion, would be well suited for steel OTEC structures. The layout of the yard is such that they could provide space for manufacturing of the four CWP concepts. LHA also expects Bethlehem to bid on Navy auxiliaries.

The yard is well qualified to undertake the steel ship platform, either at its own facilities or as a second choice through its San Francisco affiliate for which it could supply the engineering, skill and supplemental management. Due to limited local and access channel depths, the yard would have difficulty with concrete construction. Bethlehem also builds jack-up rigs in Beaumont, Texas.

3.3.4 Newport News

Newport News is the largest shipyard in the world and the premier Navy shipbuilder. In the foreseeable future, combat ship Navy construction will be the principal business at Newport News. The new commercial yard is designed particularly to construct very large cargo carriers (VLCC) and LNG ships. If work of this type is available, it would probably be preferred over OTEC work. Nevertheless, of all the U.S. shipyards, Newport News is considered the most capable with a large building dock, a 900 ton crane, complete support shops, and the largest and most diversified shipyard engineering force in the U.S. It could also fabricate any of the CWP types. Newport News does have an offshore technology interest and can be expected to follow the emergence of OTEC projects.

3.3.5 Ingalls Shipbuilding Co.

The new Ingalls shipyard is at present totally dedicated to Navy construction and intends to remain in that field if at all possible. In the absence of in-hand extensions to its present Navy program, it is considering the construction of drill rigs. Ingalls has its older East Bank yard which could still construct medium sized merchant ships; however, it is not active in shipbuilding at present.

The layout of the shipyard and the space available could provide excellent potential for OTEC construction of the steel or concrete ship type platforms and all types of CWP. If Navy combat ship construction does not fully utilize the yard's capacity, it is expected that its secondary preference would be Navy auxiliaries and non-nuclear Navy warship overhauls.

3.3.6 Avondale Shipyards

The Avondale Shipyard in New Orleans is one of the most versatile and successful shipyards in the United States. It has shown a preference for commercial construction over a wide range of products from barges to LNG ships. This range of work includes Coast Guard Cutters, tankers, cargo ships, Navy frigates, drill ship conversions, Navy tankers, etc. LHA believes the steel OTEC structure would be of interest to Avondale in view of past experience of successfully taking on unusual projects. It is believed, however, that Avondale would give preference to construction of commercial ships of their own design, of which there are many, rather than to Navy combat ships or OTEC work, if it required a large capital investment.

Avondale has another offshore construction facility in Bayou Black, Louisiana, that builds steel offshore structures. This facility offers a potential site for CWP construction and possibly the concrete ship platform; however, there will be a draft problem.

3.3.7 National Steel (NASSCO)

National Steel is the largest private shipyard on the Pacific Coast and historically builds large merchant type ships, i.e., dry cargo, bulk carriers, tankers, and Navy auxilaries. It is believed that NASSCO would have an order of work preference placing tankers first, Navy auxiliaries second, and OTEC structures third, because of the probable need to make capital investment and the lack of space. With existing facilities NASSCO could build the steel ship platform using Methods 2a through 5. It is questionable if space is available for CWP construction. It should be noted that NASSCO is owned by Morrison-Knudsen, a large international construction contractor fully experienced in concrete work.

3.3.8 Bethlehem Steel, San Francisco

This Bethlehem yard is presently undertaking repair work; however, up to about 10 years ago had been constructing merchant ships. There is no present indication that this Bethlehem yard will venture back into shipbuilding. However, the parent Bethlehem company has the financial, managerial and technical ability to support its San Francisco repair facility.

It is believed that this yard would not endeavor to undertake platform work, but it certainly could manufacture any type of CWP with the required special equipment.

3.3.9 Lockheed S. B., Seattle

Lockheed and its predecessor, Puget Sound Bridge and Dredge Co., have been active in shipbuilding for many years in the Seattle area. Lockheed is highly versatile and has constructed complex merchant ships, ice breakers, Navy auxiliaries and large ferries. The yard will endeavor to continue its Navy work. The shipbuilding facility has been expanded from the original yard, Plant #1, to include Plant #2 located just across the river in West Seattle. This latter plant is expandible.

While the present yard does not have the capability to construct any of the several versions of the steel ship platforms or concrete platforms, it does have the close proximity to deep water in Puget Sound. In addition, the Lockheed Missile and Space Company's interest in OTEC programs makes Lockheed S. B. a prime candidate for construction of the platforms, especially in the concrete field.

3.3.10 Tampa Ship Repair and Triple A Machine Shop

Both of these repair yards have been included in the assessment since they have adequately sized graving docks to build the steel ship platform under Method 5. However, they, as well as many other repair yards which were not considered in this study, do not meet the overall requirements to undertake a successful OTEC platform construction. They lack depth of experience, skilled manpower, engineering, etc., which are all requisites for an OTEC undertaking. It is anticipated that these two and other repair yards will emerge in the OTEC program through civil engineering or turn-key contractors. The yards should have the capability of acting as subcontractors for modules and for the CWP.

3.3.11 Offshore Structure Manufacturing Facilities

Along the Gulf Coast a number of facilities have been expanded or especially established for building offshore structures, such as drilling platforms, production jackets, and semi-submersible drilling platforms. Among the largest of these yards are:

J. Ray McDermott & Co.
Avondale - Bayou Black (See Avondale Shipyards).
Levingston Shipyard
Bethlehem - Beaumont
Alabama Dry Dock
Marathon Shipbuilding - Vicksburg and Brownsville

Offshore structure facilities have a good potential for building OTEC structures; first, because phases of OTEC technology are familiar to these firms; and secondly, their facilities are generally more flexible and easier to rearrange than the conventional shipyards.

If these facilities are not fully committed in the 1980's to their customary work, the OTEC program might look attractive, providing the yards can write off capital costs for new required facilities, and providing sufficient water depths become attainable.

In addition, consideration may be given to Off-shore Power Systems, Jacksonville, Florida, who are normally geared to floating nuclear power plants. This company could handle concrete, providing platform design changes were to be considered.

4.0 ASSESSMENT OF U.S. SHIPBUILDING INTEREST IN OTEC PROJECT CONSTRUCTION

This study has thus far discussed the construction and deployment requirements of OTEC platforms and CWPs. It is clear that the construction of the steel platforms and CWPs are well within the capability of the existing U.S. shipbuilding industry, without the need of major facility investments or an appreciable change in project management practices.

4.1 Economic and Risk Assessment

The construction of the concrete platforms and CWP, other than steel, are types of work with which the shipbuilding industry has little experience. The contribution of the shipbuilding industry toward the concrete ship or spar type platforms would be its engineering, hydrodynamic expertise and experience in ship outfitting, as well as supplementing facilities with a skilled labor force. Certain large yards would also be capable of organzing a consortium of shipbuilding and non-shipbuilding skills needed for such a project. Conversely, large heavy civil engineering construction companies with experience in concrete structures and chemical or petroleum refining plant construction would be equally and possibly better equipped to take the lead in organizing and managing this type of project, with the shipyard taking a subordinate role.

The construction of concrete, FRP, and elastomer CWPs involves concepts which apply existing technology to structures much larger than ever built before. The problems of satisfactorily connecting CWP sections at the deployment site also have not been fully resolved, and are not examined in this report. It appears that the risk involved in meeting schedules and early cost estimates are great. The pipe project is one that a shipyard or civil engineering firm could organize and manage. It is believed that the closest comparison to CWP type of construction problem is the fabrication of the large tanks for LNG ships being built by G.D. Quincy and Avondale. In both instances, new facilities were built for the express purpose of fabricating these large highly complex aluminum tanks. Quality control was the principal difficulty in meeting Government regulations.

OTEC construction bears a marked similarity to the giant offshore structures, but being much larger and heavier. Offshore construction in the U.S. utilizes steel and is performed historically in shipyards or special facilities concentrating on this work. It would be expected that yards with offshore expertise, mostly in the Gulf area, might show a preferential interest in OTEC work. The aerospace industry with its extensive experience in managing multibillion dollar, high technology projects may also show great interest in OTEC. This is indicated by Lockheed Missile and Space Co. involvement in OTEC for the past several years.

As the platform and CWP selection narrows and the many design, funding and management problems are resolved, it is anticipated that other yards, industrial contractors and consortiums may show increased interest in OTEC construction.

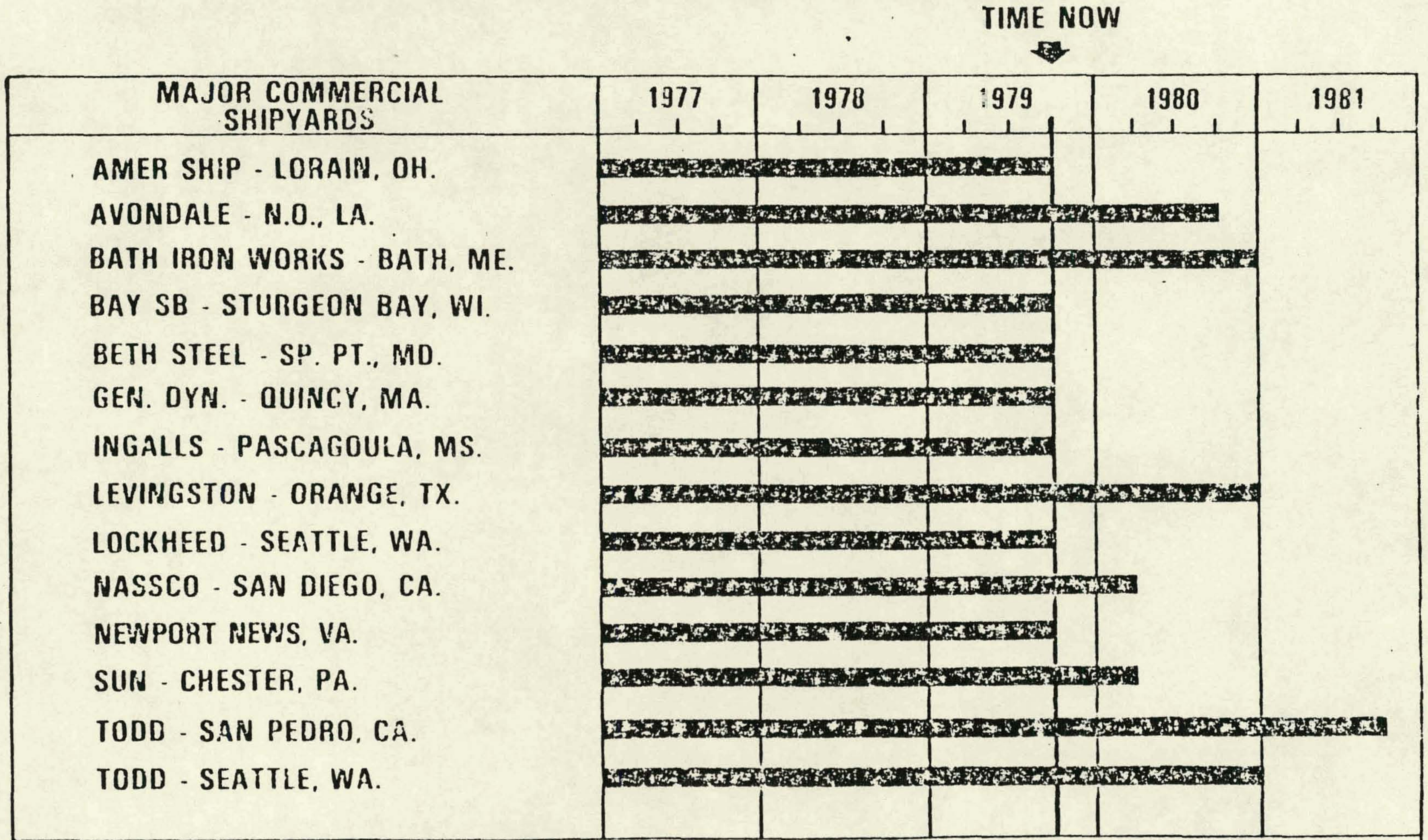
At this time, most U.S. shipyards are in need of work, as is demonstrated in a recent assessment of major yards by the Maritime Administration in Figure 4-1. This does not indicate the whole story. Figure 4-2 shows the total manning requirements for work under contract on October 1, 1979, for the 25 largest U.S. shipyards. It is apparent that new contracts are needed to maintain employment at present levels. Figure 4-2 also indicates the increase in shipyard employment on the basis of projections made by MarAd and Navy which will be discussed hereinafter.

Section 3.0 of this report further identifies the shipyards that are considered to have the greatest potential from a facility, engineering and

FIGURE 4-1

SHIPYARD STATUS: NEED FOR NEW BUSINESS

U.S. DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION



END OF BAR INDICATES WHEN YARD NEEDS NEW CONTRACTS IN ORDER TO MAINTAIN ADEQUATE BACKLOG FOR AVAILABLE FACILITIES AND MANPOWER. ASSUME 8 MONTH ADMINISTRATIVE AND PRE FAB TIME (LEAD TIME BEFORE KEEL LAYING).

management point of view to construct OTEC structures. Appendix C contains the employment projection for each of these yards which illustrates that most of the work now under contract will be essentially completed by 1982.

As already mentioned, Figure 4-2 shows the projected U.S. shipbuilding total workload based on best program estimates through FY85. Even with this additional work, the total industry employment would drop below the current 1979-80 level. This indicates a need for significant program increases to maintain employment at the current level.

These program projections are in a constant state of flux. Currently, there are a number of major initiatives the Government has under consideration that could increase the shipyard workload and employment projections substantially. Some of these are:

(1) Increased Navy construction in the 1980-1985 time frame from about 65 to 95 ships, including construction of 14 commercial type mobilization ships
(2) Program to replace large steam turbine propulsion plants with diesel engines in about 70 commercial ships
(3) A 28 ship dry bulk ship program
(4) The early rebuilding or modification of U.S. tanker fleet to meet increasingly stringent IMCO and U.S.C.G. requirements
(5) The possible enactment of cargo preference or bilateral trade agreements increasing the share of U.S. foreign trade carried in U.S. ships, and hence increased commercial construction
(6) Increased demand for offshore drilling ships, platforms, jackups, etc.

The possibilities would increase the demand on shipyards and would be competing with OTEC for skilled personnel, building dock and facility space in the 1980's.

On the other hand, there is the possibility that certain features of the "Omnibus Maritime Bill" H.R. 4769 would become law which permits certain U.S. flag ships to be built overseas. This, it is believed, would take work

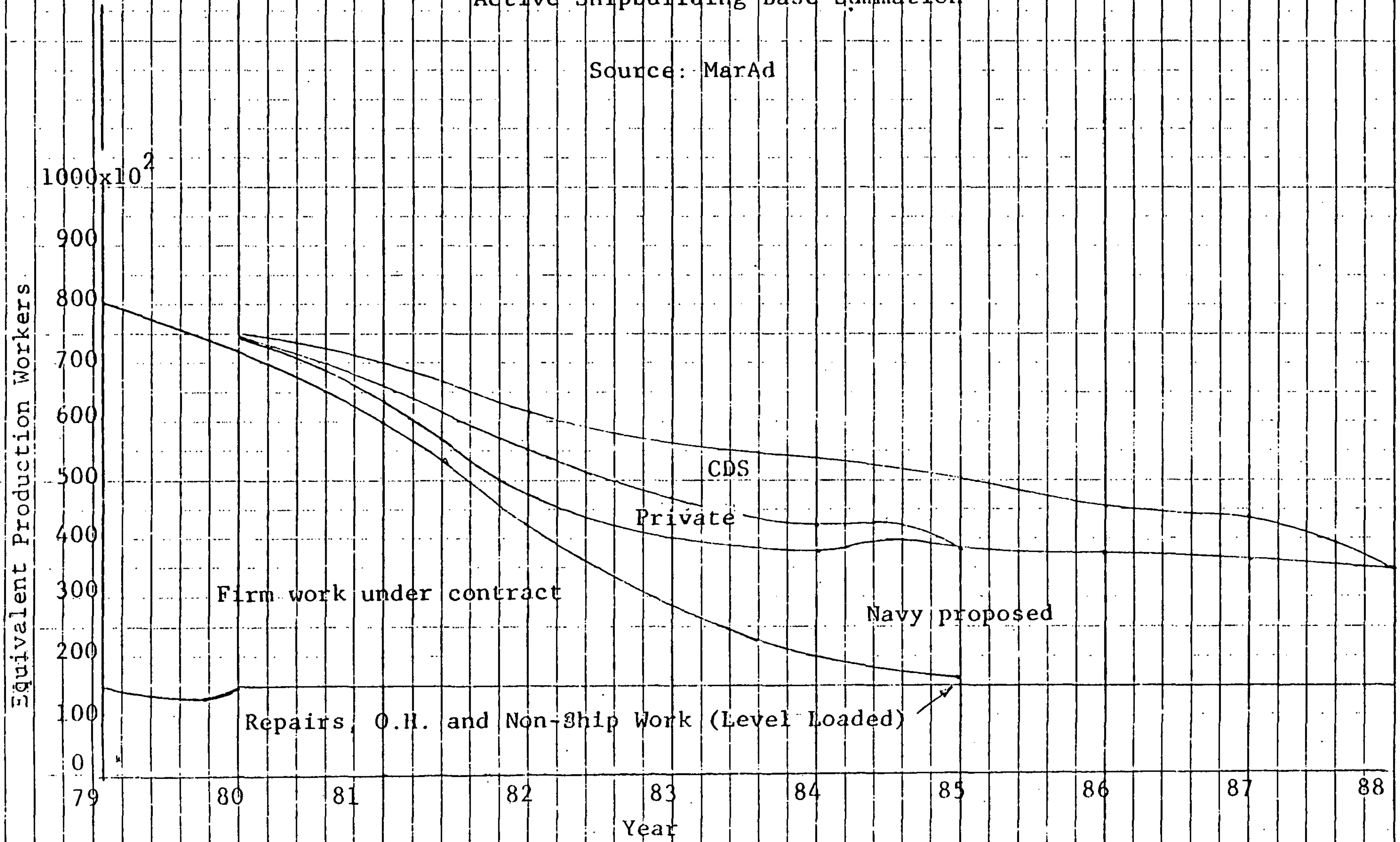
FIGURE 4-2

SHIPBUILDING INDUSTRY WORKLOAD PROJECTION

Based on 25 Major Shipyards

Active Shipbuilding Base Summation

Source: MarAd



away from U.S. shipyards and depress employment by about 11,000 production workers. However, some compromise on this legislation is anticipated. In any event, the yards best suited for OTEC construction would be the ones acquiring the bulk of the Navy and large merchant ship construction contracts in the 1980-1990 time frame.

In assessing the capability and attactiveness of OTEC construction, consideration must be given to funding, contracting methods and responsibilities. The preferable method of constructing, transporting, deploying and starting up of the 400MW OTEC plant, would be through a turn-key operation. The current cost of this project without even considering escalation into the mid 1980's will easily exceed one-half billion dollars and may well approach one billion dollars. Whether any single contractor or consortium would undertake a turn-key operation of this magnitude and risk is undertermined.

Alternatively, the project could be divided into a number of discreet contracts or combinations thereof, such as:

- Construction of complete platforms, including energy systems
- Transportation of platform and deployment
- Attachment of modules and seawater systems at site
- Construction of CWP
- Transportation of CWP to site
- Assembly of CWP and attaching to platform
- Mooring system
- Transportation system
- Start-up.

The degree of overall responsibility and dollar value of the many OTEC phases will influence potential contractor interest during the bidding and/or negotiating period.

4.2 OTEC Outlook

In an attempt to determine current interest of the shipbuilding industry in OTEC structures, officials of six major shipyards were informally contacted. The shipyards contacted were:

- Bethlehem
- General Dynamics- Quincy
- Newport News
- Avondale
- NASSCO
- Lockheed

All of these shipyards expressed interest in OTEC and were all interested in steel structures. In most cases, little interest was indicated for concrete structures or building new facilities unless the OTEC program offered good prospects for long term profitable work.

Two shipyards, Lockheed and Newport News (Offshore Systems, Inc.) seem very interested in OTEC without particular regard to materials or configuration. Avondale indicated interest also in heat exchangers and would subcontract the concrete work.

In all cases the shipyard interest would ultimately depend upon more complete technical data, and size and length of the OTEC construction program.

4.3 Risk Assessment Methodology

The preceding review of OTEC construction requirements and assessment of the present capability and experience of the U.S. shipbuilding industry, suggests that a substantial range of risks may be involved in the construction and program management of OTEC structures. The risks also involve meeting budget estimates and the associated time schedules.

4.3.1 Definition

Risk is defined as exposure to the chance of injury or loss and the degree of probability of such loss. The OTEC program has developed and analyzed a great number of alternative structures and equipment concepts which involve many new and innovative designs and construction procedures.

The credibility and success of the OTEC program will depend on thorough, objective, highly professional planning. This must include a realistic evaluation of risk factors involved in design, construction, outfitting and deployment, and also meeting time schedules and budgeted costs.

In order to evaluate the varying degrees of risk, the following factors have been identified:

I. Risk management philosophy
II. Technical state-of-the-art
III. Technical talent required
IV. Availability of construction facilities
V. Field supervisors and specialists required
VI. Deployment capability
VII. Efficiency of program organization
VIII. Capability of program management
IX. Probability of meeting schedules
X. Probability of staying within budget
XI. Probability of continuity of funding
XII. Vulnerability of "Acts of God"

For each of these above factors, four levels of risk have been identified, namely:

Level 1 - Low
Level 2 - Normal
Level 3 - High
Level 4 - Very High

Each risk level for each of the aforelisted factors is defined in Appendix D and thus each factor is defined.

4.3.2 Procedure of Analysis

In order to display the relative levels of risk, Figure 4-3 has been

FIGURE 4-3

SAMPLE OTEC STRUCTURE RISK ASSESSMENT

FACTOR	Platforms: Concrete Ship Right Side Up	Concrete Ship Upside Down	Concrete Spar XHE	Concrete Spar IHE	Steel Ship Method 1	Steel Ship Meth. 2, 2a	Steel Ship Method 5	CWP: Steel	Concrete	FRP	Elastomer	Ships: 200,000 DWT Tanker	130,000 m^3 LNG
I. Risk management philosophy.	-	-	-	-	-	-	-	-	-	-	-	1	1
II. Technical state of the art.	2	2	3	3	2	2	2	2	2	3	3	1	2
III. Technical talent required.	3	3	4	4	2	2	2	2	3	3	3	1	2
IV. Availability of construction facilities.	4	4	4	4	2	2	2	2	2	2	3	1	2
V. Field supervisors and specialists required.	2	2	3	3	2	2	2	2	3	3	3	2	2
VI. Deployment capability.	2	4	4	4	2	2	2	3	3	3	3	1	1
VII. Efficiency of program organization.	-	-	-	-	-	-	-	-	-	-	-	1	1
VIII. Capability of program management.	-	-	-	-	-	-	-	-	-	-	-	1	1
IX. Probability of meeting schedules.	3	3	4	4	2	2	3	2	3	3	3	2	2
X. Probability of staying within budget.	3	3	4	4	2	2	2	2	3	3	3	1	2
XI. Probability of continuity of funding.	2	2	3	3	2	2	3	2	2	2	2	2	2
XII. Vulnerability to "Acts of God."	4	4	2	2	4	4	4	2	2	2	2	4	4

developed as an illustrative effort showing the general consensus of the study participants. Included as a base are risk evaluations for a 200,000 DWT tanker and a 130,000 cubic meter LNG ship for comparison with the various OTEC structures considered in this report.

When analyzing the judgments enumerated in Figure 4-3, it is not recommended that the risk level of each of the several factors be averaged, since no attempt has been made to assign relative weights to individual factors. It is considered that such weight assignment would be of little value when an unacceptable risk level in any one of the factors might completely disqualify the OTEC structure from consideration.

It should be noted in Figure 4-3 that we have not considered:

I. Risk management philosophy.
VII. Efficiency of program organization.
VIII. Capability of program management.

as we have no knowledge of these specific factors. It is recommended that the evaluation of risk be a continuing process by OTEC management which would attempt to reduce unnecessary identifiable risks as the program progresses.

5.0 FINDINGS

This assessment study provides the basis to determine U.S. shipbuilding capability to construct the 400 MWe OTEC platforms and corresponding cold water pipe. The findings enumerated herein are based on design and engineering studies made available by the Government. It is recommended that when selecting the final OTEC platform to be built, that a review of the design for ease of construction be performed in order to facilitate program completion within schedule and cost.

Table 5-1, U.S. Shipyard Capabilities of Platform Construction, is a summary of each platform type under varying construction methods. It indicates the availability of graving docks, access channels, and shallow and deep water sites. A number of findings have evolved, which are:

TABLE 5-1

U. S. SHIPYARD CAPABILITIES OF PLATFORM CONSTRUCTION

Platform Type	Graving Dock		Access Channels (2)		Shallow Water Site (1)		Deep Water Site (1)	
	nwc	lwc	nwc	lwc	nwc	lwc	nwc	lwc
Concrete Ship XHE Method 1	NA	NA	Puget Sound	Puget Sound Long Beach San Fran.	Puget Sound (7)	Puget Sound (7)	Not Required	
Concrete Ship XHE Method 2	NA	NA	Puget Sound Long Beach San Fran.	Puget Sound Long Beach San Fran.	Puget Sound (7)	Puget Sound (7)	Not Required	
Concrete Spar XHE Method 1 (8) (9)	NA	NA	Puget Sound	Puget Sound Long Beach	Not Required		Puget Sound (3) (10) (11)	Puget Sound (3) (10) (11)
Concrete Spar XHE Method 2 (8)	NA	NA	Puget Sound Long Beach San Fran.	Many U.S. sites, Hawaii Puerto Rico	Puget Sound	Puget Sound	Puget Sound (3) (10) (11)	Puget Sound (3) (10) (11)
Concrete Spar IHE	NA	NA	Puget Sound (10)	Puget Sound (10)	Not Required		NA	Puget Sound (3) (10) (11)

TABLE 5-1 (continued)

Steel Ship (XHE and IHE)				
Method 1	NA	Available	Available (6)	Not Required
Method 2	1 - East Coast			
Method 2a	3 - East Coast 2 - Gulf 1 - West Coast	Available	Available (6)	Not Required
Method 3	3 - East Coast 2 - Gulf 1 - West Coast	Available	Available (6)	Not Required
Method 4	3 - East Coast 2 - Gulf 1 - West Coast	Available	Available (6)	Not Required
Method 5 (5)	4 - East Coast 3 - Gulf 3 - West Coast	Available	Available (6)	Not Required

NOTES: NA - Capability not available.

(1) Sheltered or partially sheltered sites
(2) Consider channel depths presently available.
(3) Completion site, where very large portion of work is actually performed.
(4) Original Method 2 proposes constructing two longitudinal halves in single long dock; however, it is assumed that each half may be constructed in sequence or in two separate docks, each then floated out and joined. This increases the number of potential yards in all coastal areas.
(5) Method 5 may be used, but considered impracticable and costly.
(6) Site where platform sections are floated off barges after welding together, usually in 100' water.
(7) For attaching modules; platform after outfitting may be towed to module installation site.
(8) While concrete spar XHE may be started in several U.S. sites other than Puget Sound, the greatest portion of work must be accomplished in deep water, either Puget Sound or off-shore.
(9) DNV has developed alternate construction methods; however, insufficnet design data available to evaluate shipyard capability.
(10) Puget Sound work restricted by draft limitations of 30 fathoms in Port Townsend area for tow-out to sea.
(11) Consider off-shore construction work beyond Fort Townsend in the Strait of Juan de Fuca to be hazardous and risky.

- OTEC platform construction increases in difficulty in the following sequence:
  1. Steel ship platform (either XHE or IHE)
  2. Concrete ship platform with XHE
  3. Concrete spar with XHE
  4. Concrete spar with IHE

- The steel ship platform may be built with existing facilities in a number of shipyards having complete capability throughout the U.S. (See Table 5-1)

- Construction of the concrete ship with XHE is feasible on the West Coast providing a suitable building dock and concrete plant are built. However, only the Puget Sound area has sufficient depth to permit upside-down construction, Method 2, with either nwc or lwc and complete outfitting.

- U.S. shipyards have the general capability to construct the concrete ship platform. Since a new or supplemental yard is required, large shore-side or offshore heavy construction firms, either alone or in a consortium with a shipyard or others, may also be interested.

- The concrete spar with XHE (Methods 1 and 2), with either nwc or lwc, may only be constructed in the Puget Sound area. While there is sufficient sheltered deep water between Seattle and Everett, it should be noted that channel restrictions of about 30 fathoms near Port Townsend would require the spar to be towed to sea in a horizontal position. In addition, any offshore work accomplished in the Strait of Juan de Fuca would be considered hazardous and costly.

- The concrete spar with IHE using lwc may only be constructed in a suitable dock in the Puget Sound area. The same tow-out draft problems exist, as indicated for the spar with XHE, resulting in horizontal towing to sea conditions. The construction of the spar with IHE using nwc is not possible in the continental U.S.

- The prime contracting interest for the concrete spars is believed to be large shore-side or offshore heavy construction firms, with the possibility of enlisting aid from shipyards and other specialty groups. Several shipyards have, however, shown bona-fide interest in any OTEC work. Reference has been made to possible offshore construction of the concrete spars in the Hawaiian Islands where moderate sea conditions are usually encountered. Facilities for this construction do not presently exist on the islands. Moreover, the area does encounter storms which would add to the cost and risk of construction. In addition, transportation and labor costs are greater in Hawaii than in the continental U.S.

- Assuming the designs, materials and manufacturing methods of the various CWPs have been determined, the construction of these pipes may be accomplished by any of the major shipbuilders, providing the builder is willing to establish a separate manufacturing center, preferably within the yard's physical boundaries. The CWPs can also be constructed by any competent major manufacturer in the U.S. with access to water transportation. It is noted that transportation of a sectional pipe on barges is much less complicated than towing the entirely assembled pipe.

- The shipbuilding industry is currently in a declining employment mode through 1982; however, some stablization is anticipated based on Navy and MarAd estimates through FY85.

- Planned, but yet indeterminante, Navy programs, if finally funded, would place considerable work in the major shipyards historically constructing Navy ships, thus decreasing that segment of the industry's interest in OTEC platform construction.

- Passage of the "Omnibus Maritime Bill" H.R. 4769, if passed as originally written, would depress U.S. commercial shipbuilding; however, some compromise of this bill is anticipated, which would remedy this defect.

- U.S. shipyards, in a broad context, would prefer either Navy and/or commercial ship construction, providing such long-range programs are available, unless OTEC construction offers promise of long-term more profitable work.

- It is believed that there is sufficient shipyard interest to construct the steel ship platform.

- There are a number of smaller shipyards who have neither the facilities or the present expertise to construct the platforms. However, after a final selection of platform type has been made and additional engineering has been completed, it would not be unreasonable to have one of the smaller yards, in a consortium with others, show interest in the bidding or negotiating.

- Construction of the steel ship platform could commence in the early 80's providing the final design and contract plans were completed. However, in the absence of design and plan finalization, it is believed construction could only start in the mid 80's. For similar reasons, plus the need for new facilities, the construction of the concrete ship and spar will not commence until the late 80's.

- The overall risks associated with most OTEC structures to be built within budget and on time appear to be substantially greater than large or complex commercial ships.

REFERENCES

1. L.C. Hoffmann, "Assessment of OTEC Construction in U.S. Shipyards", Lowry & Hoffmann Assoc., Inc., 29 January 1980.
2. U.S. Department of Commerce, Maritime Administration, "1978 Report on Survey of U.S. Shipbuilding and Repair Facilities", December 1978.
3. Lockheed Missiles & Space Company, Inc., "OTEC Platform Configuration and Integration Study", LMSC-D623756, April 1978.
4. M. Rosenblatt & Son, Inc., "OTEC Platform Configuration and Integration", MR&S-5142-6, 7 July 1978.
5. Gibbs & Cox, Inc., "Ocean Thermal Energy Conversion (OTEC) Platform Configuration and Integration", 18351-10, June 1978.
6. TRW, "Ocean Thermal Energy Conversion Cold Water Pipe Preliminary Design Project", D02715, 20 November 1979.
7. Science Applications, Inc., "OTEC Modular Experimental Plant Cold Water Pipe System Design Study" SAI-063-80R-071-LA, December 1979.
8. Deep Oil Technology, Inc. and Det Norske Veritas, "Construction Feasibility of OTEC Platforms," December 1978.
9. Department of Defense and Department of Commerce, Office of the Coordinator for Ship Repair and Conversion. "Principal Shipbuilding and Repair Facilities of United States", 1 September 1978.
10. John J. McMullen Assoc., Inc., "Review of Reports by Gibbs & Cox, Lockheed and Rosenblatt on 400 MWe Commercial OTEC Plants", May 1979.

Back up Blank

APPENDIX A

FACILITY CAPABILITIES OF SHIPYARDS

FACILITY CAPABILITIES FOR SHIPYARDS

Name: General Dynamics Corporation
Quincy Shipbuilding Division
97 East Howard Street
Quincy, Mass. 02169

1. Type of facility - graving docks

2. Dock dimensions - 5 qualifying docks

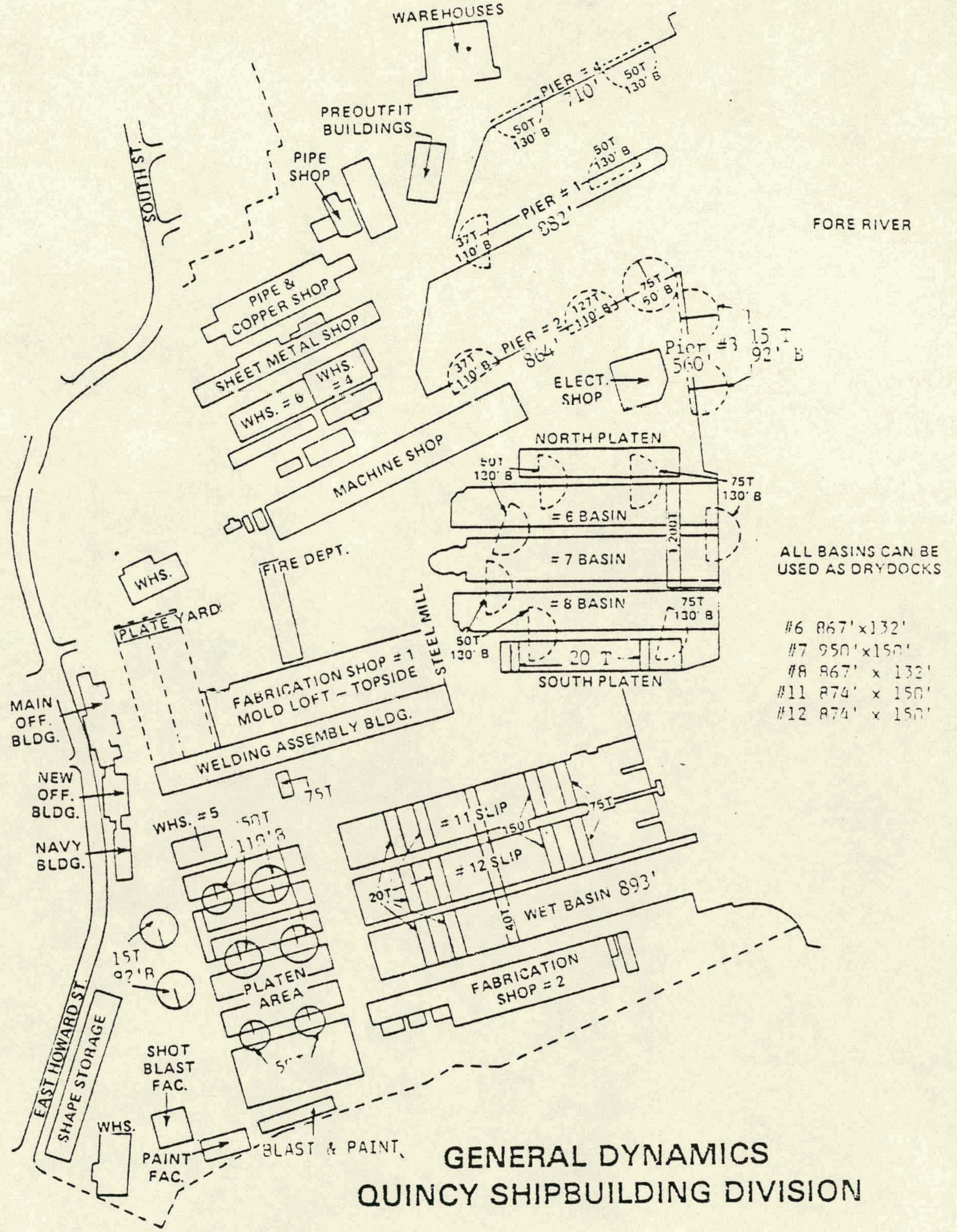
Dock Size	Maximum Ship Size LOA-Beam	Depth Over Sill
1 - 950' x 150'	936' x 143'	28'
2 - 867' x 132'	860' x 123'	28'
2 - 874' x 150'	860' x 144'	22'

3. Crane Lift Capacity

   1 - 1200 ton gantry - services (drydocks) basins #6 and #7
   1 - 150 ton gantry - slips #11 and #12

4. Nearest flotation site - 80.5 km (50 mi.) Cape Cod Bay - 20 fathoms of water

5. 175' wide bridge limits access to yard



GENERAL DYNAMICS
QUINCY SHIPBUILDING DIVISION

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Sun Shipbuilding & Dry Dock Corp.
Foot of Morton Avenue
Chester, Pa. 19013

1. Type of facility - floating drydock and shipway

2. Dock dimensions - 4 qualifying shipways

Shipway Size	Maximum Ship Size LOA-Beam	Depth Over Sill
2 - SW 700' x 197'	1400' x 195' (when joined)	
2 - SW 741' x 139'	745' x 129'	
2 - FD 350' x 197'		28' (Used for launching and (joining ship halves.)

3. Crane Lift Capacity

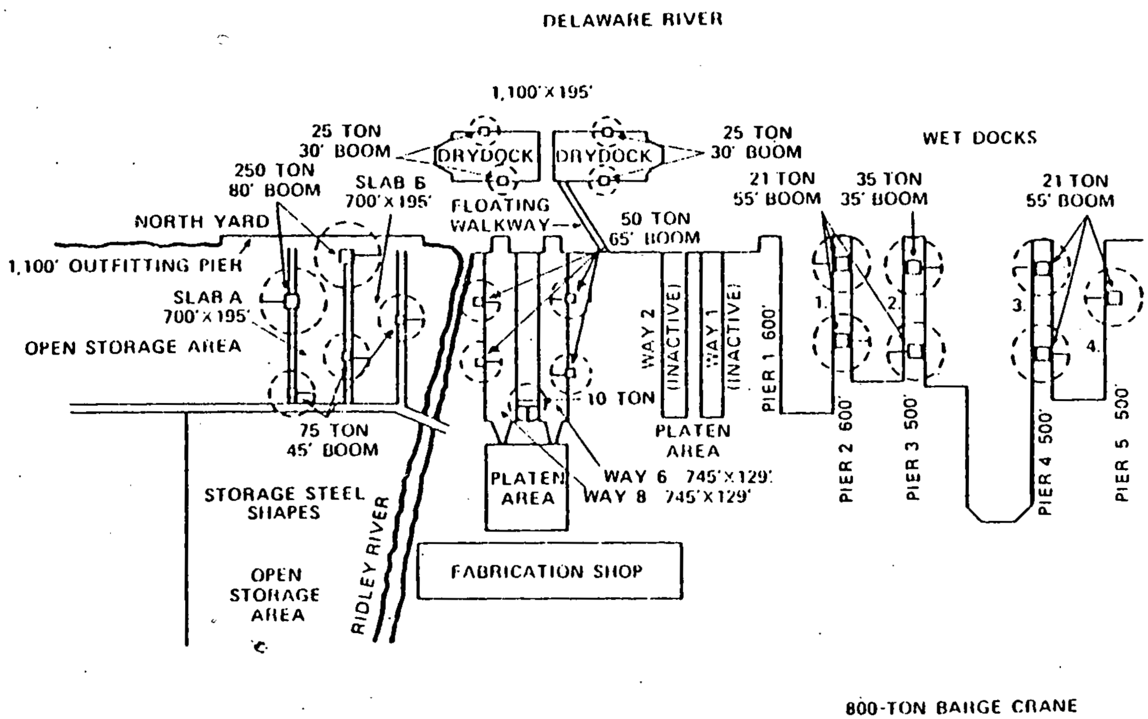
   1 - 800 ton barge crane

   1 - 250 ton boom

   - 75 ton

4. Nearest flotation site - 152.9 km (95 mi) through Delaware River and Delaware Bay to 20 fathom curve of the Atlantic Ocean. Due east of Cape Henlopen.

SUN SHIPBUILDING & DRYDOCK CO.



56

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Bethlehem Steel Corp.
Sparrows Point Yard
Sparrows Point, Md. 21219

1. Type of facility - graving dock

2. Dock dimensions - 1 qualifying

Dock Size	Maximum Ship Size LOA-Beam	Depth Over Sill
1200' x 201'	1200' x 192'	29'

3. Crane Lift Capacity

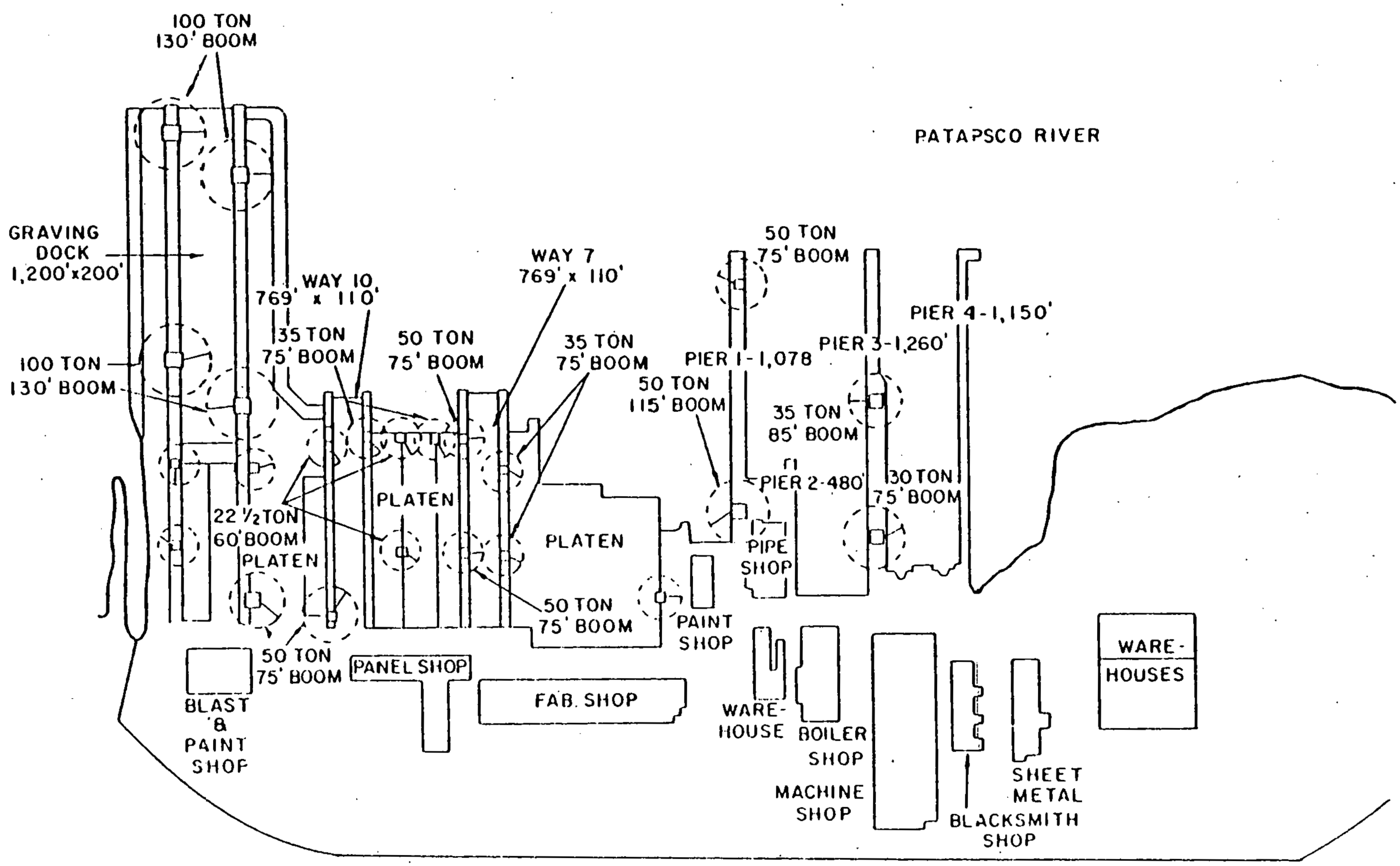
   2 - 100 ton rail cranes

   75 x 50 ton tower cranes

4. Nearest flotation site - 290 km (180 mi) through Chesapeake Bay to 20 fathom curve 72.4 km (45 mi) due east of Cape Henry.

BETHLEHEM STEEL CORPORATION

SPARROWS POINT YARD



FACILITY CAPABILITIES FOR SHIPYARDS

Name: Newport News Shipbuilding and Dry Dock Co.
4101 Washington Avenue
Newport News, Va. 23607

1. Type of facility - graving docks

2. Dock dimensions - 3 qualifying docks

Dock Size	Maximum Ship Size LOA-Beam	Depth Over Sill
960' x 128'	960' x 124'	35'
1100' x 140'	1100' x 136'	40'
1600' x 250'	1600' x 246'	32'

3. Crane List Capacity

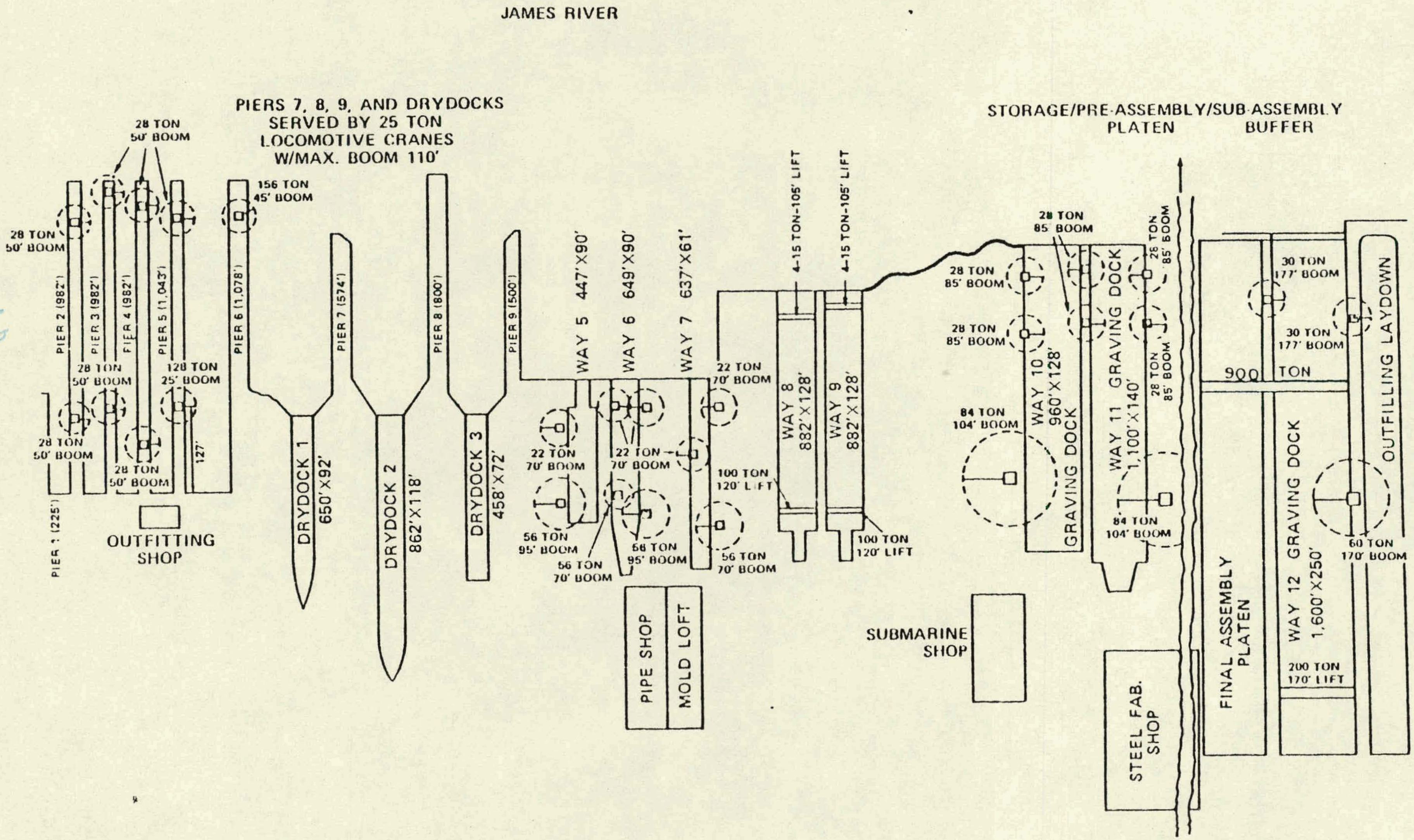
   1 - 900 ton gantry - services 1600 ft. dock

   1 - 310 ton gantry - services the 960 ft. and 1100 ft. docks

   140 ton mobile cranes
   65 ton locomotive and floating cranes

4. Nearest flotation site - 20 fathom curve 121 km (75 mi) from the shipyard or 72.4 km (45 miles) due east of Cape Henry.

NEWPORT NEWS



FACILITY CAPABILITIES FOR SHIPYARDS

Name: Tampa Ship Repair & Drydock Co., Inc.
P.O. Box 1277
Hooker's Point
Tampa, Florida 33601

1. Type of facility - graving dock

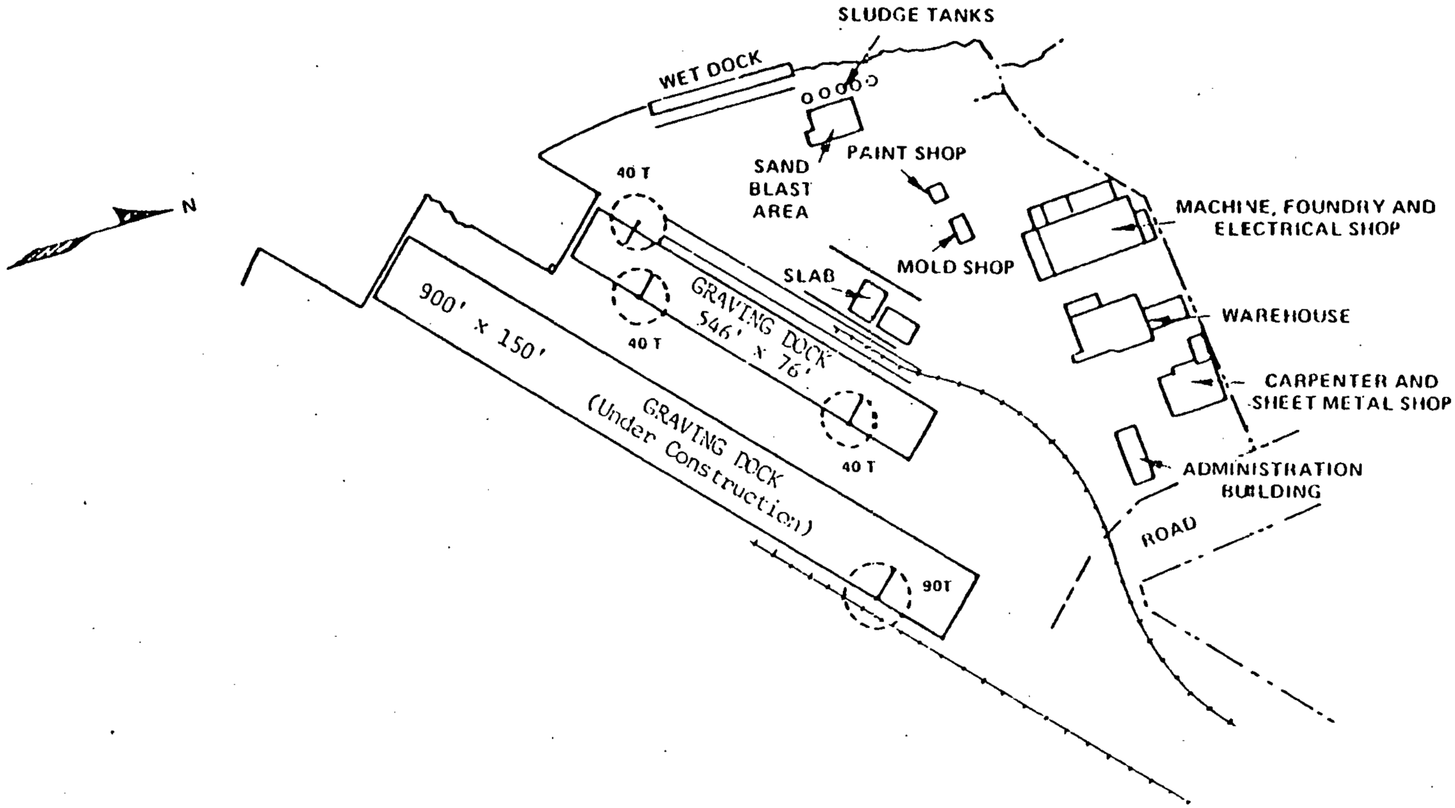
2. Dock dimensions - 1 qualifying dock

Dock Size	Maximum Ship Size LOA-Beam	Depth Over Sill
900' x 150'	896' x 146'	26'

3. Crane Lift Capacity

   175 ton gantries

4. Nearest flotation site - 56.3 km (35 mi) to 20 fathom curve in the Gulf of Mexico.



62

TAMPA SHIP REPAIR AND DRY DOCK CO.
TAMPA, FLORIDA

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Ingalls Shipbuilding Division Litton Industries
P.O. Box 149
Pascagoula, Miss. 39567

1. Type of facility - Level building positions

2. Dock dimensions - launch from 5 qualifying positions

Dock Size	Launch Maximum Ship Size LOA-Beam	Depth Over Sill
640' x 177'	800' x 173' (1)	41'

3. Crane Lift Capacity

   6 - 200 ton

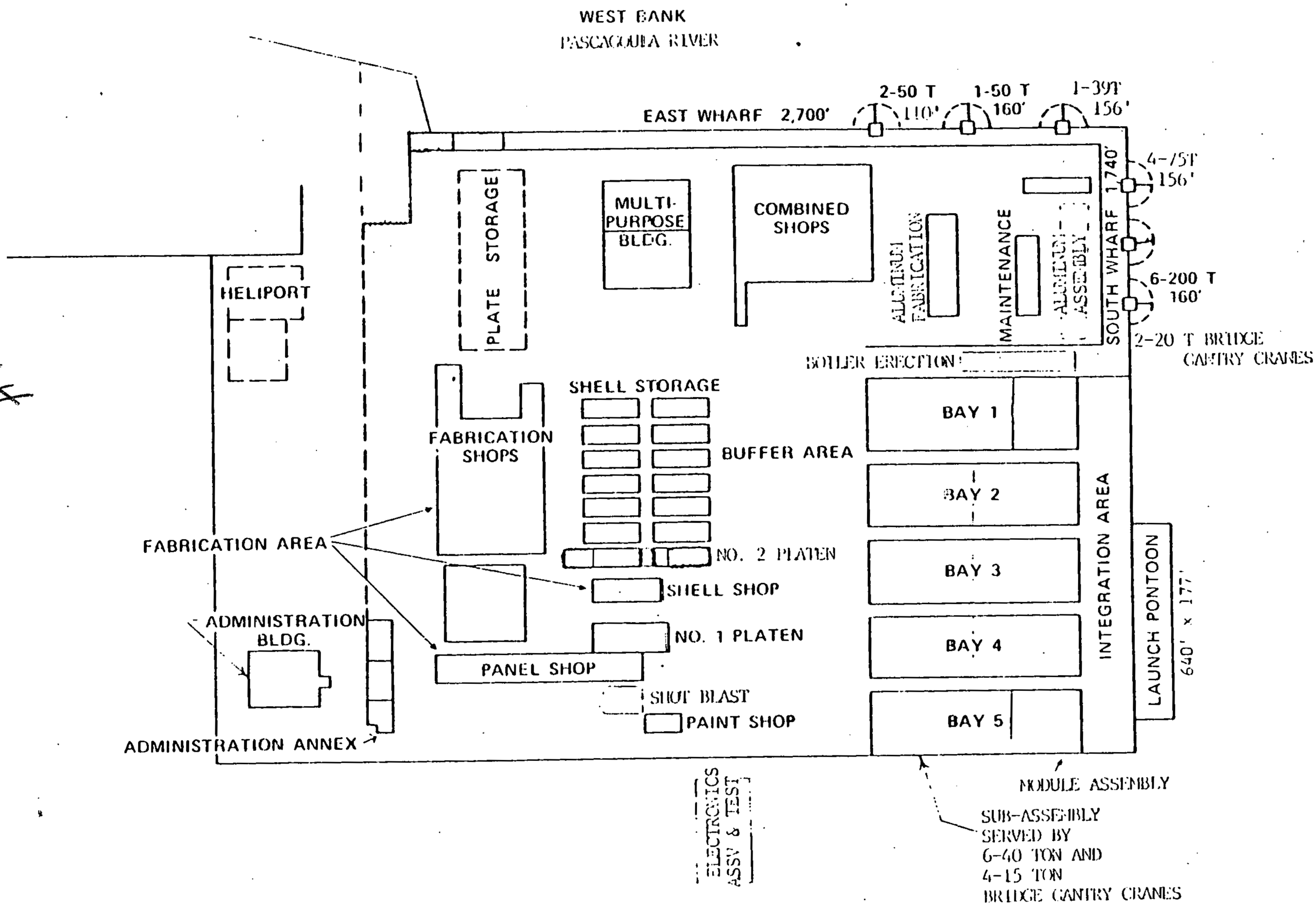
   - 25 to 75 tons

4. Nearest flotation site - 64.4 km (40 mi) to 20 fathom curve south of Pascagoula Harbor entrance.

(1) Used for launching ships.

INGALLS SHIPBUILDING
DIVISION OF LITTON SYSTEMS, INC.

14-Whirley Cranes
Serve East & South Wharves,
Integration Area and Bays



64

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Avondale Shipyards, Inc.
P.O. Box 50280
New Orleans, La. 70150

1. Type of facility - floating dock for launching and ship ways

2. Dock dimensions - 2 qualifying units

Shipway Size	Maximum Ship Size LOA-Beam	Depth Over Sill
FD 900' x 260'	1000' x 216'	37' (used for launching)
SW 1050' x 174'	1020' x 174'	(Launching on FD)
SW 1165' x 130'	1200' x 126'	(Side launching)

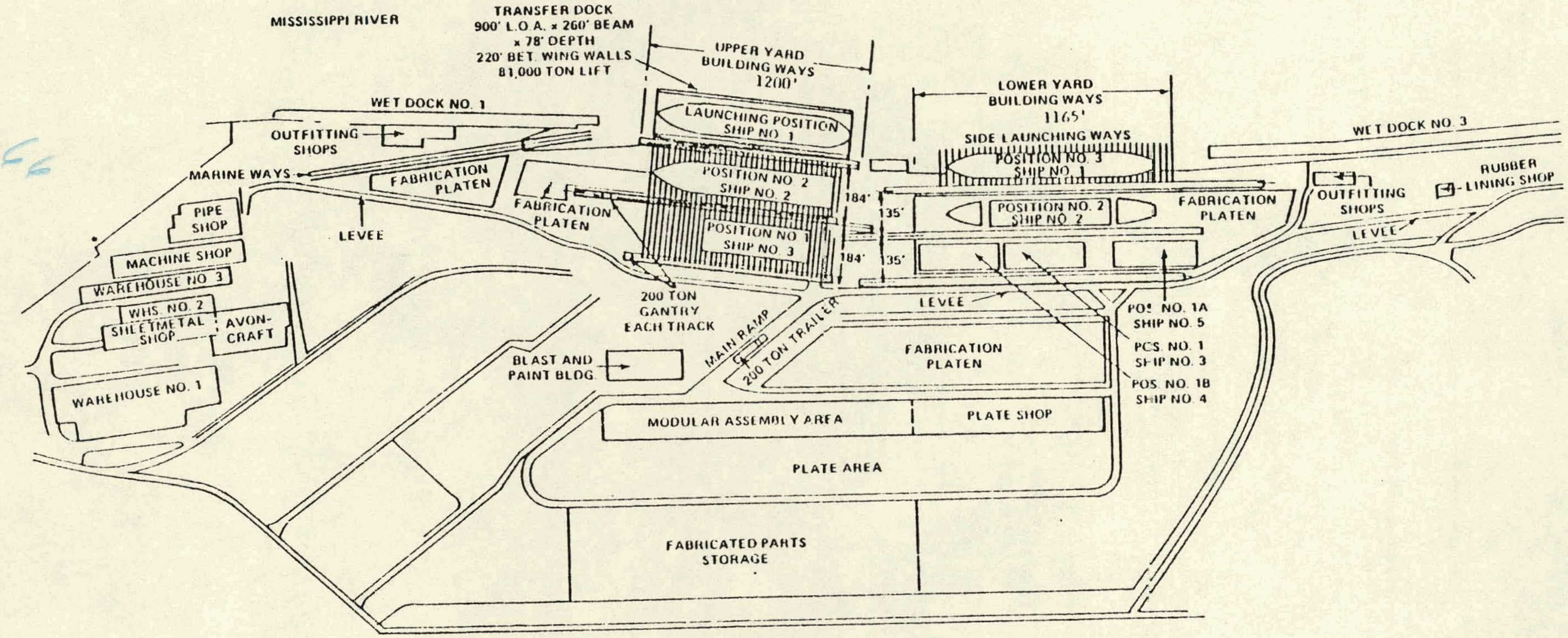
3. Crane Lift Capacity

   600 ton barge crane

   200 ton fixed

4. Nearest flotation site - 214 km (133 mi) through Mississippi River to 20 fathom curve in Gulf of Mexico

AVONDALE SHIPYARD



FACILITY CAPABILITIES FOR SHIPYARDS

Name: National Steel and Shipbuilding Co.
28th Street and Harbor Drive
San Diego, Calif. 92138

1. Type of facility - building dock

2. Dock dimensions - 1 qualifying dock

Dock Size	Maximum Ship Size LOA-Beam	Depth Over Sill
1000' x 176'	980' x 170'	16'

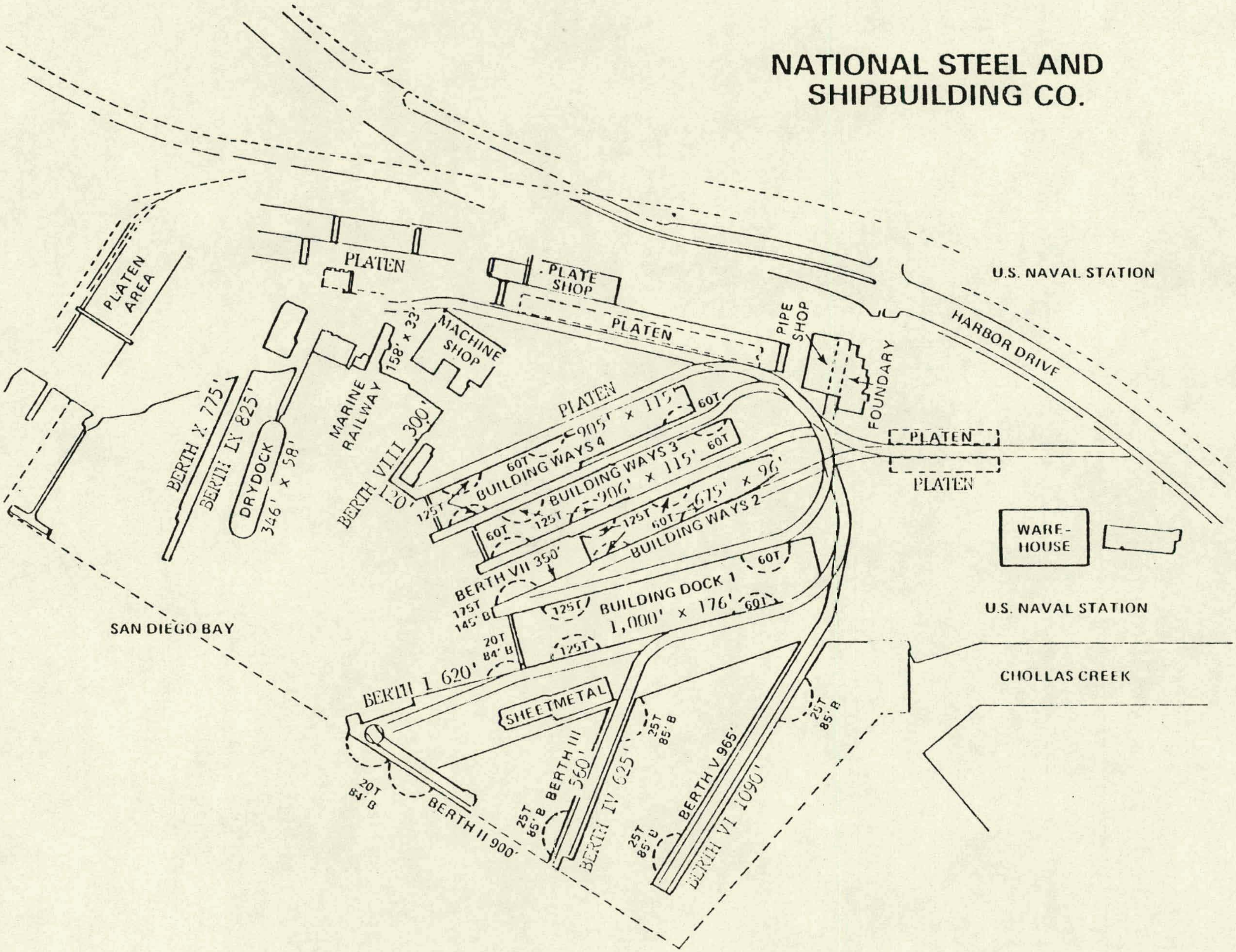
3. Crane Lift Capacity

   - 175 ton gantry

   - 60 ton

4. Nearest flotation site - 72.4 km (45 mi) to Isthmus Cove, Santa Catalina Island, Calif.

NATIONAL STEEL AND SHIPBUILDING CO.



FACILITY CAPABILITIES FOR SHIPYARDS

Name: Bethlehem Steel Corp.
San Francisco Yard
P.O. Box 7963
San Francisco, Calif. 94120

1. Type of facility - floating dry dock

2. Dock dimensions - 1 qualifying dock

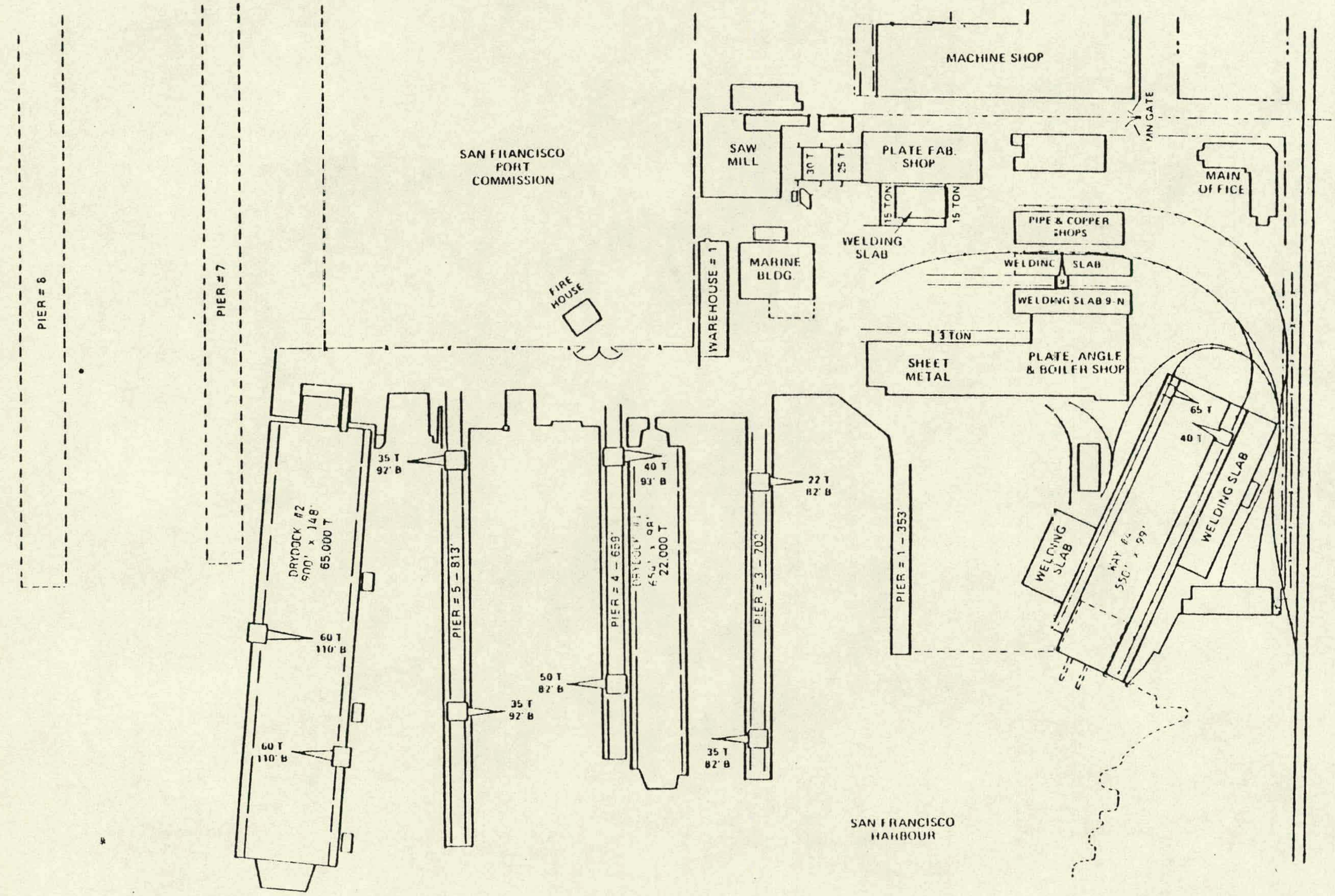
Dock Size	Maximum Ship Size LOA-Beam	Depth Over Sill
900' x 148'	950' x 144'	37.6'

3. Crane Lift Capacity

- 60 ton

4. Nearest flotation site - 611 km (380 mi) to Isthmus Cove, Santa Catalina Island, Calif.

BETHLEHEM STEEL CORP.
SAN FRANCISCO YARD



FACILITY CAPABILITIES FOR SHIPYARDS

Name: Triple "A" Machine Shop, Inc.
P.O. Box 24460, Hunters Point
San Francisco, Calif. 94124

1. Type of facility - graving dock

2. Dock dimensions - 1 qualifying dock

Dock Size	Maximum Ship Size LOA-Beam	Depth Over Sill
1092' x 143'	1088' x 136'	47'

3. Crane Lift Capacity

   1 - 300 ton fixed crane

   - 49 ton

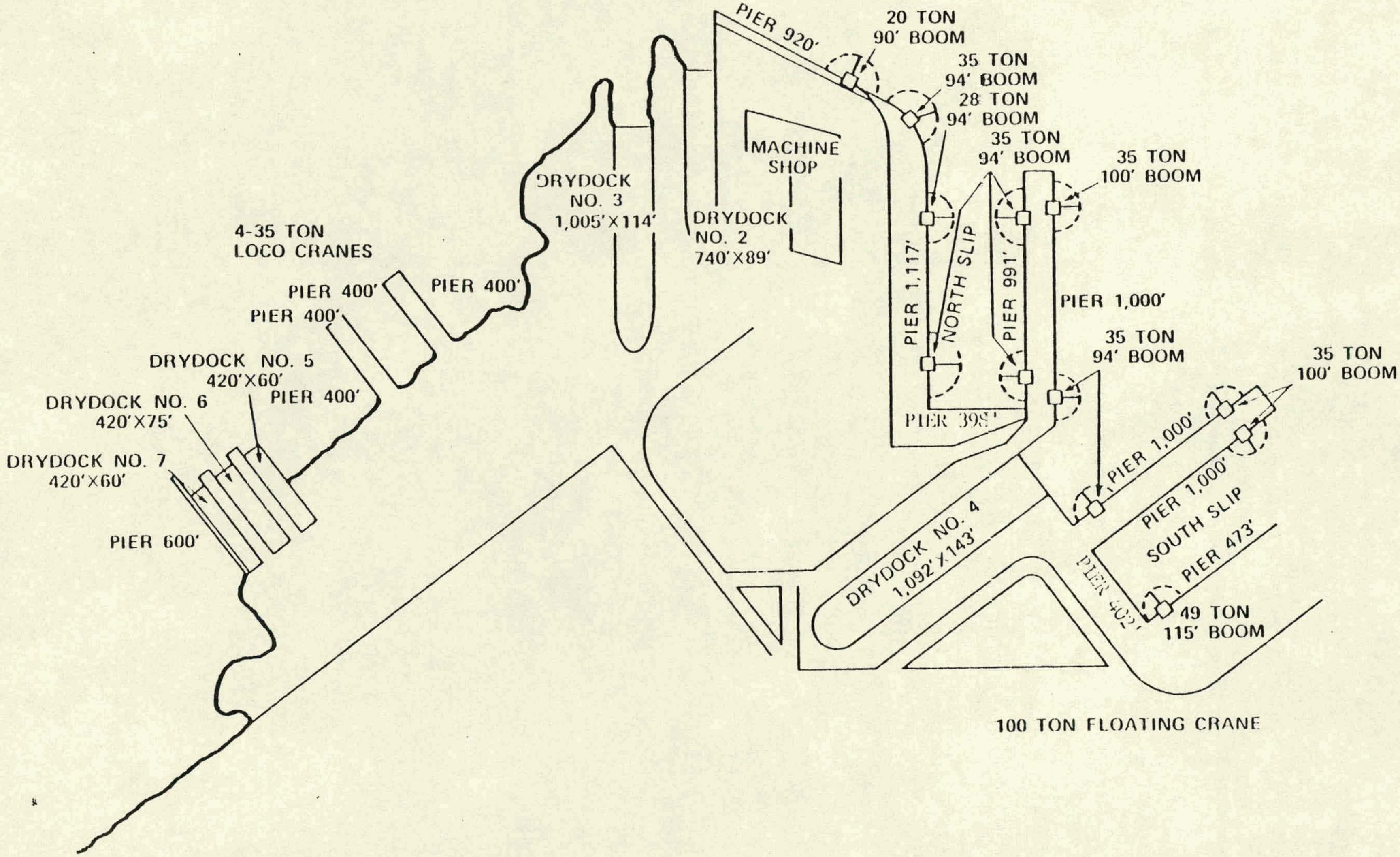
   - 35 ton

4. Nearest flotation site - 611.5 km (380 mi) to Isthmus Cove, Santa Catalina Island, Calif.

nl

TRIPLE "A" MACHINE SHOP, INC.

HUNTERS POINT



72

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Lockheed S.B. and Construction Co.
2929 16th Avenue, S.W.
Seattle, Washington 98134

1. Type of facility - 3 floating docks
   3 shipways

2. Dock dimensions - Shipways non-qualifying unless enlarged.

	Shipway Size Shipway Size	Maximum Ship Size LOA-Beam	Depth Over Sill
1 -	700' x 100'	690' x 90'	30
2 -	650' x 90'	600' x 95'	30

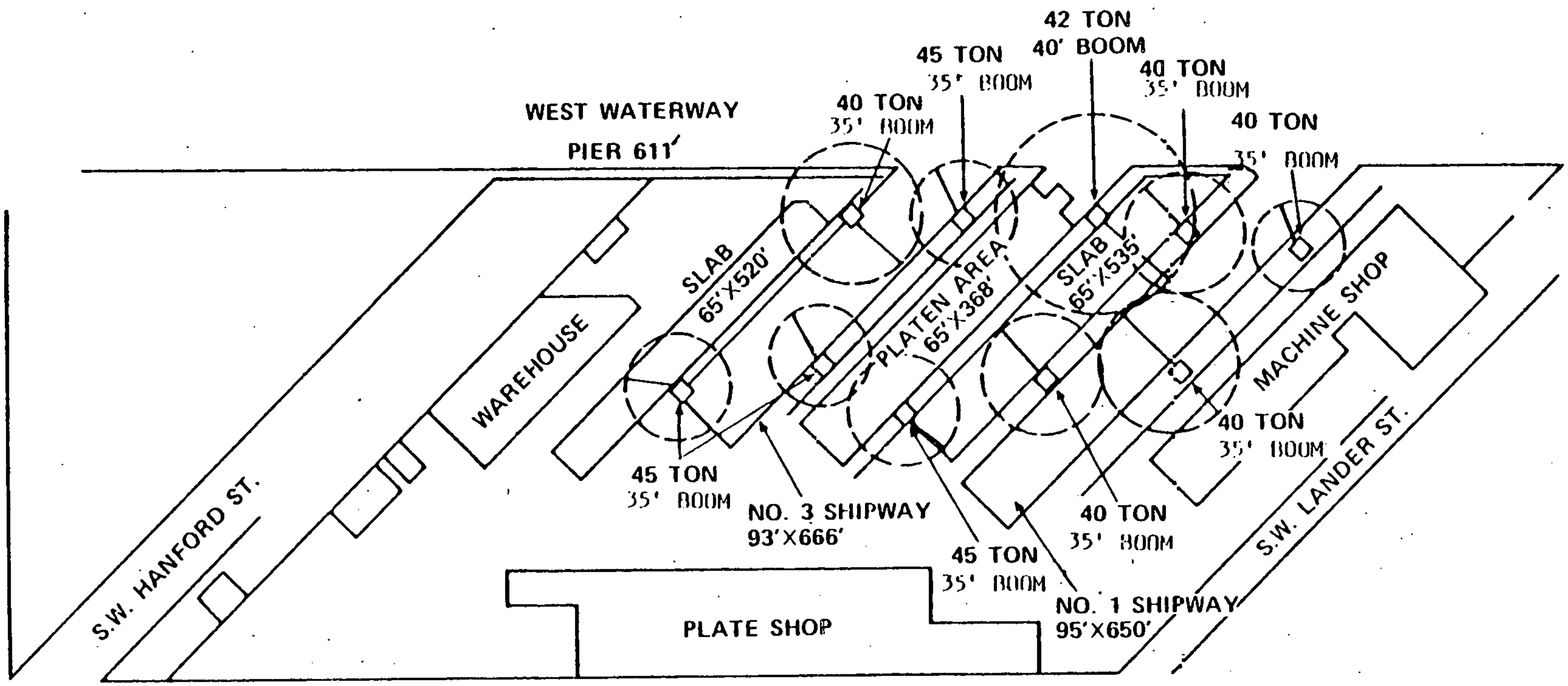
3. Crane Lift Capacity

   Whirleys up to 50 tons.

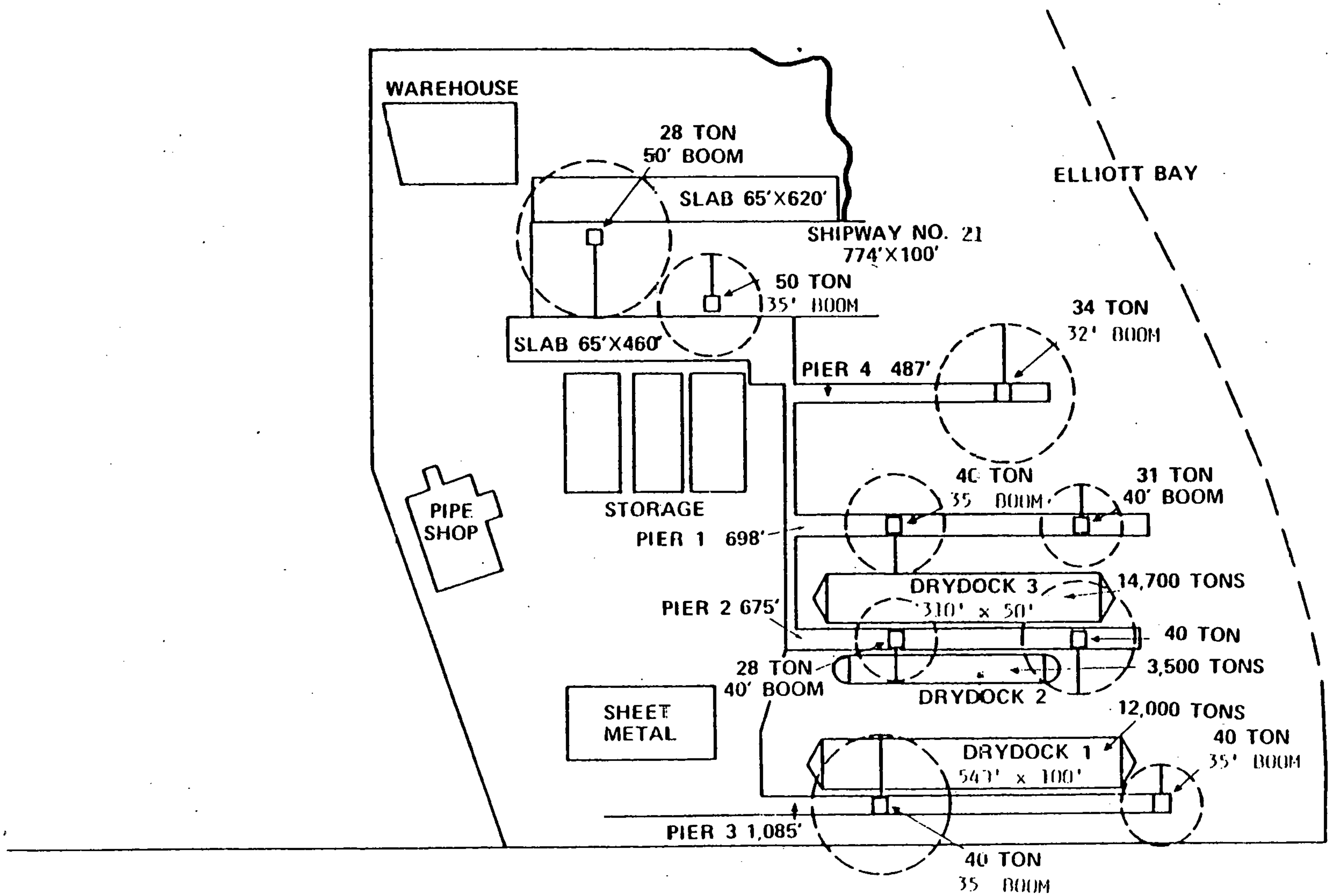
4. Nearest Flotation site - About 35 fathoms just outside yard and about 100 fathoms about 12 miles from yard.

LOCKHEED

2929 16TH AVENUE, S.W.
PLANT 1



LOCKHEED
2330 S.W. FLORIDA ST.
PLANT 2



THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

APPENDIX B

SHIPYARD CAPABILITY ASSESSMENT MATRICES

Appendix B-1

SHIPYARD CAPABILITY ASSESSMENT

Shipyard General Dynamics Location Quincy, Mass.

Platform Type

Shipyard Requirements	1a	1b	2	3	4a	4b	4c	4d	4e	4f
Construction Dock	0	0	0	0	0	0	0	0	3	3
Water Depth at Yard	0	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	3	3	3	3	3	3
Access Channel (2)	0	0	0	0	0	1	1	1	1	1
Deep Water Site	0	0	0	0	NA(3)	2	2	2	2	2
Engineering	2	2	1	1	3	3	3	3	3	3
Construction Complex Structures	0	0	0	0	3	3	3	3	3	3
Management	2	2	2	2	3	3	3	3	3	3
Skilled Force	2	2	2	2	3	3	3	3	3	3
Steel Construction	3	3	3	3	3	3	3	3	3	3
Concrete Construction	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	3	3	3	3	3	3	3	3	3	3

(1) Requires new building dock for concrete.

(2) Controlling width of 175' through Fore River Bridge.

(3) NA denotes requirement not applicable.

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar IHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

Rating Level

(Applies to all Appendices B)

3 - Full capability
2 - Good, requiring some upgrading
1 - Limited, requires considerable upgrading
0 - No existing capability

SHIPYARD CAPABILITY ASSESSMENT

Shipyard Sun S.B. & D.C. Location Chester, Pa.

Platform Type

Shipyard Requirements	1a	1b	2	3	4a	4b	4c	4d	4e	4f
Construction Dock	0	0	0	0	0	3	3	3	3	3
Water Depth at Yard	0	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	3	3	3	3	3	3
Access Channel	0	0	0	0	3	3	3	3	3	3
Deep Water Site	0	0	0	0	NA	2	2	2	2	2
Engineering	2	2	1	1	3	3	3	3	3	3
Construction Complex Structures	0	0	0	0	3	3	3	3	3	3
Management	2	2	2	2	3	3	3	3	3	3
Skilled Force	2	2	2	2	3	3	3	3	3	3
Steel Construction	3	3	3	3	3	3	3	3	3	3
Concrete Construction	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	3	3	3	3	3	3	3	3	3	3

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar IHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

SHIPYARD CAPABILITY ASSESSMENT

Shipyard Bethlehem Steel Corp. Location Sparrows Point, Md.

Platform Type

Shipyard Requirements	1a	1b	2	3	4a	4b	4c	4d	4e	4f
Construction Dock	0	0	0	0	0	0	3	3	3	3
Water Depth at Yard	0	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	3	3	3	3	3	3
Access Channel	0	0	0	0	3	3	3	3	3	3
Deep Water Site	0	0	0	0	NA	2	2	2	2	2
Engineering	2	2	1	1	3	3	3	3	3	3
Construction Complex Structures	0	0	0	0	3	3	3	3	3	3
Management	2	2	2	2	3	3	3	3	3	3
Skilled Force	2	2	2	2	3	3	3	3	3	3
Steel Construction	3	3	3	3	3	3	3	3	3	3
Concrete Construction	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	3	3	3	3	3	3	3	3	3	3

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar IHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

SHIPYARD CAPABILITY ASSESSMENT

Shipyard Newport News S.B. Location Newport News, Va.

Platform Type

Shipyard Requirements	1a	1b	2	3	4a	4b	4c	4d	4e	4f
Construction Dock (1)	0	0	0	0	0	3	3	3	3	3
Water Depth at Yard	0	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	3	3	3	3	3	3
Access Channel	0	0	0	0	3	3	3	3	3	3
Deep Water Site	0	0	0	0	NA	2	2	2	2	2
Engineering (1)	2	2	1	1	3	3	3	3	3	3
Construction Complex Structures	0	0	0	0	3	3	3	3	3	3
Management	2	2	2	2	3	3	3	3	3	3
Skilled Force	2	2	2	2	3	3	3	3	3	3
Steel Construction Experience	3	3	3	3	3	3	3	3	3	3
Concrete Construction Experience	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	3	3	3	3	3	3	3	3	3	3

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar IHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

(1) NN has very excellent engineering capability.

SHIPYARD CAPABILITY ASSESSMENT

Shipyard Tampa Ship Repair Location Tampa, Fla.

Platform Type

Shipyard Requirements	1a	1b	2	3	4a	4b	4c	4d	4e	4f
Construction Dock (1)	0	0	0	0	0	0	0	0	0	3
Water Depth at Yard	0	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	3	3	3	3	3	3
Access Channel	0	0	0	0	3	3	3	3	3	3
Deep Water Site	0	0	0	0	NA	2	2	2	2	2
Engineering	0	0	0	0	1	1	1	1	1	1
Construction Complex Structures	0	0	0	0	0	0	0	0	0	0
Management	0	0	0	0	1	1	1	1	1	1
Skilled Force	1	1	1	1	2	2	2	2	2	2
Steel Construction	1	1	1	1	2	2	2	2	2	2
Concrete Construction	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	2	2	2	2	2	2	2	2	2	2

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar IHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

87

SHIPYARD CAPABILITY ASSESSMENT

Shipyard Ingalls S.B. (Litton) Location Pascagoula, Miss.

Platform Type

Shipyard Requirements	1a	1b	2	3	4a	4b	4c	4d	4e	4f
Construction Dock (1)	0	0	0	0	0	3	3	3	3	3
Water Depth at Yard	0	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	3	3	3	3	3	3
Access Channel	0	0	0	0	3	3	3	3	3	3
Deep Water Site	0	0	0	0	NA	3	3	3	3	3
Engineering	2	2	1	1	3	3	3	3	3	3
Construction Complex Structures	0	0	0	0	3	3	3	3	3	3
Management	2	2	2	2	3	3	3	3	3	3
Skilled Force	2	2	2	2	3	3	3	3	3	3
Steel Construction	3	3	3	3	3	3	3	3	3	3
Concrete Construction	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	3	3	3	3	3	3	3	3	3	3

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar IHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

SHIPYARD CAPABILITY ASSESSMENT

Shipyard Avondale Shipyards, Inc. Location New Orleans, La.

Shipyard Requirements	Platform Type 1a	1b	2	3	4a	4b	4c	4d	4e	4f
Construction Dock (1)	0(4)	0	0	0	0	0	3	3	3	3
Water Depth at Yard	0(4)	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	3	3	3	3	3	3
Access Channel	0(4)	0	0	0	3	3	3	3	3	3
Deep Water Site	0	0	0	0	NA	3	3	3	3	3
Engineering	2(1)	2	1	1	3	3	3	3	3	3
Construction Complex Structures	0	0	0	0	3	3	3	3	3	3
Management	2	2	2	2	3	3	3	3	3	3
Skilled Force	2	2	2	2	3	3	3	3	3	3
Steel Construction	3(3)	3	3	3	3	3	3	3	3	3
Concrete Construction	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	3	3	3	3	3	3	3	3	3	3

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar LHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

SHIPYARD CAPABILITY ASSESSMENT

Shipyard National Steel & S.B. (1) Location San Diego, Calif.

Platform Type

Shipyard Requirements	1a	1b	2	3	4a	4b	4c	4d	4e	4f
Construction Dock (1)	0	0	0	0	0	0	3	3	3	3
Water Depth at Yard	0	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	3	3	3	3	3	3
Access Channel	0	0	0	0	3	3	3	3	3	3
Deep Water Site	0	0	0	0	NA	3	3	3	3	3
Engineering	2	2	1	1	3	3	3	3	3	3
Construction Complex Structures	0	0	0	0	3	3	3	3	3	3
Management	2	2	2	2	3	3	3	3	3	3
Skilled Force	2	2	2	2	3	3	3	3	3	3
Steel Construction	3	3	3	3	3	3	3	3	3	3
Concrete Construction	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	3	3	3	3	3	3	3	3	3	3

(1) Fully owned by Morrison-Knudsen

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar IHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

SHIPYARD CAPABILITY ASSESSMENT

Shipyard Bethlehem Steel Corp. Location San Francisco, Calif.

Shipyard Requirements	1a	1b	2	3	4a	4b	4c	4d	4e	4f
	Platform Type									
Construction Dock (1)	0	0	0	0	0	0	3	3	3	3
Water Depth at Yard	0	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	3	3	3	3	3	3
Access Channel	0	0	0	0	3	3	3	3	3	3
Deep Water Site	0	0	0	0	NA	3	3	3	3	3
Engineering (1)	2	2	2	2	2	2	2	2	2	2
Construction Complex Structures	0	0	0	0	2	2	2	2	2	2
Management	2	2	2	2	3	3	3	3	3	3
Skilled Force	1	1	1	1	2	2	2	2	2	2
Steel Construction	3	3	3	3	3	3	3	3	3	3
Concrete Construction	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	3	3	3	3	3	3	3	3	3	3

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar IHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

(1) Bethlehem Sparrows Point technical force available.

SHIPYARD CAPABILITY ASSESSMENT

Shipyard Triple A Machine Shop Location San Francisco, Calif.

Platform Type

Shipyard Requirements	1a	1b	2	3	4a	4b	4c	4d	4e	4f
Construction Dock (1)	0	0	0	0	0	0	0	0	0	3
Water Depth at Yard	0	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	3	3	3	3	3	3
Access Channel	0	0	0	0	3	3	3	3	3	3
Deep Water Site	0	0	0	0	NA	3	3	3	3	3
Engineering	0	0	0	0	1	1	1	1	1	1
Construction Complex Structures	0	0	0	0	1	1	1	1	1	1
Management	0	0	0	0	1	1	1	1	1	1
Skilled Force	0	0	0	0	1	1	1	1	1	1
Steel Construction	0	0	0	0	1	1	1	1	1	1
Concrete Construction	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	1	1	1	1	1	1	1	1	1	1

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar IHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

87

SHIPYARD CAPABILITY ASSESSMENT

Shipyard Lockheed S.B. Location Seattle, Wash.

Shipyard Requirements	1a	1b	2	3	4a	4b	4c	4d	4e	4f
Construction Dock	0	0	0	0	0	0	0	0	0	0
Water Depth at Yard	0	0	0	0	3	3	3	3	3	3
Heavy Lift Cranes	0	0	0	0	1	1	1	1	1	1
Access Channel	3	3	3	3	3	3	3	3	3	3
Deep Water Site	3	3	3	3	NA	NA	3	3	3	3
Engineering	2	2	1	1	2	2	2	2	2	2
Construction Complex Structures	0	0	0	0	3	3	3	3	3	3
Management	2	2	2	2	3	3	3	3	3	3
Skilled Force	2	2	2	2	3	3	3	3	3	3
Steel Construction	3	3	3	3	3	3	3	3	3	3
Concrete Construction	0	0	0	0	NA	NA	NA	NA	NA	NA
Financial Capability	3	3	3	3	3	3	3	3	3	3

Platform Type: columns 1a through 4f.

Key to Platforms

1a-Concrete Ship Method 1
1b-Concrete Ship Method 2
2 - Concrete Spar XHE
3 - Concrete Spar LHE
4a-Steel Ship Method 1
4b-Steel Ship Method 2
4c-Steel Ship Method 2a
4d-Steel Ship Method 3
4e-Steel Ship Method 4
4f-Steel Ship Method 5

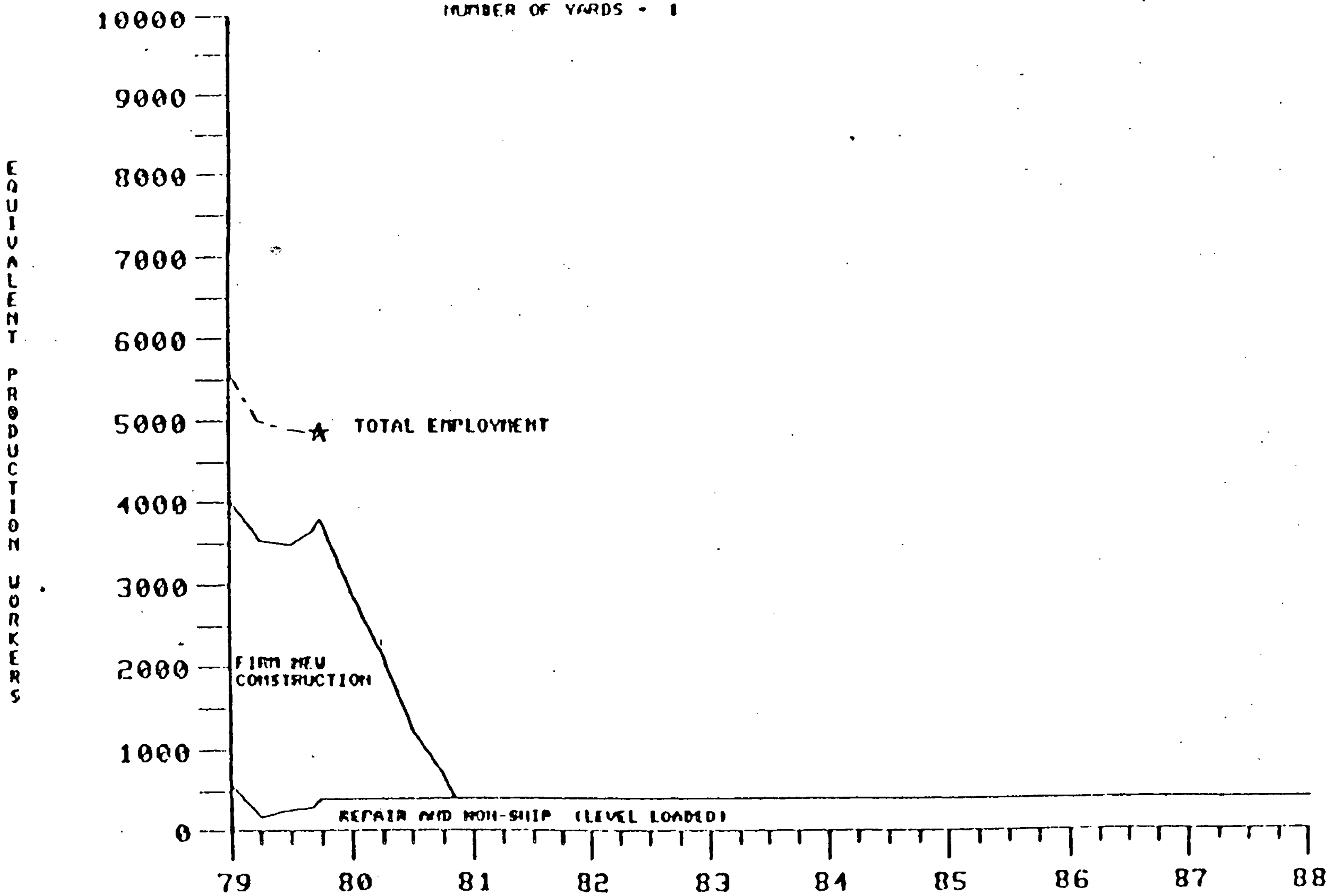
88

APPENDIX C

SHIPYARD EMPLOYMENT PROJECTIONS

GENERAL DYNAMICS, QUINCY

NUMBER OF YARDS - 1

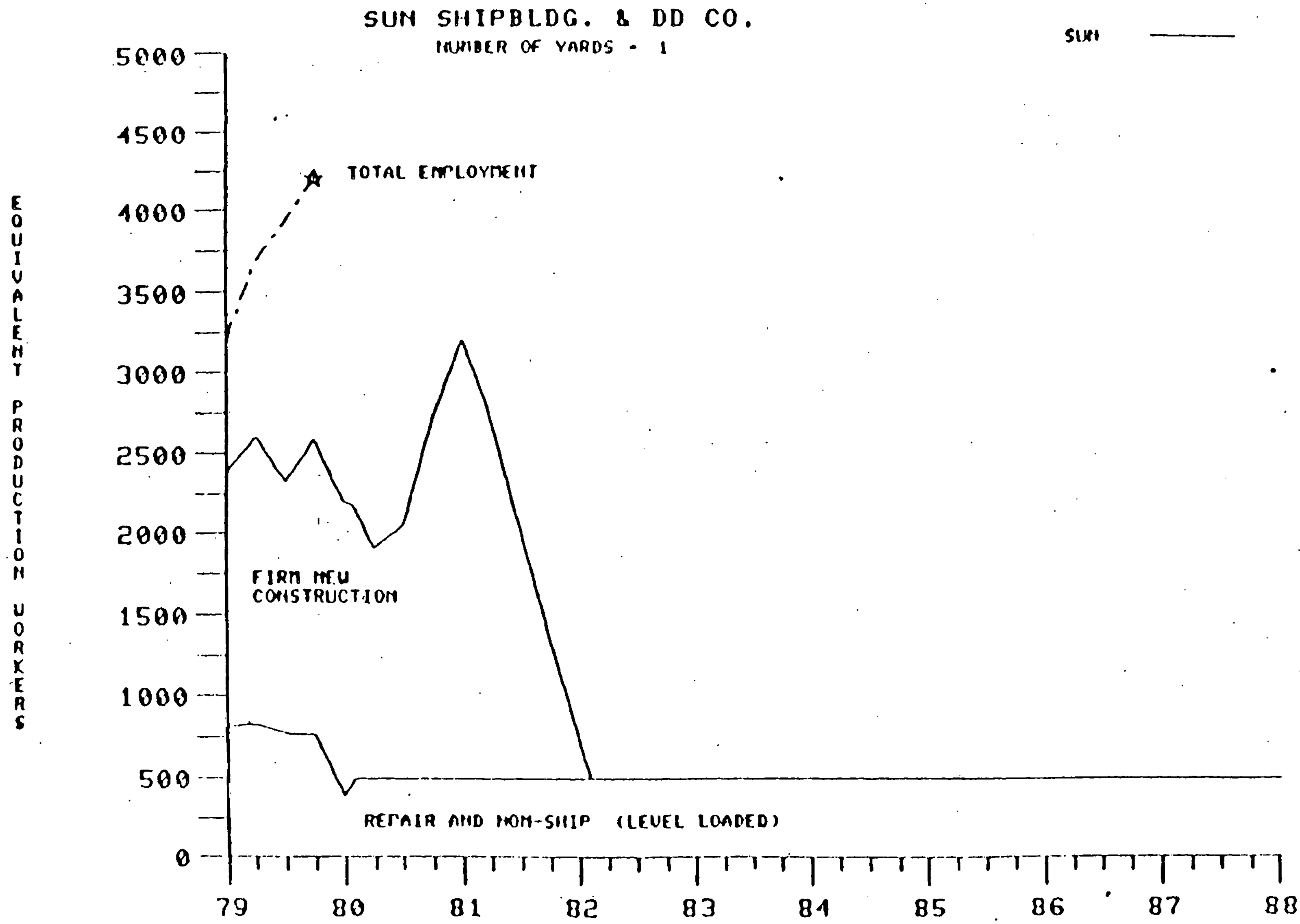


OCTOBER 1, 1979

SOURCE: SHIPYARD DATA FROM FORM MA832 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

90

Appendix C-1



OCTOBER 1, 1979

SOURCE: SHIPYARD DATA FROM FORM MA832 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

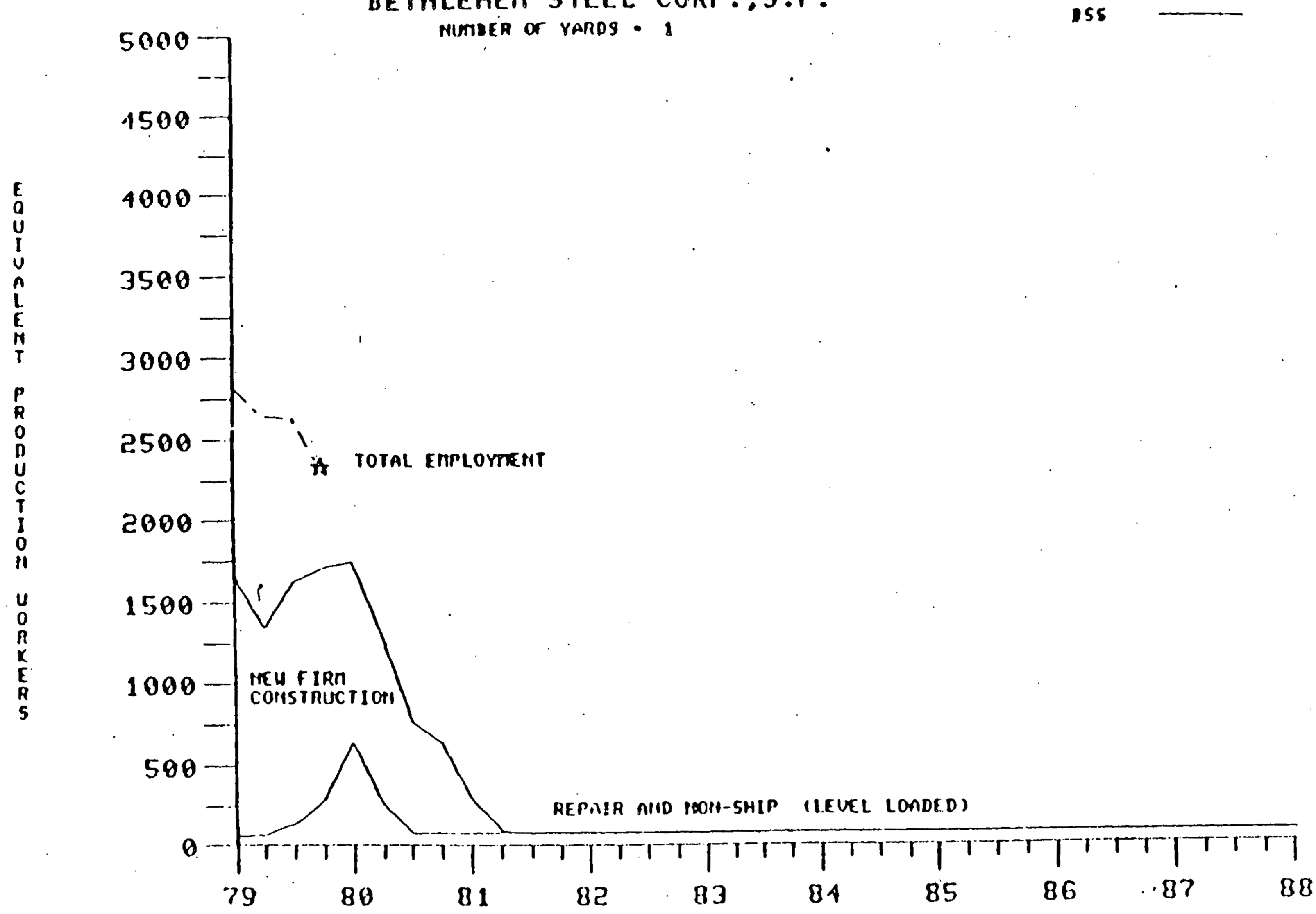
91

Appendix C-2

SHIPBUILDING INDUSTRY WORKLOAD PROJECTION

BETHLEHEM STEEL CORP., S.P.

NUMBER OF YARDS = 1

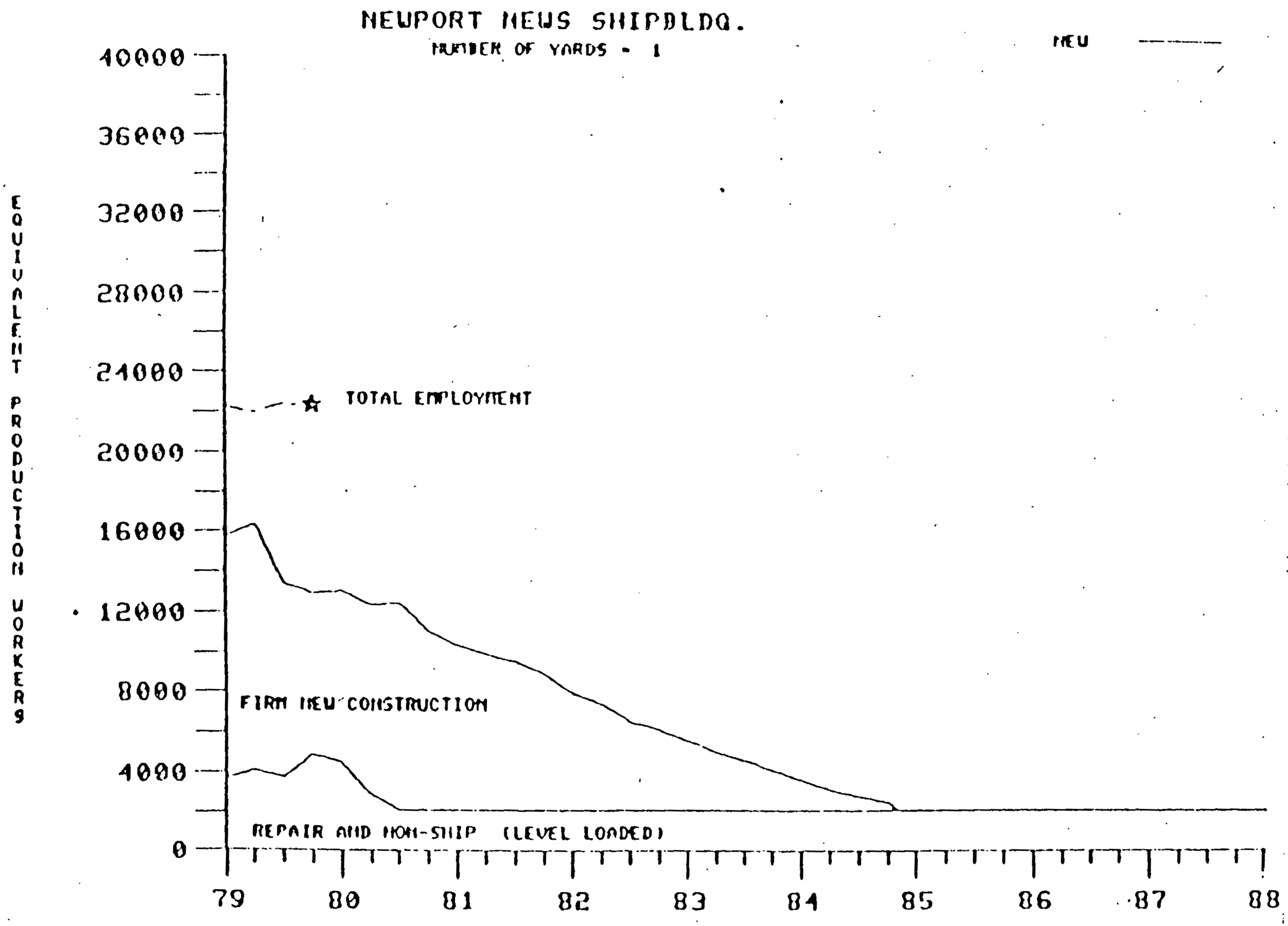


OCTOBER 1, 1979

SOURCE: SHIPYARD DATA FROM FORM MARAD WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

92

Appendix C-3

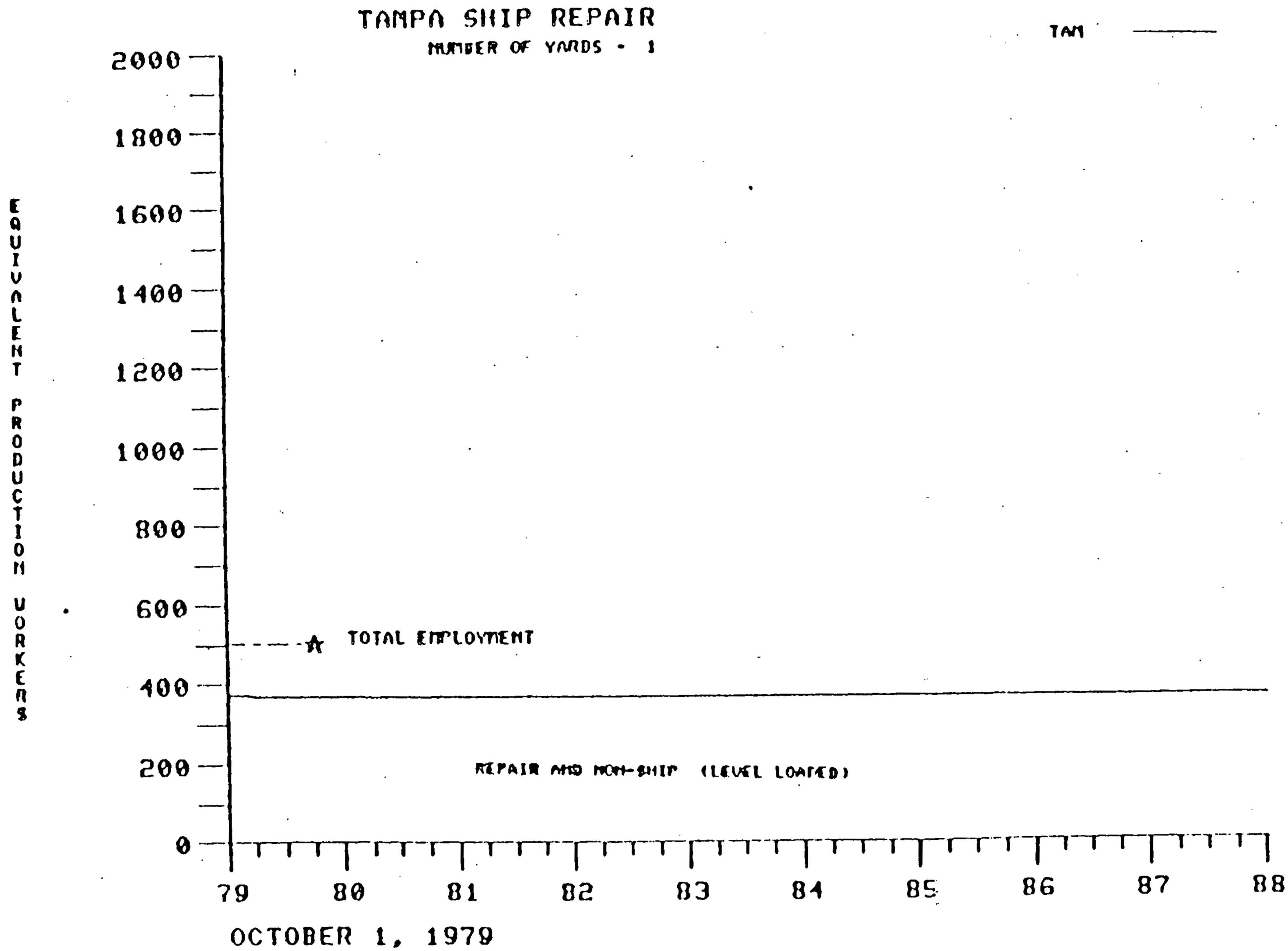


OCTOBER 1, 1979

SOURCE: SHIPYARD DATA FROM FORM MA832 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

Appendix C-4

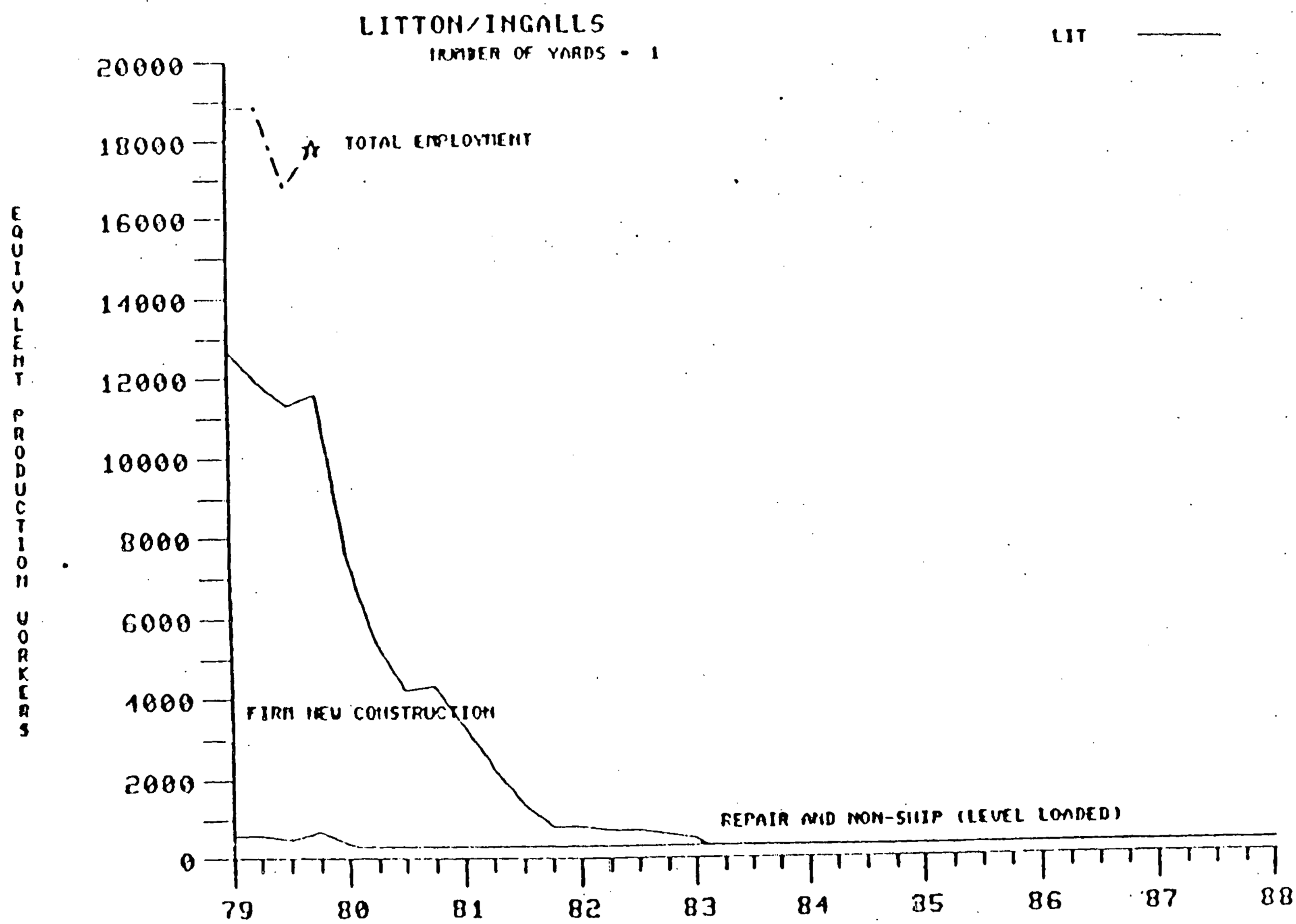
93



SOURCE: SHIPYARD DATA FROM FORM MA832 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

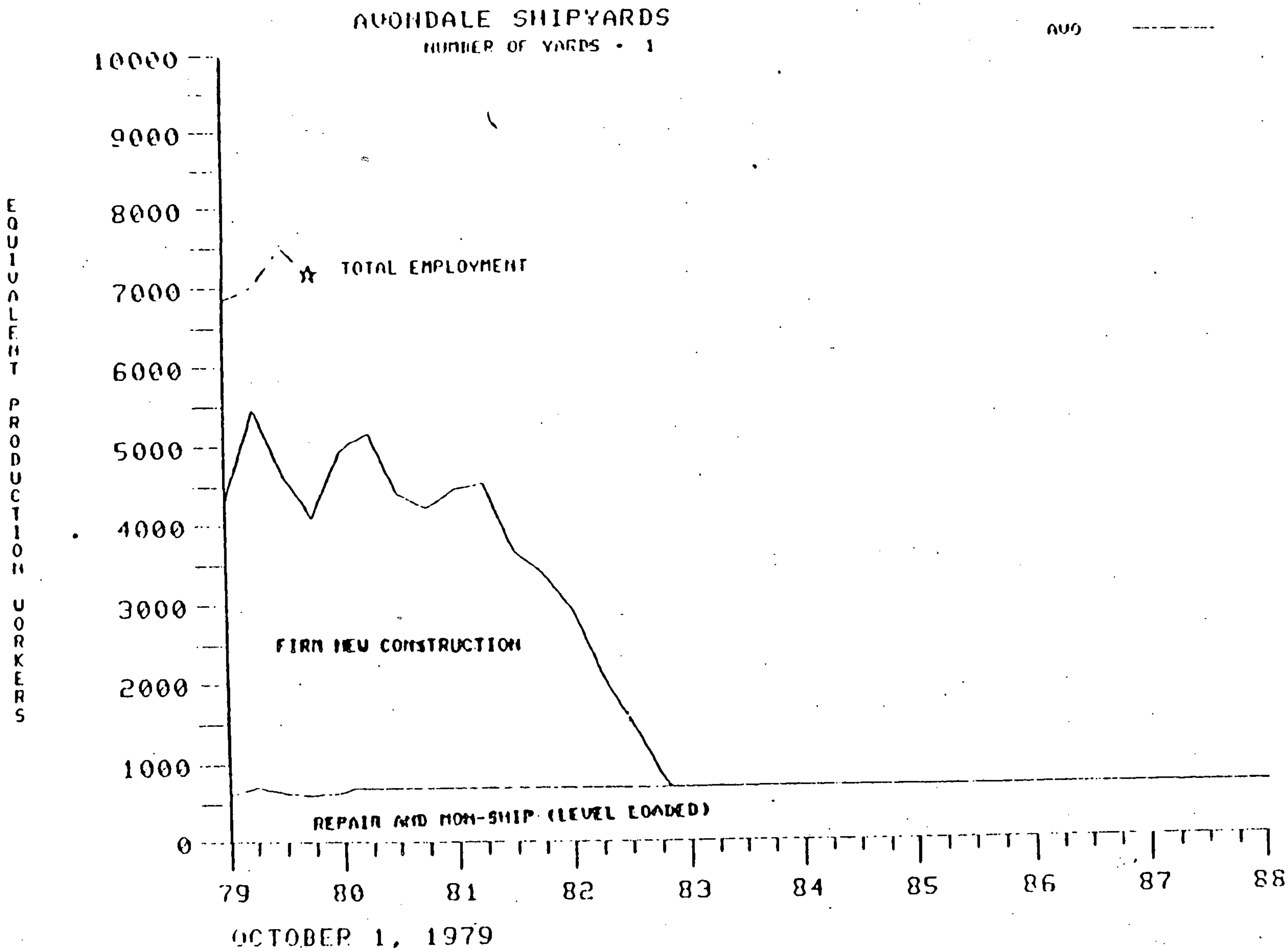
94

Appendix C-5



OCTOBER 1, 1979

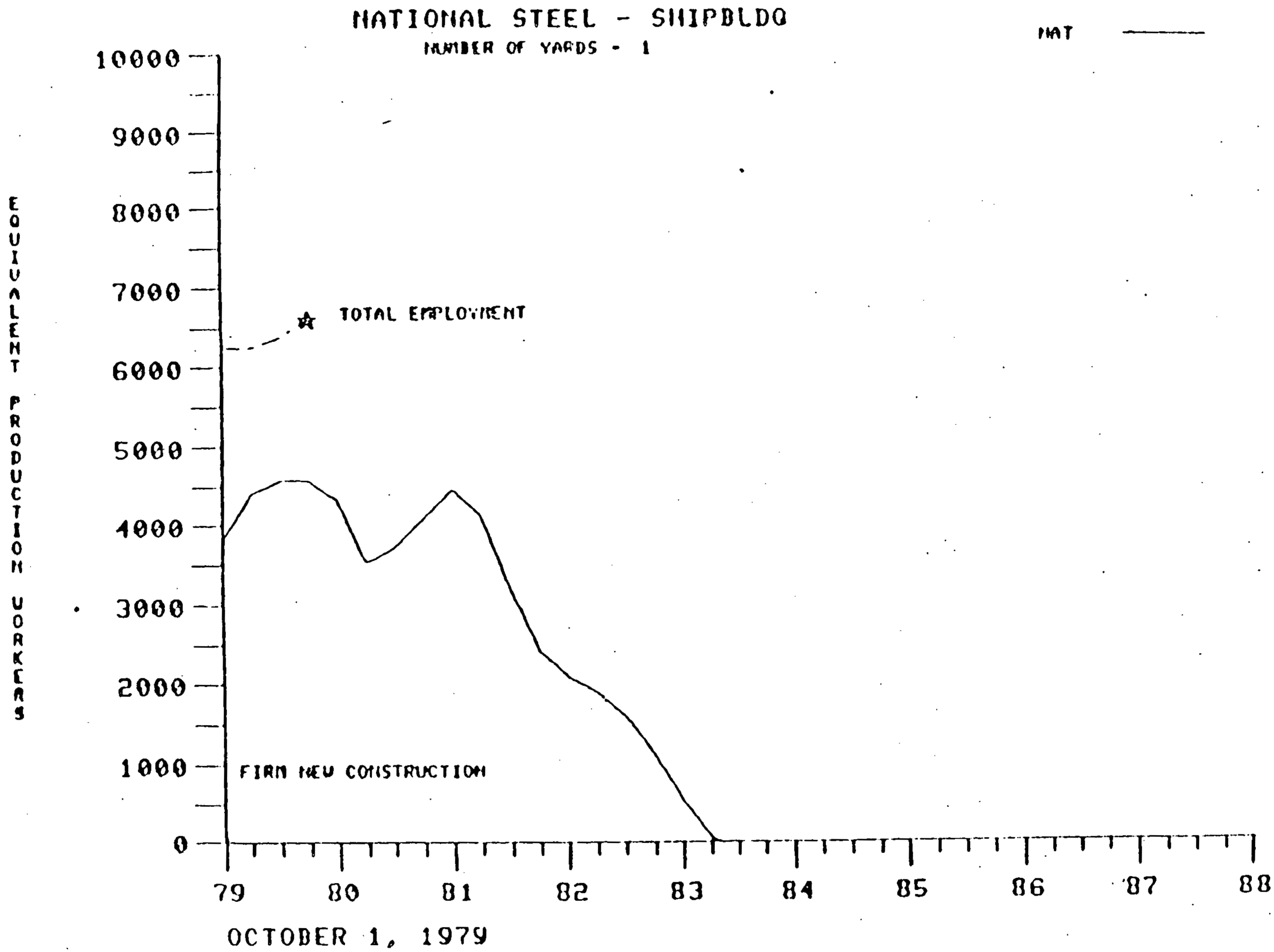
SOURCE: SHIPYARD DATA FROM FORM MA832 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION



SOURCE: SHIPYARD DATA FROM FORM MA832 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

96

Appendix C-7



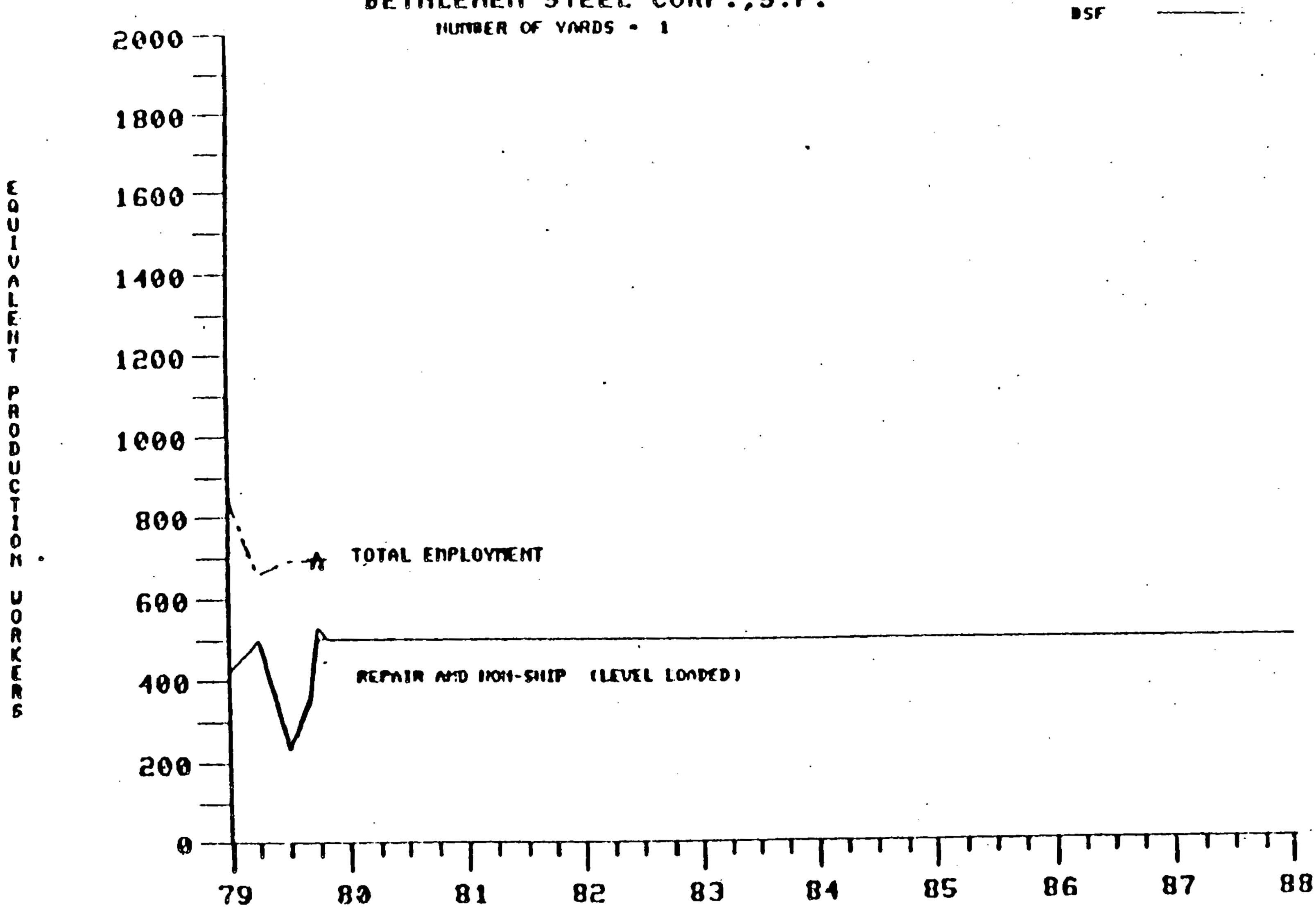
SOURCE: SHIPYARD DATA FROM FORM MA832 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

97

Appendix C-8

BETHLEHEM STEEL CORP., S.F.

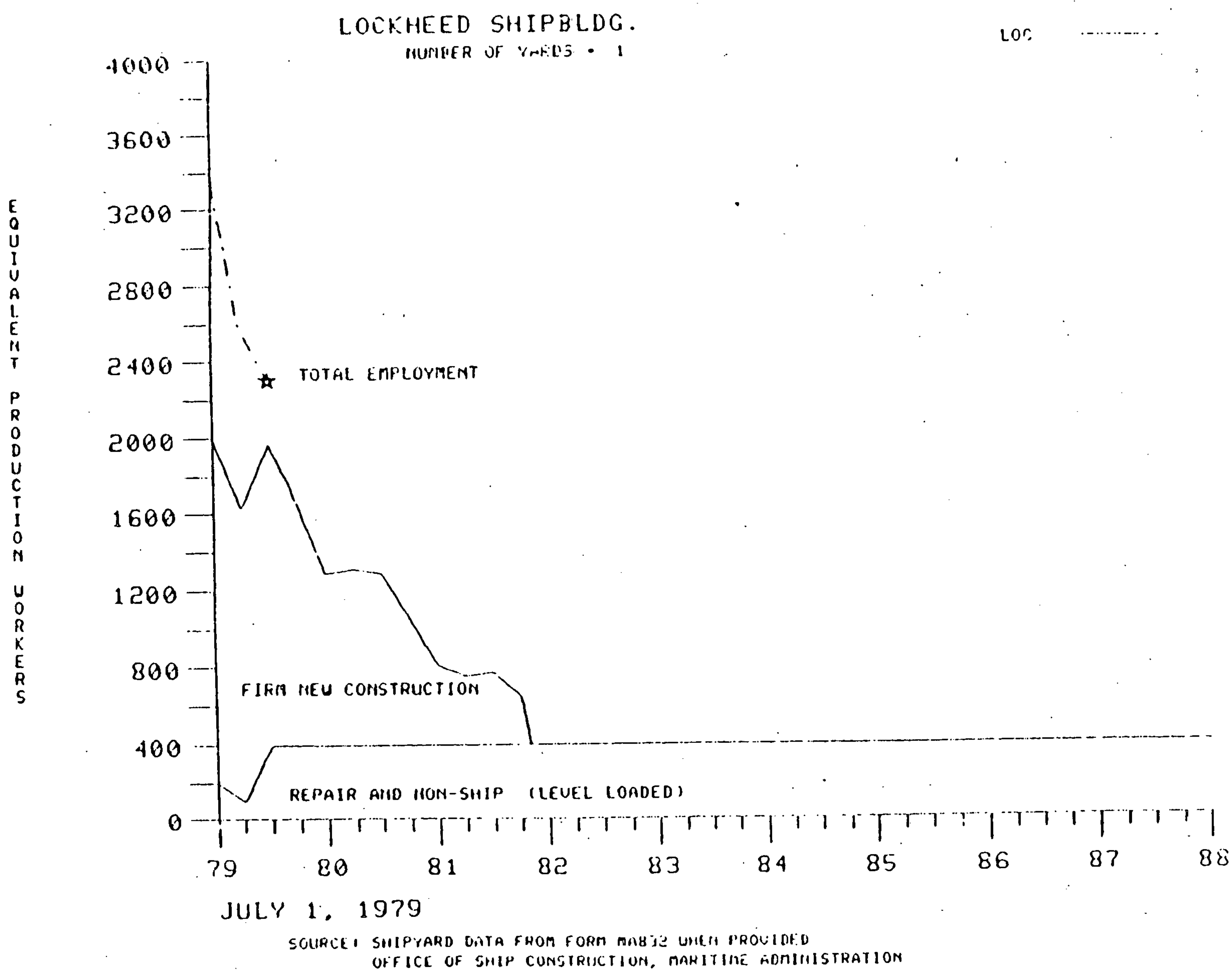
NUMBER OF YARDS = 1



OCTOBER 1, 1979

SOURCE: SHIPYARD DATA FROM FORM MA833 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

98



Appendix C-10

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

app D

DEFINITION OF RISK LEVELS

This appendix relates to Section E, Consideration of Risk. It defines each risk level for each of twelve factors identified for risk consideration.

The next step is to establish level of risk for each risk factor. Level 1 would represent least risk and Level 4 would be the greatest. The following are suggested definitions of risk level for each of the factors listed above:

I. Risk Management Philosophy

Level 1 — Work within the state of art wherever possible in matters of administration, engineering, sizing, materials, construction and handling, redundant approach to solution of all critical problems, use of mock-ups, progressive sizes, etc.

Level 2 — Exceed state of art only for a minimum carefully chosen items, limit redundancy to selected major problems, limit mock-ups.

Level 3 — Little weight to state of art, little redundancy, no mock-ups.

Level 4 — Virtually ignore state of art in attempting to follow theoretically best design and construction, no redundancy.

II. Technical State of the Art

Level 1 — Design of 50,000 DWT tanker.
Design of reinforced concrete office building.
Design of 48" concrete pipe municipal drainage system.

Level 2 Design of LNG ships.
Design of large concrete gravity arch dam.
Design of large diameter steel or concrete penstocks.

Level 3 Design of nuclear aircraft carrier (CVN).
Design of large submerged concrete oil storage structure in North Sea.
Design of Alaska oil pipe line.

Level 4 Design of large space station.
Design of English Channel vehicular tunnel.
Design of nuclear powered aircraft.

III. Technical Talent Required

Level 1 Engineers B.S., Civil, Mechanical, Electrical, (normal for small shipyard).

Level 2 Engineers M.A., Civil, Mechanical, Electrical, Specialist, (normal for large shipyard).

Level 3 Engineers D.D., Civil, Mechanical, Electrical, Specialist, Consultant (normal for designing CVNs).

Level 4 Engineers D.D., Civil, Mechanical, Electrical, highest level specialist and consultant - international.

IV. Availability of Construction Facilities

Level 1 Large number of facilities on each cost, assume about 10 firms could bid on work.

Level 2 Four, five facilities available in U.S., assume two or three bids.

Level 3 One facility capable, assume cost plus contract required.

Level 4 All new facility must be built and operated on cost plus basis.

V. Field Supervisors and Specialists Required

Level 1 Skills required for construction of office buildings, apartment house, and simple civil works.

Level 2 Skills required for construction of large civil works, Naval auxiliaries, complex merchant ships.

Level 3 Skills required for complex surface Naval ships, weapon systems, deep water off-shore exploration.

Level 4 Skills required to build major space systems.

VI. Deployment Capability

Level 1 Conventional ship launching, sliding ways or in flooded graving dock, single tug tow, single anchor.

Level 2 Multi tug tow and three or more anchors.

Level 3 Multi tug tow - three or more anchors, ocean tipping - i.e., pumping platform.

Level 4 Multi tug tow - three or more anchors, anchors on slope, ocean tipping - larger than ever done before.

VII. Efficiency of Program Organization

Level 1 Single program manager with 100% responsibility.

Level 2 Multi program managers operating under coordinator without 100% authority over program managers.

Level 3 Program management by Government Commission representing several Government agencies.

Level 4 Program management by multi-national organization.

VIII. Capability of Program Management

Level 1 Management team that has career experience in the similar types of projects.

Level 2 Experienced management team working on new type projects.

Level 3 New management team that has not worked together before, but individually experienced.

Level 4 New management team that has not worked together before and has not had much experience or whose interest is divided.

IX. Probability of Meeting Schedule

Level 1 Construction of automobile.

Level 2 Construction of common civil works, office buildings, simple ships.

Level 3 Construction of large Naval ship - subway system.

Level 4 Construction of space station - arctic pipe line - MX missile system.

X. Probability of Staying Within Budget

Level 1 Manufacture of mass production items, i.e., autos, household appliances, etc.

Level 2 Common office buildings, roads, etc.

Level 3 Naval ships, subway systems.

Level 4 Space station - underwater colony - arctic pipe line.

XI. Probability of Continuity of Funding

Level 1 Projects that can be completed in less than one year, e.g., public purchase of cars, small construction projects.

Level 2	Public projects that can be completed in two to five years, but financed by a single Government agency.
Level 3	Public projects that take five to fifteen years that require separate financing for each of several phases.
Level 4	Same as Level 3, plus the uncertainty of multi-government or international financing.

XII. Vulnerability to "Acts of God."

Level 1	Underground structures.
Level 2	Underwater structures.
Level 3	Surface structure, land.
Level 4	Surface structure, ocean.

ORI, Inc.
1400 Spring Street, Silver Spring, Maryland 20910
(301) 588-6180