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Contract Report

CR 88.004
December 1987
An Investigation Conducted By
MAR Incorporated, Rockville, MD
Sponsored By Naval Facilities
Engineering Command

DEPLOYABLE WATERFRONT TRANSPORTABILITY STUDY USING HEAVY LIFT SUBMERSIBLE SHIPS: FINAL REPORT

ABSTRACT The Navy is engaged in a program to define and demonstrate Deployable Waterfronts that will provide worldwide logistics support for our forces in CONUS and overseas. These deployable waterfront facilities would serve such functions as: a) Strategic Sealift Ship unloading at fixed ports or Logistics Over the Shore (LOTS) sites, b) Advanced base pre-positioning, c) Advanced Logistics Support Bases for fleet replenishment, and d) Relocatable piers for homeporting and for Strategic Sealift Support Facilities restoration in the event of damage. Homeported and pre-positioned platforms could also provide some peacetime cost offsetting advantages over present support systems.

An investigation was conducted into the use and availability of heavy lift semi-submersible ships for transporting deployable waterfronts.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

METRIC CONVERSION FACTORS

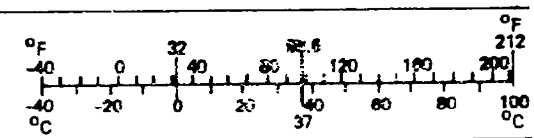
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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The Navy is engaged in a program to define and demonstrate Deployable Waterfronts that will provide worldwide logistics support for our forces in CONUS and overseas. These deployable waterfront facilities would serve such functions as: a) Strategic Sealift Ship unloading at fixed ports or Logistics Over the Shore (LOTS) sites, b) Advanced base pre-positioning, c) Advanced

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Logistics Support Bases for fleet replenishment, and d) Relocatable piers for homeporting and for Strategic Sealift Support Facilities restoration in the event of damage. Homeported and pre-positioned platforms could also provide some peacetime cost offsetting advantages over present support systems.

An investigation was conducted into the use and availability of heavy lift semi-submersible ships for transporting deployable waterfronts.

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SECTION 1

1.0 Introduction

The Navy is engaged in a program to define and demonstrate Deployable Waterfronts that will provide world wide logistics support for our forces in CONUS and overseas. The Memorandum of Agreement on U.S. Navy and U.S. Army Joint Strategic Mobility Program Development and Coordination, signed by VADM T. J. Hughes, DCNO Logistics, OP 04 and LTG B. F. Register Jr., DCS Logistics, DALO-ZA, on 8 Dec 86, outlines a balanced program and capability to ensure the necessary resources of ships, cargo offload systems and theater logistics systems to provide the required flow of materiel in support of forces worldwide. The Navy has specific tasking to determine if a requirement exists for a family of deployable waterfront facilities. These facilities would serve such functions as: a) Strategic Sealift Ship unloading at fixed ports or Logistics Over The Shore (LOTS) sites, b) Advanced base pre-positioning, c) Advanced Logistics Support Bases for fleet replenishment, and d) Relocatable piers for homeporting and for Strategic Sealift Support Facilities restoration in the event of damage. Homeported and pre-positioned platforms could also provide some peacetime cost offsetting advantages over present support systems.

1.1 Scope of Work

An investigation was conducted into the use and availability of heavy lift semi-submersible ships for transporting deployable waterfronts. The results of this investigation is in the form of technical data suitable for use in preparing program documents.

1.2 Summary

The deployment waterfront concept is a family of large modules that can be configured to accomplish a variety of missions. These modules can be outfitted with special mooring, fendering and cargo handling equipment which allow use in unsheltered offshore locations. When equipped with storage modules the deployable waterfront can function as an Advanced Logistics Support Base supporting the deployed fleets. The basic pier facility could be used for advanced base pre-positioning of stores and equipment. Other utilities and repair outfitting packages would provide a standard homeport pier facility. The focus of this study is on the transportability of these pier units on heavy lift semi-submersible ships. The number and characteristics of ships available world-wide are tabulated with size and weight limits noted. The major conclusions are that the pier modules can be constructed to fit on the cargo deck of 105 feet or wider ships and in multiples to fit on cargo decks up to 426 feet long. The weight of multiple units can be up to 14668 short tons. This envelope would fit on any of the available ships.

1.3 Conclusions

With the oil exploration impetus, a significant capability to safely transport large structures long distances across oceans has been provided.

1.4 Recommendations

The design of deployable waterfronts should include the requirement to be compatible with the available transport ships. Provisions need to be made to acquire the services of these ships in time of need. Further, through out the design, development of the deployable waterfront basic modules including the add-on features there will be a need to test, demonstrate, validate and revalidate the concept through out its life by conducting full scale exercises utilizing the heavy lift semisubmersible ships. Further work is needed to determine the limiting environmental conditions of current, wind and wave conditions that loading and offloading of these heavy lift ships with military cargo can be accomplished. Universal seafastenings need to be developed to speed up the loading process. Methods and equipment required to protect the cargo from waves breaking over the deck while underway need to be developed.

SECTION 2

2.0 Discussion

The deployable waterfront consists of a family of large modules that can be configured to accomplish a variety of missions. These basic modules when outfitted with special mooring, fendering and cargo handling equipment can be used in sheltered or unsheltered offshore locations. When storage modules are added the deployable waterfront can function as an Advanced Logistic Support Base supporting the deployed fleets. The basic pier facility could be used for advanced base pre-positioning of stores and equipment. Utilities and repair outfitting packages would provide a standard homeport pier facility. These facilities could also serve as the Strategic Sealift Support Facilities port restoration in the event of damage. Homeported and pre-positioned platforms could also provide some peacetime cost offsetting advantages over present support systems.

The use and availability of heavy lift semi-submersible ships for transporting deployable waterfronts was demonstrated by the British operations in the Falklands. Figure 2-1 shows the load out in transit and figure 2-2 shows the installation in place. The British deployed this floating pier facility from England to the Falklands in March 1984 to support the after action operations. Six offshore oil field ballastable support barges (328 feet x 98.4 feet x 30 feet deep) were outfitted in England and transported the 8000 miles in three trips using the DYVI semisubmersible heavy lift ships. The first load was made up of the support crane barge, 2 quayside barges, and the six mooring dolphins. The second load contained the causeway sections, the roll-on roll-off pontoon and one storage barge.

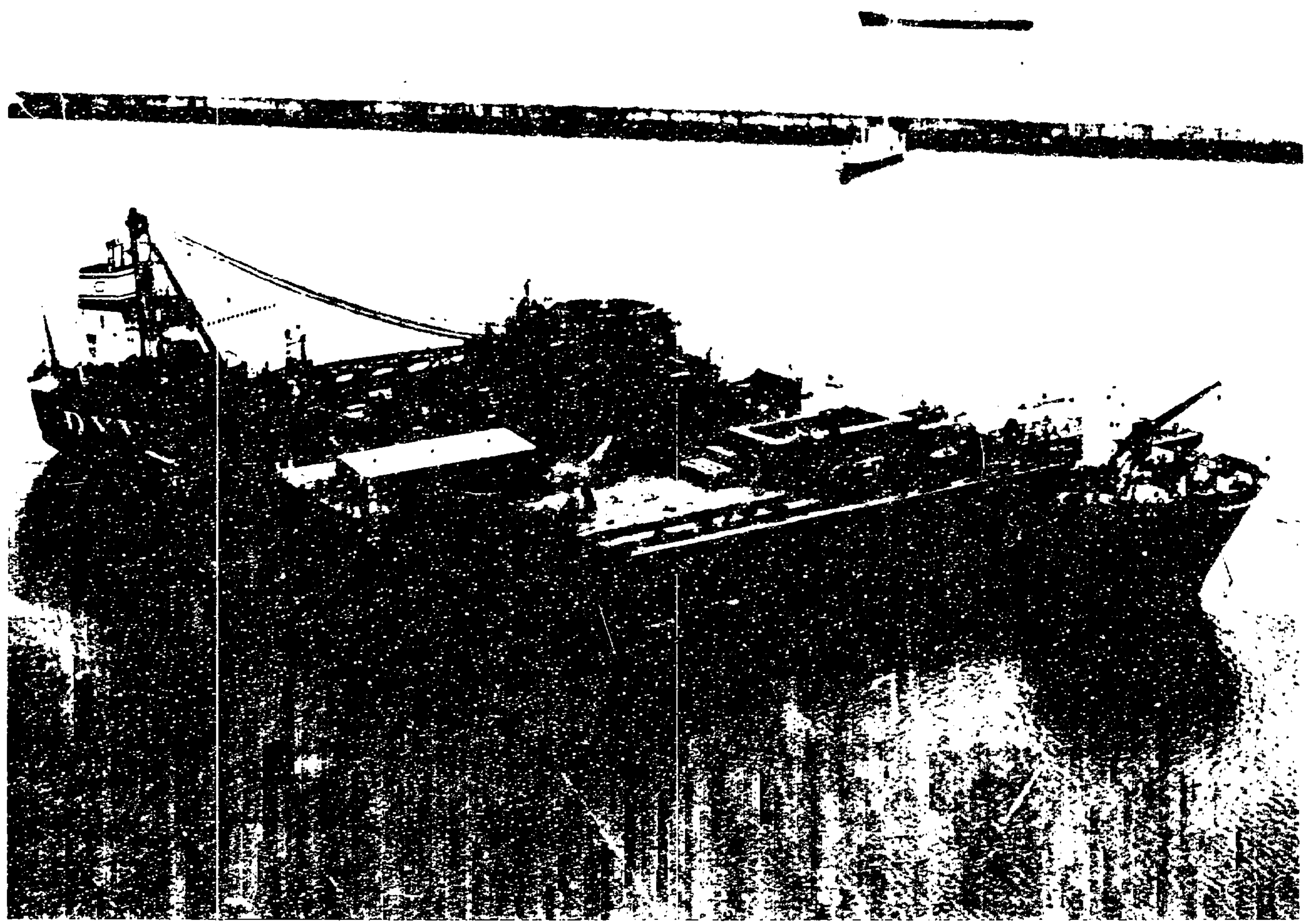

Figure 2-1 The British Flexiport in transit to the Falklands.

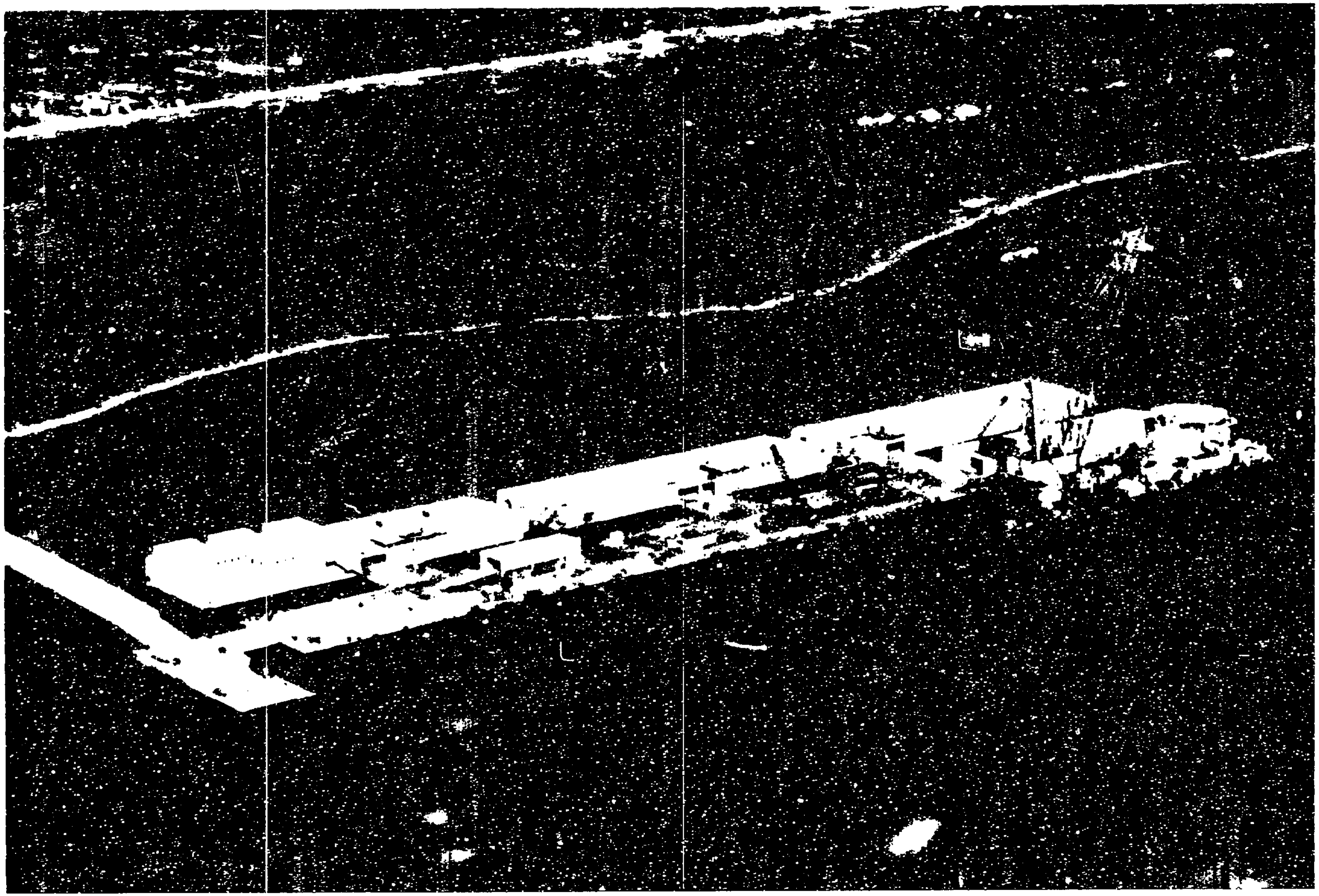

Figure 2-2 Flexiport installed in the Falklands in 1985.

The third load was made up of 2 storage barges and one quayside barge. This facility provided 900 feet of ship berthing, 18,000 square feet of quayside work area, 1,270,000 cubic feet of covered storage and a roll-on roll-off facility. The link to shore was provided by 600 feet of ballasted causeway. The 2-way causeway was fabricated in 5 sections and designed to carry loads up to 30 tons over a single axle. The onsite installation took about 75 days. Office, accommodation and support facilities were built as second stories over the storage areas. The total cost of this facility was $32M.

2.1 Deployment

The planning for deployment will take into account the ships available to make the transit. Since it is not known what vessels will be available, and with the limited assets available, the deployable waterfront planning and module design should be based on the capability of the smaller heavy lift ships. The module design specifications should contain loading criteria based on loads expected during transit. This, along with the cargo deck dimensions, will guide the design envelope (overhangs) into compatibility with the transit ships. Early trade-offs will be required to cost out the transit methods of tow vs carry. The benefits of carrying the modules vice towing are that the modules do not have be designed to withstand the same loads as a ship. Experience has shown the dynamics of carry, i.e. dry tow, put less dynamic loads on the module structure (including the internal machinery and outfittings) than would be experienced when under tow. The result would be modules weighing and costing less. The safety of open ocean transport has been dramatically demonstrated with the successful movement of the large jack-up oil rigs. Two rigs being transported 13100 nautical miles on the DYVI SWAN, had an overhang of 114' encountered a gale force cyclone off Madagascar. Waves reached 27' causing the ship to slow from an average 15 knots to 12 knots and the maximum roll was less than 3.5 degrees. Many similar trips have been experienced transporting other oil rigs and large structures. As a measure of how well the transport industry has progressed, the insurance premiums for wet tows was around 10% of the value of the cargo. With the faster and safer dry tow the premiums were reduced to 2-3%. Rates for self-propelled vessels are now around 0.2%. This dramatic difference points out the value of the self-propelled vessels carrying the cargo. The value can be traced all the way back to the cost savings in the design of the equipment, foundations and basic structure of the cargo.

2.1.1 Preparations

The cargo load must be laid out to provide the most efficient use of space available considering the stability, dynamic motions, overhang, slamming, freeboard, list and trim of the vessel. Also the destination, time of year and expected weather conditions is included in the load planning. Seafastenings are designed, fabricated and installed according to the planned load out. The design of the fastenings is critical since the load is considered integral with the ship for the overall stability calculations. Guide fenders are positioned and welded on the deck to hold the cargo in place as the ship is ballasted. The items making up the load are rafted together for ease of handling and the loading is sequenced according to the cargo draft. i.e. the deep draft cargo is loaded prior to the shallow draft cargo. An area with sufficient water depth to allow for the max submergence draft plus desired clearance is located near were the cargo is located. Float-on or off takes about 6-12 hours depending on the load configuration. The loading area should have relatively calm water and wind conditions and the weather forecast over the expected loading time should be desirable.

2.1.2 Loading Cargo

The transit ship is moored, in a 4 point moor, in the desired location and ballasted down. The cargo load is rafted according to draft, positioned with tug boats, secured to the fender guides for the sequenced loading. As the ship is deballasted the loads settle into the desired positions. See Appendix A for sample loading sequence of AMERICAN CORMORANT.

2.1.3 Seafastenings

The seafastenings are positioned and the cargo welded for the sea transit.

2.2 Transit

Transit time for the ships vary from 13 to 16 kts with ranges up to 30,000 miles. Some varying of the ship's heading will be made as necessary to minimize the dynamic loads on the cargo. Also, slamming loads on the cargo overhangs is a condition to avoid and is typically experienced in beam seas. Change in heading to quartering sea will reduce or eliminate the frequency and intensity of the wave slamming. Bulwarks have been constructed on some of the ships to reduce the impact of the wave slap on the cargo.

The AMERICAN CORMORANT had deck extensions added, about 20 feet wide by 60 feet long both port and starboard about midships, to protect the cargo items that overhung the deck from wave slap.

2.3 Offload Cargo

The transit ship is moored in the selected location and ballasted down. As the cargo load is floated according to draft, the cargo is rafted with tug boats, secured to the fender guides for the sequenced unloading.

2.3.1 Preparations

A location with adequate water depth and shelter from the wind and waves needs to have been selected as close as possible to the objective area. The mode of transit from the unloading area to the location of final use must be planned early on and specific tugs either provided on location or carried with the cargo.

2.3.2 Offloading Cargo

The sequence of offloading will be the reverse of the loading where the shallow draft cargo will be floated-off first. A sufficient number of tow vessels need to be on hand to move the cargo to the desired locations. Some temporary nearby anchoring capability for the cargo may be required during the float-off. The transit ship could also carry tug boats to handle the offload and assembly.

2.3.3 Ship Turnaround

Since there are a small number of these heavy-lift float-on float-off ships, ship turnaround is very important. This makes it very important to have a detailed plan and the resources available to carry it to a successful conclusion.

2.3.4 Actual Operations

An example, reported in Ocean Industry Magazine in May 1982, of a commercial load/transit/offload operation of two large oil jack-up rigs contains a break down of time for each operation:

Preparation. The time required for preparation of cribbing and installation on the ship was not given.

Load. The loading of the two oil rigs was done in one day. Starting at 0800, they were in position over the ship at 1210, and dry at 1700. Four more days were required to weld the seafastenings and one more day for fueling before getting underway.

Transit. The ship was in transit 36 days from Singapore to Cameron LA.

Offload. Discharging the two oil rigs was accomplished in one day. Total elapsed time was 42 days.

For comparison, the same trip would have taken about 95 days if the oil rigs were loaded on barges and towed. There was no mention of environmental conditions encountered during load/offload.

Another example of the load/offload operation is included in Appendix A, with the "-my cargo on the AMERICAN CORMORANT.

2.4 Heavy Lift Semisubmersible Ships

Table 2-1 contains the principle characteristics of the heavy lift semisubmersible, self propelled, ships in the free world . There are 18 ships identified as potentially usable for the transport of deployable waterfront modules. Different sources were used to construct this table, some with conflicting information. Where possible, owner/operator provided information was considered to be the most authoritive and used in the table. From the table a range of dimensions can be defined. For all but the Dock Express Class ships the overhang is only limited by the

TABLE 2-1 CHARACTERISTICS OF HEAVY LIFT SEMISUBMERSIBLE SHIPS

OWNER/ OPERATOR		SHIP NAME	FLAG	SER-VICE DATE	LOA FEET	BEAM FEET	DEPTH FEET	LOAD LTONS	SPEED CRUISE/MAX KNOTS	RANGE NMILES	DRAFT TRANSIT/SUBM FEET	DECK SUBM FEET	CARGO LENGTH/WIDTH FEET	LOAD LTONS/FT2	BAL-LAST HOURS	CRANES/ CAPACITY NO/LTONS
American Automar	1/	AMERICAN CORMORANT	United States	1982	738	135	39	47000	13 / 16	29000	34/65	26	394 / 135	2.0	6	none
Dock Express	2/	DOCK EXPRESS 10	Dutch	1977	505	89	49	12795	16 /	20600	23/39	16	380 / 66			2/500
Dock Express		DOCK EXPRESS 11	Dutch	1977	505	89	49	12795	16 /	20600	29/39	16	380 / 66			2/500
Dock Express		DOCK EXPRESS 12	Dutch	1977	505	89	49	12795	16 /	20500	29/39	16	380 / 66			2/500
Dock Express		DOCK EXPRESS 20	Dutch	1982	556	90	49	14074	15 /	20500	29/39	16	418 / 66			2/600
Dyvi		DYVI SWAN	Norway	1981	593	106	44	24500	13 / 16	16000	32/68	24	416 / 106	1.8	6	none
Dyvi		DYVI SWIFT	Norway	1983	593	106	44	24500	13 / 16	16000	32/68	24	416 / 106	1.8	6	none
Dyvi		DYVI TEAL	Norway	1984	593	106	44	24500	13 / 16	16000	32/68	24	416 / 106	1.8	6	none
Dyvi		DYVI TERN	Norway	1982	593	106	44	24500	13 / 16	16000	32/68	24	416 / 106	1.8	6	none
ITC		SIBIG VENTURE	Norway	1982	728	138	41	43120	14 / 15	30000	31/64	23	423 / 138	1.3	6	3/3
Wijsmuller		SUPER SERVANT 1	Dutch	1979	456	105	28	14221	13 / 15	13730	21/48	19	335 / 105	1.3	6	none
Wijsmuller		SUPER SERVANT 3	Dutch	1981	456	105	28	13889	13 / 15	13730	21/48	19	335 / 105	1.3	6	none
Wijsmuller		SUPER SERVANT 4	Dutch	1981	456	105	28	13889	13 / 15	13730	21/48	19	335 / 105	1.3	6	none
Wijsmuller		SUPER SERVANT 5	Dutch	1982	456	105	28	13109	13 / 15	12480	20/48	19	335 / 105	1.3	6	none
Wijsmuller		SUPER SERVANT 6	Dutch	1982	456	105	28	13109	13 / 15	12480	20/48	19	335 / 105	1.3	6	none
Wijsmuller	3/	MIGHTY SERVANT 1	Dutch	1979	525	132	39	21160	13 / 15	14784	31/65	26	361 / 105	1.3	6	none
Wijsmuller		MIGHTY SERVANT 2	Dutch	1979	553	132	39	22834	13 / 15	14784	31/65	26	394 / 105	1.3	6	none
Wijsmuller		MIGHTY SERVANT 3	Dutch	1979	591	132	39	24304	13 / 15	14784	31/65	26	426 / 105	1.3	6	none

NOTES:
1. Max beam is 175' in way of port and starboard cantilever sections 60' long about midships, the basic hull has 135' beam.
2. Well deck similar to Navy LSD. Overhead clearance is 26 feet under removable pontoon deck. Deck is removed to give unobstructed well deck.
3. MIGHTY SERVANT 1 has cargo hold 263'x53'x25' and unobstructed cargo deck of 394' with aft buoyancy cases stowed recessed into fwd housing. MIGHTY SERVANT 2 has cargo hold 295'x53'x25' and unobstructed cargo deck of 426' with aft buoyancy cases stowed recessed into fwd housing. MIGHTY SERVANT 3 has cargo hold 328'x53'x25' and unobstructed cargo deck of 459' with aft buoyancy cases stowed recessed into fwd housing.

ship stability and structural strength of the cargo being carried. As a practical matter the overhang may be limited by dynamic stability and slamming. For example, the DYVI ships, with a max beam of 106 feet transported the Flexiport modules 8000 miles with an overhang of about 108 feet as shown in Figure 2-3. There are many examples of these ships carrying outsized cargo such as drill rigs, assembled refineries and drydocks.

Figures 2-4 through 2-9 show the plan and profile outlines of each class of ship drawn to the same scale of 1"= 100 feet. Salient characteristics of length overall, extreme beam, cargo loading and deck dimensions, draft while loading and depth of water over the cargo deck are included on each figure for ready reference.

2.5 Results

The Deployable Water Front module width could be limited by the 66 foot well deck of the Dock Express Class and with a module length of about 300 feet which would be compatible with all the heavy lift semisubmersible ships.

The limiting environmental conditions of current, wind and wave conditions that loading and offloading military cargo can be accomplished need to be determined. Some universal methods of padeyes, lashings and seafastenings need to be developed to speed up the labor intensive completion of the loading process. Operational methods and equipment need to be developed to protect the cargo from the waves breaking over the deck when in transit.

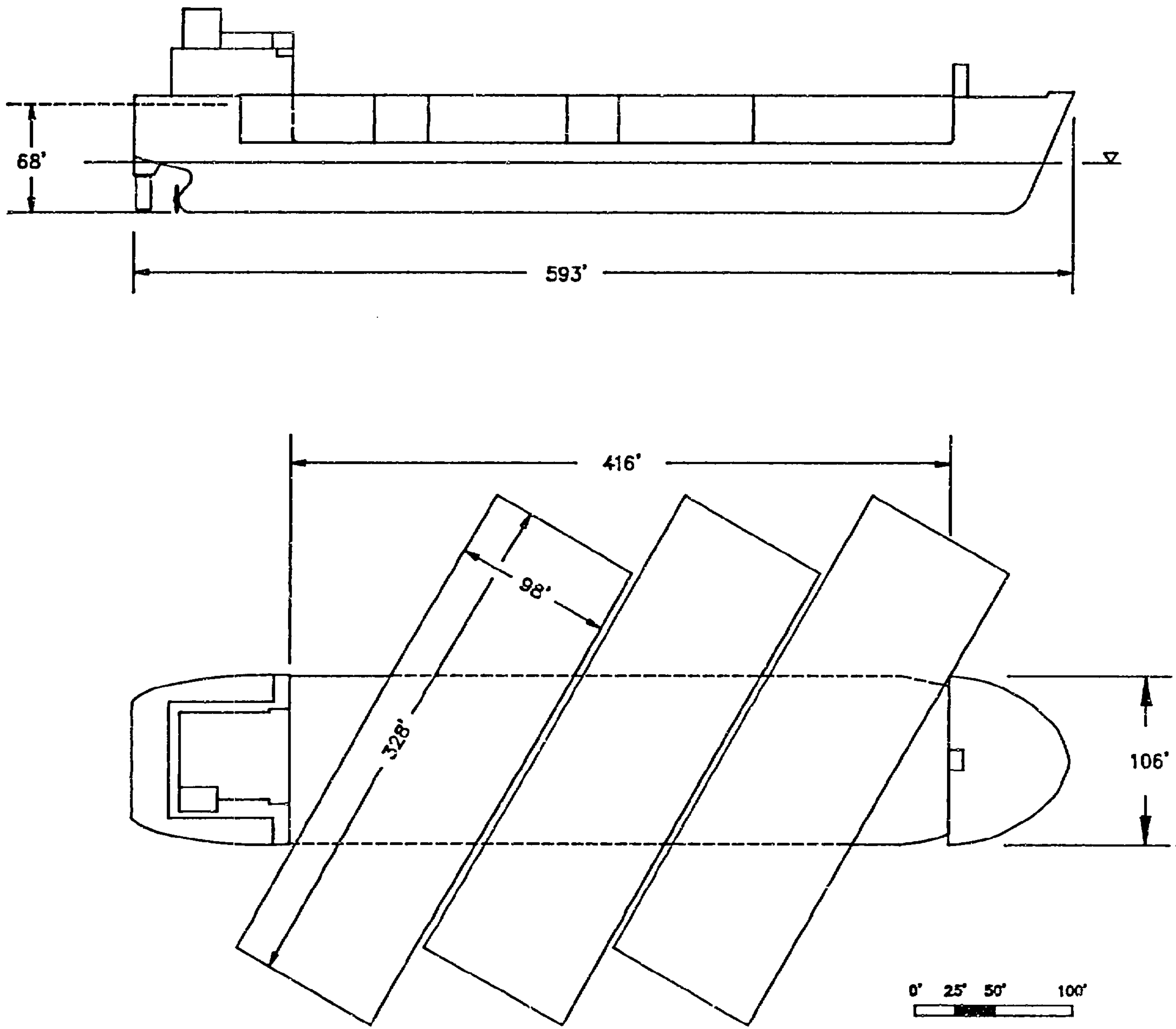

Figure 2–3. DYVI SWAN loaded with three Flexiport modules.

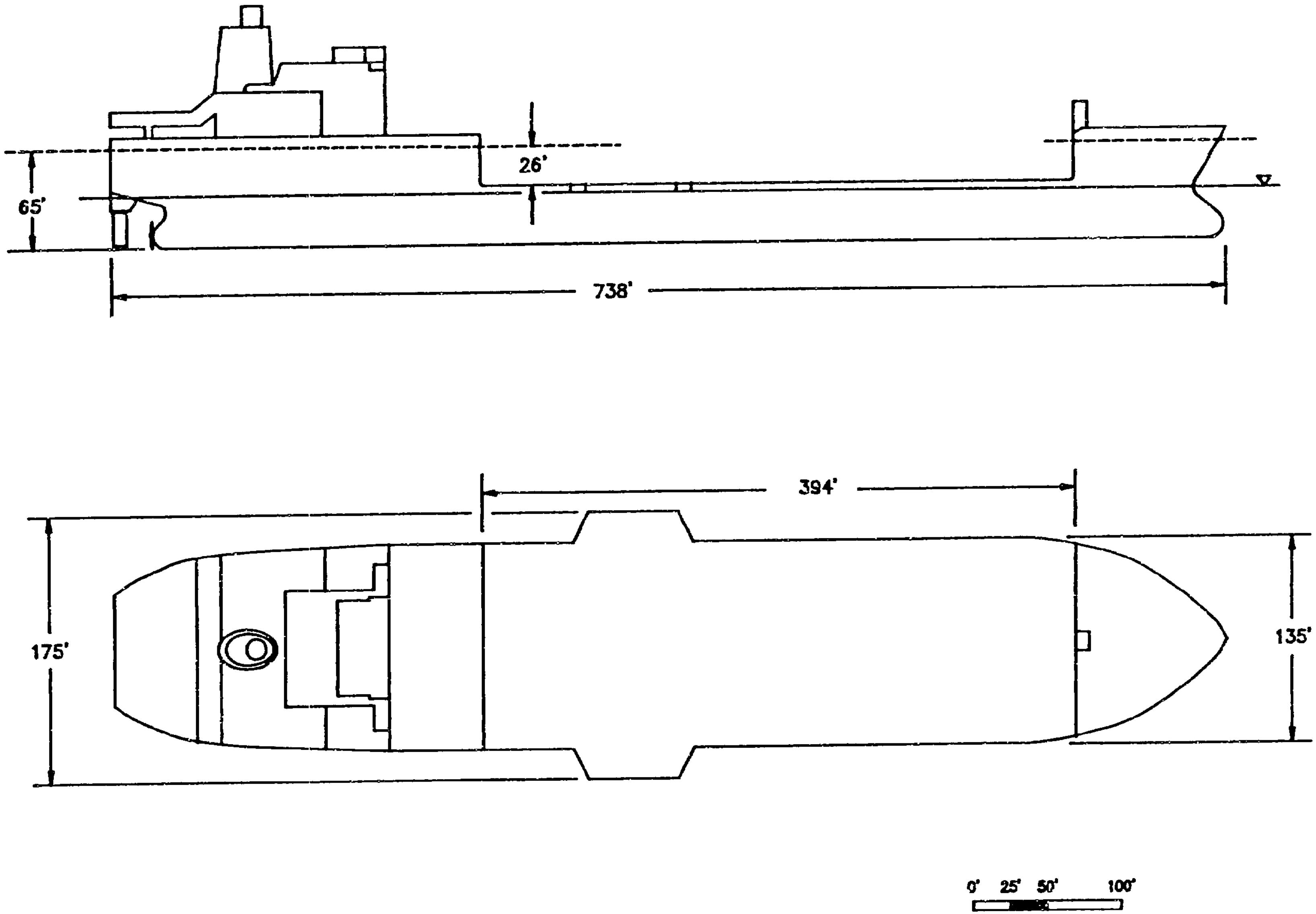

Figure 2–4. The AMERICAN COMORANT.
Cargo DWT: 47,000 Lton

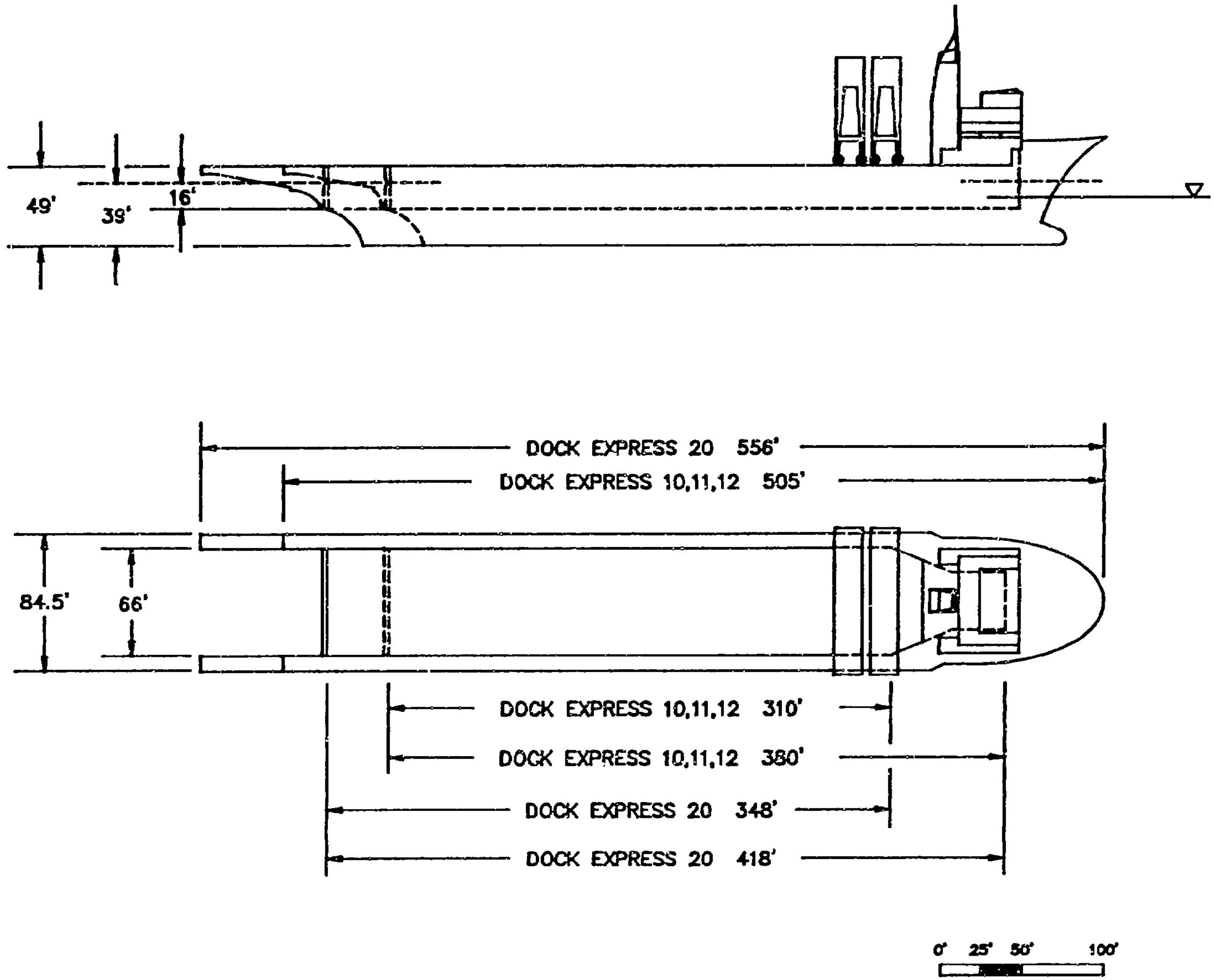

Figure 2-5. The DOCK EXPRESS Class.
Cargo DWT: DOCK EXPRESS 10,11,12 12,795 Lton
DOCK EXPRESS 20 14,074 Lton

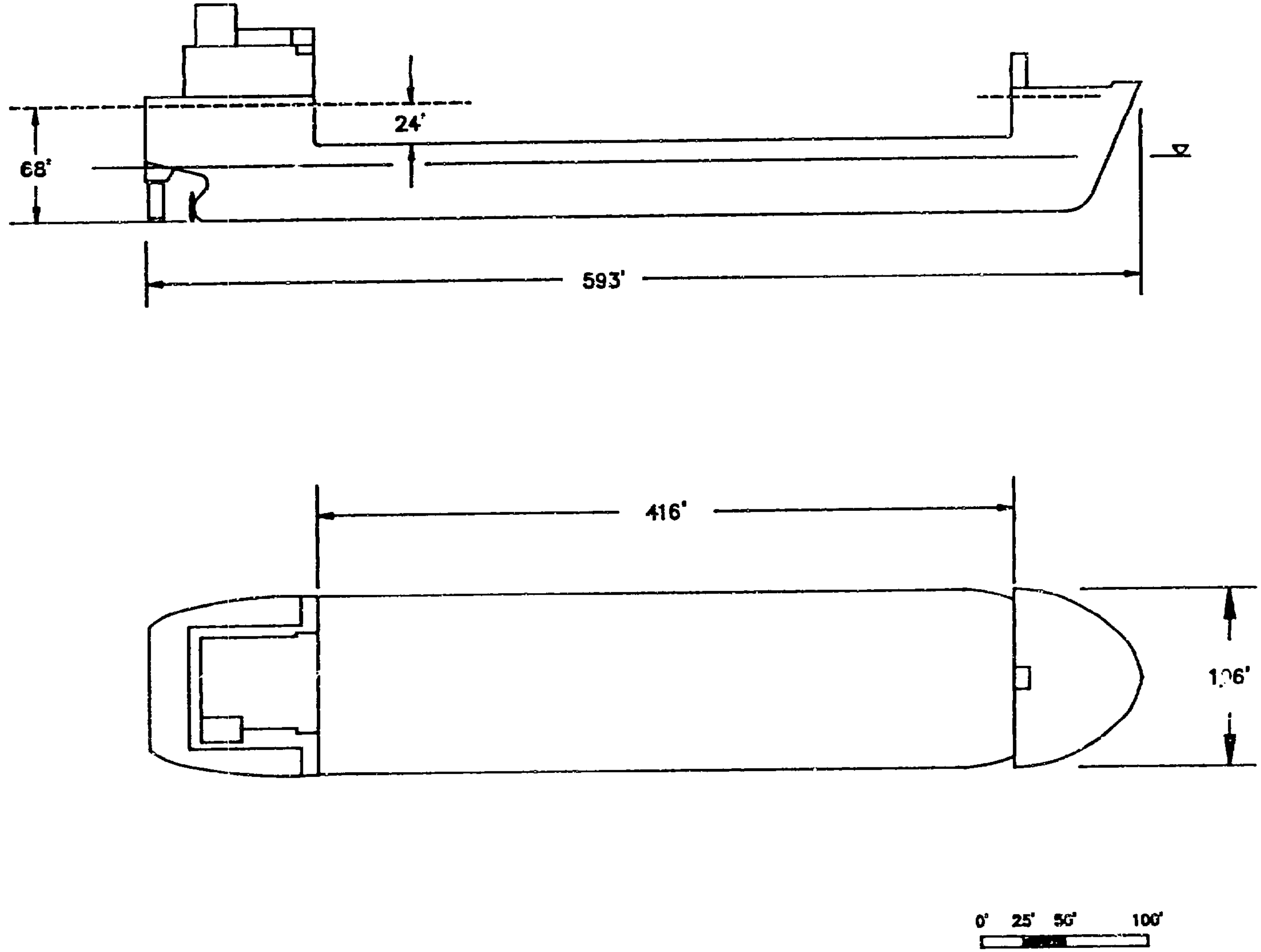

Figure 2-6. The DYVI Class.
Cargo DWT: 24,500 Lton

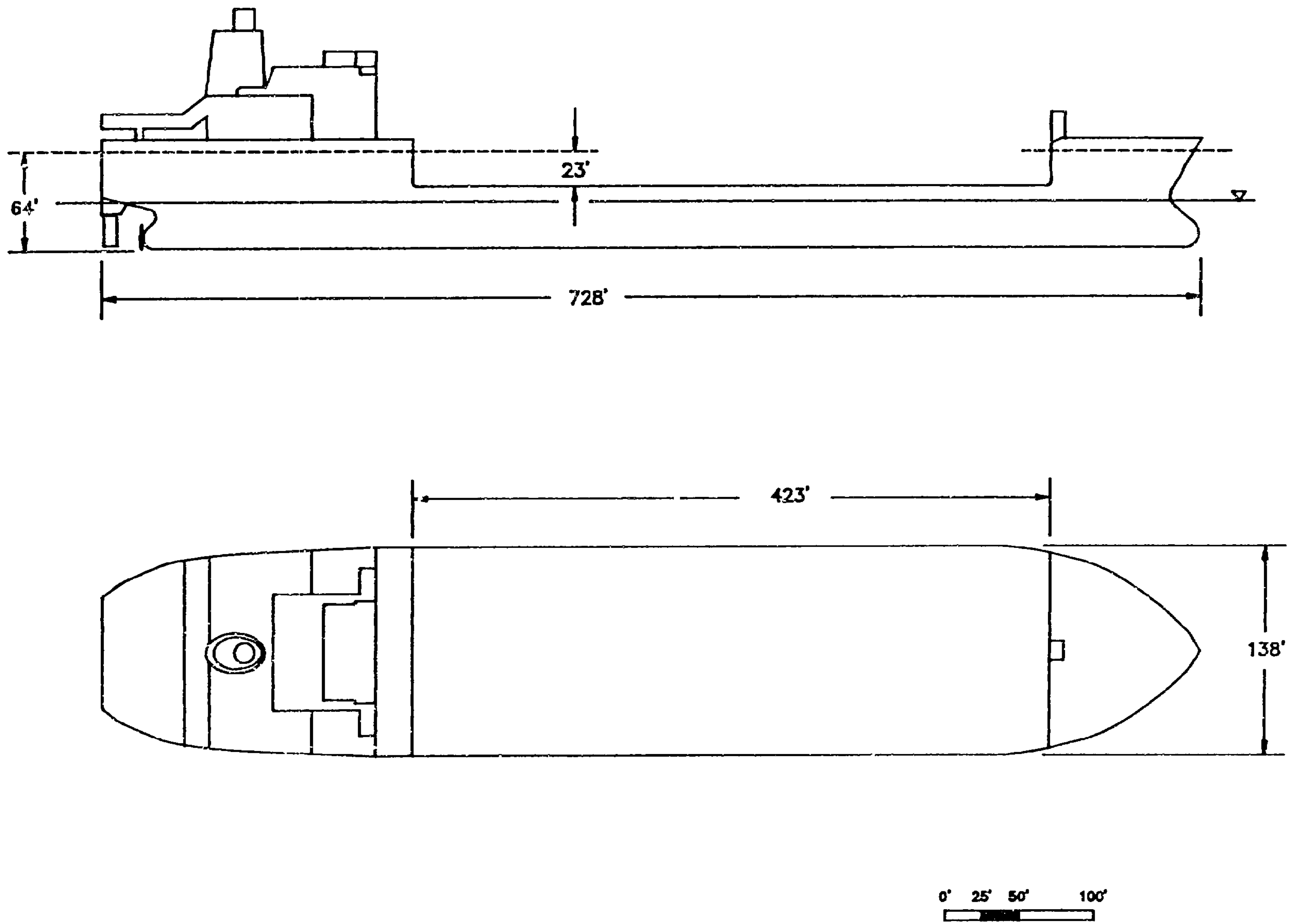

Figure 2–7. The SIBIG VENTURE.
Cargo DWT: 43,120 Lton

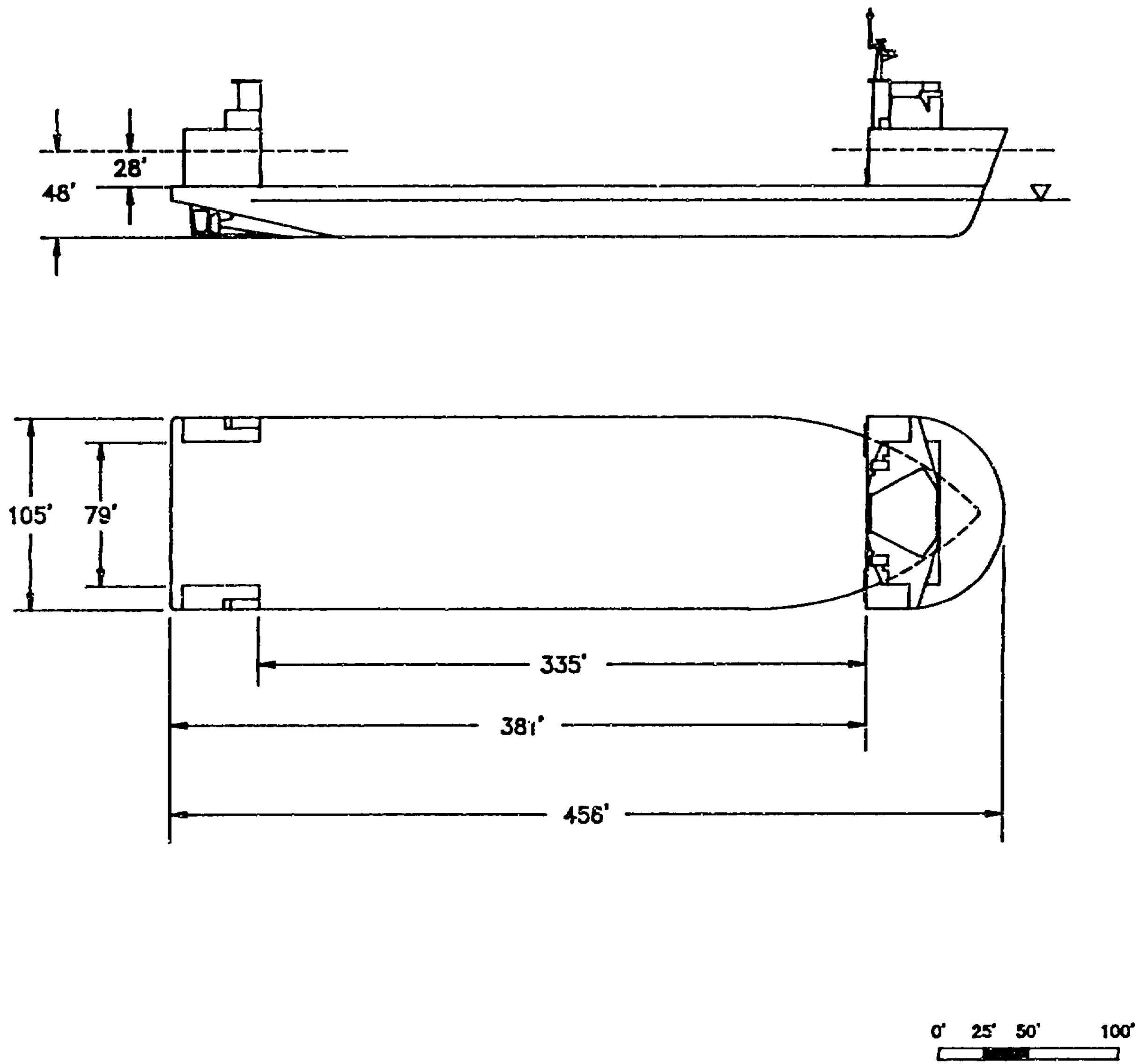

Figure 2-8. The SUPER SERVANT Class.

Cargo DWT: SUPER SERVANT 1 14,221 Lton
SUPER SERVANT 3,4 13,889 Lton
SUPER SERVANT 5,6 13,109 Lton

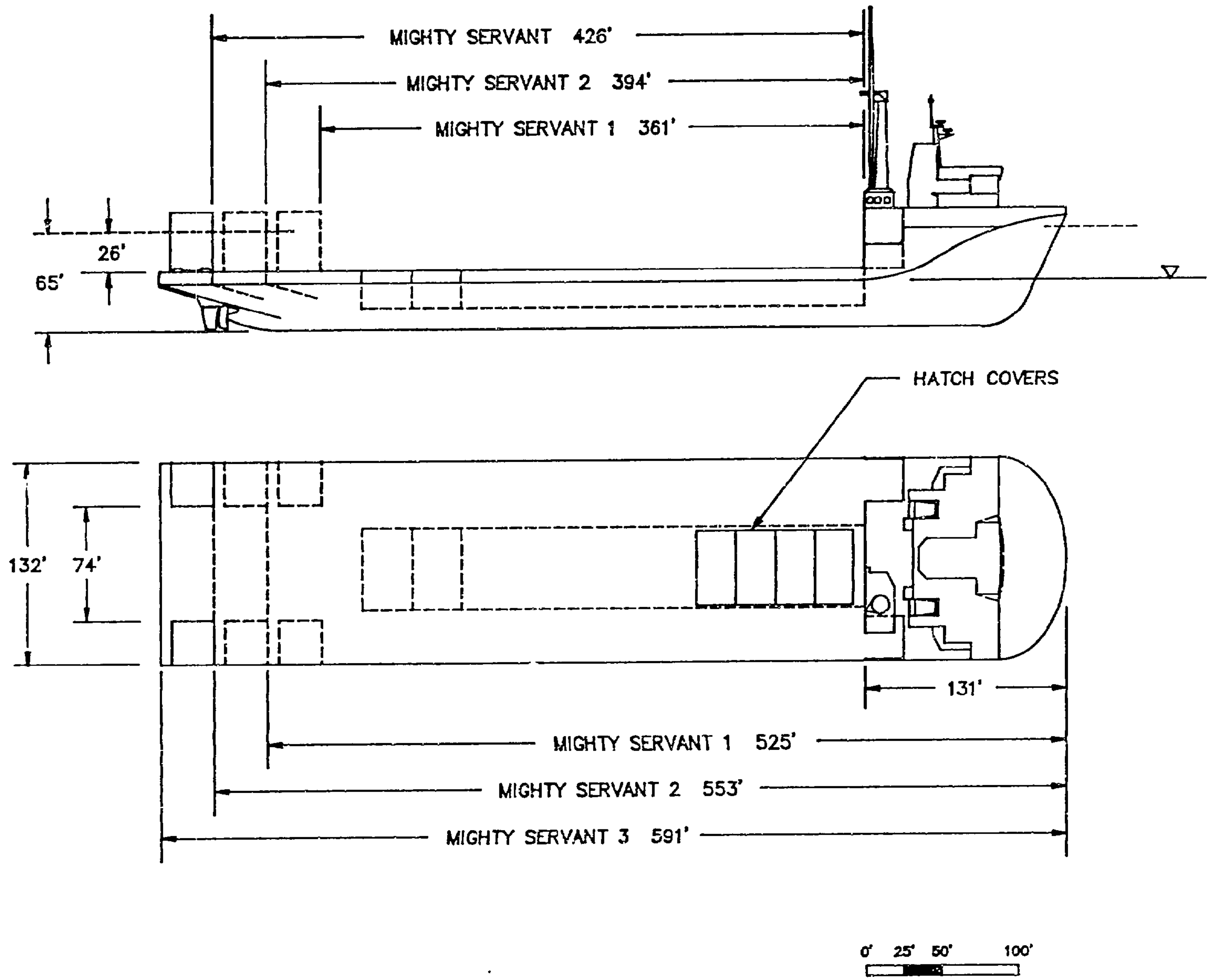

Figure 2–9. The MIGHTY SERVANT Class.
Cargo DWT: MIGHTY SERVANT 1 21,160 Lton
MIGHTY SERVANT 2 22,834 Lton
MIGHTY SERVANT 3 24,304 Lton

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Appendix A

The following photos show the AMERICAN CORMORANT float-on loading sequence of Army cargo 25-27 November 1985 in Charleston, S.C. This represents a typical loading operation which shows the complexity and support assets required.

Preparation time required to design, fabricate and install the foundations, tiedowns and guide posts was not available.

The 22 pieces of Army cargo was loaded in about 16 hours, 6 hours to moor and ballast-down the ship and four hours to load the cargo, and 6 hours to ballast-up the ship. Four tugs were used to handle the two nested tug boats, three nested LCM 8 craft and the two nested floating cranes. Other small craft were used to handle lines, etc. Three more days were required to attach the padeyes, lashings and seafastenings. The use of the four point moor was a unique requirement for this particular location, since then, this load has been discharged and reloaded with the ship swinging on its anchor. Also, on these subsequent loadings of the same equipment the tiedown time has been reduced to 8 hours of mechanical attachments.

The offload required 6 hours to ballast-down the ship with the cargo being removed within an hour.

The environmental conditions during the initial loading were minimal wind and wave action but with a 5 knot tidal current hence the requirement for the four point moor. The actual loading took place during slack water on each side of the tide.

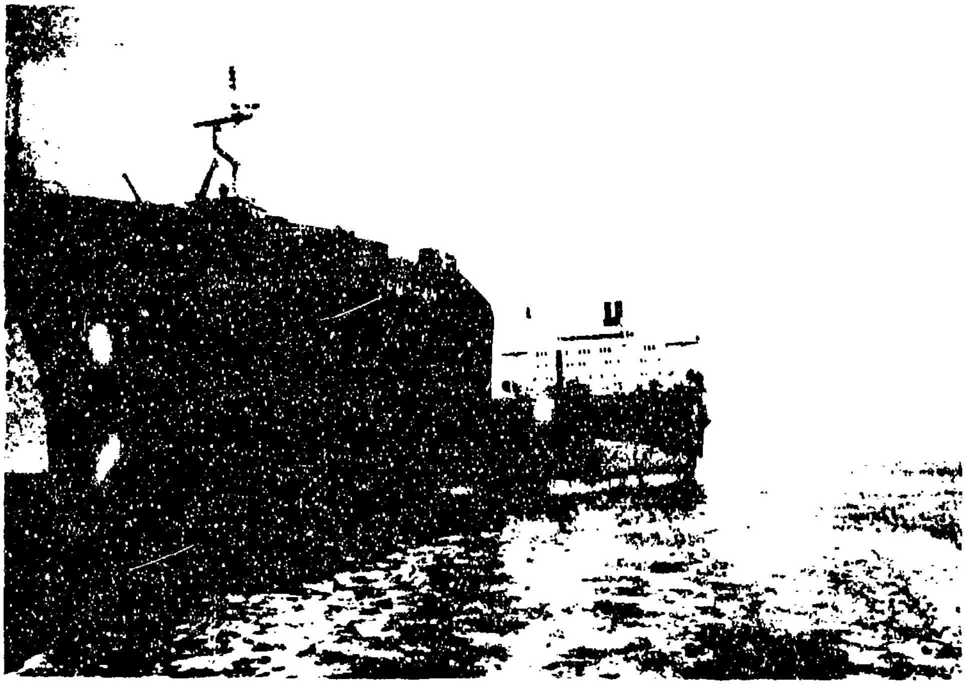

Figure A-1 Ship positioning in four point moor with the two bow anchors.

Figure A-2 Ship stern anchors ready to deploy.

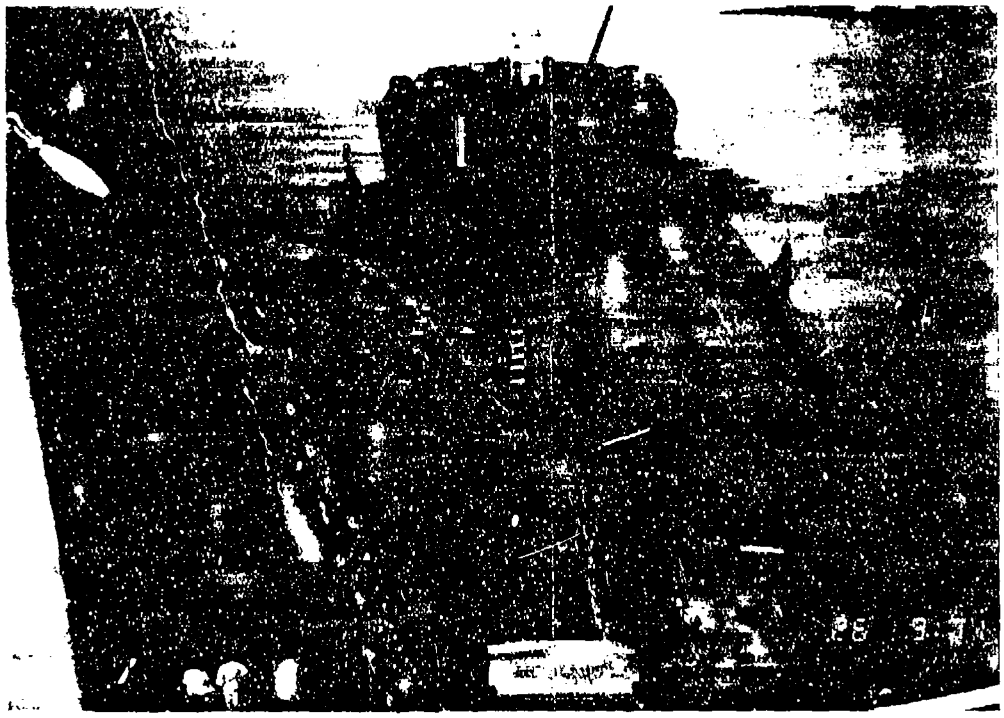

Figure A-3 Ship ballasting down, note the chocks and guide posts welded to the deck.

Figure A-4 Ship fully ballasted ready for cargo.

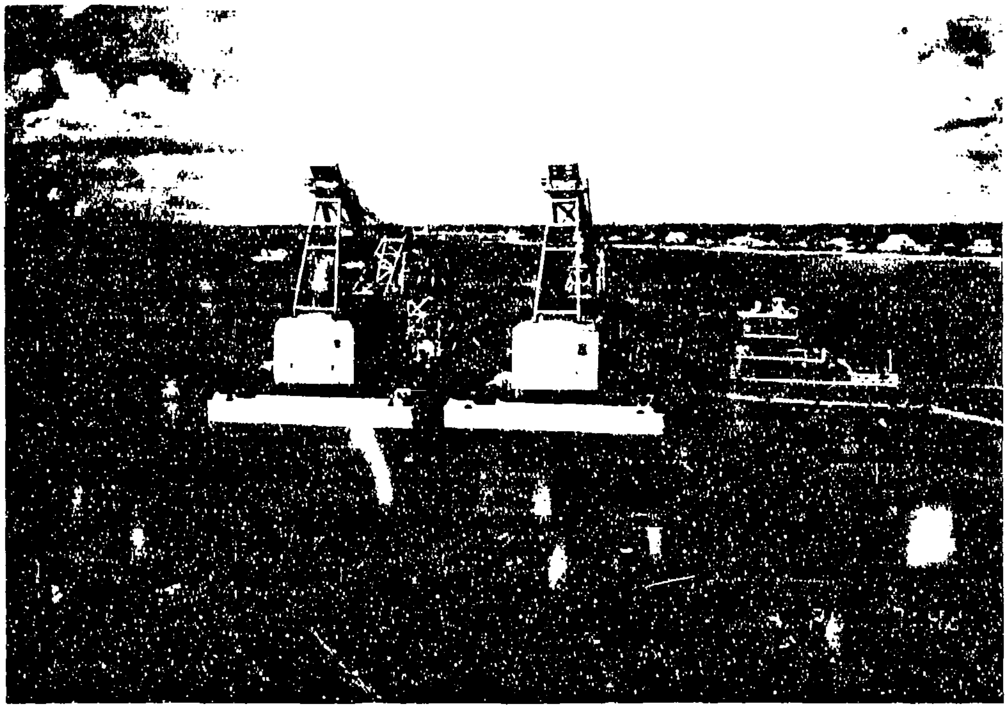

Figure A-5 Two YD 100 ton barge cranes rafted together, maneuvered into position.

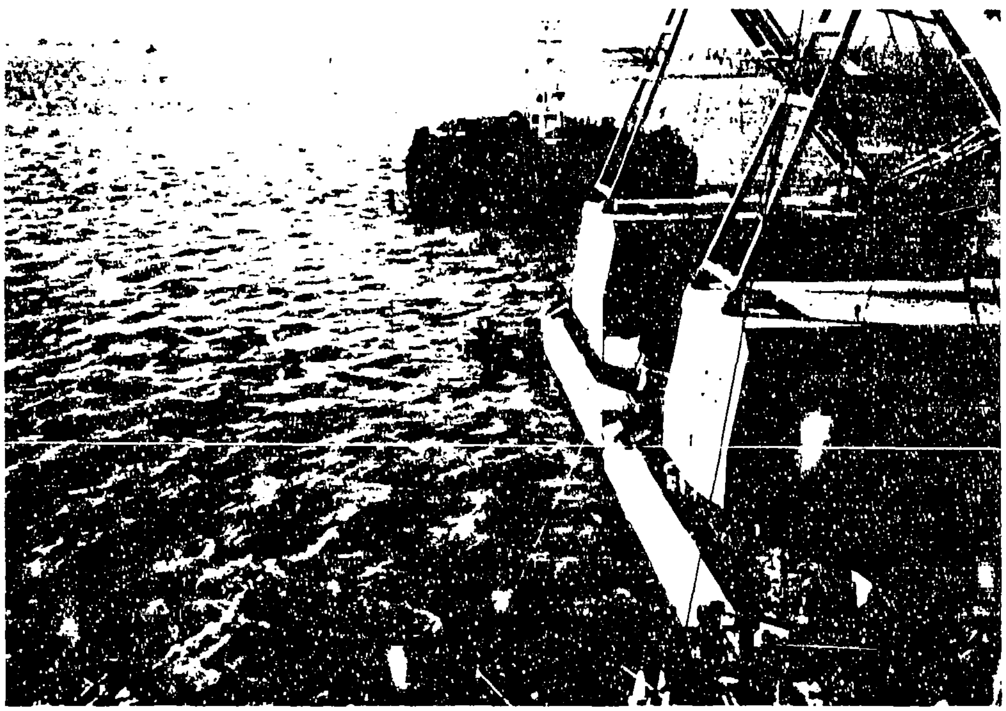

Figure A-6 Barge cranes positioned over ship.

Figure A-7 Two 100' Army tug boats, rafted together, being maneuvered into position.

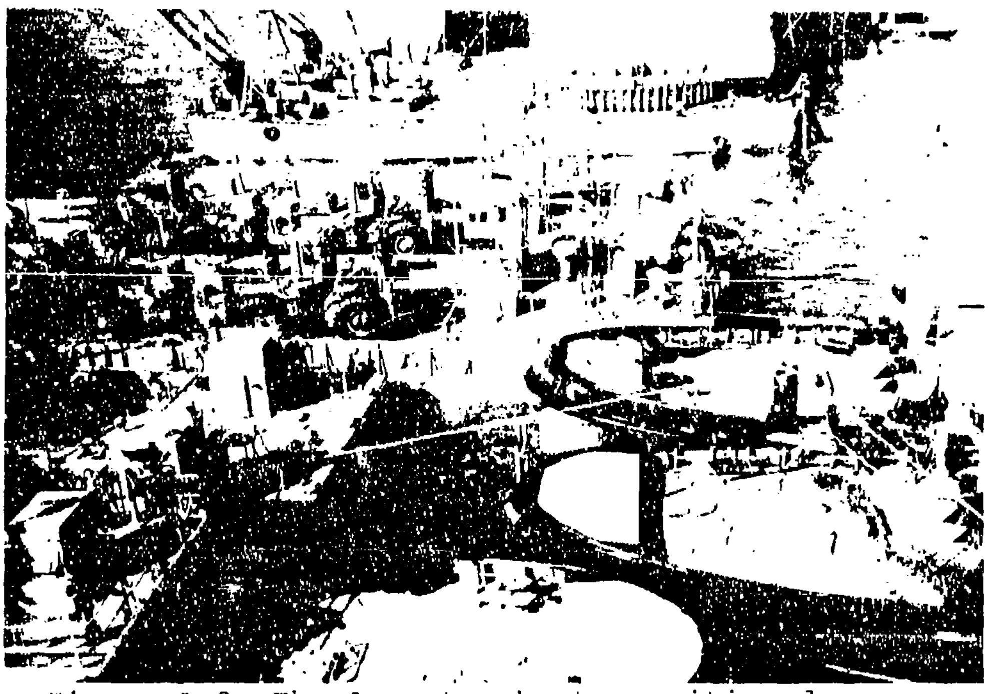

Figure A-8 The Army tug boats positioned over blocks on ship.

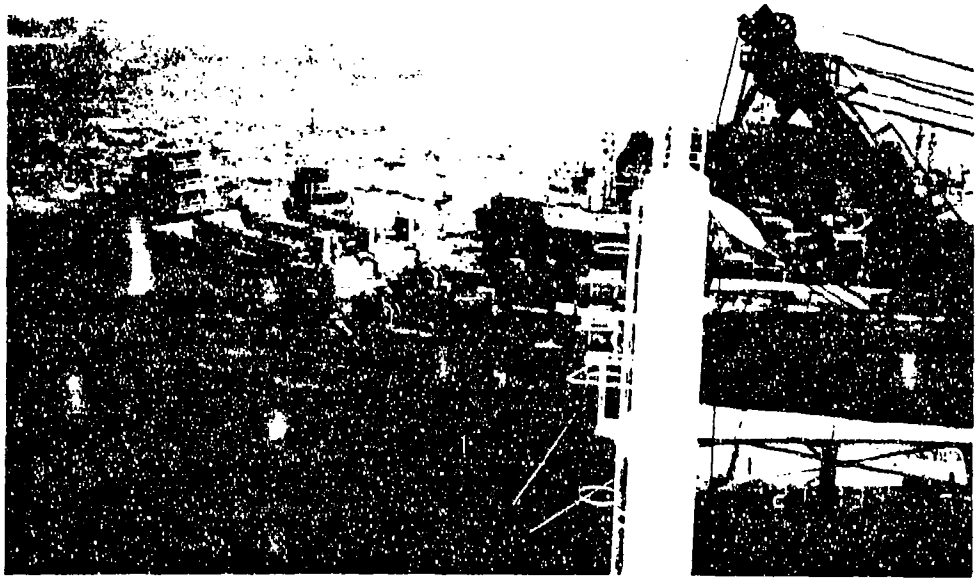

Figure A-9 Three LCM-8 being positioned by two tugs over ship.

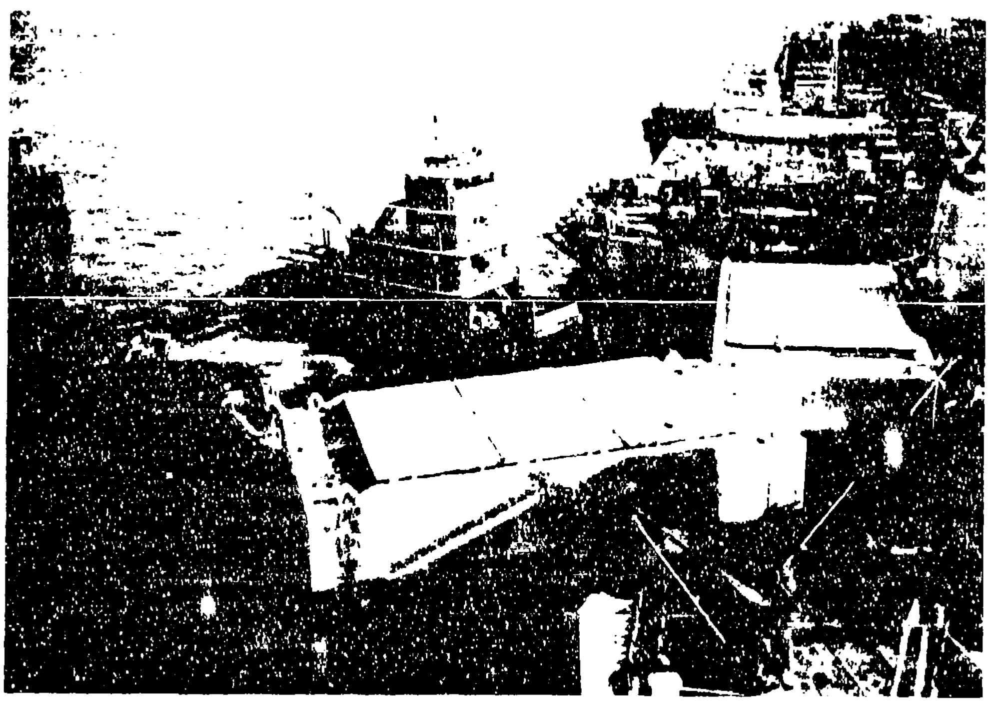

Figure A-10 Small craft used to assist in the positioning of LASH barges.

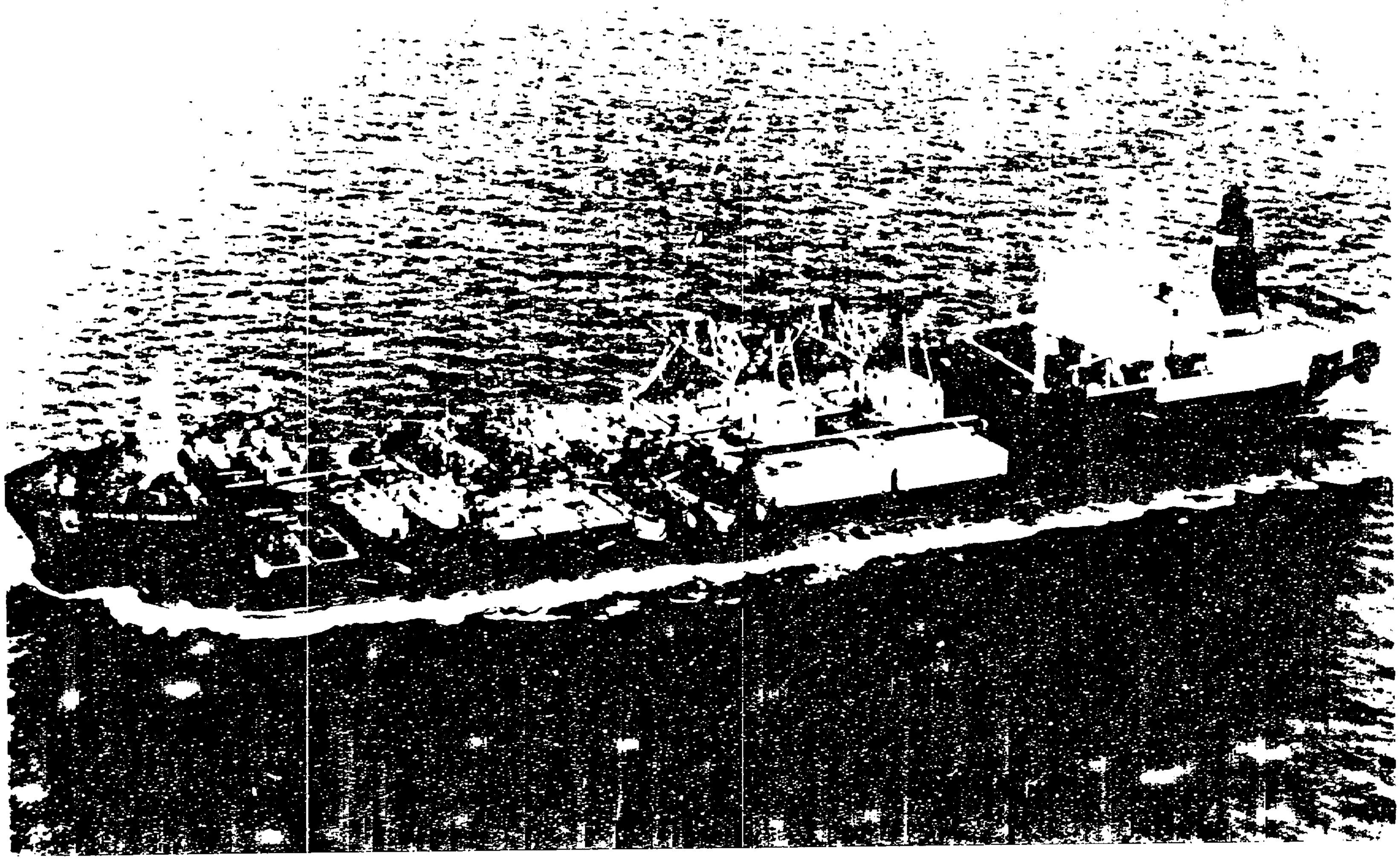

Figure A-11 AMERICAN COMORANT underway with total load.

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