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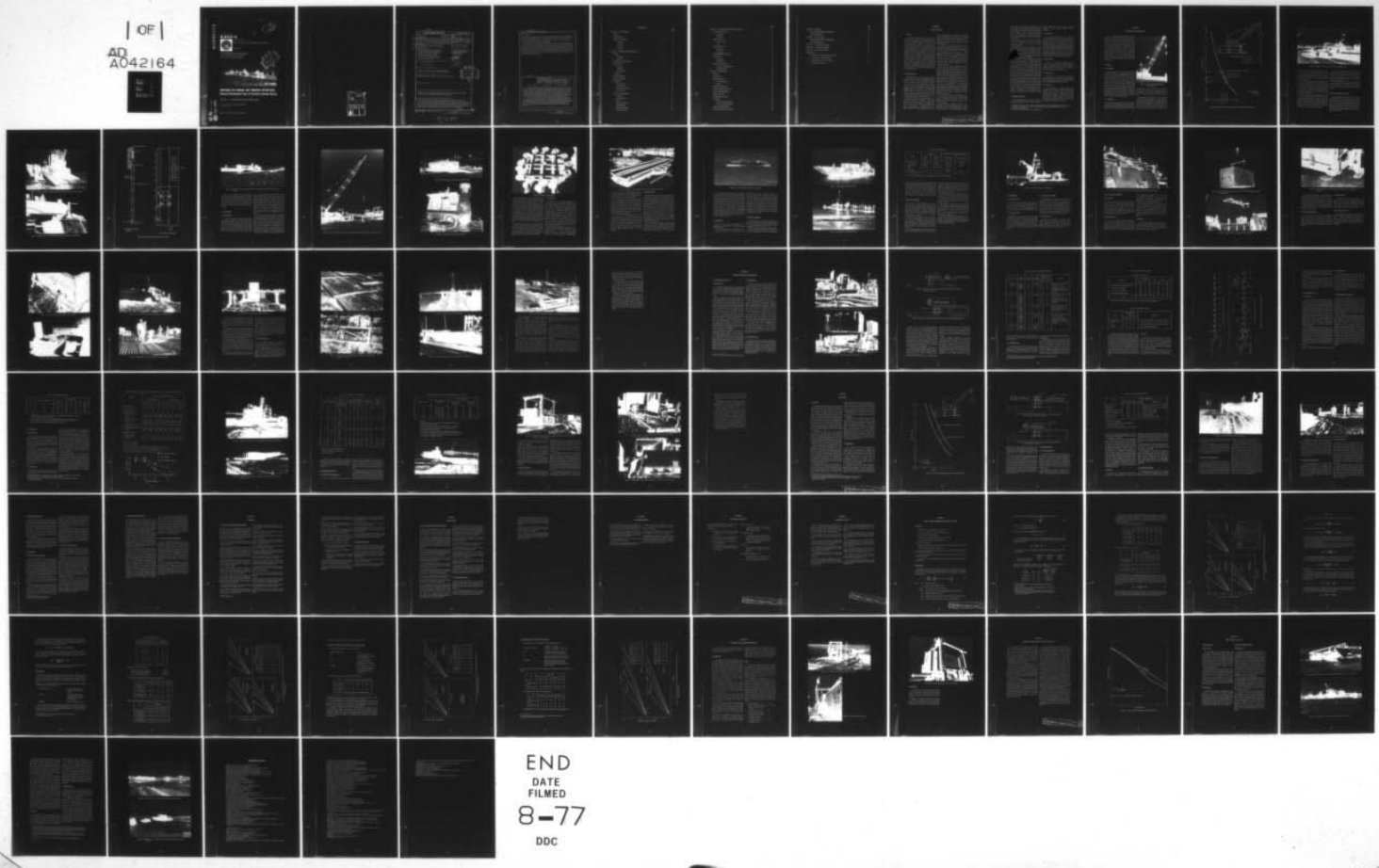

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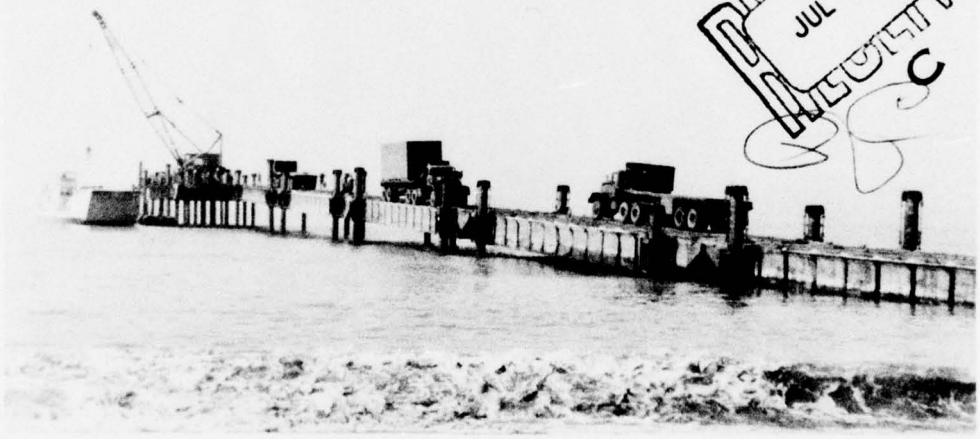

CONTAINER OFF-LOADING AND TRANSFER SYSTEM (COTS)
Advanced Development Tests of Elevated Causeway System

VOLUME V — CONTAINER-HANDLING OPERATIONS

by J. J. Traffalis, J. J. Hromadik, M. J. Wolfe,
and R. A. Bliss

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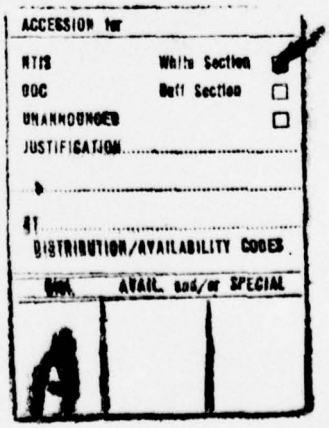
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A two-phase advanced development test program was conducted to evaluate the elevated causeway system installation, operations, and demobilization. This volume covers the container-handling operations of the Phase II tests (no containers were handled during Phase I) and provides container transfer rates and operational data pertinent to container-handling cranes, containers, spreader bars, lighters, truck/trailers, pontoon deck

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reinforcement, turntable, beach transition ramp, beach matting, and air bearing transporter. Also tested during Phase II, and reported in this volume, was the Lo/Ro concept which delivers containers deck-loaded on a causeway ferry; the ferry is beached and containers are off-loaded with commercial container handlers.

Under the ideal sea conditions at the Coronado test site, crane-container handling rates of 20 containers per hour were attained, but the overall productivity was degraded to 15.4 containers per hour with a causeway ferry because of truck/trailer movement on the causeway which could not keep up with the crane operation. A rate of 14 containers per hour was attained with the LCU. Time to unload containers during the Lo/Ro tests varied from an average of 1.6 minutes per container on the first section (nearest shore) to 2.4 minutes per container on the third section.

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Volume V – Container-Handling Operations by J. J. Traffalis, et al
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1. Elevated causeway 2. Containerization I. Y41X6-001-01-001

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CONTENTS

SECTION 1

INTRODUCTION

1.1 SCOPE

The advanced development tests of the elevated causeway were performed to evaluate system hardware using an adequate number of pontoon sections, existing military lighters and trucks, and 8 x 8 x 20-foot (2.4 x 2.4 x 6-m) commercial containers. The equipment tested included four specially assembled NL pontoon pierhead sections with internal spudwells, five existing pontoon sections equipped with external spudwells, two types of plastic foam fender systems, three types of Navy lighters, one type of Marine Corps tractor/trailer, a turntable, and two types of commercial container handlers. In addition, other selected hardware items were evaluated during the operation. Timing data were taken at all pertinent points of the operation; however, this information was considered to be secondary to determining any operational limitations, proper procedures, and problems requiring further development efforts.

1.2 BACKGROUND

DOD planning for the logistics support to sustain major contingency operations, including amphibious assault operations and Logistics-Over-the-Shore (LOTS) evolutions, relies extensively on the utilization of U.S. Flag commercial shipping. Since the mid-1960s commercial shipping has been steadily shifting towards containerships, Roll-On/Roll-Off (RO/RO) ships, and bargeships (e.g., LASH, SEABEE). By 1985 as much as 85% of U.S. Flag sealift capacity may be in container-capable ships – mainly non-self-sustaining (NSS) containerships. Such ships cannot operate without extensive port facilities.

Amphibious assault and/or LOTS operations are usually conducted over undeveloped beaches, and expeditious response times preclude conventional port development. The handling of containers in this environment presents a serious problem. This problem is addressed in the overall DOD Over-the-Shore Discharge of Cargo (OSDOC) efforts, which involve developments by the Army, Navy, and Marine Corps. Guiding policy is documented in the "DOD Project Master Plan for Surface Container Supported Distribution System" and the OASD I&L system definition paper "Over-the-Shore Discharge of Cargo (OSDOC) System."

In response to the DOD Master Plan, Navy Operational Requirement (OR-YSL03) has been prepared for an integrated Container Off-Loading and Transfer System (COTS) for discharging container-capable ships in the absence of port facilities. The COTS Navy Development Concept (NDCP) No. YSL03 was promulgated July 1975, and the Navy Material Command was tasked with development. The Naval Facilities Engineering Command has been assigned Principal Development Activity (PDA) with the Naval Sea Systems Command assisting.

The COTS advanced development program includes the ship unloading subsystem, the ship-to-shore subsystem, and common system elements. The ship onloading subsystem includes: (a) the development of Temporary Container Discharge Facilities (TCDF) employing merchant ships and/or barges with add-on cranes and support equipment to off-load non-self-sustaining containerships alongside; (b) the development of Crane on Deck (COD) techniques and equipment for direct placement of cranes on the decks of NSS containerships to render them self-sustaining in an expedient manner; (c) the development of equipment and techniques to off-load RO/RO ships offshore; and (d) the development of interface equipment and techniques to enable ship discharge by helicopters (either existing or projected in other development programs).

The ship-to-shore subsystem includes the development of elevated causeways to allow cargo handling over the surfline and development of self-propelled causeways to transport cargo from ships to the shoreside interface.

The commonality subsystem includes: (a) the development of wave attenuating Tethered Float Breakwaters (TFB) to provide protection to COTS operating elements; (b) the development of special

cranes and/or crane systems to compensate for container motion experienced during afloat handling; (c) the development of transportability interface items to enable transport of essential outsized COTS equipment on merchant ships – particularly bargeships; and (d) the development of system integration components, such as moorings, fendering, communications and services.

These five volumes cover only that portion of the ship-to-shore subsystem related to the elevated causeway components and associated container-handling operations.

CEL planned the elevated causeway tests in two phases. The first phase tests conducted by CEL from 16 June to 16 July 1975 at Point Mugu, California, were designed to investigate operational and structural capabilities of the NL elevated causeway and to develop operational procedures. No container-handling tests were included in this phase.

The Phase II tests were designed to be conducted by the military operators, i.e., PHIBCB-ONE and ACU-ONE, Coronado, California, to determine operational limitations and any further development requirements. A survey of the landing site showed a beach gradient of about 1:30 and a water depth of 20 feet (6 m) at 600 feet (183 m) offshore at zero tide. The pier was elevated by PHIBCB-ONE on Silver Strand Beach, Green Beach Two at coordinates 32°39′08″ latitude, 117°09′25″ longitude, beginning 12 November 1975 and finishing on 26 November 1975. Container-handling operations began on 2 December and were completed on 5 December 1975. The container-handling crane was positioned on the pierhead on 1 December. The pier was left elevated until 5 January 1976 to check for piling settlement and to provide an opportunity for the pier to encounter rough seas; it was disassembled from 5 January to 10 January 1976. Movies have been prepared covering the Phase I* and Phase II** tests.

1.3 REPORT COVERAGE

The final documentation that covers the results of both Phase I and Phase II tests consists of a Summary Report (Volume I)*** and four separate technical volumes. The four technical volumes cover the following.

1.3.1 Volume II

The elevating mechanism or lift system and alternative lift procedures and associated equipments are discussed. This includes a description of the elevated causeway, pier installation and retrieval (including pro and con of elevating from shore out or offshore in), pile hammer and driving, beach gradients and surveys, ladders and scaffolding, and multisection lift. A human engineering study was made of both the elevated causeway system hardware and the associated operational procedures. This study was conducted by the Human Factors Technical Division, Naval Electronics Laboratory Center, San Diego.

1.3.2 Volume III

The pontoon equipment (including section assembly and internal and external spudwells), structural reinforcements required for the container-handling crane, side connectors, and results of structural behavior tests are described.

1.3.3 Volume IV

A description of the fender system and installation procedures is given along with lighterage impact tests. Also, lighterage motion data as recorded during the container-handling operation are shown.

1.3.4 Volume V

Container handling, i.e., container transfer rates, container crane, containers, lighters, Marine Corps truck/trailers, pontoon deck reinforcement, turntable, beach ramp and matting, and air bearing transporters, are detailed. An alternate method of ship-to-shore container transfer, i.e., the load-on/load-off causeway ferry system (Lo/Ro), using a commercial top-lift loader is described.

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*CEL movie, 16-mm, sound, color, 22 minutes, Elevated Causeway Tests, Point Mugu, California, Jun 1975 (Phase I).

**CEL movie, 16-mm, sound, color, 25 minutes, Elevated Causeway Advanced Development Tests, Coronado, California, Nov 1975 (Phase II).

***Also contains environmental data observed during the tests.

SECTION 2

EQUIPMENT AND PERSONNEL

The container-handling operation consists primarily of transferring containers from lighters to the elevated causeway and then transporting the containers to the storage areas on shore. Empty truck/trailers are driven out on the elevated causeway, over the pierhead, onto a turntable where they are rotated 180 degrees, and then driven to a position adjacent to the container-handling crane. The crane on the pierhead transfers the containers from the lighters moored alongside the pierhead to the truck/trailers stationed adjacent to the crane. Once loaded, the truck/trailers move from the pierhead along the elevated causeway to the beach. To accomplish this operation the following equipment and personnel were employed.

2.1 CRANE

2.1.1 Description

The crane (Figure 1) employed for handling the containers was a 90-ton (81.6-Mg) rated, rubber-tired commercial truck crane, P&H Model 8100. The crane was leased for the tests from Enniss Crane Services of El Cajon, California. It was fitted with a 70-foot (21.3-m) long tubular-constructed boom having a standard tip. Hydraulically actuated outriggers with 30-inch (76.2-cm) square by 6-inch (15.24-cm) high low-profile floats could be extended approximately 21 feet (6.4-m). The working weight of the crane, including a 26,000-pound (11.8-Mg) counterweight, was approximately 74 tons (67.12 Mg). A load-versus operating-radius curve for 360 degrees of operation (outrigger fully extended and locked) and operating from a stable platform is given in Figure 2.

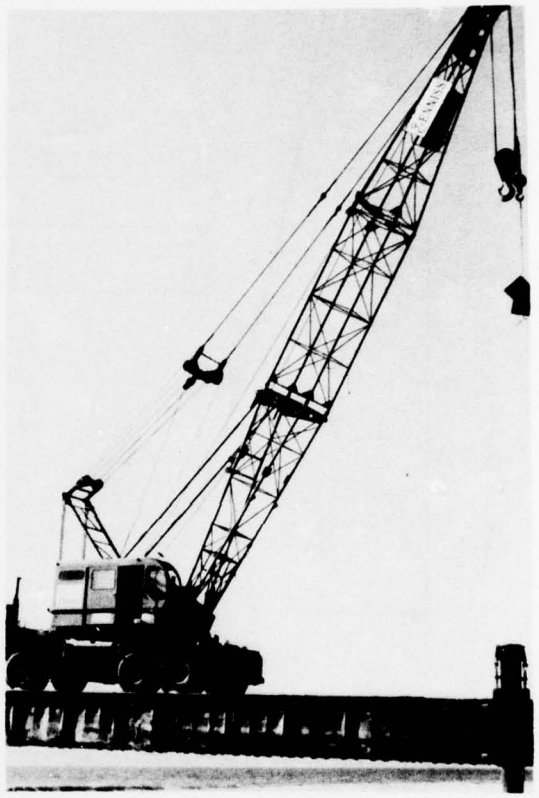


Figure 1. Container-handling crane (P&H Model 8100-TC).

2.1.2 Installation

The crane was transported to the site under its own power via surface roads from El Cajon, California, a distance of approximately 25 miles (46.25 km). Because of California's state highway load and length restrictions, the crane traveled with only a 50-foot (15.25-m) long boom (butt and tip section); the 26,000-pound (11.8-Mg) counterweight and 20-foot (6.1-m) boom insert section were delivered separately.

The assembly of the 20-foot (6.1-m) insert into the boom was accomplished by a two-man crew, the company operator and rigger, in approximately 1 hour. This time included the off-loading of the boom insert and counterweight from the truck/trailer. The boom was laid down, and the tip section was removed. The crane was then rotated to align the butt

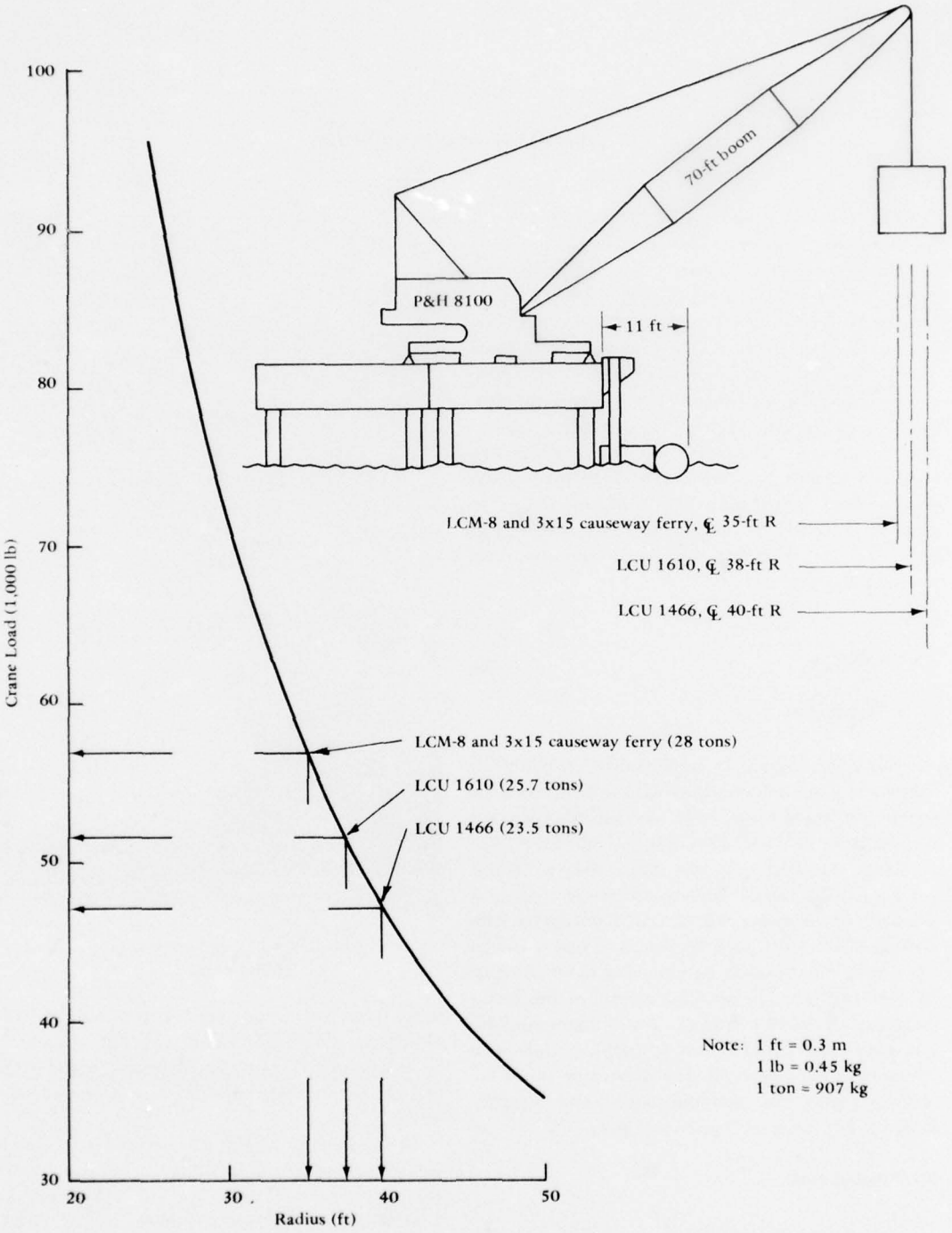


Figure 2. Maximum crane lift/radius relative to centerline of various lighters.

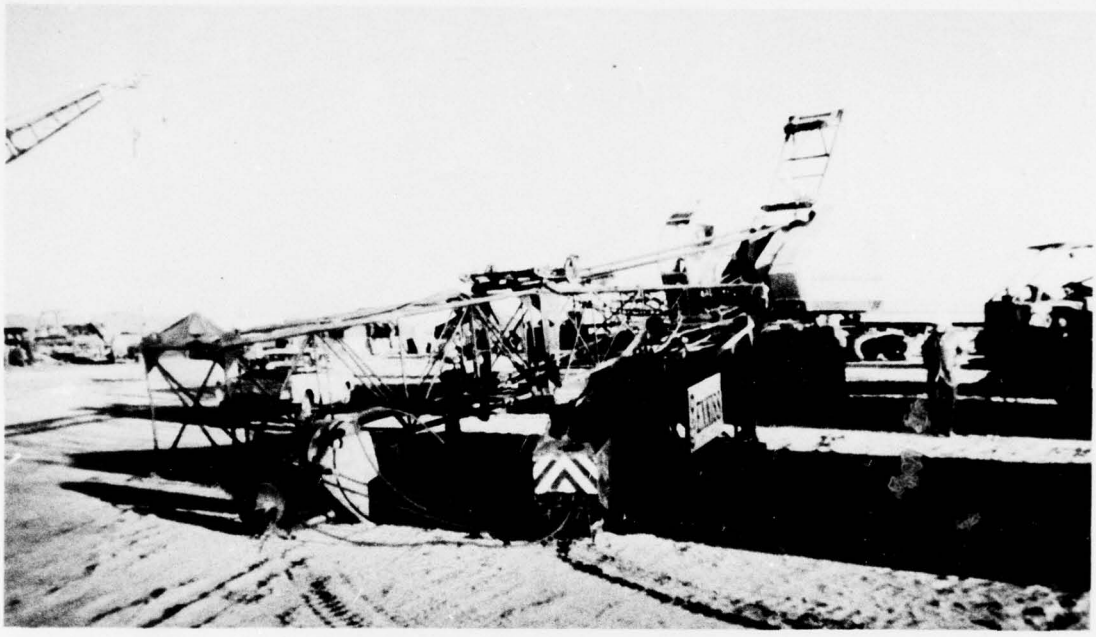


Figure 3. Insertion of boom section on container-handling crane.

section with the boom insert section (Figure 3), and the four pins were driven into the connectors to secure the sections together. The crane was then rotated back and aligned with the tip section, where four pins were driven into the connectors, completing the boom assembly.

Because there was concern over the effect of the crane's traveling weight of 74 tons (67.1 Mg) on the structural causeway angles, the crane was transported to the pierhead without the counterweight. The total weight of the crane traversing the elevated causeway to the pierhead was 61 tons (55.3 Mg). The 13-ton (11.8-Mg) counterweight was transported separately on an M127 truck/trailer.

The crane negotiated the steel mat roadway and ramp to the causeway without difficulty (Figure 4). Upon reaching the pierhead, the crane was positioned with a minimum of effort, requiring only three cuts (direction changes) during final positioning. The outriggers with floats were extended and placed on timber beams that were provided to distribute the float loads to the causeway deck (Figure 5).

The counterweight, which was delivered to the pierhead without incident, was lifted from the trailer by the crane and positioned on a rack to the rear of the carrier cab. The crane was rotated 180 degrees, and the counterweight was raised into position with hydraulic jacks on the crane.

The entire operation – transit to pierhead, final positioning, installation of outriggers, and installation of counterweight – required 60 minutes. The orientation of the crane on the pierhead is shown in Figure 6.

2.2 BEACH TRANSITION RAMP

A ramp (Figure 7) was constructed for the transition of vehicular traffic from the beach to the elevated causeway, a vertical differential of about 5 feet (1.5 m). The ramp was constructed in two parts, each 30 feet (9.2 m) long by approximately 8 feet (2.4 m) wide; each ramp section weighed 18,000 pounds (8.2 Mg). The roadway of the ramp was surfaced with heavy industrial grating with openings of 3-1/2 by 1 inch (8.9 x 2.5 cm).

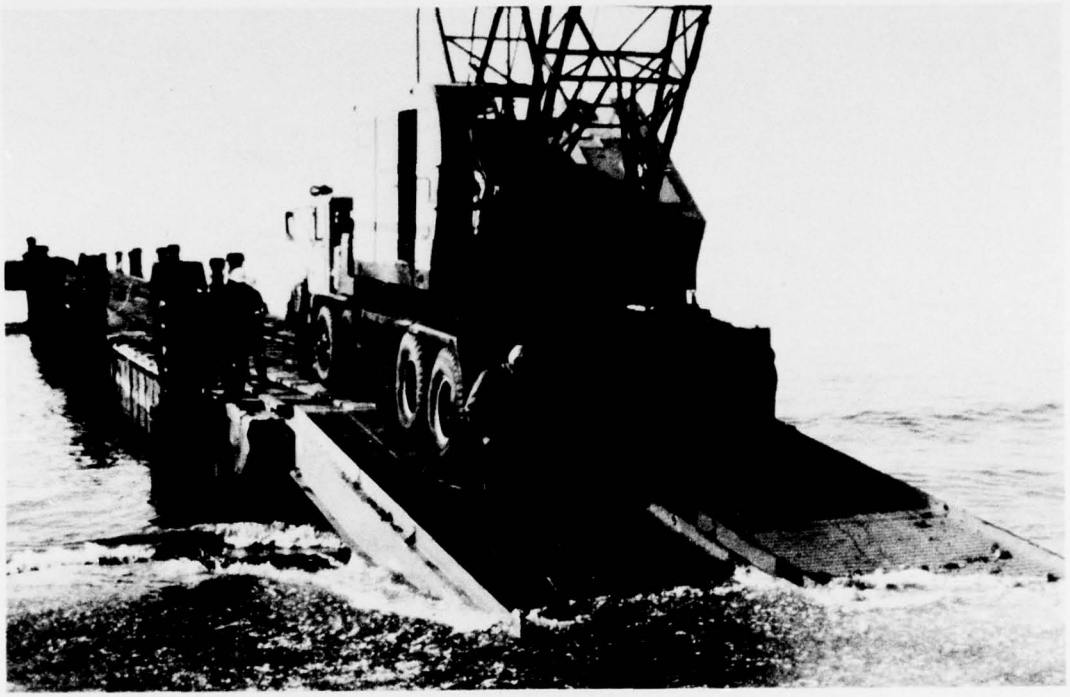


Figure 4. Container-handling crane negotiating beach transition ramp to elevated causeway.

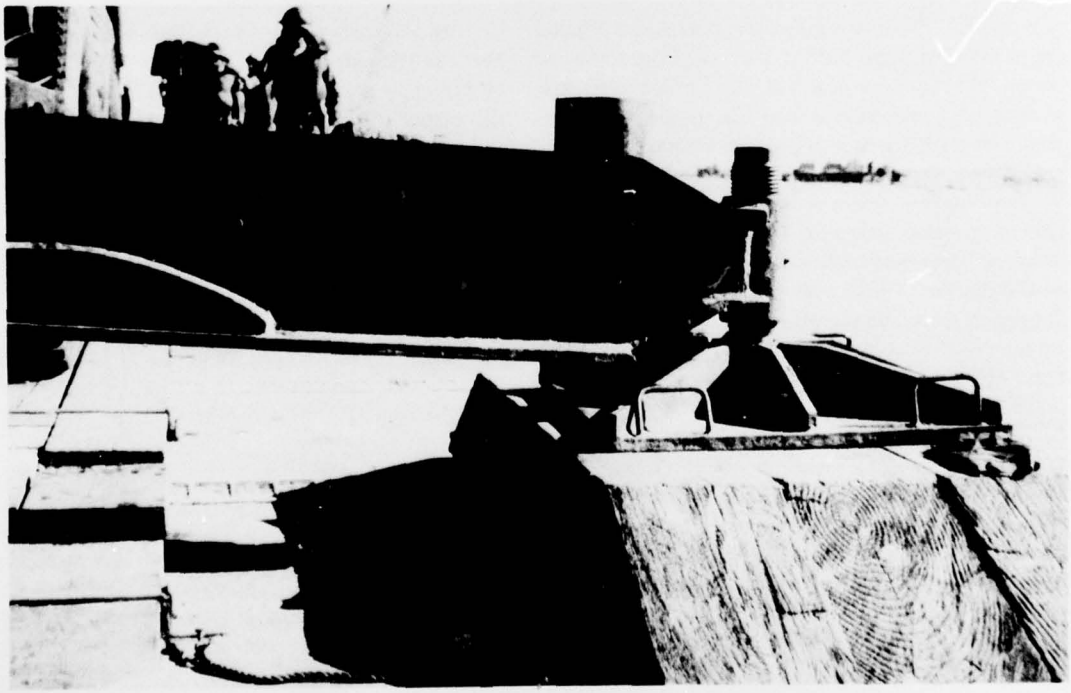
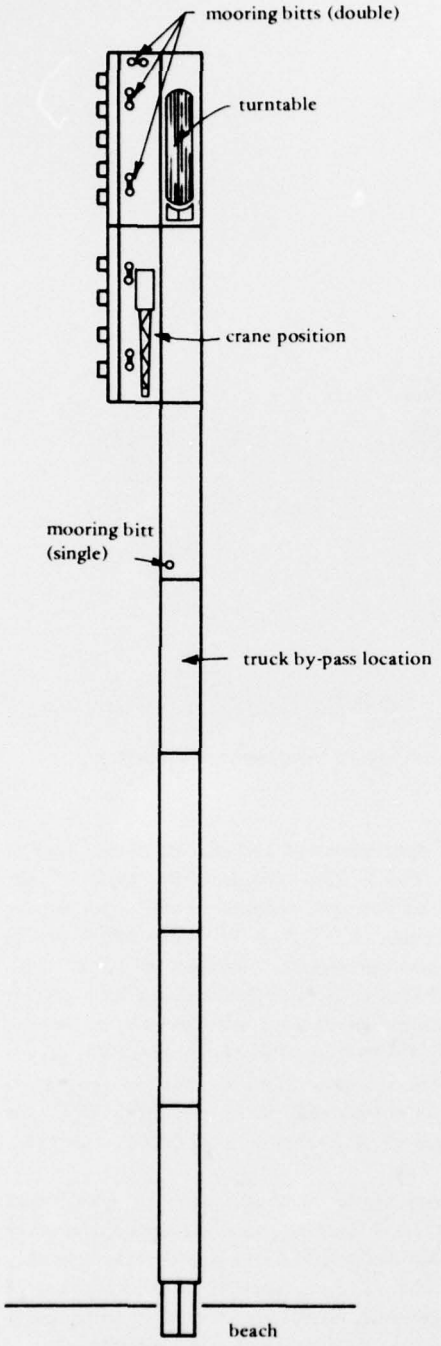
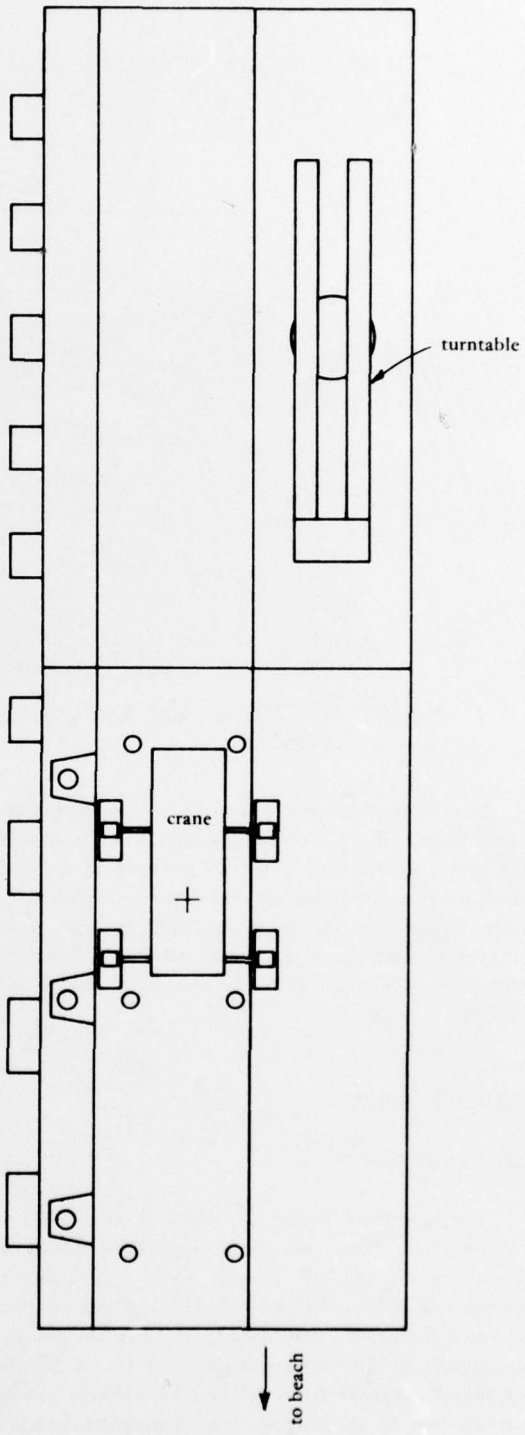


Figure 5. Outrigger float of container-handling crane positioned on load-bearing beam.



(a) Overall view of elevated causeway.



(b) Closeup view of pierhead.

Figure 6. Elevated causeway with various key locations.

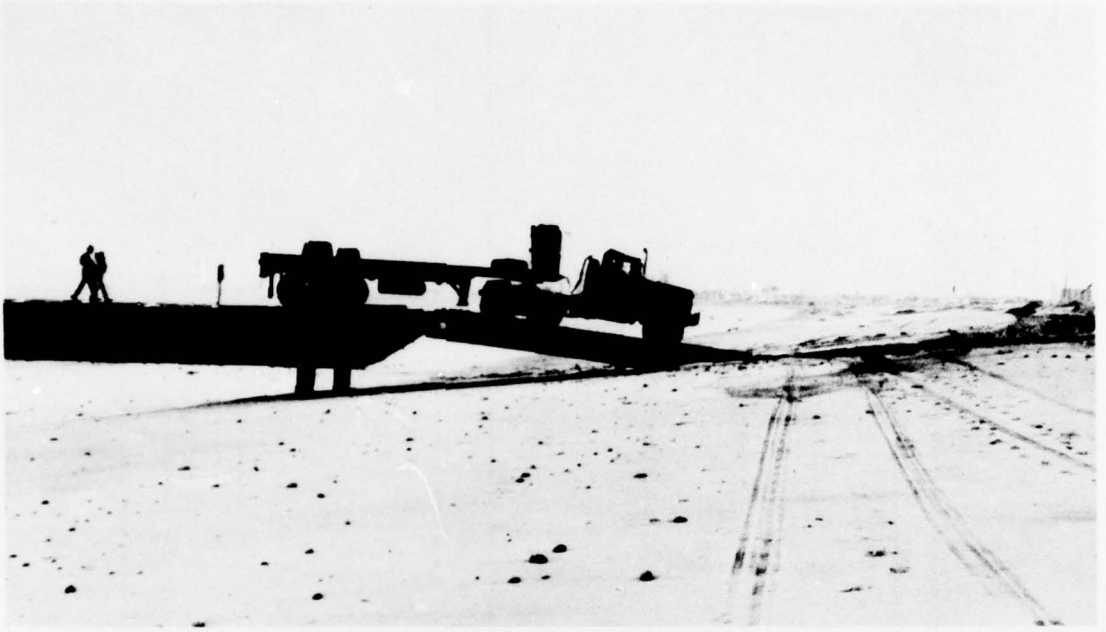


Figure 7. M52/M127 truck/trailer negotiating beach transition ramp from elevated causeway at low tide.

The ramp was installed with the construction crane (Figure 8) by dropping fixed pins on the end of the ramp section into the open padeyes of the end connector on the causeway; the free end of the ramp bore directly on the sand. A 2-foot (61-cm) high transition from the ramp end to the beach was constructed with sand and covered with timber or matting.

2.3 TURNTABLE

2.3.1 Description

The turntable (Figure 9), which is 48 feet (14.6 m) in length, is capable of rotating a balanced load of approximately 80,000 pounds (36.3 Mg) using a moment of 800 lb-ft (1,084 Nm) to overcome inertia and a moment of 2,400 lb-ft (3,252 Nm) to rapidly accelerate the load to accomplish a rotation of 180 degrees in approximately 15 seconds. The turntable rotates on 12 air bearings that require an external source of approximately 250-cfm (0.12-m^3/s) air at 100 psi (689.5 kPa) (Figure 10). Each of the individual air bearings, which is capable of supporting 10,000 pounds (4.5 Mg), is 34 inches (86.4 cm) in diameter and operates at a pressure of 12 to 15 psi (83 to 103 kPa) at the interface with the load. The air bearing centers are located 30 degrees apart on the perimeter of a 16-foot (4.9-m) diameter circle on the base of the structure. The air bearing raceway is centered on the bottom of the rotating section. The total weight of the turntable is 36,000 pounds (16.3 Mg).

The base of the turntable, which is a weldment fabricated of W8x40 beams, distributes the load of the rotating platform and its cargo over the assembly angles of the causeway section. It is composed of three welded sections that are bolted together, and it can be readily disassembled for transport by ship or truck. The air bearings are mounted on this base. The air distribution system for the bearings is also incorporated in the base. The weight of the base complete with air bearings and an air distribution system is approximately 4,000 pounds (1.8 Mg) (Figure 11).

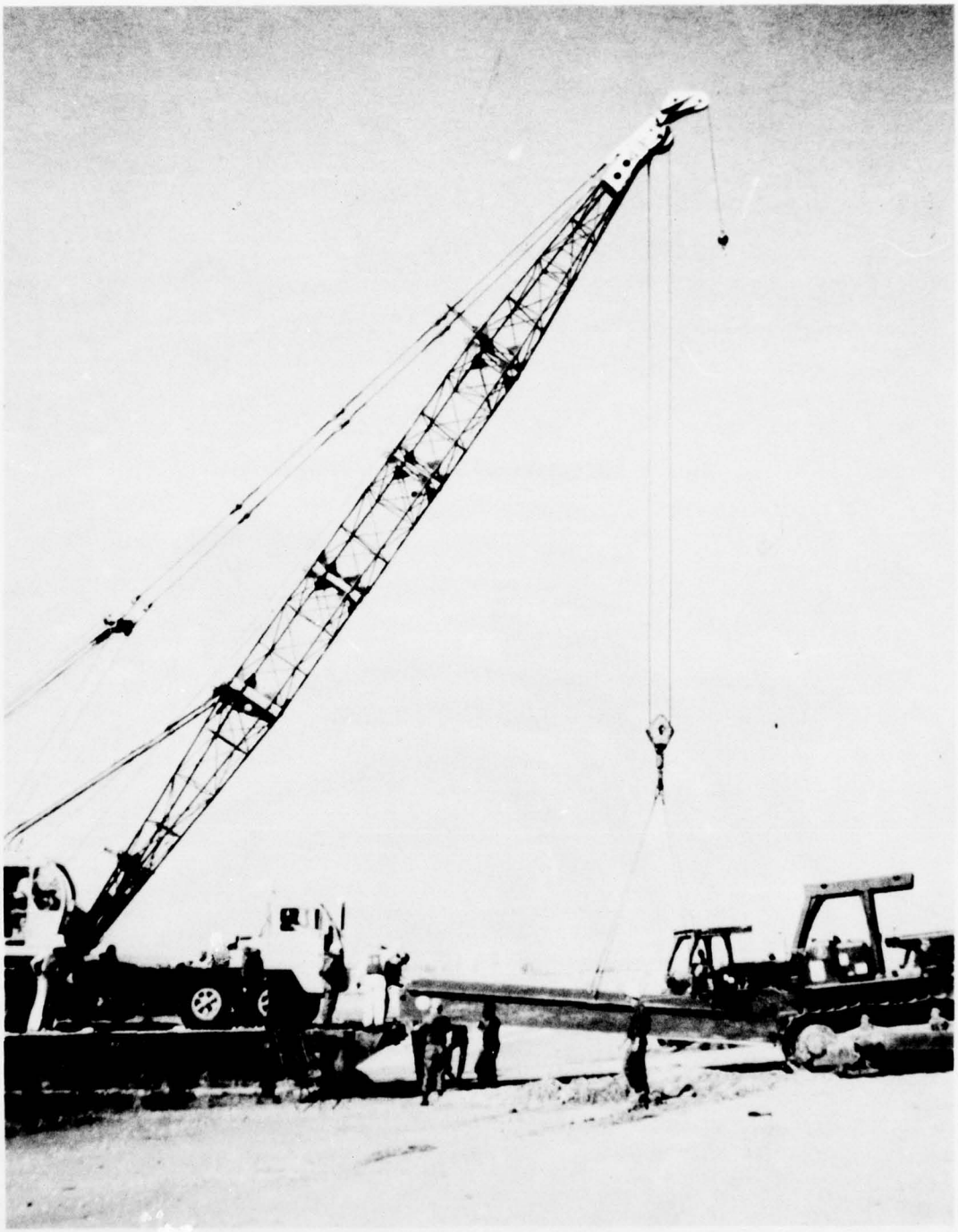


Figure 8. 35-ton (31.7 Mg) construction crane installing beach transition ramp on elevated causeway.

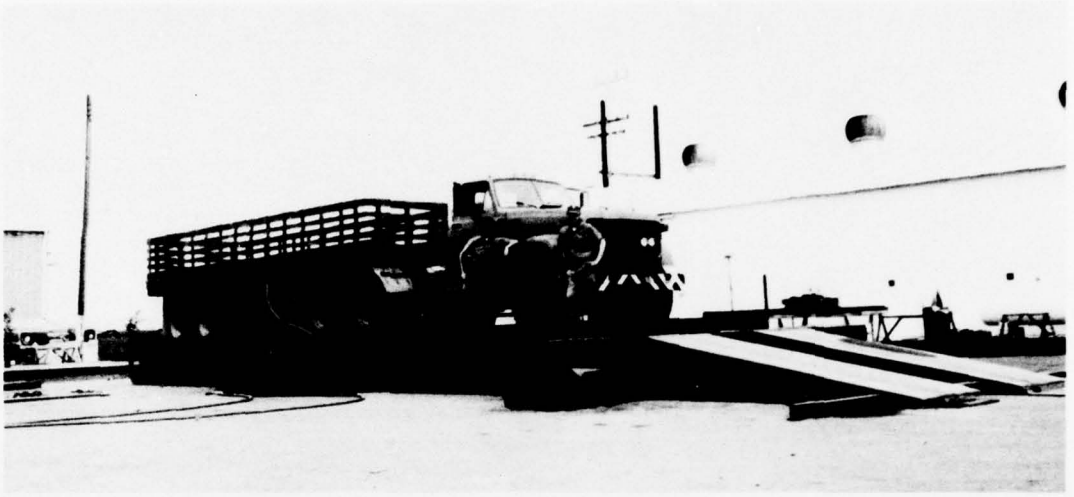


Figure 9. M52/M127 truck on turntable during tests at CEL.

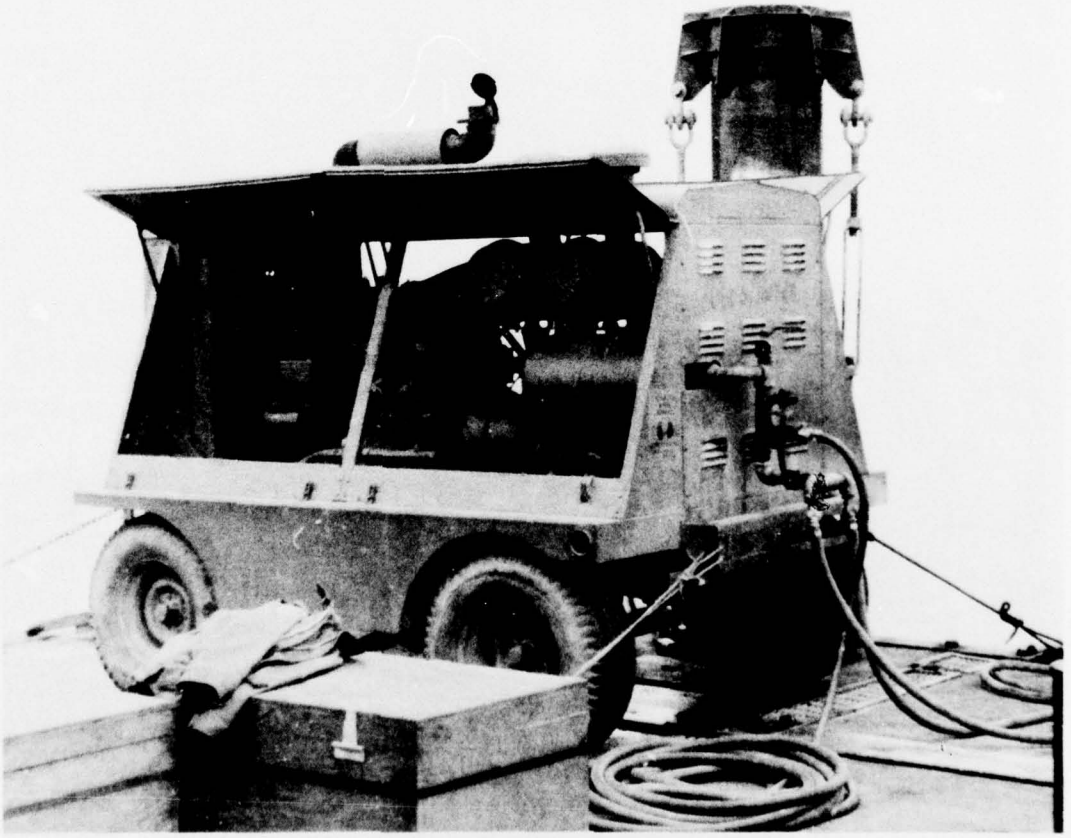


Figure 10. 360-scfm air compressor for turntable.

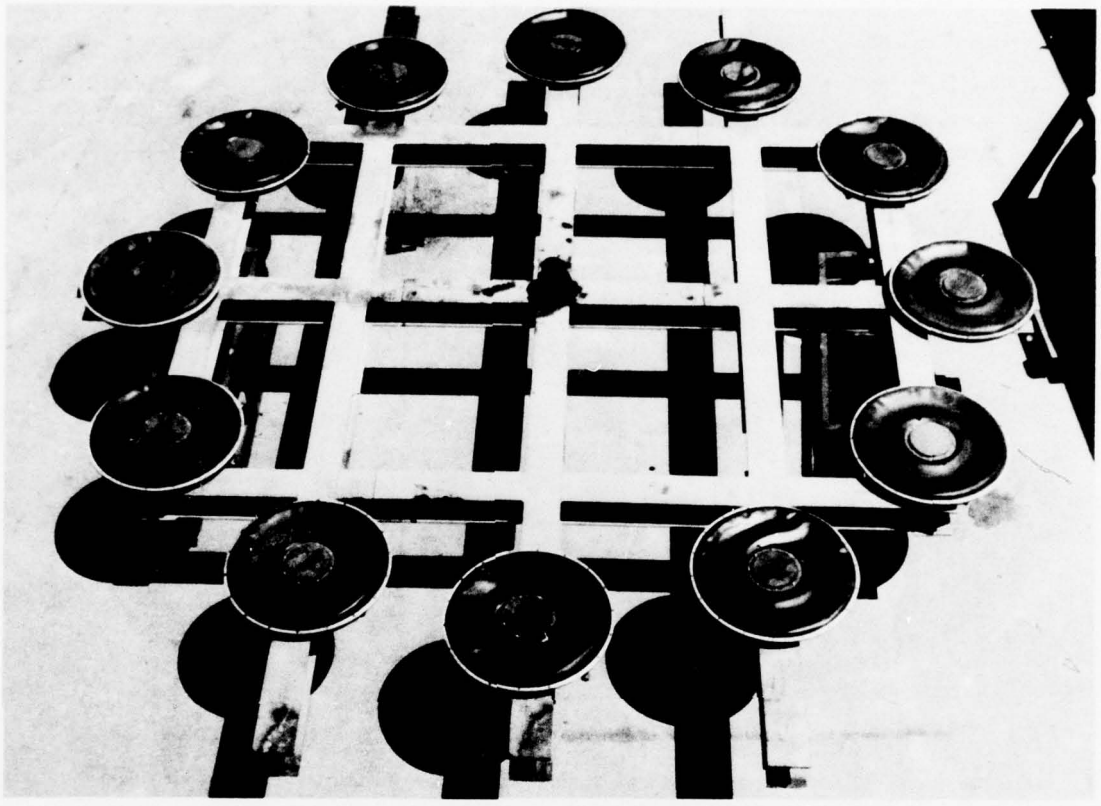


Figure 11. Turntable mounting base.

The rotating section is fabricated of W12x27 and W21x55 beams that are bolted and welded together to form a roadway 10 feet (3.1 m) wide by 48 feet (14.6 m) long (Figure 12). The roadway deck is AM-2 matting. The roadway structure separates into four sections that are capable of being transported by ship or truck. The air bearing raceway is a circular, hollow core weldment that is bolted to the bottom center of the rotating section. It is composed of two semi-circular elements that can be separated for transport. A male/female slip fit center pin established and maintains the alignment between the rotating section and the stationary base. When assembled, the rotating section weighs approximately 30,000 pounds (13.6 Mg).

A steel ramp that is capable of being separated into three sections provides access and exit between the turntable and the causeway section deck (Figure 9). Two W14x30 beams are used under the ends of the rotating section to eliminate tilting due to unbalanced loading during entry or exit of the trucks. The ramp sections weigh 2,000 pounds (905 kg).

2.3.2 Installation

The assembly of the turntable components on a causeway section is straightforward and requires no special skills. All pieces are match marked, and one size of bolt is used throughout the main structure. Four men with suitable lifting equipment [10-ton (9.1-Mg) crane or forklift] can assemble the base, rotating structure, and ramp in 8 hours. The installation and preparation of the assembly for operation require another 4 hours and the use of a crane of at least 35-ton (31.7-Mg) capacity. This procedure calls for one crane operator, three structural iron workers, one welder, and one lead and layout man. An air compressor [375-cfm (0.18-m^3/s) capacity] and air impact wrenches will simplify and speed up the assembly process.

The turntable was shipped to PHIBCB-ONE as an assembled base structure and an assembled rotating platform stowed on a 3x15 causeway pierhead section. The turntable was then installed on a 3x15 causeway section furnished by PHIBCB-ONE.

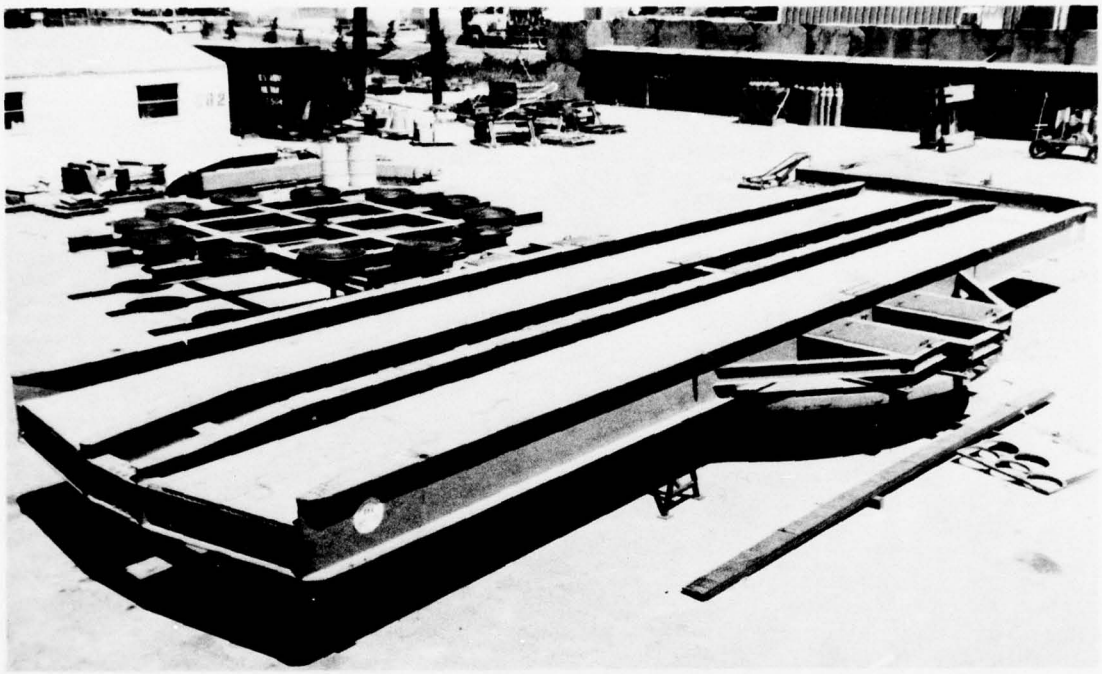


Figure 12. Turntable rotating section. Unit fits over and rides on base section.

Because the furnished section was older with some bent assembly angles and a slight longitudinal twist, some shimming of the base was required to attain a reasonably plane surface at the air bearings.

The causeway section was end-connected to the number one pierhead section. Because this pierhead section was equipped with the Flexor-type end connector and the turntable section was equipped with a standard end connector, they were not compatible. Therefore, the connection was made with chain. The turntable section then became the seaward end of the elevated causeway system that was towed to the test site by PHIBCB-ONE warping tugs.

Before the turntable section was elevated the chain connection to the pierhead causeway section was damaged by wave action. The turntable section was returned to PHIBCB-ONE's dock, removed from the section, loaded onto truck/trailers, and transported to the installed elevated causeway. The turntable sections were then installed on the number one pierhead section, as shown in Figure 6, using the 35-ton (31.7-Mg) construction crane to set the assemblies.

2.3.3 Initial Testing

Initial laboratory tests with the turntable were conducted on a paved area to determine the amount of off-center loading that could be tolerated. The surface was relatively smooth and had a slope of about 1 to 144. The turntable was set up on this area with no preparation of the surface or effort to level the base. During the tests, it was noted that the heavier portion of the load tended to rotate to the lower corner of the turntable base. The loading tests also indicated that the turntable would function with a 26,000-pound (11.8-Mg) load with its center of gravity offset from the centerpin ±27 inches (68.6 cm). Three different tractor/trailer units weighing 22,500 pounds (10.2 Mg), 24,800 pounds (11.2 Mg), and 26,400 pounds (12 Mg) were manaully rotated successfully (see Figure 9).

The air bearings as installed in the turntable have a rated total capacity of 120,000 pounds (54.4 Mg). Capacity tests were performed using 60,000 pounds (27.2 Mg) of concrete weights installed on the air bearing raceway supports. The concrete weights plus

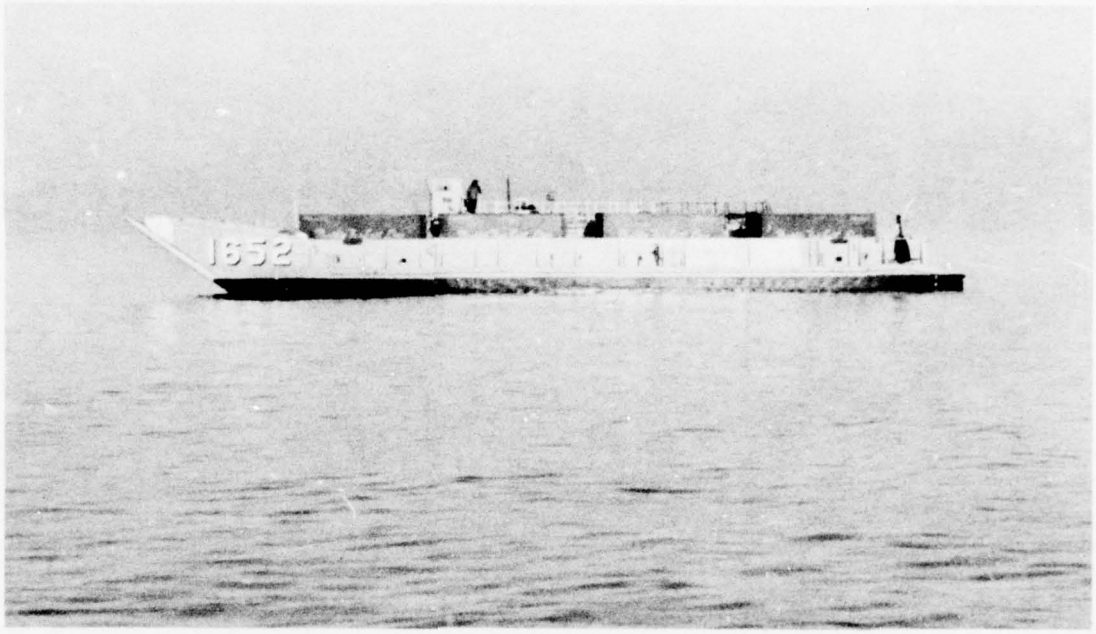


Figure 13. Navy 1610 Class LCU with four containers.

the turntable rotating structure totaled 90,000 pounds (40.8 Mg). Rotation was normal and without problems. The load was then increased by adding a rough terrain forklift with a total weight of slightly over 30,000 pounds (13.6 Mg). This load of over 120,000 pounds (54.4 Mg) was rotated many times without incident. Early in the tests it was noted that the operation of the turntable tended to smooth out and become more stable as the total load being rotated increased. A truck/tractor unit weighing 26,400 pounds (12 Mg) was slowly rotated using a small spring hand-held scale at the extremity of the structure. Movement was maintained using a force of less than 50 pounds (222 N).

2.4 LIGHTERS

Three types of existing Navy lighters – LCU, LCM-8, and causeway ferry – were employed during the Phase II tests.

The LCU (Figure 13) was loaded with four containers for the tests. The LCM-8 (Figure 14) was initially loaded with two containers; however, subsequent operations were conducted with only one container loaded in the well. The three-section causeway ferry (Figure 15) was loaded with 12 containers, four on each section. The containers were loaded both transversely and longitudinally on the causeway sections for evaluation purposes. Timber pads were positioned on the causeway deck so as to protect the container from damage by the A6 bolts. The causeway ferry was propelled by a 3x15 causeway warping tug lashed alongside. Lighter characteristics are summarized in Table 1.

2.5 TRUCK/TRAILERS

Six M52/M127 truck/trailer combinations with drivers were obtained from USMC, Camp Pendleton for the tests. The tractor/trailer combination, shown in Figure 7, is 43 feet (13.1 m) long.

The M52 is a 6x6 truck/tractor, which is rated at 5 tons (4.5 Mg). The truck/tractor is nominally 21 feet (6.4 m) long by 8 feet (2.4 m) wide and weighs

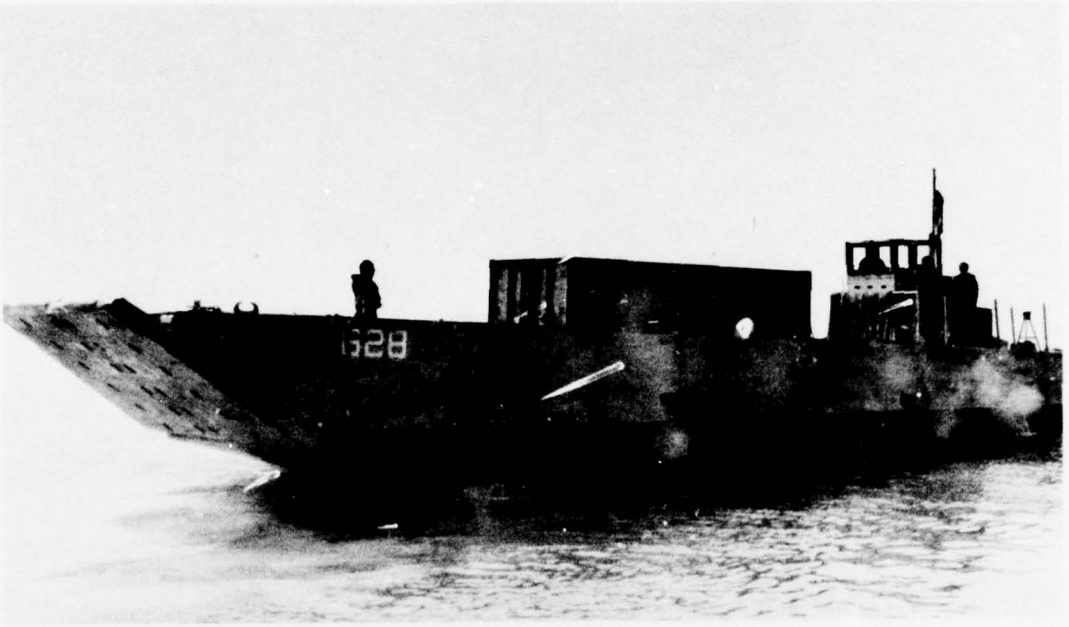


Figure 14. LCM-8 lighter with one container.

Figure 15. Causeway ferry alongside pierhead.

Table 1. Lighter Characteristics

Lighter	Dimensions		Lift Radius (ft, m) Required to Reach[a]	
	Beam (ft, m)	Length (ft, m)	Two Containers	Four Containers
Class 1466 LCU	34 (10.4)	115 (35.1)	39 (11.9)	52 (15.9)
Class 1610 LCU	29 (8.8)	135 (41.2)	37 (10.4)	50 (15.3)
LCM-8	21 (6.4)	74 (22.6)	33 (10.1)	—
Three-section 3x15 causeway ferry	21 (6.4)	90 (27.5)	33 (10.1)	46 (14)

[a]Lift values assume 21-foot (6.4-m) wide pierhead and 11-foot (3.4-m) wide fendering.

approximately 17,800 pounds (8.1 Mg). The M127 is a standard military tactical flatbed trailer. The trailer is nominally 29 feet (8.8 m) long [bed is 28 feet (8.5 m) long] by 8 feet (2.4 m) wide and weighs approximately 13,400 pounds (6.1 Mg). The trailer has a rated cross-country payload of 12 tons (10.9 Mg) and a highway payload of 18 tons (16.3 Mg). The combined length of the truck/trailer is 42 feet (12.8 m).

2.6 TOP-LIFT LOADER

The top-lift loader employed is a 26-ton (23.6-Mg) capacity pneumatic-tired (16.00 x 25-24 ply) truck (Hyster Model 620-B) equipped with a basic container attachment on a high mounting frame (Figure 16). The unit as configured is capable of handling and stacking (two high) standard ISO-USASI 8 x 8 x 20-foot (2.4 x 2.4 x 6.1-m) containers weighing 20 tons (18.1 Mg).

The basic unit is nominally 22 feet (6.7 m) long by 15-1/2 feet (4.7 m) high (top of cab) by 11 feet (3.4 m) wide. When the container attachment and mounting frame is added, the length is extended to approximately 30 feet (9.2 m), the width to 20 feet (6.1 m), and the height to top of mounting frame to 22 feet (6.7 m).

The operating weight of the unit with container attachment is 83,000 pounds (37.6 Mg). However, the weight on the drive wheels with a fully loaded container is approximately 136,170 pounds (61.7 Mg), which results in a deck loading of approximately 100 psi (689.5 kPa). This loading exceeds the design limit of 75 psi (517 kPa) for a causeway deck, thus requiring deck reinforcement.

The operator's station is located about 12 feet (3.7 m) above the ground, which provides the operator with a good view of the operation. Hydraulic controls for operating twist locks, boom extension, and spreader articulation are located in the operator's station.

The container attachment provides a capability for articulating and laterally adjusting the spreader bar to compensate for nominal misalignment when positioning onto a container. A lateral shift of ±18 inches (45.7 cm), a forward and rear tilt of ±15 degrees, and slewing adjustments of ±5 degrees are possible with the machine.

The Model 620-B forktruck is powered with a 197-hp (146.9 kW) diesel engine, which allows it to negotiate a 31% grade under full load (dry pavement) and attain speeds ranging from 3.3 to 26.4 mph (5.3 to 42.5 km/hr) under full load.

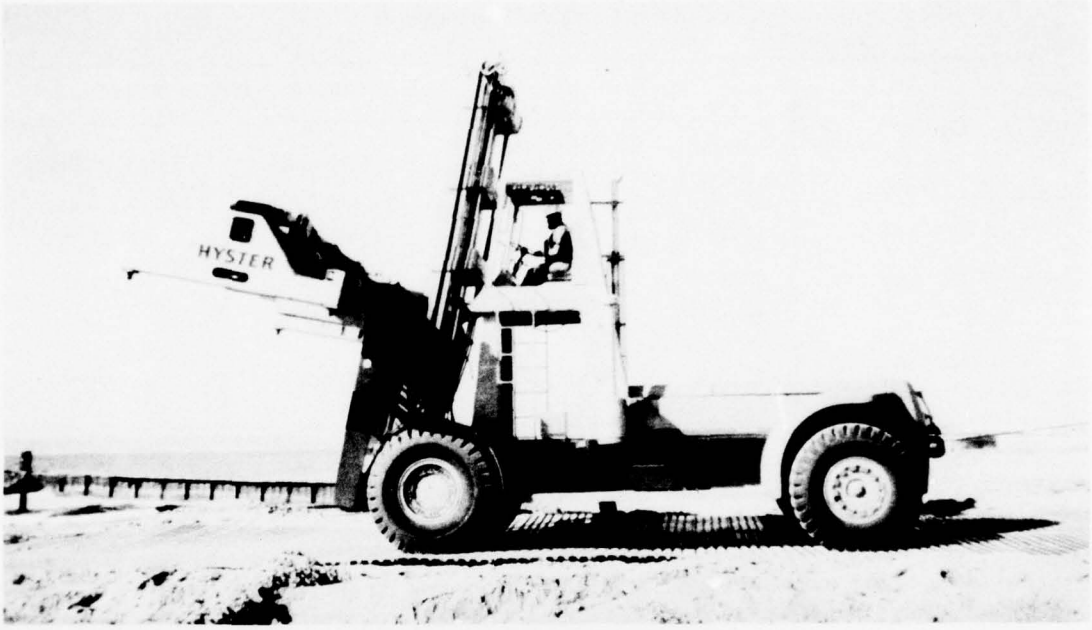


Figure 16. Top-lift loader (Hyster Model 620-B).

2.7 PERSONNEL

2.7.1 Crane Operator

A civilian crane operator and a rigger were provided as a part of the crane lease agreement. The crane operator had approximately 15 years experience, the last three on the Model 8100 crane. The operator had no prior experience working over water.

2.7.2 Tagline Handlers

Amphibious Construction Battalion-ONE (PHIBCB-ONE) personnel were employed as tagline handlers and signalmen. The military personnel were typical enlisted personnel with little or no experience in container-handling operations. The signalman on the deck of the elevated pierhead was rated. Tagline handlers maneuvering the spreader bar are shown in Figure 17.

2.7.3 Mooring Line Handlers

PHIBCB-ONE personnel were employed as mooring line handlers. The function of the line handlers was to receive and secure mooring lines from the various lighters working alongside the pierhead and to slip the lines during warping operations. Two men are required at each active mooring station to handle the lines. Upon completion of each operation, the lines were cast off to the lighters. The crew chief in charge of the mooring line handlers was rated.

2.7.4 Truck Drivers

Drivers for the M52/M127 truck/trailers were enlisted personnel furnished by the First Force Service Regiment, First Marine Division, Camp Pendleton, California. The drivers were completely familiar with the operation of the trucks.

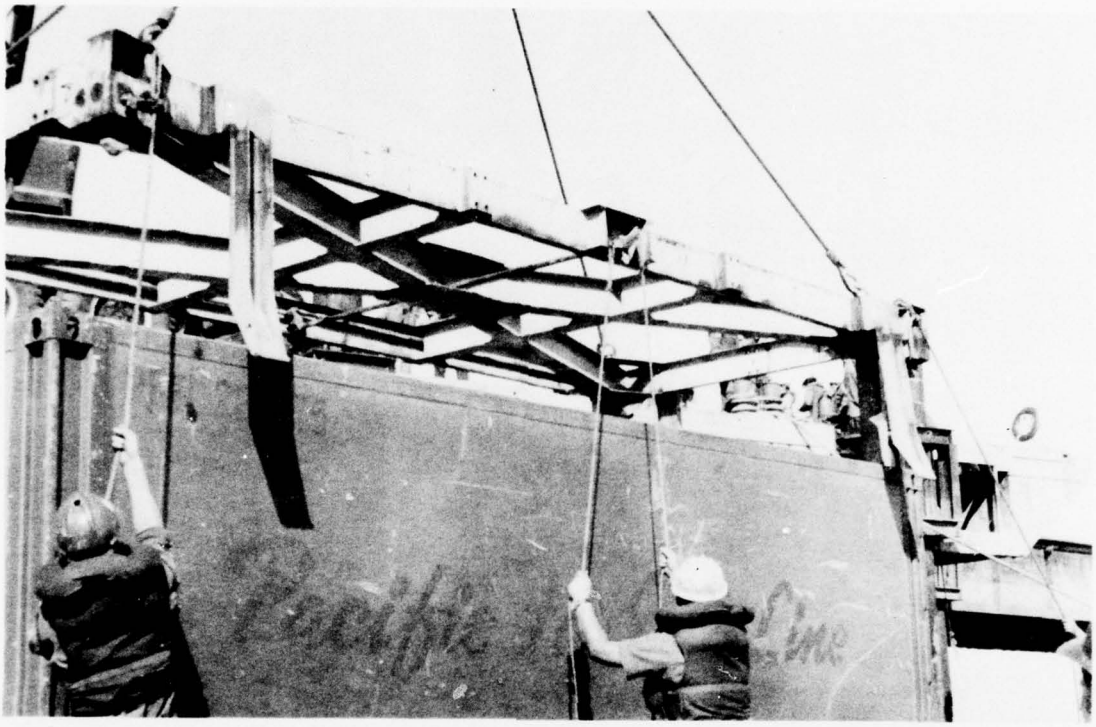


Figure 17. Tagline crew positioning and locking manual spreader bar on container.

2.8 ANCILLIARY EQUIPMENT

2.8.1 Containers

Eighteen commercial ISO 8 x 8 x 20-foot (2.4 x 2.4 x 6.1-m) containers were leased for the Phase II operation. The containers (Figure 18) which are fabricated with a steel frame covered with a laminate of fiberglass and plywood, have a tare weight of approximately 4,000 pounds (1.8 Mg). Two of the containers were loaded to approximately 20 tons (18.1 Mg) with concrete weights.

2.8.2 Manual Spreader

A 20-foot (6.1-m) single-point suspension, manually operated spreader bar that is capable of handling any 8 x 8 x 20-foot (2.4 x 2.4 x 6.1-m) container having a maximum gross weight of 44,800 pounds (20.3 Mg) was used. The spreader bar weighed 3,000 pounds (1.4 Mg) and came equipped with bolt-on aligning arms (Figure 19). The twist locks were manually activated with a lever arm located in the center of the long side of the spreader. Four aligning arms — two on one short side and two on one long side — were mounted on the spreader.

To position the spreader on the container, the spreader is swung over the container until the aligning arms are in contact with the container sides; then the spreader is lowered to engage the twist locks into the container corner fittings (Figure 17). To lock the spreader to the container, the twist locks are actuated by manually rotating the lever arm approximately 45 degrees.

2.8.3 Slings

A soft sling arrangement was employed to determine its effectiveness under high sea conditions where resulting lighter motions would make positioning of the manual spreader more difficult and hazardous, and at times not possible.

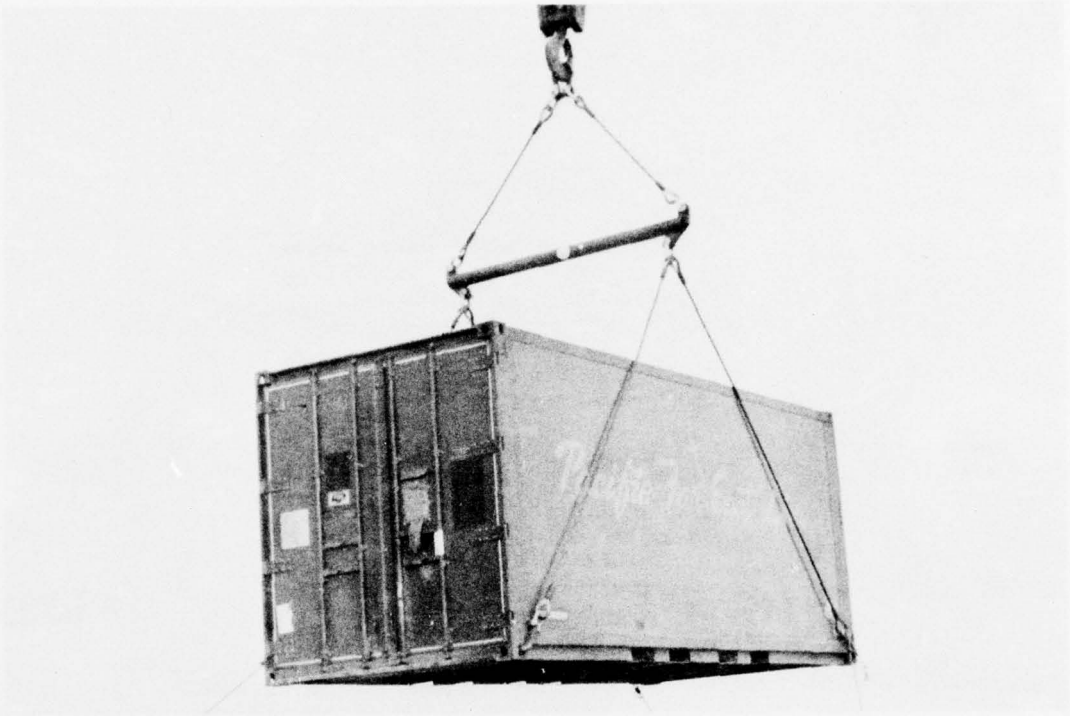


Figure 18. Commercial 8 x 8 x 20-foot (2.4 x 2.4 x 6.1-m) ISO container being lifted with sling spreader.

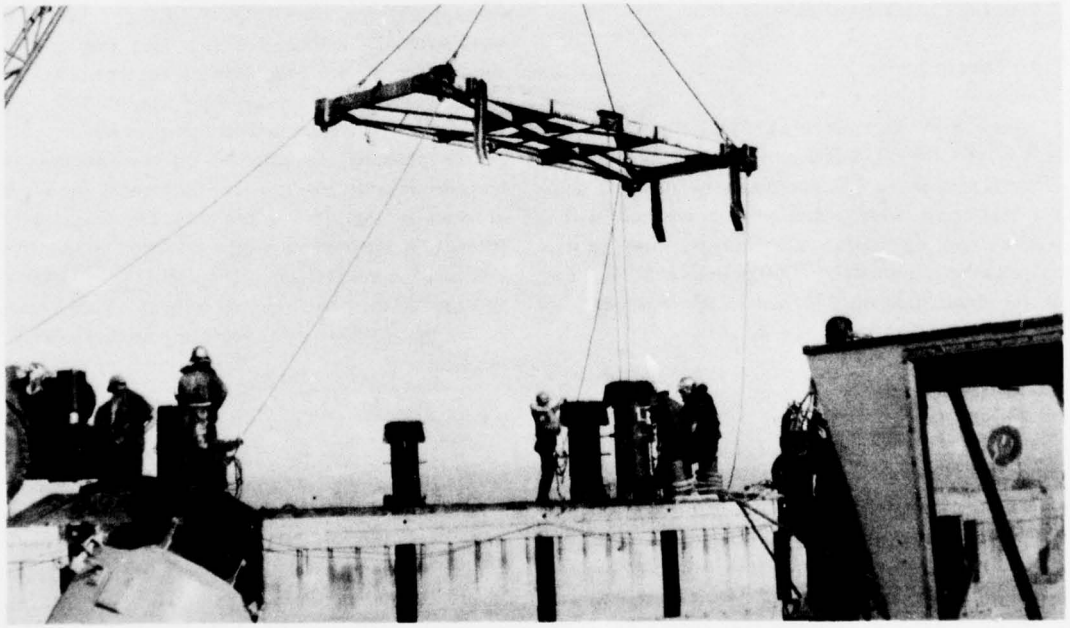


Figure 19. Manual spreader bar guided on two sides only.

Figure 20. Modified bulb hook on sling spreader being inserted into corner fitting of container.

The soft sling arrangement, which weighs 325 pounds (147.2 kg), consisted of an 8-1/2-foot (2.6-m) long strongback pipe with two 1-inch (2.5-cm) diameter wire rope cables approximately 14 feet (4.3 m) long attached to each end (Figure 18). Modified bulb hooks (Figure 20) were attached to each cable for lifting the containers. The connections were made into the bottom container corner fittings by four crew members (Figure 21).

2.8.4 Crane Outrigger Beam

Four timber beams – one under each outrigger float – were required to spread the load over the causeway deck. Three nominal 12 x 12-inch (30.5 x 30.5-cm) timbers, 8 feet (2.4 m) long, were bolted together to form the beams. The beams (Figure 22) weighed approximately 800 pounds (362 kg) each.

2.8.5 Beach Matting

A roadway from the beach staging area to the beach ramp was stabilized with M8A1 steel matting (Figure 23). A six-man crew, augmented with a rough terrain forktruck to handle the bundles of matting, was required to install the 24-foot (7.3-m) wide by 150-foot (45.8-m) long roadway (Figure 24).

2.8.6 Deck Reinforcement

The pontoon deck is designed to support an H20 highway loading – 32,000 pounds (14.5 Mg) axle load at a 75-psi (517-kPa) wheel pressure. The pontoon assembly angles, which run longitudinally on the sections, increase the load-carrying capability if the axle/wheel loads are concentrated over or near the angles.

Figure 21. Tagline handlers placing sling spreader on container.

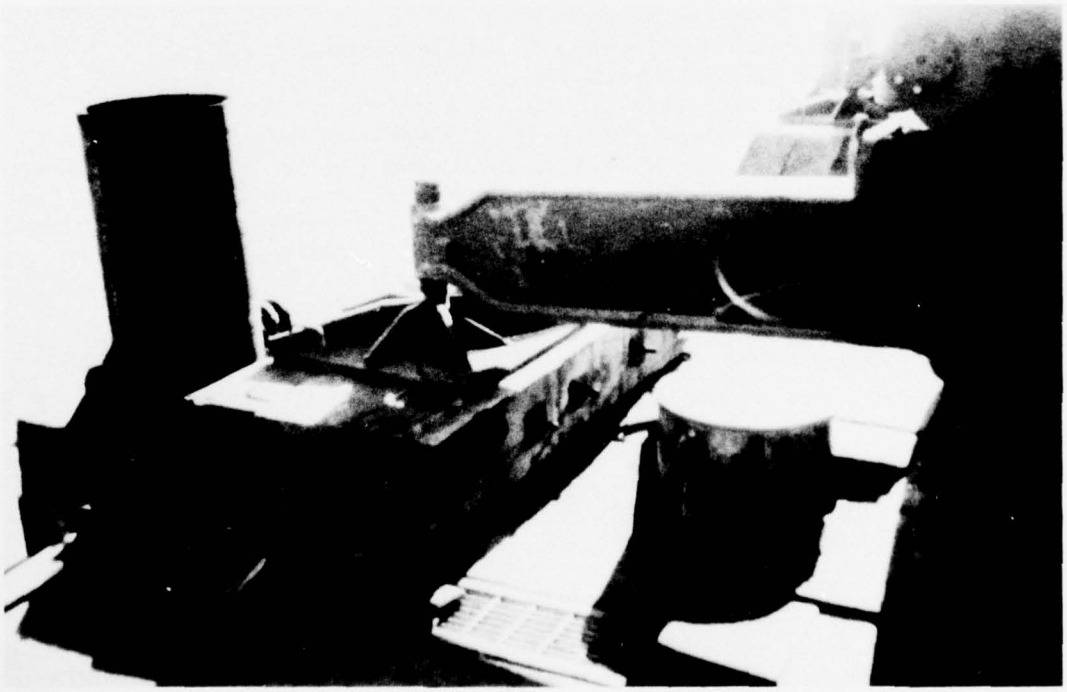


Figure 22. Timber load-bearing beam to support crane outrigger float.

Figure 23. M8A1 steel matting roadway across beach to elevated causeway.

Figure 24. PHIBCB-ONE crew installing M8A1 steel beach matting.

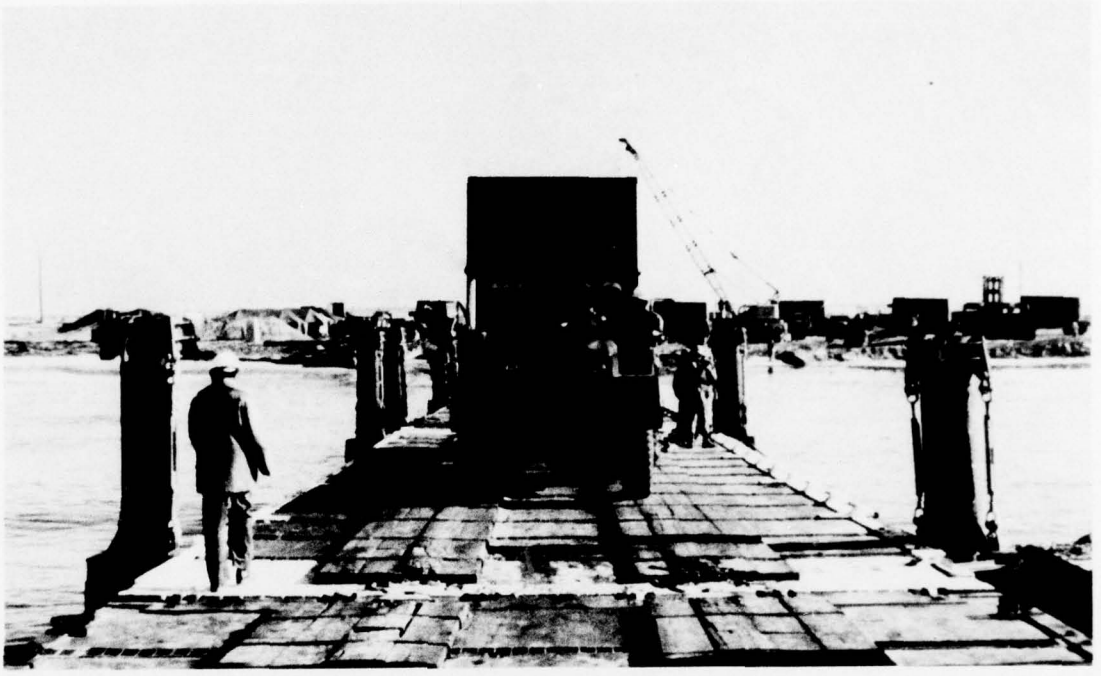


Figure 25. Timber roadway on elevated causeway.

Container handlers that weigh 62 tons (56.2 Mg) when carrying a container and mobile cranes that weigh 74 tons (67.1 Mg) create tire pressures approaching 100 psi (689.5 kPa) when traversing the causeways. These loads require the deck to be reinforced.

The causeway sections used in the Phase II tests were reinforced with two 4-foot (1.2-m) wide longitudinal lanes of 4 x 12-inch (10 x 30.5-cm) timbers to provide a roadway for the heavy vehicles (Figure 25). The timbers were secured to the deck with 3/8 x 2-inch (9.4 x 51-mm) steel straps laid across the roadway and welded to the steel deck (Figure 26).

The AP1 plates and A6 bolts were not at the same elevation as the timber roadway and, therefore, had to be covered separately. A plywood section was fabricated to cover the plates and bolts and lay flush with the roadway. The plywood section was secured with short steel straps welded to the A6 boltheads (Figure 27).

Because of the amount of traffic on the pierhead, the two inshore pierhead sections were nearly covered with timber. Loose 4 x 12-inch (10 x 30.5-cm) planks were placed between the roadway planks to fill in the area (Figure 28). The placement of two timber reinforced lanes on a single 3x15 causeway section required 2-1/2 man-days to cut and layout the timber, 1-1/2 man-days to secure the plywood covers, and 1-1/2 man-days to weld the steel straps to the deck. Fabricating the steel straps for the causeway section required 1/2 man-day shop time. An analysis of the load-carrying capability of the causeways is contained in Volume III.

2.8.7 Air Bearing System

The air bearing system that was used to stuff/unstuff the containers consisted of a master pallet, an air bearing transporter, and a portable dock.

2.8.7.1 Master Pallet. The load is supported on a master pallet that provides clearance for the transporters to be pushed underneath. The master pallet is a deck with three skids underneath: one along each side and one down the middle. The overall height of the master pallet is 9 inches (11.5 cm).

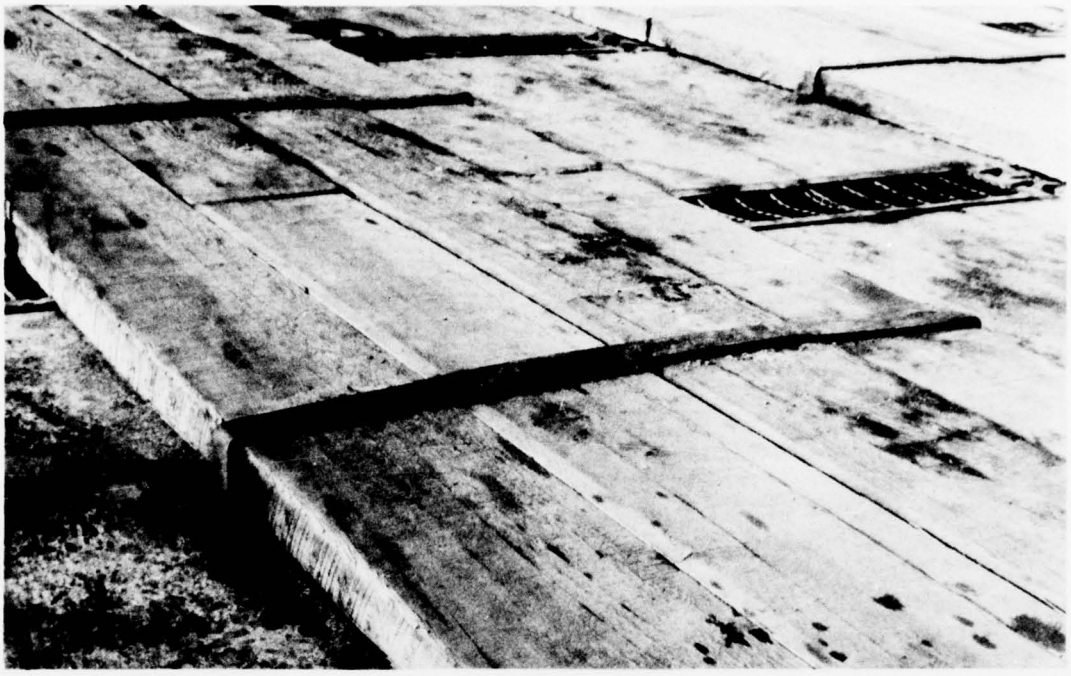


Figure 26. Timbers for roadway secured to pontoon deck.

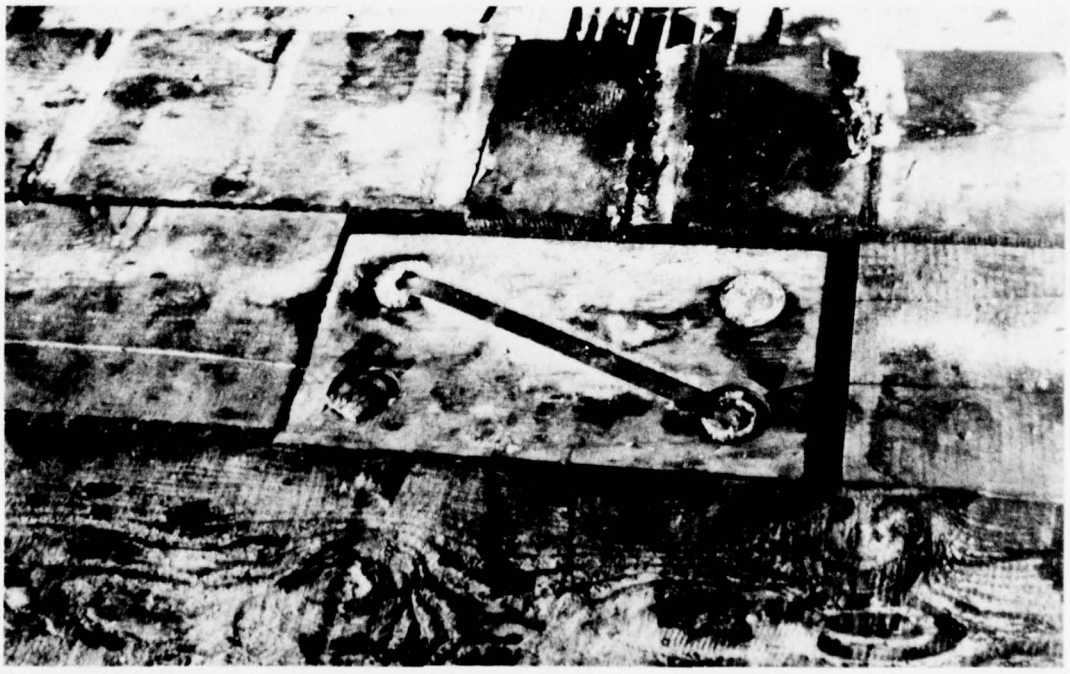


Figure 27. Plywood insert to cover AP1 plates and A6 bolts. Note steel strap securing insert to bolts.

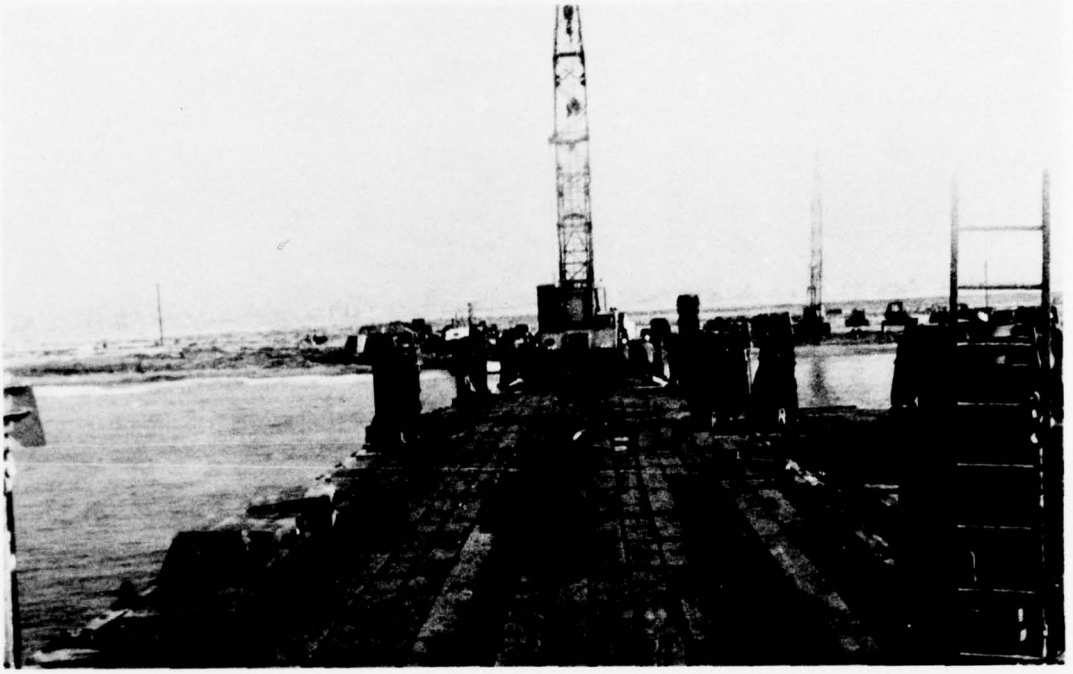


Figure 28. Pierhead deck covered with timber.

Figure 29. Air bearing transporter. Note air bearings used to support load.

Figure 30. Partially assembled portable dock for air bearing system.

2.8.7.2 Transporter. The self-loading/unloading transporters consisted of six 34-inch (86.4-cm) diameter air bearings placed along the length of a 3-foot (91.4-cm) wide by 20-foot (6.1-m) long transporter (Figure 29). Each bearing has a 10,000-pound (4.5-Mg) lift capacity under ideal conditions, for a total capacity of 60,000 pounds (27.2 Mg). The two transporters used to stuff and unstuff the containers had a total lift capacity of 120,000 pounds (54.4 Mg). With the heaviest container loads [20 tons (18.1 Mg)], the 12 air bearings were operating at 4 psi (27.6 kPa).

Each transporter is equipped with two inflatable load bars that run its full length. When deflated, the load bars lie flat on the face of the transporter; when inflated, they assume a circular cross section. The load bars take up the gap between the transporter and master pallet. There is one main valve for the air bearings and a valve for each inflatable load bar. The latter valves have three positions: (1) fill, (2) closed so no air can enter or leave the load bar, and (3) dump the air to the atmosphere when the load bars are deflated. In the dump position the line from the compressor is sealed off by the valve so that no air is lost.

2.8.7.3 Dock. Normally, the transporters operate on a knockdown, easily assembled dock that elevates them to the same height as the floor of the container. The dock, shown partially assembled in Figure 30, consists of I-beams spaced at 6-foot (1.8-m) intervals. The ends of each I-beam bear on 2-foot (61-cm) square plates that are designed (through the use of shims) to provide a leveling capability.

AM-2 matting, a stiff aluminum panel used for constructing expedient air fields, is placed across the top of the I-beams. The AM-2 panels are designed to interlock with adjacent panels to provide a stiff, relatively smooth surface on which to operate. To ensure that operation of the air bearing transporters is as trouble-free as possible, pieces of 20-gage sheet

metal are spread over and taped to the AM-2 paneling. The final components in the system are the angles along each side of the platform that are installed to keep the transporters from floating off the side of the dock.

All of the components of the knockdown dock can be handled by two men. They can set up the dock in less than 3 hours, including leveling. The heaviest pieces are the 12-foot (3.7-m) long AM-2 panels, which weigh 150 pounds (68 kg). Usually the pieces are shipped in a container along with the air bearings. It is a compact load for which no unusual packaging precautions are involved.

There are occasions when adjustments have to be made to accommodate differences in container floor thicknesses due to different manufacturers. Four small hydraulic jacks are included in the system to provide for this adjustment, which is as much as 1 inch (2.5 cm). The container is set on the jacks, and, as required, the jack height is adjusted to bring the floor of the container to the same elevation as the dock.

SECTION 3

CONTAINER-HANDLING OPERATIONS

3.1 CRANE/TRUCK CYCLE

3.1.1 Description

The container-handling operations (off-loading and retrograde) consisted primarily of driving truck/trailers on the causeway and docking lighters alongside and pierhead, and then transferring containers from one to the other with the container-handling crane.

When containers are off-loaded, lighters are docked alongside the pierhead, within reach of the crane (Figure 15). The crane rotates the boom over the lighter and lowers the spreader bar to the container, where it is positioned with taglines handled by lighter personnel and secured to the container (Figure 17). The crane then lifts the container from the lighter and rotates it to the truck/trailer positioned on the pierhead adjacent to the crane. The empty truck/trailer has previously been driven onto the causeway, over the pierhead, and onto a turntable positioned seaward of the crane. The truck/trailer is rotated 180 degrees on the turntable (Figure 31), driven off, and positioned at the loading site. The crane lowers the container to the trailer, while the four tagline handlers maneuver the containers in position (Figure 32). The truck is then driven forward down the causeway, passing other trucks waiting to proceed to the crane for a container.

The procedure for retrograde is the reverse to the off-loading procedure, except as noted. The truck/trailer with containers is driven onto the causeway to the off-loading position adjacent to the crane, where the containers are removed from the trailer. The empty truck/trailer is then driven onto the turntable, turned around, and driven back off the causeway. Meanwhile, the crane is loading the container into the lighter. Tagline handlers on the lighter maneuver the container into position as the crane lowers the container to the deck. The spreader bar is released, and the crane is rotated back for the next container.

3.1.2 Performance

In order to simulate a realistic operation, the crane was restricted to lifts not to exceed a 40-foot (12.2-m) radius, which is the maximum allowable radius for handling a fully loaded 20-foot (6.1-m) container. Because of this lift restriction, the crane was able to reach only two containers for each position of a lighter. This required the lighter to warp (make position changes) for each two containers. Figures 33 and 34 show the effect of the restricted lift radius on the LCU and 3x15 causeway ferry.

The container-handling operations required a driver for each truck, a crane operator, a signalman and four tagline handlers on the pierhead, a signalman and four tagline handlers* on the lighter, and at least three men to operate the turntable. The operation was completed when all containers had been off-loaded, or retrograded, and the lighter had cast off.

The containers were removed from the truck/trailers and positioned at the dock on the beach by the top-lift loader. Once in position, the container doors were opened, the transporter inserted, the air bearings activated, and the concrete weights removed.

The 4 days of crane container-handling operations are summarized in Table 2. Off-loading and retrograde operations with the crane were timed for each container. Average times for discrete points in the crane cycle are summarized in Table 3. Lighter operation times (mooring and warping times) are summarized in Table 4.

3.2 LIGHTER CYCLE

Five double bitts were located on the pierhead for securing the mooring lines from the various lighters. One additional single bitt was located on the first elevated section shoreward of the pierhead to handle lines from the causeway ferry. The location of the bitts is shown in Figure 6. The line employed for mooring the lighters was 7-inch (17.8-cm) double-braided polyester line.

*Only three tagline handlers required with manual spreader bar.

Figure 31. PHIBCB-ONE personnel turning truck/trailer 180 degrees on turntable.

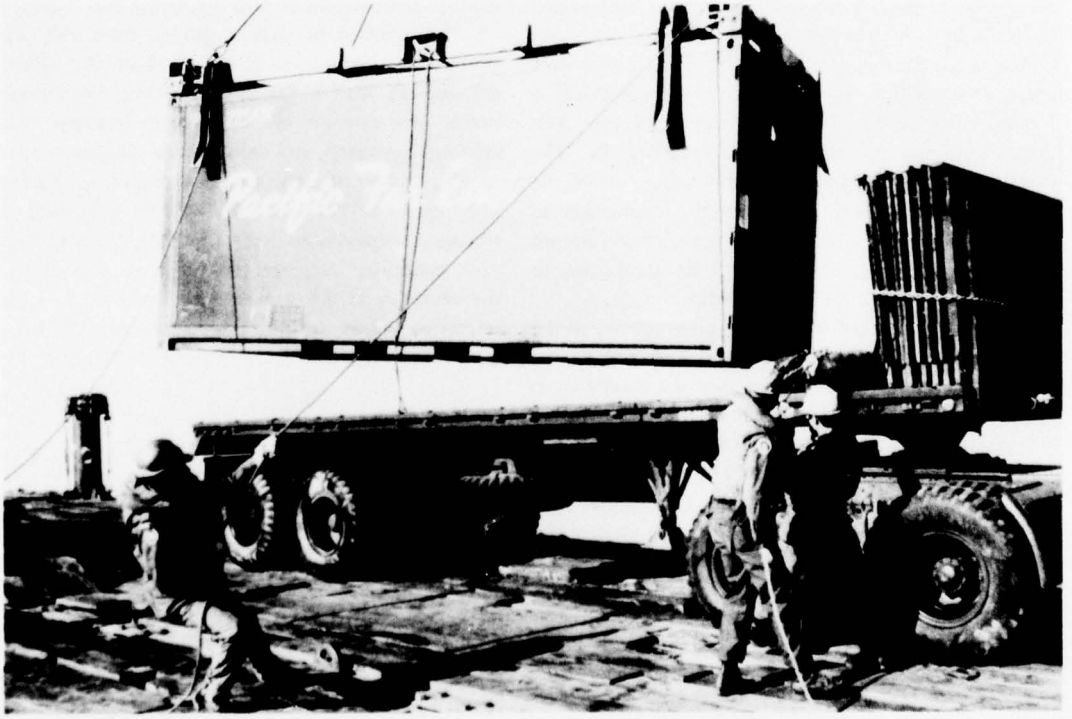


Figure 32. Container being positioned on trailer.

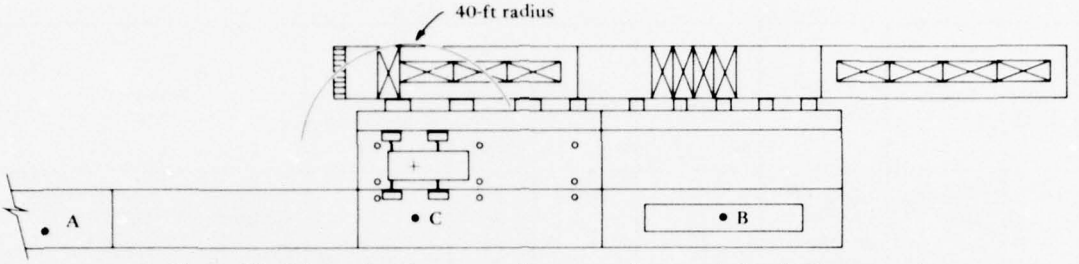


Figure 33. Schematic of causeway ferry operations at pierhead. Note container loading configuration.

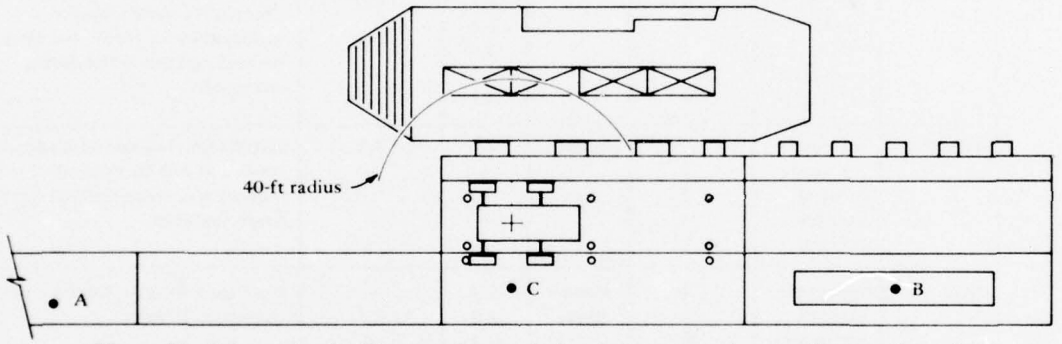


Figure 34. Schematic of LCU operation at pierhead. Note container loading configuration.

Because of the calm conditions encountered during the operation, only two mooring lines were employed with the LCU and LCM-8 lighters. Because of the length of the causeway ferry, as many as four lines were used to moor it to the pierhead. Additional mooring lines and spring lines would be required when operating in rougher sea conditions. During warping operations, the line handlers slipped the mooring lines as directed by lighter personnel. It was necessary to warp the LCU once and the causeway ferry 5 times for the crane to reach all the containers; the LCM-8 did not require warping.

A time plot with critical path was constructed for the lighter unloading operations (Figure 35). Construction was based on overall averages of Phase II data (relatively calm seas) for unloading (a) a three-section causeway ferry with 12 containers on board, and (b) a wave* of three LCUs, each with four containers on board. The time cycle begins with the lighter just off the pier approaching the moor and ends as the truck with the twelfth container arrives on shore.

While the lighter is mooring, the crane and truck/trailer are being positioned to receive the first container (position C of Figures 33 and 34 for the ferry and LCU, respectively). The crane picks up the first container and loads the trailer. The second truck/trailer in the wait position (position A) must delay until the first truck passes. In the interim, the crane begins its second cycle, but must wait to complete the cycle until the second truck has proceeded to the turntable (position B), turned

*Each successive LCU positioned ready to move into the moor.

Table 2. Summary of Container-Handling Times

Day	Lighter	Type of Operation	Containers Handled	Type of Spreader	Average Time per Container (min)		Remarks
					Crane Cycle	Crane/Truck Cycle	
1	Causeway ferry	retrograde off-load retrograde off-load	12 12 12 12	manual	2.4 2.5 2.0 2.3	– 3.4 – 3.4	See Figure 33 for orientation of containers on ferry. Crane/truck cycle includes waiting time for truck. No truck waiting time was noted during retrograde.
2	LCU	off-load retrograde off-load retrograde off-load retrograde off-load	4 4 4 4 4 4 4	manual	2.4 1.7 2.1 1.5 2.0 1.7 2.1	2.9 – 4.0 – 2.7 – 2.9	See Figure 34 for orientation of container on LCU. Crane/truck cycle includes waiting time for truck. No truck waiting time was noted during retrograde.
	LCM-8	off-load retrograde off-load retrograde off-load	2 1 1 1 1	manual	2.7 – – – –	3.3 – – – –	Initial LCM-8 loaded with two containers side by side; subsequent operations restricted to single container.
3	LCU	retrograde off-load retrograde off-load retrograde off-load	4 4 4 4 4 4	manual slings	1.3 2.8 2.2 2.4 2.5 2.6	– 4.5 – 2.6 – 2.8	See Figure 34 for orientation of containers in lighter. Crane/truck cycle includes waiting time for truck. No truck waiting time was noted during retrograde.
4	Causeway ferry	retrograde off-load retrograde	12 12 18	slings slings manual	1.5 2.3 1.5	– 2.5 –	–

around, and returned to position C. These delays are noted several times in both the causeway ferry and LCU operations.

3.2.1 Causeway Ferry

The overall cycle time for the 12-container causeway ferry was determined to be 46.8 minutes, which translates into a container-handling rate of 15.4 per hour. The mooring time of 6.7 minutes is critical, and any improvement in this operation will be reflected as a savings in time.

Except for the first container, the truck operation is on the critical path, thereby delaying the crane. (The first container has no crane delay as the equipment is in position before the ferry moors to the pierhead.) Since delays occurred 11 times in the 12-container sample, a savings of 8 to 10 minutes is possible by improving the truck cycle time to that of the crane cycle.* A savings of 8 minutes would increase the container-handling rate to 18.6 per hour.

*The original plan for truck movement with the turntable forward of the pierhead would have made the truck time more concurrent with that of the crane.

Table 3. Average Crane Cycle Times

(Cycle time is in minutes.)

Operation	Causeway Ferry		LCU	
	Manual	Slings	Manual	Slings
Rotate and lower spreader to container	0.67	0.24	0.35	0.26
Position and lock spreader	0.45	0.65	0.46	0.80
Lift and rotate container[a]	0.92	0.92	0.92	0.92
Position and release container	0.35	0.53	0.43	0.65
Total	2.4	2.3	2.2	2.6

[a]These were not discrete test measurements, but were reconstructed from the operational data.

Table 4. Lighter Operation Times

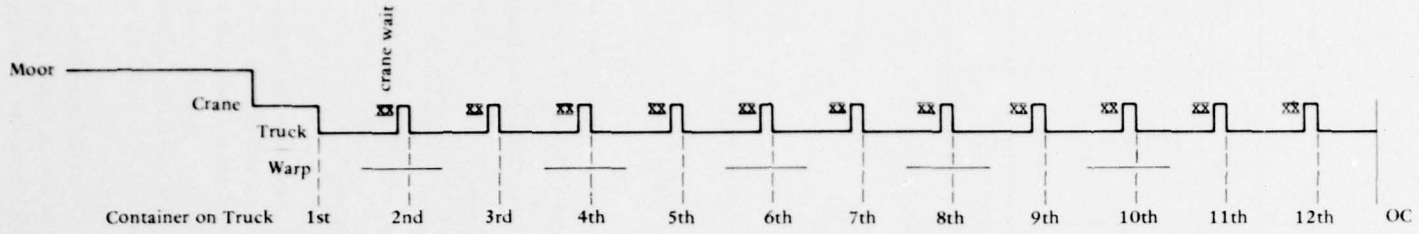
Lighter	Lighter Operation (min)		Remarks
	Moor	Warp	
Causeway ferry	6.7	3.0	Must be warped 5 times to reach all 12 containers
LCU	2 4	6.0	Must be warped once to reach all four containers
LCM-8	3.5	–	Does not require movement

Since the warping time of 3 minutes for every two containers is not on the critical path, it will not have an impact on the overall cycle unless it exceeds 5 minutes. The warping time required to adjust the ferry position to accommodate crane reach/lift begins after the second container is lifted from the ferry and is completed before the truck is in position to receive the container. The lighter is warped along the pier for each pair of containers. In relatively calm water, say no greater than lower sea state 2, it is safe for the crane to swing and lower the spreader bar to the container on the lighter during the end of the warping cycle.

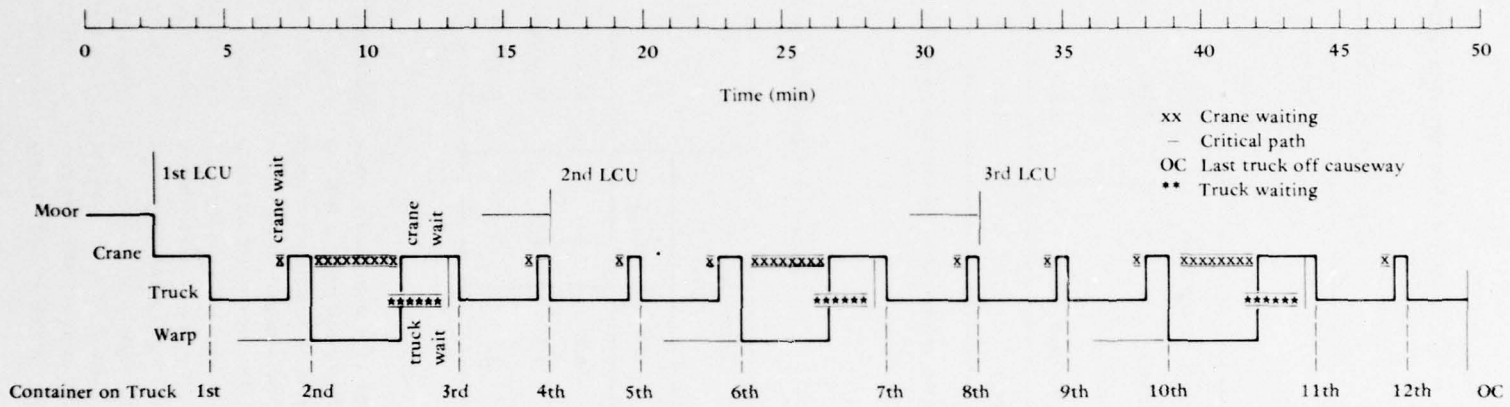
3.2.2 LCU

The overall cycle time for the 12-container, three-LCU operation was determined to be 49.4 minutes, which translates into a container-handling rate of 14.6 per hour. The mooring time of 2.4 minutes is not an area for significant improvement, and, in the plot, the second and third LCU mooring was not on the critical path.

As with the ferry, the truck operation is on the critical path and occurs 8 times during the 12-container sample, accounting for approximately a



(a) Three-section causeway ferry with 12 containers.



(b) Three LCUs with four containers each.

Figure 35. Elapsed time plot for lighter unloading operations.

0.7-minute delay each time. With an improved truck cycle, a savings of about 5.5 minutes is possible, which would increase the container-handling rate to 16.4 per hour.

Of the 6 minutes required to warp the LCU, 3.3 minutes of it are on the critical path, which is reflected in a crane delay. Since this delay occurs 3 times in the 12-container sample, a savings of several minutes could be realized by improving this operation. (As with the ferry, the LCU warps after a pair of containers is lifted.)

3.3 TURNTABLE CYCLE

3.3.1 Description

The Marine Corps truck/trailers (M52 tractor with M127 trailer) that were used to haul the containers from the pierhead to the beach are approximately 42 feet (12.8 m) in length and weigh about 34,000 pounds (15.4 Mg). This truck/trailer unit requires an area equivalent to eight causeway sections to execute a 180-degree turnaround at the pierhead. The use of a turntable reduces this requirement to a single causeway section and allows two-way forward traffic throughout the length of the pier. The backing up of semitrailer units with the attendant slowness and inherent risks is eliminated. The operational cycle of the turntable is essentially one of driving the truck/trailer onto the turntable, rotating the turntable 180 degrees, and driving the truck/trailer from the turntable.

The empty truck/trailer first negotiates a steel ramp onto the rotating section of the turntable. Some maneuvering is then usually required to balance the load of the truck/trailer over the center pin of the rotating section. Once balanced, air is applied to the air bearings to raise the rotating section approximately 3/4 inch (19 mm). The turntable was then rotated 180 degrees, where it was stopped in line with the steel access ramp. The truck/trailer then proceeded from the turntable to the container crane for a load.

3.3.2 Performance

During the Phase II tests at Coronado, 148 truck/trailer units were turned on the turntable, which was located on causeway pierhead section 1 (see Figure 6). Three men operated the turntable: one man to spot the trucks and tend the air control valve, and two men to push the turntable around.

A time study based on data collected from the time wheels touched the turntable ramp at entry to the time wheels cleared the ramp on exit is summarized in Table 5.

3.4 ENVIRONMENTAL EFFECTS

The container-handling times, crane cycle times, and lighter cycle times contained in Tables 2, 3, and 4, are based on operations carried out in a calm environment. With an increase in wind and wave conditions, the mooring and warping times for the lighter will become longer, and the hook-up time for the crane/lighter operation will increase. Operations on the elevated causeway, such as truck cycle times, turntable operation, and the crane/truck interface, will not be affected.

Based on experience gained during the OSDOC I and II operations and the pre-OSDOC II engineering tests, estimates* were made to degrade the crane/lighter interface operations (Table 6). It should be noted that the times listed for each phase of the operation are not directly additive because some operations are being conducted concurrently, as shown in Figure 35. The crane cycle time results in a transfer of 20 containers, but the truck cycle time reduces the container throughput to 15 containers per hour in calm waters and to 7 containers per hour in rougher seas. Thus, the critical factor is truck movement time, and any improvement in this area will increase the productivity. It is estimated that truck movement time can be decreased to a level compatible with the crane cycle times with the turntable forward of the pierhead, as originally planned.

*Statistics are based on employing an experienced crane operator.

Table 5. Turntable Operation Times

Day	Number of Operations[a]	Average Time (sec)			
		Enter	Turn	Leave	Total
1	43	22.4	64.1[b]	20.3	106.8
2	33	19.8	52.5[c]	18.1	90.4
3	23	18.3	39.7	17.0	75.0
4	41	11.9	30.6	12.2	54.7

[a] Number of operations was 148; of these, eight were discarded from the analysis because the delays were not attributed to the turntable operation.

[b] Includes one 8-minute delay due to a clearance problem with the turntable (see Discussion section). If this operation is discarded, the average for the remaining 42 operations is 54.2 seconds.

[c] Includes seven operations where truck-balancing problems were incurred.

3.5 LO/RO CYCLE

3.5.1 Description

In the Lo/Ro scheme, containers are delivered loaded transversally on the causeway ferry. Normally, the ferry would consist of five sections for a total length of 450 feet (137 m). This length of ferry permits the warping tugs that power and control the causeway to remain beyond the surf zone when the ferry is beached.

The ferry can carry four containers per section when loaded to 20 tons (18.2 Mg) per container, or five per section when loaded to 15 tons (13.6 Mg) or less.* The loaded ferry beaches at a prepared beach with matting (or other beach hardstand) in place. A top-lift loader sequentially traverses the causeway, picks up a container, and delivers it to an off-load point. The off-load point is normally a beach storage area and/or a truck/trailer in close proximity to the beached ferry.

3.5.2 Performance

During Phase II, a three-section ferry loaded with 12 containers (Figure 36) was tested. Upon beaching, the ferry was pulled higher onto the beach with the same tractors that pulled the steel matting to the ferry. These operations took about 15 minutes.** The causeway R1A ramps were then lowered onto the beach, and the top-lift loader proceeded to unload the containers and deliver them to a storage area (Figures 37 and 38) some 400 feet (122 m) of travel from the beach. Average times for traversing the causeway and trip times to and from the storage area are given in Table 7. The data from this table were then extrapolated to give the hypothetical Lo/Ro cycle rates of Table 8. The number of causeway ferries required to sustain an operation is examined in Appendix A.

In an earlier, alternate test, a five-section ferry with 12 containers loaded on the first three sections only was beached. A sand ramp was then constructed to provide a level road bed so that the top-lift loader would not have to negotiate the ramp. The sand ramp construction plus the steel matting installation took approximately 1-1/2 hours. Since the loader was able to negotiate the causeway ramp without time loss to the container-handling operations, it was demonstrated that the sand ramp approach is undesirable and not necessary.

*Based on data for support of a MAF operation, 64% of the containers will weigh out at 20 tons (18.2 Mg), and the balance will cube out at weights of 14.7 (13.4 Mg) tons or less.

**In continuous operations under contingency conditions, the causeway would normally hit a prepared beach, as discussed earlier.

Table 6. Estimated Degradated Container-Transfer Rates Between Lighter and Elevated Causeway

Operation	Container Transfer Rates (min) Using —							
	Three-Section Ferry				Class 1610 LCU			
	SS-1[a]	SS-2	SS-3	SS-4	SS-1	SS-2	SS-3	SS-4
Moor to pierhead	6.7	6.7	10	13	2.4	2.4	10	NR[b,c]
Warp along pierhead	3.0	3.0	5	8	6.0	6.0	8	NR
Unload Containers								
Rotate and lower unit								
Spreader bar	0.67	0.67	0.67	NR	0.35	0.35	0.35	NR[d]
Sling	0.24	0.24	0.24	0.24	0.26	0.26	0.26	NR
Lock onto container								
Spreader bar	0.45	0.45	2.5	NR	0.46	0.46	5.0	NR
Sling	0.65	0.65	2.5	3.0	0.8	0.8	4.0	NR
Lift and rotate container	0.92	0.92	0.92	1.1	0.92	0.92	0.92	NR
Position and release container								
Spreader bar	0.38	0.38	0.38	NR	0.38	0.38	0.38	NR
Sling	0.57	0.57	0.57	0.57	0.57	0.57	0.57	NR
Container retrograde[e]								
Position on lighter								
Spreader bar	2.1	2.1	2.6	3.1	1.8	2.0	6.0	NR
Sling	2.3	2.3	NR	NR	2.3	2.3	NR	NR

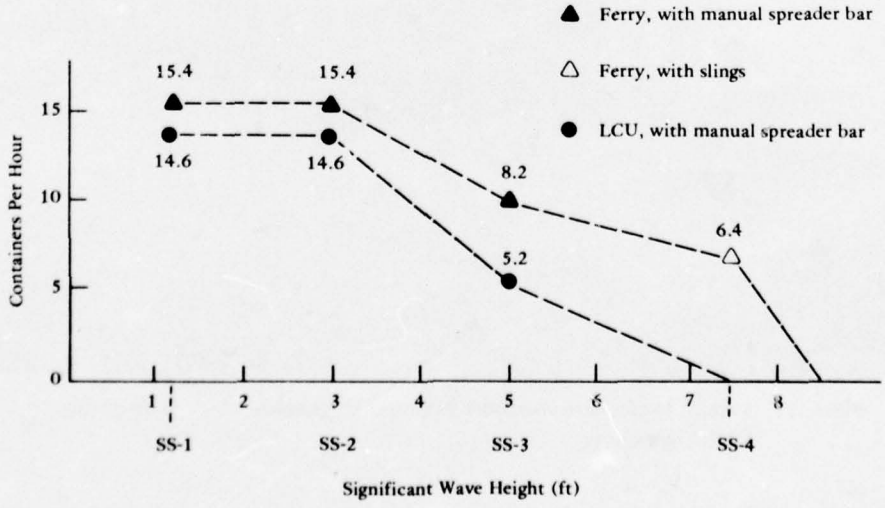
[a] SS = sea state, see diagram.

[b] NR = not recommended.

[c] Average time to moor LCU to elevated Delong (OSDOC II) was 13 min, <SS-3.

[d] Average time to unload LCU onto elevated Delong (OSDOC II) was 7.3 min, <SS-3.

[e] Recommend manual spreader bar only for retrograde operations.



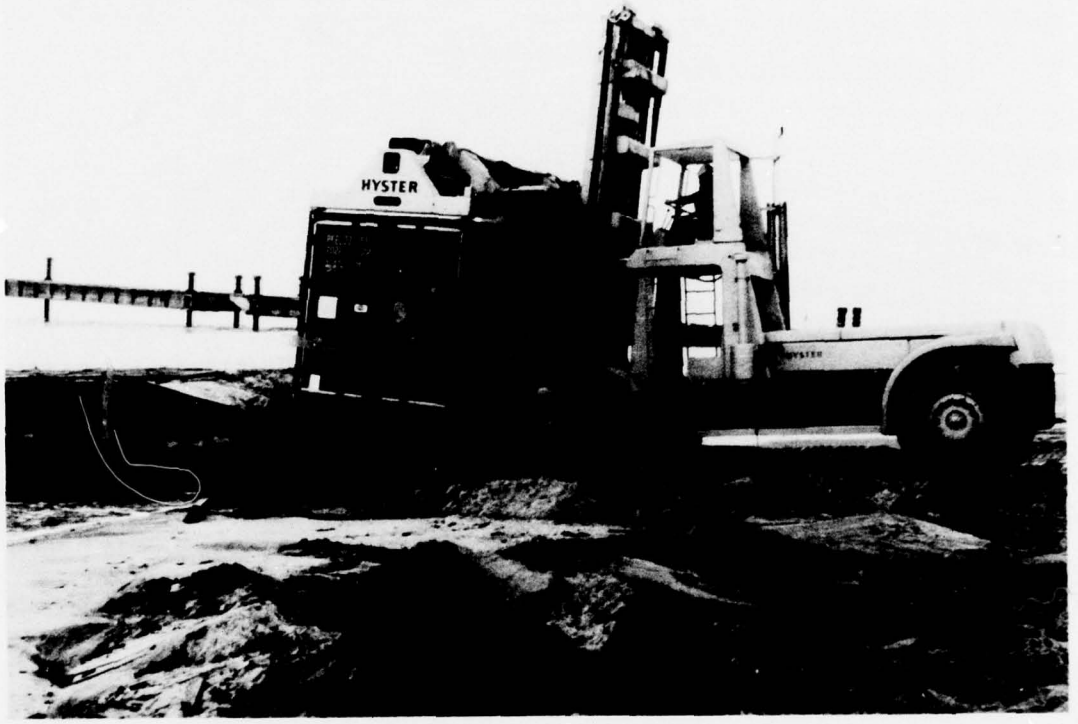


Figure 36. Causeway ferry with 12 containers being beached during Lo/Ro operation.

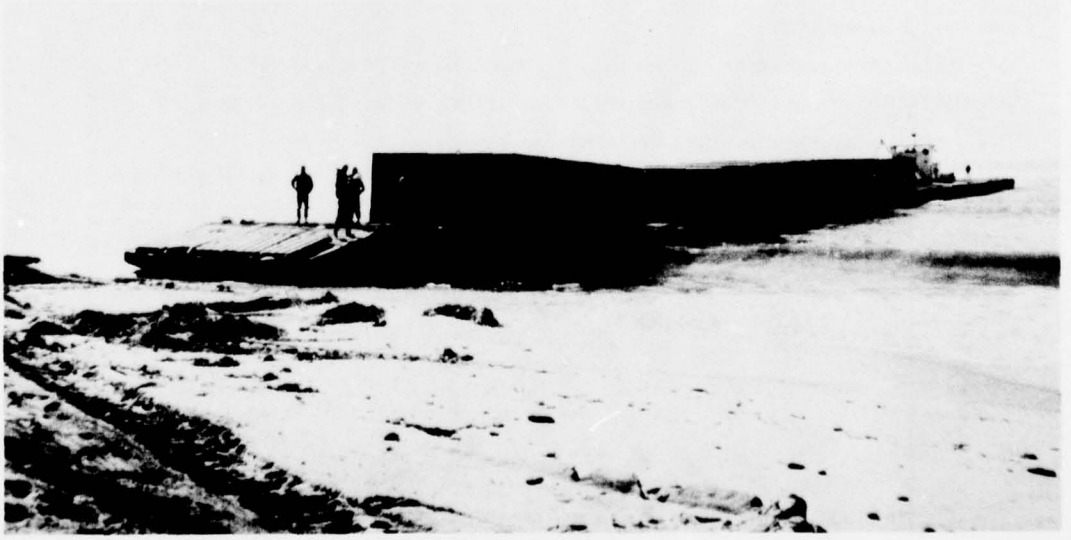


Figure 37. Top-lift loader with container negotiating causeway beach ramp during Lo/Ro operation.

Table 7. Cycle Times for Lo/Ro Operation

Causeway Section	Container Position[a]	Pick Up Container and Traverse Causeway Both Directions (min)	From Ramp to Storage[b] (min)	Discharge Container in Storage (min)	From Storage to Ramp (min)	Total Round Trip Plus Container Handling (min)
1	1	1.83	1.5	0.4	1.5	
	2	1.67				
	3	1.00				
	4	1.92				
		1.6 avg				5.0
2	5	1.67				
	6	1.83				
	7	1.92				
	8	2.08				
		1.9 avg				5.3
3	9	2.25				
	10	2.42				
	11	2.50				
	12	2.58				
		2.4 avg				5.8
4[c]		2.9				6.3
5[c]		3.4				6.8

[a] Container no. 1 is the shoreward-most unit.

[b] Approximately 400-foot (122-m) distance.

[c] Data are extrapolations.

An alternate container handler, a straddle-lift (Figure 39) for the Lo/Ro operation was tested prior to the Phase II tests. Cycle times of 11 minutes per container were attained. These tests are discussed in Appendix B.

3.6 AIR BEARING DEVICE

3.6.1 Container Stuffing Operation

Except for the compressor, all of the components of the system (including two master pallets) were shipped to the Public Works Center, San Diego, in one 8 x 8 x 20-foot (2.4 x 2.4 x 6.1-m) ISO container. The dock was set up on a pier in about 2-1/2 hours by two men who were both familiar with the dock.

The wood floors of the containers provided for the stuffing operation were in very poor condition. It was decided that galvanized sheet metal should be placed on the floors to ensure that the air bearings would operate smoothly in the containers. The sheet metal was held down on the floors with roofing nails.

Table 8. Hypothetical Lo/Ro Container-Handling Cycle — Unloading[a]

Causeway Section	Time per Container (min)	Total Time (min) for —	
		Four-Container Section	Five-Container Section
1	1.6 + 1.5 = 3.1	12.4	15.5
2	1.9 + 1.5 = 3.4	13.6	17.0
3	2.4 + 1.5 = 3.9	15.6	19.5
4	2.9 + 1.5 = 4.4	17.6	22.0
5	3.4 + 1.5 = 4.9	19.6	24.5
Total	4.0 (avg)	78.8	98.5

[a] Assumptions:

1. Causeway ferry beaches at prepared beach with matting (hardening) in place.
2. One top-lift loader per operation.
3. Top-lift loader deposits container on truck/trailer at beach in 1.5 minutes.
4. On causeway loader's traverse plus container-handling time per Table 7.
5. Five-section causeway ferries in cycle.
6. 64% of containers weigh out at 20 tons (18.1 Mg); 36% of containers cube out at 14.7 tons (13.3 Mg) or less (based on data for support of a MAF operation).
7. Ferry will carry four 20-ton (18.1-Mg) containers per section or five 14.7-ton (13.3-Mg) or less containers per section.

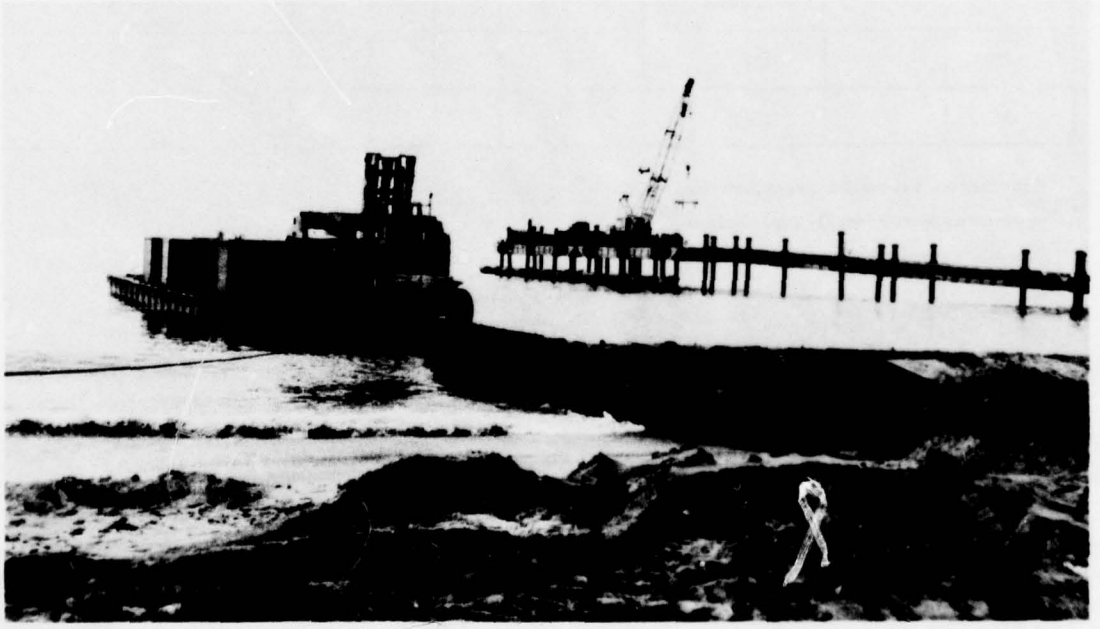


Figure 38. Top-lift loader unloading containers from causeway ferry during Lo/Ro operation.

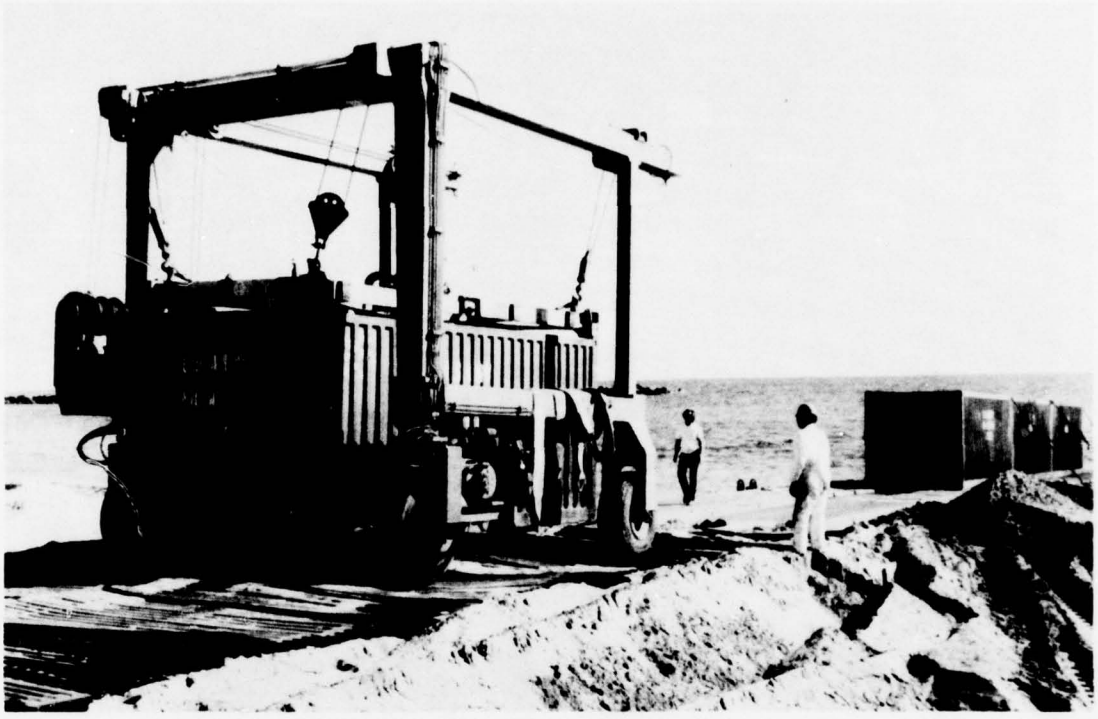


Figure 39. Straddle-lift loader unloading container from beached causeway section. Note level ramp to causeway.

For new containers or for containers that have not been abused, the sheet metal on the floor would normally not be required.

Once the dock was set up, each container was stuffed with 36,000 pounds (16.3 Mg) of concrete blocks. The blocks, which were 2 feet (50.8 cm) square in cross section and 7 feet (2.1 m) long, were placed lengthwise across the two master pallets used in the tests. A compressor from the Public Works Center supplied air during the stuffing operation.

The entire stuffing operation was accomplished by two CEL personnel with some assistance from a forklift operator when the blocks were being handled. No difficulties were encountered during the container stuffing.

3.6.2 Beach Operations

The dock was disassembled and shipped to the beach area in a container. The containers loaded with their concrete blocks were taken by warping tug to PHIBCB-ONE, where some dunnage was installed between the walls of the container and the blocks to prevent excessive shifting of the concrete blocks. The top four corners of the containers were painted orange to identify them as heavy loads, and then they were put in the container pool for the elevated causeway tests.

The container with the pieces of the knockdown dock was delivered to the beach on a truck and unpacked. The dock was assembled and leveled on the beach about 40 yards (36.6 m) inland from mean high tide. No difficulties were encountered, and no special provisions were made even though this was the first time the dock had been set up on sand. Total time for unpacking, assembling, and leveling the dock was about 2 hours with four men doing the work. All were familiar with the dock and assembly requirements.

Two weeks after the dock had been set up, the first container was brought ashore to be unstuffed. The dunnage was removed, and a top-lift loader

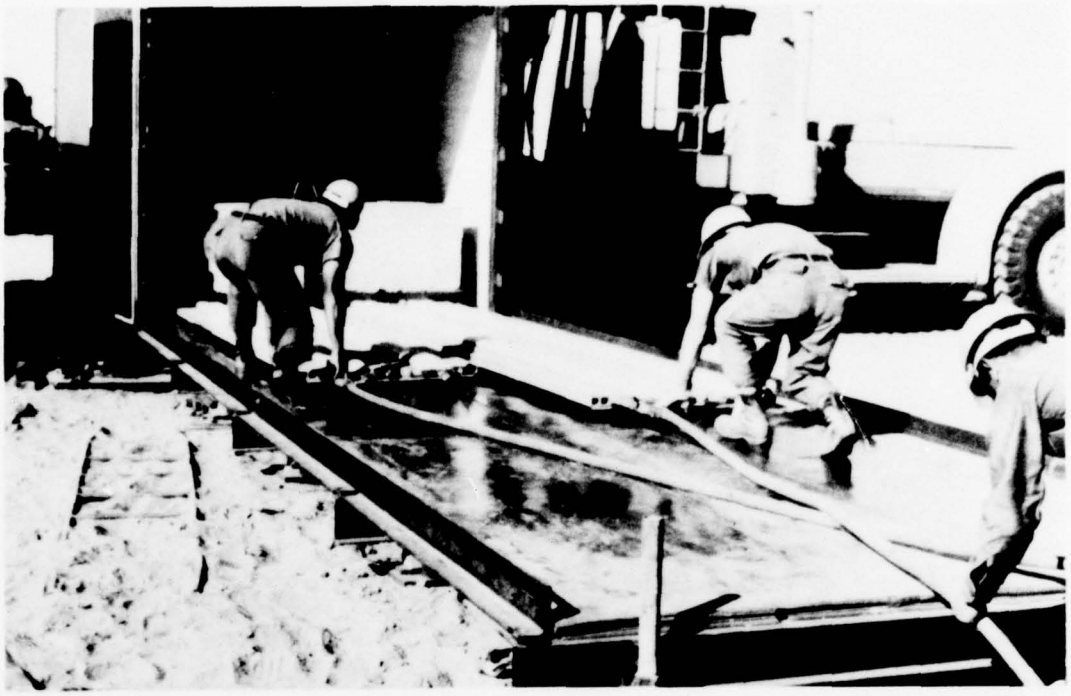


Figure 40. PHIBCB-ONE crew inserting transporters into container. Note inflatable load bars on each transporter.

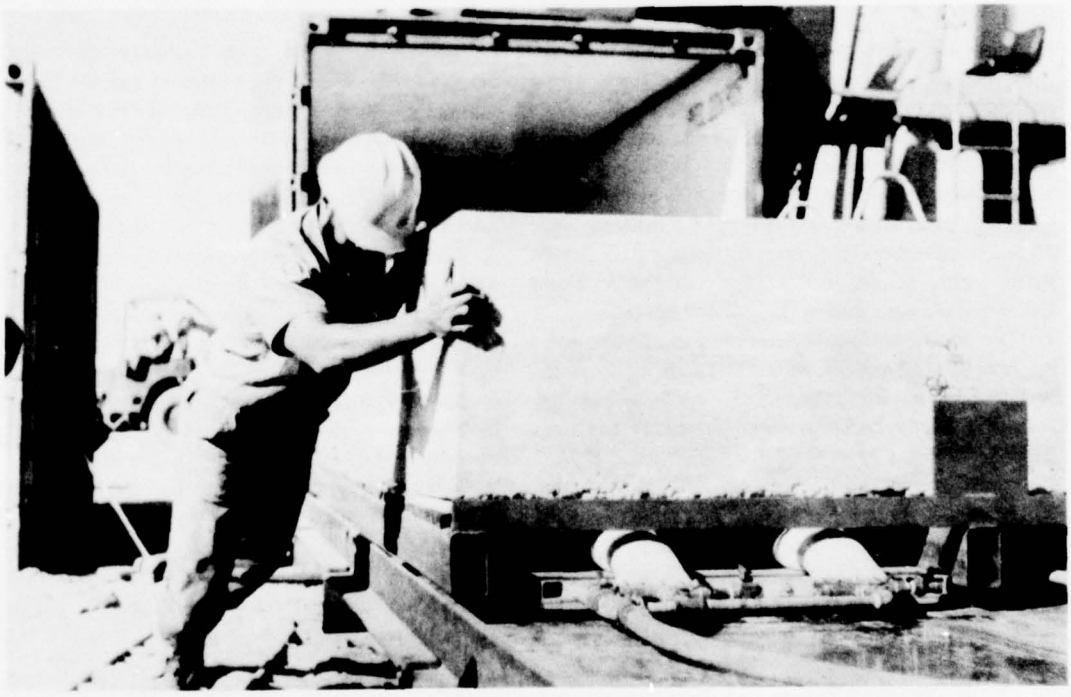


Figure 41. PHIBCB-ONE crew member pushing 20-ton (18-Mg) load out of container.

placed the container at the end of the dock. A slight settlement of one support of the dock that had occurred during the 2-week period was noticed and corrected.

A Worthington compressor, which was supplied by PHIBCB-ONE, was connected to the transporters. This compressor is a standard item in the SeaBees and has a maximum capacity of 365 scfm (0.18 m^3/s).

Three Seabees were assigned to the air bearing operation. None had even seen the system before. They were given one demonstration on the operation and some brief instructions on steps to be taken to safely and efficiently use the equipment. Figure 40 shows the crew placing the transporters into the container; the dock can be seen in the foreground and the top-lift loader in the background. Figure 41 shows one of two crew members pushing a load out of a container. The unstuffing operation was accomplished in less than 5 minutes. Later in the tests the blocks were removed from the master pallets with a rough terrain forklift.

SECTION 4

DISCUSSION

4.1 CRANE

The P&H Model 8100 crane that was employed during the Phase II tests was restricted to lifts not to exceed a 40-foot (12.2-m) radius so as not to exceed the allowable lift capacity of the crane. At this operating radius, the crane was able to reach only two 20-foot (6.1-m) containers for each position of the lighter. This required the lighter to be warped for each two containers unloaded. The warping operation was initiated while the crane was transferring the second container, thus reducing the waiting time.* Because of the calm conditions during the tests, the crane operator was able to off-load the containers during the warping operation. Rough sea conditions with accompanying lighter motions would degrade this operation.

A larger crane, 140-to-150-ton (127-to-137-Mg) rated capacity, would relieve many of the lift/reach problems associated with the 90-ton (81.6-Mg) rated crane. A load-versus-operating-radius curve for 360 degrees of operation (outriggers fully extended and locked) and operating from a stable platform is given in Figure 42. The curves are based on the capabilities of P&H 9125-TC and American 8450 mobile cranes.

The operating weight of the P&H 9125-TC crane, including a 70-foot (21.4-m) long boom and a two-piece 31-ton (28.1-Mg) counterweight, is approximately 95 tons (86.2 Mg). The counterweights can be removed to reduce the crane weight to approximately 65 tons (60 Mg), thereby permitting safe transport over the elevated causeway to the pierhead. The counterweights can be transported to the pierhead in truck/trailers for installation by the crane crew. The limiting crane transit loads for the elevated causeway are discussed in Volume III.

The P&H 9125-TC crane with the addition of a front float will permit a greater operating radius [25 tons (22.7 Mg) at 53-foot (16.2-m) radius] and provide the additional capacity to better withstand shock loads expected during rough sea conditions. The added working radius will permit handling of all four containers loaded into an LCU without moving the lighter. It also permits off-loading all four containers from each 3x15 causeway ferry section before warping of the ferry is required. The effect of this added working radius is shown in Figures 43 and 44.

The pedestal crane, an alternative to the mobile crane for the elevated causeway system, is discussed in Appendix C.

Deployment of the container-handling crane was not an objective of the Phase II tests. Various alternative ships for deploying the container-handling crane are discussed in Appendix D. Cranes being deployed on breakbulk-type ships will require some degree of disassembly for handling and stowage. Because of this requirement, the crane will require some assembly on the beach or on the pierhead. Assembly requirements for three mobile and two pedestal-type cranes are summarized in Table 9. The information contained in this table was obtained from the crane manufacturers and from observations of various military operations.

4.2 PERSONNEL

The experience of the crane operator was manifested in the ease with which he operated the crane during the container-transfer operation. The calm conditions existing during the tests also made the crane operator's job easier. It was not possible to let military operators run the crane because of insurance liability restrictions. However, from the post-OSDOC II tests** it is estimated that the crane cycle time would have been twice as long due to the inexperience of the operator.

The crane operator is the keyman in handling and positioning the spreader bar and/or containers. Working with the tagline crew and signalman, the crane operator makes all of the gross movements and many of the finer movements of the load-transfer

*See Section 3 on Container-Handling Operations for times.

**Civil Engineering Laboratory Technical Note N-1381: Offshore discharge of containership II, Post-OSDOC-II, test and evaluation of ancillary aspects of container handling, by J. J. Traffalis. Port Hueneme, Calif., Feb 1975.

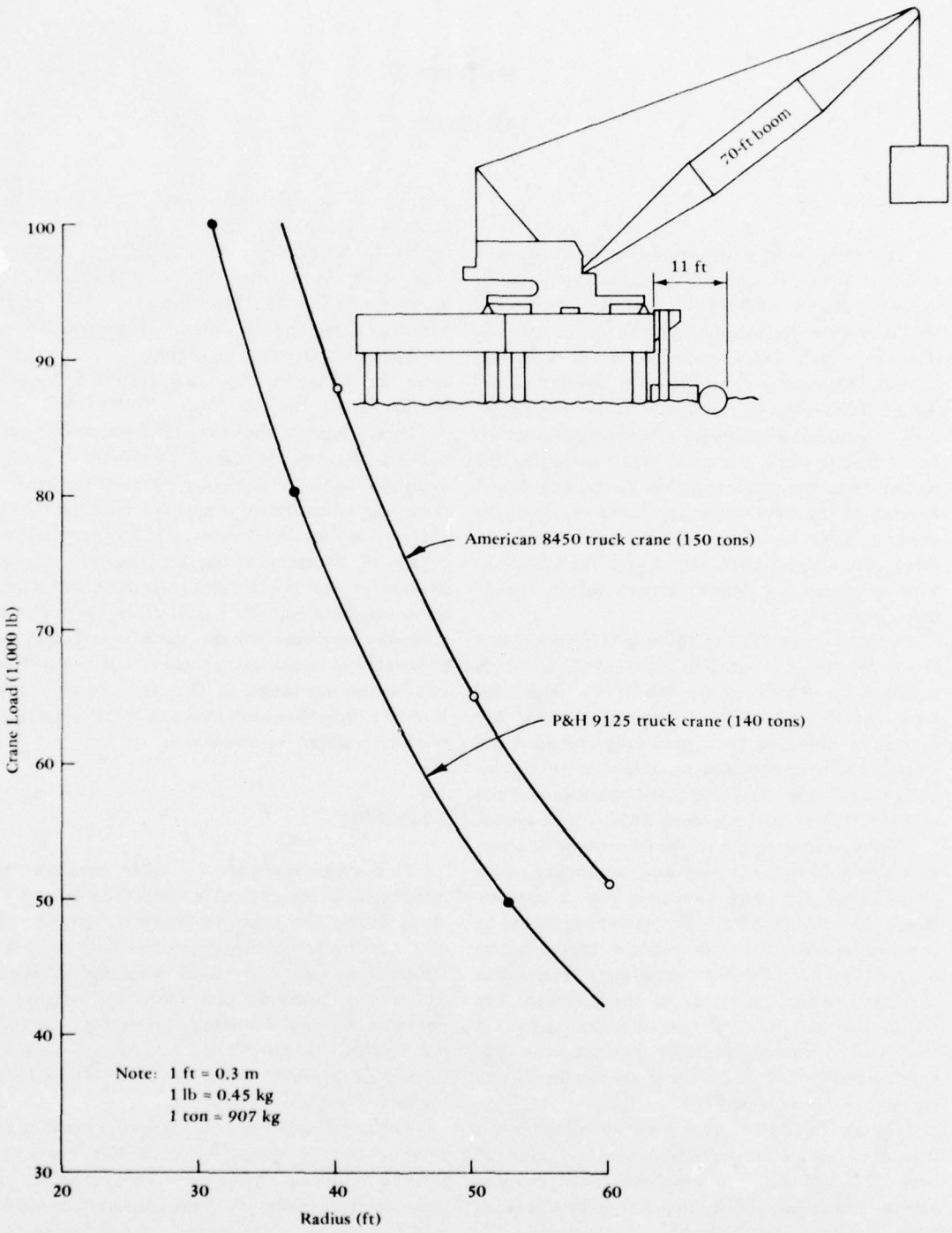


Figure 42. Crane lift versus operating radius for two mobile cranes.

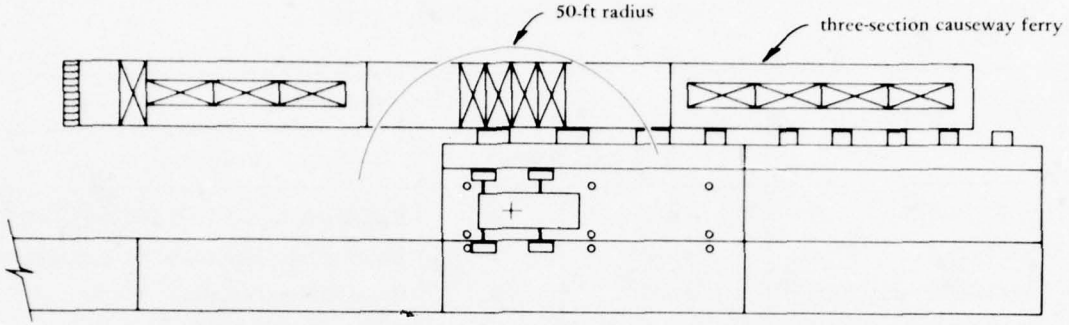


Figure 43. Causeway ferry operation at pierhead. Note crane operating radius of 50 feet (15 m) reaching four containers.

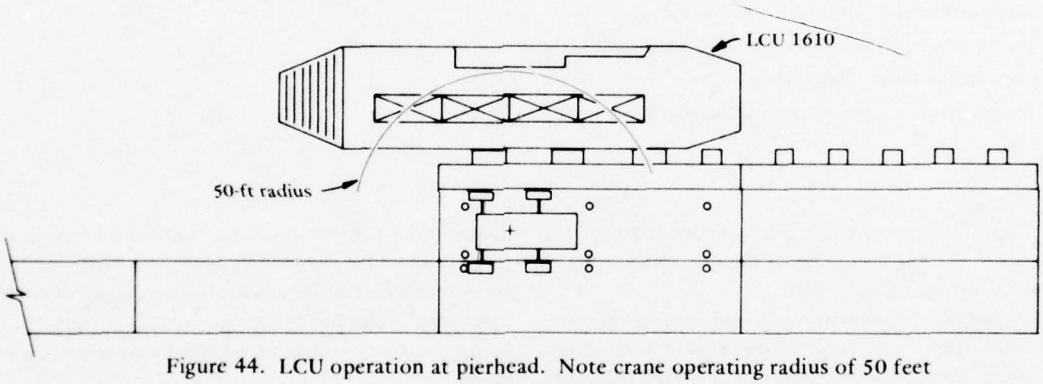


Figure 44. LCU operation at pierhead. Note crane operating radius of 50 feet (15 m) reaching four containers.

operations. The only maneuvers initiated by the tagline crew are rotating of the loads (spreader bar or containers) for proper alignment and, at times, minor lateral movements during final positioning of the load.

Since there is no platform motion associated with the elevated pierhead, load pendulation was not a factor, which made the tagline crew's job much easier. After an initial indoctrination of the operation of the manual and sling spreader bars, the deck crews had little difficulty in making the connection. The sling spreader took more time to position and lock because it required four men to make the connection. The signalman also had to make sure all four men were clear before he could give the crane operator the signal to lift the load.

4.3 SPREADER BARS

4.3.1 Manual Spreader Bar

The manual spreader bar with guides on two sides is a sturdy piece of equipment that was designed for the rigors of shipboard and dockside operations. No difficulties or failures were experienced during the container-handling operations. The 3,000-pound (1,360-kg) weight of the spreader bar presented little trouble for the tagline handlers because of the calm conditions of the test and because load pendulation was not a factor.

The spreader bar required an average of 27.3 seconds to position and lock on a container loaded in a lighter. Three tagline handlers were found to be

Table 9. Crane Assembly Requirements

Crane	Assembly Requirements		
	Trained Personnel	Time (days)	Equipment
P&H 8100-TC[a]	4 to 6	1[b]	Rough terrain fork truck, 6 ton (5.4 Mg)
P&H 9125-TC	4 to 6	1[b]	Rough terrain fork truck, 6 ton (5.4 Mg)
P&H MC/50 pedestal crane	3 to 5	2	Crane, 10 ton (9.0 Mg)
BE MK-60 pedestal crane	3 to 5	3 to 4	Crane, 10 ton (9.0 Mg)
Pedestal crane base[c]	3 to 5	1 to 2	Welding equipment
P&H 6250-TC[d]	6 to 10	2 to 4	Crane, 140 ton (127.0 Mg)

[a] Comparable to P&H 790-TC.

[b] Assume crane brought ashore tactically disassembled.

[c] Common for both pedestal cranes.

[d] Assume crane brought ashore administratively disassembled.

adequate for maneuvering the spreader bar over the container and for maneuvering the spreader/container onto the lighter or the trailer.

Retrograde operations with the manual spreader bar were faster and more efficient than with slings. This was attributed primarily to the fact that only one operation is required to lock and/or release the container, whereas each of the four sling hooks has to be engaged or disengaged. Because of this more efficient method of locking and unlocking, the manual spreader bar is judged to be less hazardous than the sling spreader for the personnel working with the taglines on the lighters. This was particularly noticeable during retrograde operations on the causeway ferry. Tagline handlers were required to go between containers when positioning in the transverse direction to disengage the sling hooks from the container. Under rougher sea conditions with correspondingly greater lighter motions, this would be a hazardous operation.

4.3.2 Slings

Soft slings are an effective alternative to the spreader bar when operations at sea begin to deteriorate. Lighter motions make positioning the manual spreader bar onto a container more difficult and hazardous. While additional personnel could be required, the off-loading operation would be permitted to continue under the more severe conditions.

Soft slings have a weight advantage and can be easily carried on the crane or can be quickly made up in remote sites. Slings require little, if any, maintenance or adjustments.

The average time of 43.5 seconds required to position and lock the slings onto the container was about 1.5 times longer than the manual spreader bar under the calm conditions of the test. However, under rougher sea conditions with larger lighter motions, the slings should prove more effective than the manual spreader bar for container off-loading operations.

4.4 OUTRIGGER BEAMS

The 800-pound (362-kg) weight of the outrigger beam was difficult to manhandle over the deck. However, this was easily solved by having the crane

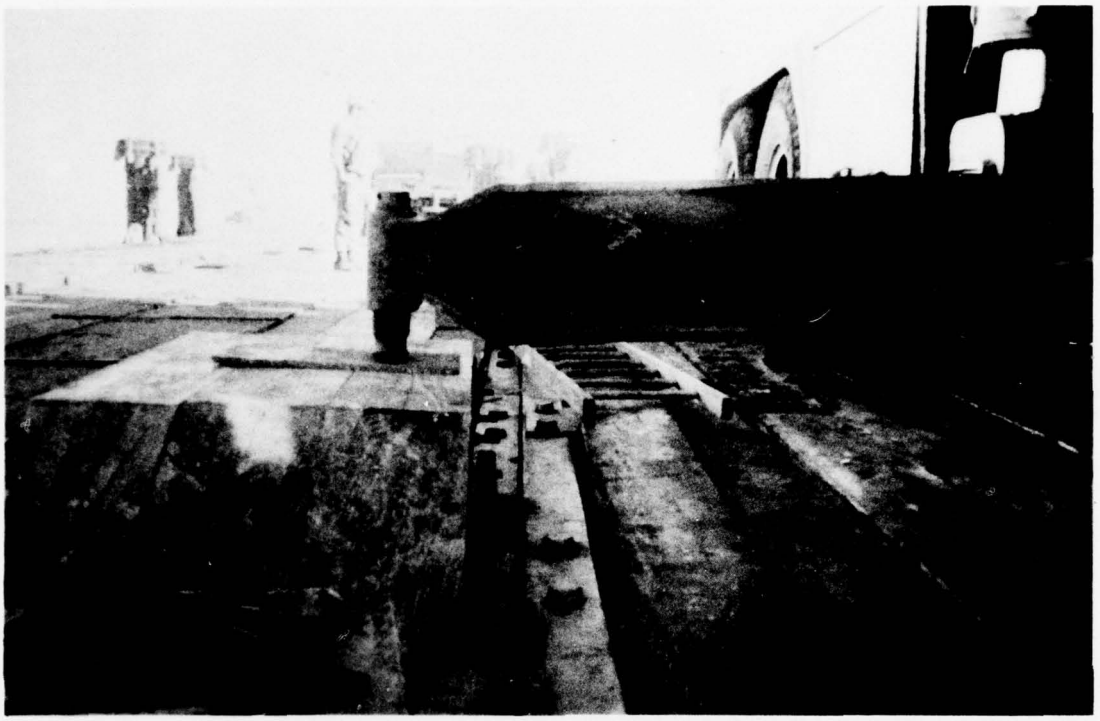


Figure 45. Steel plate substituted for outrigger float.

lift and position each of the beams prior to extension of the outriggers. Hinged plate padeyes were provided for this purpose.

Two of the outrigger floats provided with the crane were not compatible with the outrigger beam. Two 1-inch (2.5-cm) thick steel plates were employed as substitutes for the floats (Figure 45). Since these were on the inboard and short-working radius of the crane, no problems were experienced.

4.5 BEACH TRANSITION RAMP

The Phase I and Phase II tests provide comparative data for a built-up sand ramp and the 30-foot (9.2-m) fabricated steel ramp. The sand ramp, which was undermined daily by the surf action at high tide, required a daily, time-consuming rebuilding effort. The steel ramp with sand ramp installation (Figure 46) required considerable time and effort to build and maintain. However, once the steel ramp settled to the level of the normal beach profile, little or no follow-on maintenance was required (Figure 7).

It was found during the tests that it is futile to reconfigure and maintain a new beach profile to accommodate the causeway/beach transition ramp. Three apparent choices are available. The preferred method is to push the causeway far enough ashore so that the beach end of the ramp lands outside the high water level. The second method is to prepare the beach so that the ramp deck lays at the same elevation as the normal beach profile. Finally, and least attractive, a small retaining wall can be built with sheet piles to prevent washouts. Pushing the causeway higher up the beach reduces the distance a causeway extends offshore. Burying the end of the ramp, as in the second method, could result in shallow water and wave run-up at the beach. The sheet piling could be required in a long-term installation. If the beach gradient is slight, it could be more important to gain an extra 50 feet (15.3 m) seaward and tolerate a little water at the ramp's end during high tide.

Figure 46. Beach transition ramp with built-up sand ramp.

Structurally, the ramp was capable of supporting the 150,000-pound (68-Mg) crane and any other loads applied during the test. The ramp installation was reasonably simple with the 35-ton (32-Mg) capacity crane. During retrieval, the removal of the ramp presented some difficulties because the end of the ramp was buried 2 feet in the sand. This sand had filtered through the grating and into the voids created by the 6 x 8-foot (1.8 x 2.4-m) bearing plate, making the ramp much heavier.

4.6 DECK REINFORCEMENT

The timber reinforcement for the pontoon deck performed satisfactorily for the wheeled traffic during the tests. However, the steel cleats on the tractors destroyed some timber and tore loose some of the steel restraining straps. Additional deck reinforcement is required on the elevated causeway to provide for continuous two-way truck traffic from beach to pierhead.

4.7 BEACH MATTING

The M8A1 steel beach matting performed well in supporting the container-carrying truck/trailers material-handling equipment (MHEs), and cranes across the sand areas. It was possible to move sections of the matting from one area to another with a crane or tractor as the need arose. This permitted the servicing of several areas with a minimal amount of beach matting. It was found that the matting was not reuseable after an operation, because the pin joints securing the sections together were bent or damaged by the traffic. A number of joints were welded in the field to repair or reinforce the matting during the operation.

The Mo-Mat employed during the Lo/Ro tests did not perform satisfactorily. The heavy wheel loads of the top-lift loader with container coupled with the poor subgrade of the sand beach caused the Mo-Mat to form a wave in front of the wheel and allow the wheels to bog down in the sand. The Mo-Mat was replaced with M8A1 steel mat, and the operation was permitted to continue.

4.8 AIR BEARING SYSTEM

During normal operation the container is placed at the end of the dock with doors open and the transporters under the load (master pallet). The inflatable load bars are activated, and the entire contents are pulled out by hand onto the dock. Since the dock is only 8 feet (2.4 m) wide, cranes, forklifts, and any other MHE of suitable capacity can approach from either side and can either clear the entire master pallet or remove just a portion of the cargo. This is generally the technique followed for repeated container unstuffings.

If a crane is used to place the container at the end of the dock, the entire operation from the time the container arrives until the load is out on the dock seldom exceeds 5 minutes. Theoretically, the dock is extendable to any length, so many container loads could be pulled out and lined up on the dock.

4.9 LIGHTERS

4.9.1 Causeway Ferry Operations

The causeway ferry operations were scheduled for the first and fourth day of the container-handling operation. A three-section causeway ferry carrying 12 containers (four on each section) was employed. Two complete retrograde and off-loading cycles were made during the first day's operation. During the fourth day, two retrograde and off-loading cycles of 12 containers each were followed by the retrograding of all 18 containers employed during the operation. For the latter operation, six containers were loaded transversely on each of the three causeway sections.

The 40-foot (12.2-m) working radius imposed on the crane made it necessary to warp the three-section causeway five times for the crane to reach all 12 containers.

The 3x15 causeway ferry is essentially limited to a maximum loading of 100 tons (90.7 Mg),* which means only four fully loaded 8 x 8 x 20-foot (2.4 x 2.4 x 6.1-m) containers can be handled per section. These can be loaded transversely or longitudinally on the causeway section. One disadvantage to transverse loading is that it provides minimal passage area for tagline handlers along the causeway length. Transverse loading also requires more precision and time in positioning the 20-foot (6.1-m) long containers onto the 21-foot (6.4-m) wide causeway. This action may become very difficult with rising sea conditions.

Dimensionally, the 90-foot (27.5-m) length of the causeway section limits the loading to ten containers transversely and only eight containers longitudinally. The 21-foot (6.4-m) width of the causeway section provides more tolerance for loading the containers longitudinally onboard. Longitudinal loading also provides adequate passage area for tagline handlers and provides free passage for the line handlers during mooring operations.

4.9.2 LCU and LCM-8 Operations

Container-handling operations employing the LCU as a lighter were conducted on the second and third day of the tests. LCM-8 operations were conducted in conjunction with the LCU operations during the second day.

The 40-foot (12.2-m) working radius imposed on the crane made it necessary to warp the LCU along the pierhead one time for the crane to reach all four containers onboard. The LCU provided adequate space for the tagline handlers. Some motion (surge, sway, and yaw) was noticeable at the pierhead.** However, because of the calm conditions during the tests, the motions were never severe enough to degrade container-handling operations. Some care must be exercised by the tagline handlers and crane operators to not impact the container against the superstructure of the LCU.

Only four containers were off-loaded and two retrograded during the test with the LCM-8. The initial LCM-8 test was with the two containers loaded side-by-side. The crowded conditions resulting from this loading required the line handlers to work from the wing walls of the craft. This is an unsafe working condition, especially during rough water conditions. Subsequent off-loadings were made with only one container in the LCM-8.

*NAVFAC P-401, "Pontoon Gear Handbook."
**Lighter motions are covered in Volume IV.

4.10 TURNTABLE OPERATION

Successful operation of the turntable is dependent on having the center of gravity of the load directly over the centerpin of the turntable. The load can then be rotated quite easily as the air bearings are practically friction free. The only force required is that needed to overcome inertia and accelerate the load; deceleration and stopping of rotation requires an equal braking force in the opposite direction.

Deployment of the turntable and its assembly presented no serious problems. The unit was shipped from Port Hueneme to Coronado stowed on a 3x15 causeway section in the well of an LSD. There the turntable was removed from the transporting section and assembled on a second 3x15 causeway section by PHIBCB-ONE personnel. A CEL representative was provided to assist PHIBCB-ONE personnel who were unfamiliar with the structure.

During the first day's operation with the turntable, the total lift developed by the air bearings on the rotating section was only 1/4 inch (6.3 mm) in comparison to the 3/4 inch (19 mm) required for adequate operating clearance. This condition, which resulted from air leaks and poor leveling of the turntable, made centering of the truck/trailer units extremely critical. Air leakage through a gasket in one of the air bearings added to the day's problems. During this initial operation, several rotational problems occurred due to the combination of trucks being spotted off-center and the loss of one air bearing in one sector. Re-leveling of the base section, correction of the air leakage problem, and the replacement of the damaged air bearing restored the 3/4-inch (19-mm) clearance, and the turntable operated without problems throughout the balance of the tests.

The establishment and maintenance of the balance point of each load (truck/trailer) on the turntable was the key factor in the successful and rapid operation of the turntable. The weight distribution of all the truck/trailer units employed varied. However, as soon as the drivers and the turntable operator became familiar with the characteristics of each unit, the balancing problem was resolved. This is reflected in Table 5, where operations show a day-by-day improvement. A turntable cycle time of 1 minute is possible as the crews gain experience.

4.11 TRUCK/TRAILER OPERATIONS

The six truck/trailers employed in the tests performed well. The drivers indicated some difficulty with trailer tracking when the truck drove off the timber-reinforced roadway during a by-pass maneuver. The loss of deck area on the pierhead resulting from the mounting of the turntable on one of the pierhead sections so congested the area that it was not possible for the truck/trailers to by-pass on the pierhead. As many as four truck/trailers were waiting on the elevated causeway sections while one truck/trailer was being loaded by the crane on the pierhead.

Had the turntable been positioned on a separate causeway section seaward of the number one pierhead section as originally planned, there would have been sufficient room on the pierhead for a truck/trailer by-pass maneuver; this would have eliminated the truck/trailer delay times and would have provided a truck/trailer cycle time to match the crane cycle time.

SECTION 5

FINDINGS

5.1 CONTAINER-HANDLING OPERATIONS

1. Under ideal sea conditions, crane container-handling rates of up to 20 containers per hour were attained, but the overall productivity was degraded to 15.4 containers per hour because truck movement on the causeway could not keep up with the crane operations. Truck time dominates the critical path for both causeway ferry and LCU operations.

2. The 15.4 containers per hour rate was attained with the causeway ferry; a rate of 14.6 per hour was attained with the LCU.

3. Based on the estimate given in Table 6, the container-handling rate of 15.4 per hour can be expected to degrade to 8.2 and 6.4 per hour in sea states 3 and 4, respectively, for the causeway ferry, and the 14.6 per hour rate to 5.2 per hour for the LCU in sea state 3. Operations with the LCU are not advisable in sea state 4.

4. A 90-ton (81.6-Mg) rated mobile crane, lifting a fully loaded 8 x 8 x 20-foot (2.4 x 2.4 x 6.1-m) container at a radius of 40 feet (12.2m), is working at or near its maximum capacity.

5. The 90-ton (81.6-Mg) rated crane, working to a maximum radius of 40 feet (12.2 m), was able to reach only two containers before repositioning of the LCU or 3x15 causeway ferry was required.

6. The fully operational 90-ton (81.6-Mg) rated mobile crane, which weighs 74 tons (67.1 Mg), was able to safely travel the elevated causeway to the pierhead and could easily negotiate the access ramp at the beach end of the causeway.

7. The spreader bar, guided on two sides, performed well under the calm conditions of the test.

8. The spreader bar was faster and easier to position and lock onto a container than the sling spreader under the calm conditions of the test.

9. Three tagline handlers appear adequate to maneuver and position the spreader bar or spreader bar with container.

10. The test conditions were not sufficiently severe to fully evaluate the spreader bar.

11. The slings performed adequately under the calm conditions of the test.

12. The slings require more time to position and secure to a container than the manual spreader under the calm conditions of the test.

13. Four tagline handlers were required to position and secure the slings on the container.

14. The use of slings to retrograde and off-load containers placed transversely on the causeway ferry can be hazardous for the tagline handlers.

15. The test conditions were not sufficiently severe to fully evaluate the effectiveness of the slings.

16. The 3 x 1 x 8-foot (91.5 x 30.5 x 244-cm) long outrigger beams provided an adequate load-spreading device for the 90-ton (81.6-Mg) rated crane.

17. The beach ramp was not difficult to install; however, burial of the end of the ramp presented problems* during removal.

18. A built-up sand ramp that falls within the high water mark requires constant rebuilding and maintenance.

19. When the end of the ramp coincides with the normal beach profile, a reasonably stable condition exists, even with waves running up at high tide.

20. The timber reinforcement for the pontoon deck performed satisfactorily for wheeled vehicles.

21. Steel cleats on the tractors shattered some timbers and tore loose some of the steel restraining straps.

*Discussed in Volume II.

22. Additional deck reinforcement is required to provide for improved continuous two-way traffic on the causeway.

23. The M8A1 steel beach matting performed well in supporting the container-laden truck/trailers and cranes across the sand beach.

24. The turntable reduces the area required for truck/trailer turnaround from an equivalent of eight causeway sections to a single causeway section.

25. While the turntable performed adequately in turning the truck/trailer units on the causeway, several additions to simplify and improve its operation were found to be necessary. These are:

(a) Power to rotate and stop the turntable.

(b) An air manifold system to provide equal distribution of air to all air bearings.

(c) Lifting padeyes to facilitate handling of the turntable assemblies.

(d) An indicator scale painted on the rotating platform to assist the operator in achieving load balance.

26. Containers loaded transversely across the causeway ferry restrict the passage area for line handlers during container-loading and mooring operations.

27. The width of the causeway ferry provides a larger spotting area when loading containers longitudinally onboard.

28. During retrograde, more empty containers can be loaded transversely (10) than longitudinally (8) on the causeway section.

29. The LCU provided adequate areas for tagline handlers and mooring line handlers.

30. The superstructure of the LCU is very close to the container-loading area, thus inviting damage from impacting containers.

31. The crowded conditions resulting from loading two containers side-by-side in the LCM-8 generated unsafe working conditions for the line handlers.

5.2 LO/RO OPERATIONS

1. The top-lift loader performed satisfactorily during the Lo/Ro tests. The unit was able to easily negotiate the causeway ramps with a fully loaded container.

2. Times to unload the containers varied from an average of 1.6 minutes per container on the first section (nearest shore) to 2.4 minutes per container on the third section.

3. The Mo-Mat requires a properly prepared subgrade to support the top-lift loader.

4. The M8A1 steel matting that replaced the Mo-Mat performed satisfactorily with the top-lift loader.

SECTION 6

CONCLUSIONS

6.1 CONTAINER-HANDLING OPERATIONS

1. With the crane operating with a 40-foot (12.2-m) maximum radius restriction, the elevated causeway system as tested at Coronado can be used to transfer 20-ton (18-Mg) containers from lighters to the beach.

2. Under ideal sea conditions and with improved truck movement, container-handling rates of up to 20 containers per hour can be sustained if given experienced crane operators. The crane operator is the key determinanat to the crane-handling rate. Significant degradation will occur as the seas pick up in excess of sea state 2.

3. With trained but inexperienced crane operators, the container-handling rate will probably be lower than the test results; even under ideal conditions, the rates may degrade to 10 containers per hour.

4. Based solely on productivity, there is no significant difference between the causeway ferry and the LCU; the LCM-8 is less effective.

5. A 90-ton (81.6-Mg) rated mobile crane is marginal, but it can be used with the restrictions imposed as during the Coronado exercise.

6. A mobile crane with a greater lift/radius capability [25 tons (22.7 Mg) at 50 feet (15.3 m) radius] is required for more effective container handling.

7. A device to reduce shock loads to the crane boom may be required during operations in rough seas.

8. The alternative pedestal crane provides sufficient advantages to warrant further investigation.

9. A mobile crane that could handle 40-foot (12.2-m) containers would be larger and heavier than the crane employed to handle 20-foot (6.1-m) containers. The operational weight of such a crane appears impractical for use on the elevated causeway.

10. There were not sufficient lighter motions to fully evaluate the capabilities and limitations of the manual spreader bar or the sling spreader.

11. The manual spreader bar is more effective than the sling spreader under calm conditions, whereas the sling will be more effective when operating under severe sea conditions. However, the manual spreader bar will be more effective than the sling spreader for retrograde operations under all sea conditions.

12. A transition ramp is required from the elevated causeway to the beach. The one presently developed meets the requirements.

13. A more effective method for securing the timber reinforcement to the pontoon deck is required.

14. Street pads on tractors would result in much less damage to the timber deck reinforcement.

15. The turntable is essential to the conduct of cargo-handling operations on the elevated causeway system. However, simplified and improved turntable operations need to be developed.

16. The causeway ferry makes a more stable platform than the LCM-8 or the LCU and is less susceptible to damage.

17. Longitudinal loading of containers is more efficient than transverse loading in that it provides more working area for tagline handlers, provides free passage for mooring line handlers, and requires less tolerance when spotting containers on the deck.

6.2 LO/RO OPERATIONS

1. The Lo/Ro causeway ferry is a current Fleet capability available for all types of cargo movement, particularly while the more permanent-type of facility is being constructed or for short-duration contingencies.

2. For most effective operations, a ferry that is long enough to keep the power and control unit beyond the surf zone when the ferry is beached is desired.

3. Under ideal conditions, the causeway ferry in the Lo/Ro mode can sustain delivery rates of 20 containers per hour with the present level of personnel training if given the proper number of ferries in the shuttle.

4. A sand ramp to provide a level roadway to the beached causeway ferry is unnecessary; construction of such a ramp is time consuming.

5. The advantages of loading the containers longitudinally on the causeway warrants further investigation into a straddle-type container handler in lieu of the front-lift loader.

SECTION 7

RECOMMENDATIONS

1. A large mobile crane, such as the P&H 9125-TC rated at 140 tons (127 Mg), should be employed on elevated causeways for container-handling operations.

2. Straddle-lift container handlers with sufficient power to negotiate the causeway ferry beaching ramp should be investigated for handling containers loaded longitudinally on the causeway ferry.

3. Street pads should be used on all tracked vehicles traversing the elevated causeway.

4. Modifications for simplifying and improving the operation of the turntable should be provided.

5. Means of improving truck movement on the causeway to increase container-handling productivity should be investigated.

6. The impact of 40-foot (12.2-m) containers on the Elevated Causeway System should be investigated.

7. Investigations and advanced development plans and testing of the pedestal crane should be continued to develop its potential to cope with the impact of the 8 x 8 x 40-foot (2.4 x 2.4 x 12.2-m) containers on the COTS Elevated Causeway System.

SECTION 8

FOLLOW-ON PROGRAM

Component modifications and studies presently completed, underway, or planned are as follows:

- Turntable

  (1) The addition of air motor with chain drive to power the turntable has been completed.

  (2) The fabrication of an air manifold system to the air bearings has been completed.

  (3) Lifting padeyes have been added to facilitate handling.

  (4) An indicator scale has been painted on the side of the rotating platform to aid in load balancing.

- Deck reinforcement

  An improved method for securing the timber reinforcement to the pontoon deck has been developed.

- Alternative cranes

  A mounting base that is nominally compatible with the P&H MC/50 and BE MK/60 pedestal crane has been designed. Advanced engineering tests with the pedestal crane are planned.

- Lo/Ro

  An investigation of straddle-lift container handlers for the Lo/Ro operation is planned.

- Container-handling operations

  An investigation of the impact of the 40-foot (12.2-m) container on the Elevated Causeway System is planned.

SECTION 9

ACKNOWLEDGMENTS

The following organizations provided direction, equipment, experience, and personnel necessary to achieve the excellent results of the advanced development tests. Without their cooperation and support the program could not have been accomplished:

- Commander, Naval Surface Forces, Pacific, authorized the Amphibious Units to support the program.
- Commander, Naval Beach Group, Amphibious Refresher Training Group, Coronado, approved and coordinated the beach support operations.
- Amphibious Construction Battalion One provided the personnel and equipment to direct, install, and operate the elevated causeway.
- Amphibious Assault Craft Unit One furnished and LCU landing craft and crews used to ferry the containers.
- First Force Service Regiment, First Marine Division, Camp Pendleton, California, provided the drivers and truck/trailers used to move the containers on the causeway.
- Naval Ship Research Development Center, Carderock, Maryland, conducted the motion measurements and analysis of the lighters moored to the pierhead.
- Naval Electronics Laboratory Center, Human Factors Division, Code 3400, San Diego, provided the human engineering study of the elevated causeway system.
- Public Works Center, U.S. Naval Station, San Diego, fabricated the spudwells, installed and load-tested the external spudwells, and provided welders during the operation.
- Construction Equipment Department and Marine Terminal Division, NCBC, Port Hueneme, assembled all of the pierhead pontoon sections.
- Transportation Division, NCBC, Port Hueneme, provided operators and a construction crane for both the Phase I and Phase II tests.
- CEL Support Operations Department. Logistics Support Division; Planning Branch; and Technical Support Branch.

Appendix A

SHIP-TO-SHORE LIGHTERAGE SHUTTLE ANALYSIS

CRITERIA

Four different modes of operation are considered:

1. Lo/Ro mode unloaded at beach with top-lift loaders
2. Ro/Ro mode rolling off at beach
3. Causeway ferry as lighter unloaded at elevated causeway
4. LCU as ferry unloaded at elevated causeway.

The criteria for analysis are:

1. Operating conditions near ideal; degradation due to more severe seas not included.
2. Test data reconstructed to match scenario.
3. Causeway ferry speeds based on theoretical power curves for a waterjet propulsion plant that is under development.
4. The limited amount of data in hand does not permit greater precision or more sophisticated modeling.
5. The analysis is for sustained loading rates per crane at the Container Discharge Facility (CDF).

LO/RO MODE

Mathematically the round trip time for a causeway ferry is defined as travel from loading platform (fully loaded) to unloading point and return (empty). The container-loading time at the offshore-loading point is excluded. This round trip time (in minutes) can be expressed as

$$S = 60\left(\frac{D}{K_i} + \frac{D}{K_o}\right) + T_m + T_q + 60\,\Sigma\,\frac{N}{R_u} \qquad (1)$$

where S = round trip time (min)

D = distance offshore to beach (nmi)

K_i, K_o = ferry speed (kt) in and out, respectively

T_m = time (min) to moor ferry at unloading platform and at the beach

T_q = equipment queue time (min)

R_u = unloading rate at beach (containers/hr) for section under consideration

N = number of containers handled (section under consideration)

Likewise, the ferry container-loading time (in minutes) can be expressed as

$$C = \frac{60\,N}{R_L} \tag{2}$$

where C = time (min) to load ferry

R_L = loading rate (containers/hr)

Thus, the total cycle time (in minutes) for each ferry, T_F, is

$$T_F = S + C \tag{3}$$

The pacing parameter in the system is the offshore loading rate, which sets the delivery rate. Accordingly, the number of ferries required, F_R, in a shuttle to sustain operations is given by

$$F_R = \frac{S + C}{C} = \frac{S}{C} + 1 \tag{4}$$

In evaluating S, the term $60\,\Sigma(N/R_u)$ is obtained from the test data given in the text, and is as follows:

	Three-Section Ferry	Four-Section Ferry	Five-Section Ferry
Time* (min) to unload ferry (four containers/section)	23.6	35.2	48.8

Also, the term $60\,[(D/K_i) + (D/K_o)]$ can be evaluated by calculating speeds of the causeway ferry for light and fully loaded conditions; the results are:

Ferry Make Up	K_i**	K_o**	$60\left(\frac{D+\frac{1}{2}}{K_i} + \frac{D+\frac{1}{2}}{K_o}\right)$***
Three sections	5.0	7.4	20.1 (D + 1/2)
Four sections	4.5	6.6	22.4 (D + 1/2)
Five sections	4.1	6.1	24.5 (D + 1/2)

*Assumes two top-lift loaders at the beach discharging to truck/trailers just off the causeway.

**Based on theoretical power curves for the self-propelled causeway power plant now under contract for fabrication.

***Mathematically allows 1/4 mile for lighter to accelerate from zero to full speed and 1/4 mile to decelerate from full speed to zero, on the trip out and trip in. Actual distance out is still "D."

The terms T_m and T_q are judgment values. Assuming T_m, the time to moor on beach with preparation to begin unloading, is 15 minutes, and allowing 10 minutes for contingency (T_q), the required number of ferries to sustain continuous operations was calculated for various loading rates, **C**, and distances offshore, **D**. The results are presented in Figure A-1.

Values for round trip times, **S**, in minutes, are:

Ferry	1 Mile Out	2 Miles Out	3 Miles Out
Three sections (12 containers)	78.8	98.8	119.0
Four sections (16 containers)	93.8	116.2	138.6
Five sections (20 containers)	110.6	135.0	159.6

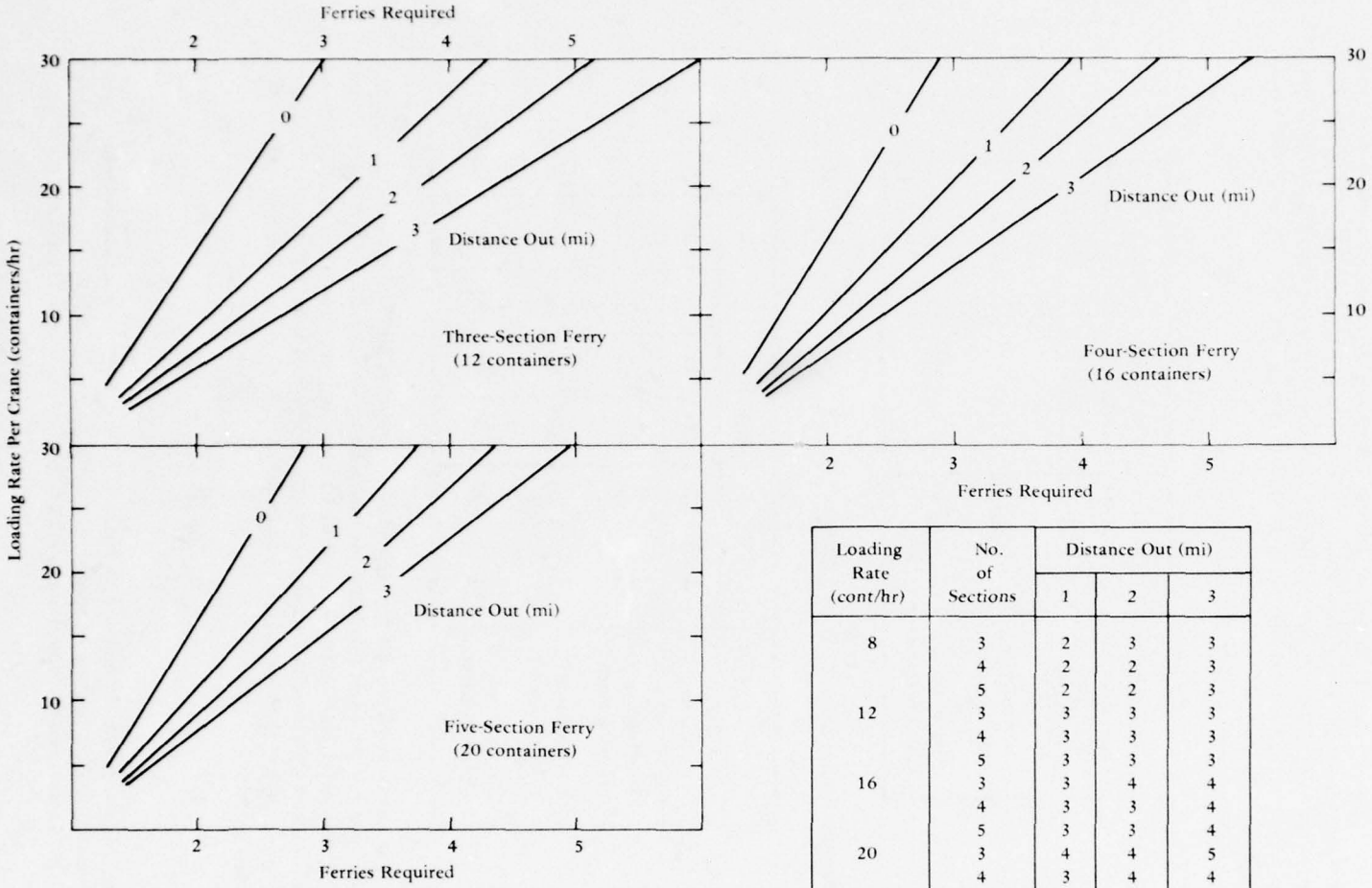
Values for loading times, **C**, in minutes, are:

Ferry	Rate, R_L					
	8	12	16	20	24	28
Three sections (12 containers)	90	60	45	36	30	25.7
Four sections (16 containers)	120	80	60	48	40	34.3
Five sections (20 containers)	150	100	75	60	50	42.9

The curves of Figure A-1 illustrate ferry requirements for distances out of 1, 2, and 3 miles (a 0-mile distance is included for interpolating when distance out is less than one mile), and for various loading rates up to 30 containers per hour. The curves can also be used to determine the effect on the operation (in terms of time) when ferries in service are more or less than required. For convenience this is termed margin of safety, M_s. Mathematically,

$$M_s = 60 \frac{N}{R_L} (F_s - F_R) \qquad (5)$$

where F_s designates the number of ferries in service. For example, assume four-section ferries will be used to carry 16 containers; the distance out is 1-1/2 miles; and the loading rate is 14 containers per hour. Interpolating from the curves for four-section ferries,



Loading Rate (cont/hr)	No. of Sections	Distance Out (mi)		
		1	2	3
8	3	2	3	3
	4	2	2	3
	5	2	2	3
12	3	3	3	3
	4	3	3	3
	5	3	3	3
16	3	3	4	4
	4	3	3	4
	5	3	3	4
20	3	4	4	5
	4	3	4	4
	5	3	4	4

Figure A-1. Number of ferries required in Lo/Ro mode to sustain loading rate when off-loading at beach.

$$F_R = 2.5$$

If three ferries are placed in service, each ferry will have an additional margin of safety of

$$M_s = (3.0 - 2.5)\frac{(60)(16)}{14} = 34 \text{ minutes}$$

If only two ferries are placed in service,

$$M_s = (2.0 - 2.5)\frac{(60)(16)}{14} = -34 \text{ minutes}$$

This means the loading crane will have a 34-minute wait for each ferry, which in turn will effect the overall loading rate, unless other types of lighterage are introduced into the cycle. (It can be noted from the curves that two ferries will sustain a loading rate of no more than nine containers per hour.)

If values of T_m and T_q are expected to vary from those assumed in preparing the curves (15 and 10 minutes, respectively), an increase, or decrease, will be required in the number of ferries. This additional requirement can be calculated by

$$\Delta F_R = \frac{T'_m + T'_q - 25}{60\,N/R_L} \qquad (6)$$

where T'_m and T'_q are differing judgment values. For example, assume three-section ferries with four containers per section will be used at a distance out of 1 mile and at a loading rate of 16 containers per hour. But, T'_m = 22 minutes and T'_q = 20 minutes. Then,

$$\Delta F_R = \frac{22 + 20 - 25}{60(12)/16} = 0.38$$

F_R from Figure A-1 is 2.75; thus, the total requirement is 2.75 + 0.38, or approximately 3.1 (4 ferries).

The times for the various causeway ferries were computed on the basis of two top-lift loaders working the beached ferry. If only one is available to load truck/trailers just off the causeway, the cycle time for the top-lift loader will be increased by approximately 1-1/2 minutes per container. This in turn will affect the number of ferries required. Mathematically,

$$F_R = \frac{S + C}{C} + \frac{t_q N}{C} \qquad (7)$$

where t_q is the que time per container, and the increase in ferry requirements is given by the second term. By substituting the value for C from Equation 2 in the second term, and 1.5 minutes for t_q, the new ferry requirement is established

$$F_R = \frac{S + C}{C} + 0.025\,R_L$$

As an example, consider four-section ferries, each carrying 16 containers; the distance out is 2 miles; the loading rate is 16 containers per hour; and only one top-lift loader is available at the beach. From Figure A-1 the number of ferries required is 2.95. But with only one top-lift loader, the ferry requirement becomes

$$F_R = 2.95 + 0.025(16) = 3.35 \text{ or } 4 \text{ ferries}$$

The above could also be handled as the total queing time, T_q. A que of 1-1/2 minutes per container results in 24 minutes for the four-section ferries; thus, the total que is 34 minutes (includes the 10 minutes allowed for contingencies). Equation 6 defines the additional requirement:

$$\Delta F_R = \frac{15 + 34 - 25}{60(16)/16} = 0.4$$

The above demonstration clearly illustrates the need to use an adequate number of top-lift loaders to maintain a steady flow of containers at the beach.

RO/RO MODE*

The loading for the Ro/Ro mode differs from the Lo/Ro mode in that the former is loaded with two truck/trailer combinations on the shore section, two on the offshore stern section, and four on the intermediate sections. Accordingly, a three-section ferry would haul eight containers; a four-section, 12 containers; and a five-section, 16 containers.

Equations 1 through 6 apply with modifications to some of the terms. In calculating round trip time the terms are as follows:

Speed and distance out	Unchanged as payloads are approximately equivalent to Lo/Ro
T_m, T_q	Unchanged; time to moor at loading point and at beach is equivalent to Lo/Ro; same for contingency
$60\ \Sigma N/R_u$	Re-evaluated as given below

Based on Lo/Ro travel times, and assuming the truck speeds match that of the top-lift loader, the trucks can roll-of or roll-on in one half the causeway round trip time for the top-lift loader. Thus, the truck roll-off time (loaded) plus roll-on time (empty) is equal to one round trip time for the top-lift loader.

*The causeway ferry in the Ro/Ro mode is discussed in Appendix F, Volume I, of the OSDOC II report, Oct 1972.

Roll-Off Plus Roll-On Cycle

Position (section)	Time (min)	Containers per Section	Time per Section (min)
1	1.6	2	3.2
2	1.9	4	7.6
3	2.4	2	4.8
		4	9.6
4	2.9	2	5.8
		4	11.6
5	3.4	2	6.8

Therefore, the Ro/Ro cycle time is:

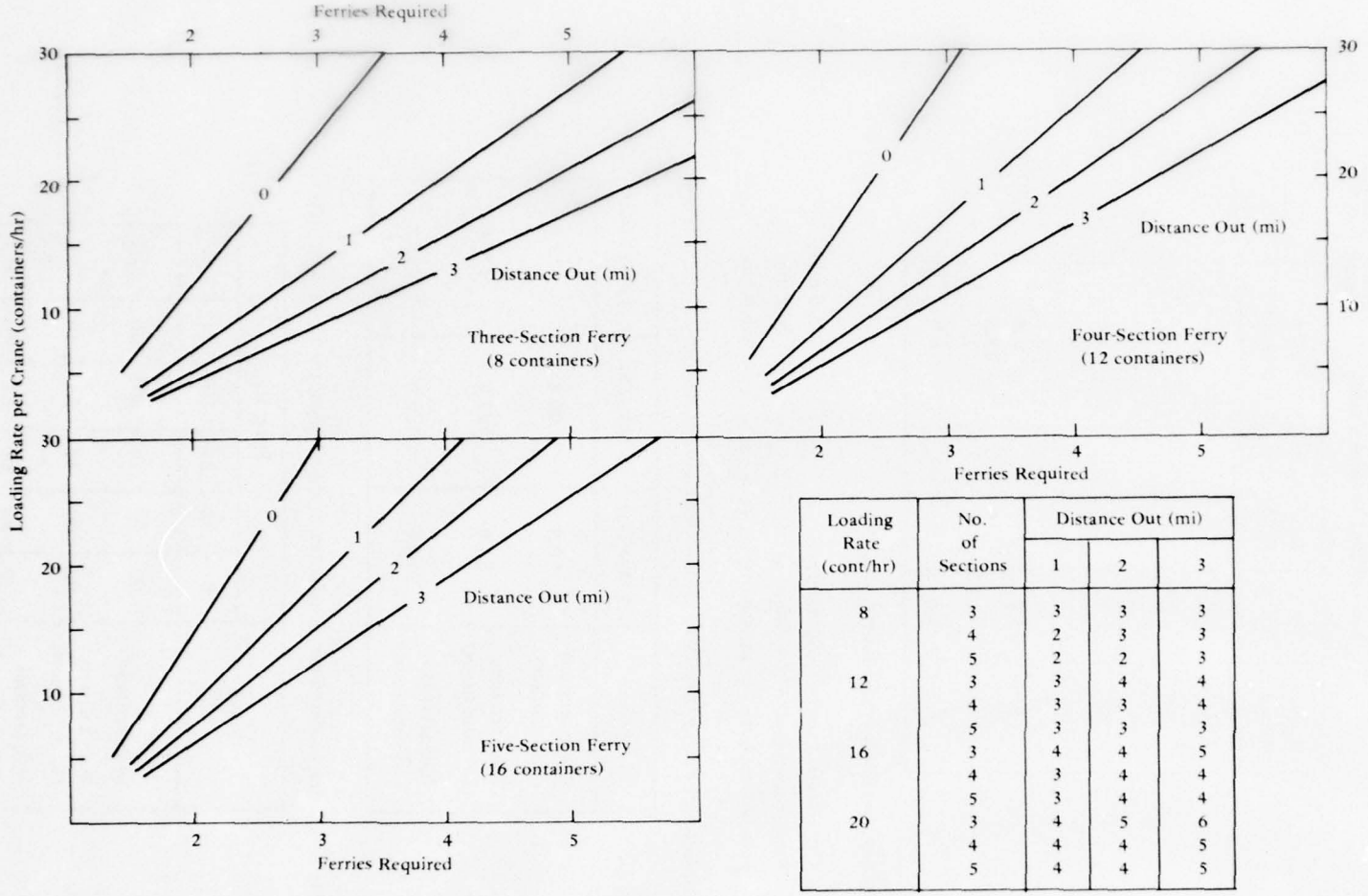
Three-section ferry (8 containers) . . . . . 15.6 min
Four-section ferry (12 containers) . . . . . 26.2 min
Five-section ferry (16 containers) . . . . . 38.8 min

Accordingly, the round trip times, **S**, in minutes, are as follows:

Ferry	1 Mile Out	2 Miles Out	3 Miles Out
Three sections (8 containers)	70.8	90.8	111.0
Four sections (12 containers)	84.8	107.2	129.6
Five sections (16 containers)	100.6	125.0	149.6

Values for **C**, the loading time, in minutes, at the offshore point, are as follows:

Ferry	Rate, R_L					
	8	12	16	20	24	28
Three sections (8 containers)	60	40	30	24	20	17.1
Four sections (12 containers)	90	60	45	36	30	25.7
Five sections (16 containers)	120	80	60	48	40	34.3



Loading Rate (cont/hr)	No. of Sections	Distance Out (mi)		
		1	2	3
8	3	3	3	3
	4	2	3	3
	5	2	2	3
12	3	3	4	4
	4	3	3	4
	5	3	3	3
16	3	4	4	5
	4	3	4	4
	5	3	4	4
20	3	4	5	6
	4	4	4	5
	5	4	4	5

Figure A-2. Number of ferries required in Ro/Ro mode to sustain loading rate when off-loading at beach.

The results are presented in Figure A-2 for the above **S** and **C** values.

CAUSEWAY FERRY AS LIGHTER AT ELEVATED CAUSEWAY

The previous analysis applies. To arrive at values of **S**:

Speed and distance out	Same
T_m	= 0, since mooring time at elevated causeway is included in the 60 N/R_u term
T_q	Increased to 15 minutes to account for moor time at loading point plus contingency
60 $\Sigma N/R_u$	R_u = 18.0 containers per hour or 3-1/3 minutes per container; reconstructed from COTS Coronado data with improved truck cycle time

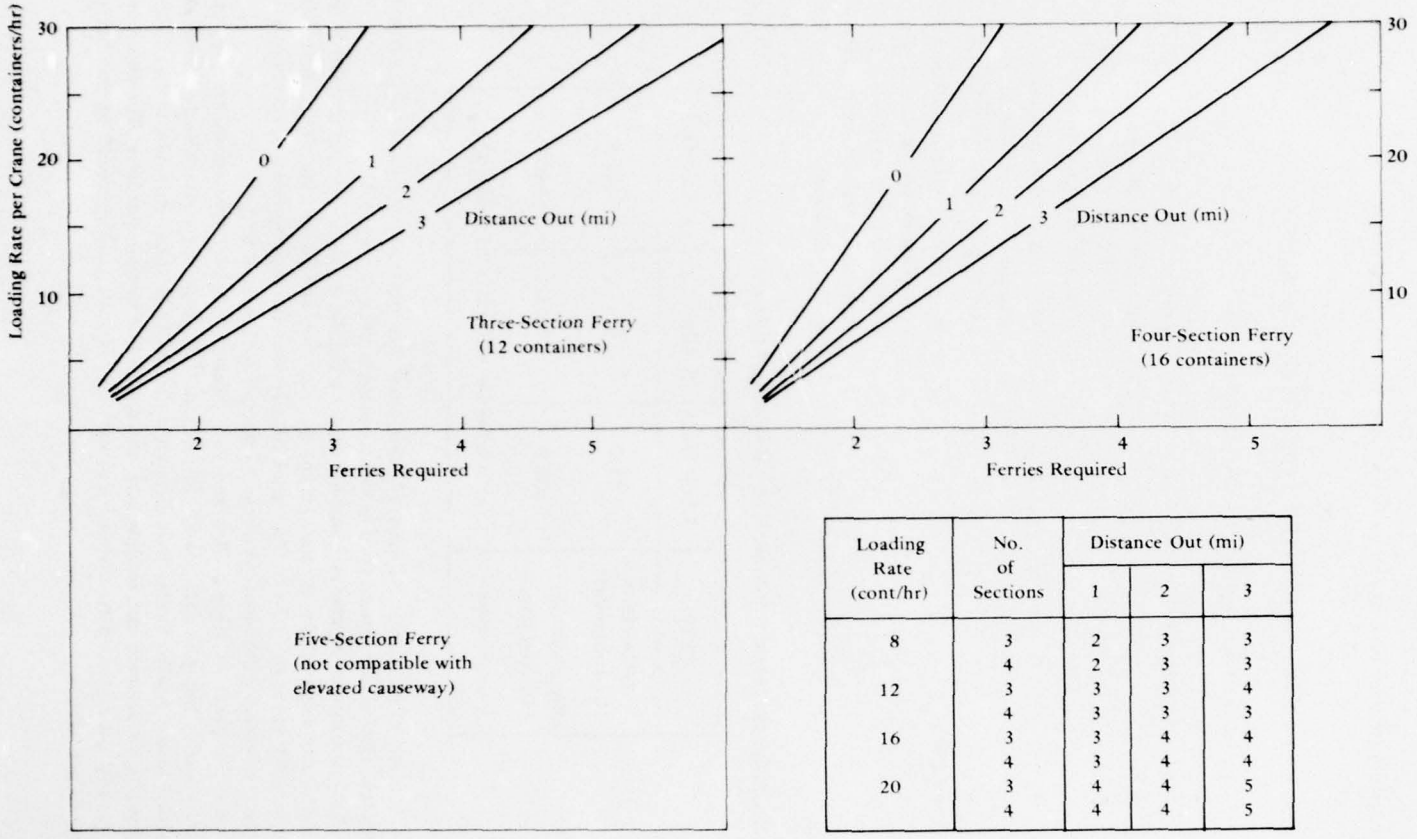
Accordingly, the round trip *time*, **S**, in minutes, is as follows:

Ferry	1 Mile Out	2 Miles Out	3 Miles Out
Three sections (12 containers)	85.2	105.2	125.4
Four sections (16 containers)	101.9	124.3	146.7
Five sections	Not compatible with elevated causeway		

The loading rates, **C**, for 12 and 16 containers per ferry are the same as previously recorded. The resulting number of ferries required is given in Figure A-3.

A comparison of Figures A-1 and A-3 shows a slightly greater ferry requirement at the elevated causeway than at the beach due to the unloading rate. This difference theoretically varies from 3% to 9%; varies directly with the loading rate and inversely with distance out; and is independent of the number of sections per ferry.

A comparison of Figures A-1 and A-2 shows a greater ferry requirement for the Ro/Ro mode; the principal reason for this is that four less containers per ferry are shuttled in the Ro/Ro mode. This difference theoretically varies from about 3% to 32%, depending on distance out, loading rate, and number of sections per ferry. The difference is directly proportional to distance out and loading rate, and inversely to number of sections per ferry.



Loading Rate (cont/hr)	No. of Sections	Distance Out (mi)		
		1	2	3
8	3	2	3	3
	4	2	3	3
12	3	3	3	4
	4	3	3	3
16	3	3	4	4
	4	3	4	4
20	3	4	4	5
	4	4	4	5

Figure A-3. Number of ferries required in Lo/Ro mode to sustain loading rate when off-loading at elevated causeway.

LCU AS LIGHTER AT ELEVATED CAUSEWAY

In analyzing the LCU in a like manner, the following values are used:

Travel time in and out* . . .	$60\left(\frac{D+\frac{1}{2}}{8.5}+\frac{D+\frac{1}{2}}{10.0}\right)=13.1\left(D+\frac{1}{2}\right)$
T_m	= 0. Mooring time at elevated causeway is included in container-handling rate
T_q	15 minutes to allow for tie up at offshore loading point, plus 10 minutes contingency
$60\ \Sigma N/R_u$	R_u = 16 containers per hour or 3.75 minutes per container; reconstructed from COTS Coronado data with improved truck cycle time

For an LCU payload of four and five containers, the loading times, **C**, in minutes, are as follows:

Craft	Rate, R_L					
	8	12	16	20	24	28
LCU (4 containers)	30	20	15	12	10	8.6
LCU (5 containers)	37.5	25	18.75	15	12.5	10.7

The round trip times, **S**, in minutes, are as follows:

Craft	1 Mile Out	2 Miles Out	3 Miles Out
LCU (4 containers)	49.7	62.8	75.8
LCU (5 containers)	53.4	66.5	79.6

The required number of LCUs to sustain the loading rates is given in Figure A-4.

*Based on 10.0 knots, light; 8.5 knots, loaded. Also, mathematically allows 1/4 mile for acceleration and 1/4 mile for deceleration.

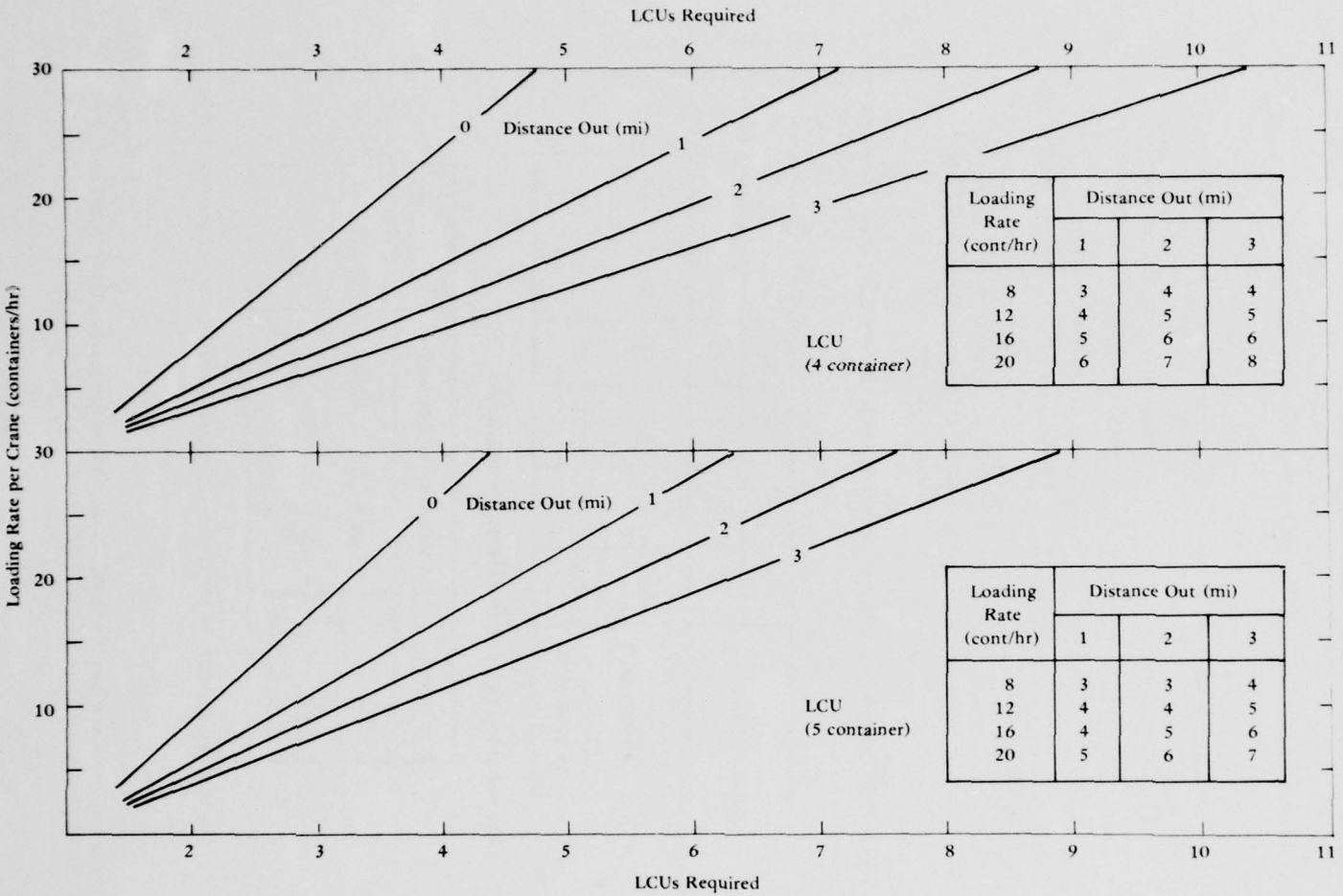


Figure A-4. Number of LCUs required to sustain loading rate when off-loading containers at elevated causeway.

Appendix B

STRADDLE-LIFT CONTAINER HANDLING

Tests with a straddle-lift container handler for the Lo/Ro concept were conducted by CEL at Port Hueneme, California, in October 1975.

DESCRIPTION

The straddle-lift (Figure B-1) employed for the tests was a Marine Travelift Model 30AMO, 30-ton (27.2-Mg) capacity rubber-tired mobile marine boat hoist. The unit was modified (narrowed) to permit travel on the 21-foot (6.3-m) wide 3x15 causeway section. The modified unit is 18 feet (5.5 m) high by 24 feet (7.3 m) long by 16 feet (4.9 m) wide and has an interior clear width of 11 feet (3.4 m). Since the straddle-lift is of open-ended construction, it can straddle an 8 x 8 x 20-foot (2.4 x 2.4 x 6-m) container. Two double-drum hoists, which are controlled simultaneously or individually from the operator's station, are used to lift containers.

The straddle-lift is powered with a 95-hp (70.5-kW) gasoline engine which provides sufficient power to negotiate a 6-1/2% grade or to attain a travel speed of 110 fpm on level grade at full load. The unit is supported by four wheels (46x16-28 ply tires), two of which are driven and controlled from the operator's station.

The operator's station is located at the lower end of one of the forward columns. Controls for starting and controlling the engine, operating the two lift hoists, and travel and steering are located at the operator's station.

The total operating weight of the straddle-lift with manual spreader bar is about 25,000 pounds (11.3 Mg). However, the total weight with a fully loaded container is about 70,000 pounds (31.7 Mg). Since this wheel load exceeds the design limit of 75 psi (516 kPa) for the causeway, deck reinforcement is required.

To facilitate transportation and erection, the main frame is designed in bolt-together sections. Three men, one of which is a trained mechanic, can assemble the unit in approximately 3 days. Minimal equipment required for the assembly is an 8-ton (7.2-Mg) crane with a 25-foot (7.5-m) boom. The unit breaks down into seven major structural pieces, four wheels, and the power unit. The heaviest single piece weighs about 2-1/2 tons (2.3 Mg). The shipping weight of the unit is about 10-1/2 tons (9.5 Mg).

TESTS

A single 3x15 causeway section with a timber-reinforced deck was loaded with four 8 x 8 x 20-foot (2.4 x 2.4 x 6-m) containers for the test (Figure B-1). A 30-foot (9-m) long steel ramp was connected to the causeway section and laid on a built-up sand ramp reinforced with steel matting. The sand ramp was graded to provide a level approach from the beach to the causeway deck.

The straddle-lift was equipped with four steel cables and hooks for attachment to the top corner fittings of the containers. The straddle-lift traveled across the reinforced sand ramp, over the ramp to the causeway, to straddle the first container. Two men secured the four hooks to the corners, and the container was lifted (Figure B-2). Then the straddle-lift backed off the ramp and across the beach to a waiting flatbed trailer. There it raised the container to clear the trailer, straddled the trailer, and deposited the container directly onto the trailer (Figure B-3). This cycle was repeated until all four containers were unloaded. The results of the test are summarized below.

Beach preparation	1 hour
Beach matting and stabilization	2-1/2 hours
Number of containers off-loaded	4
Total off-load time (min)	45
Average cycle time, round trip per container (min)	11
Average time on-board causeway (min)	3-1/2
Average time to pick up container (min)	2

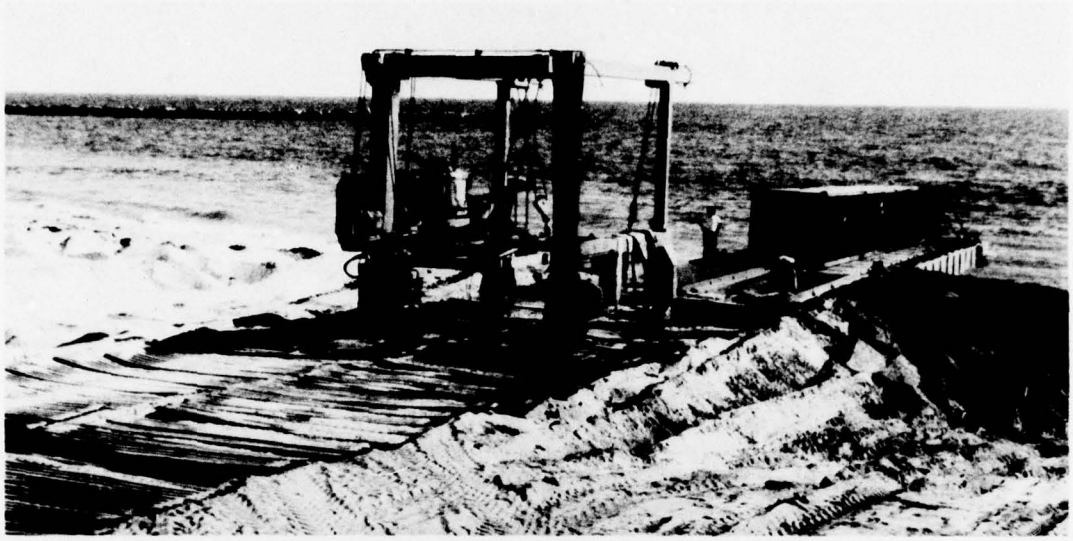


Figure B-1. Straddle-lift traversing leveled ramp to causeway.

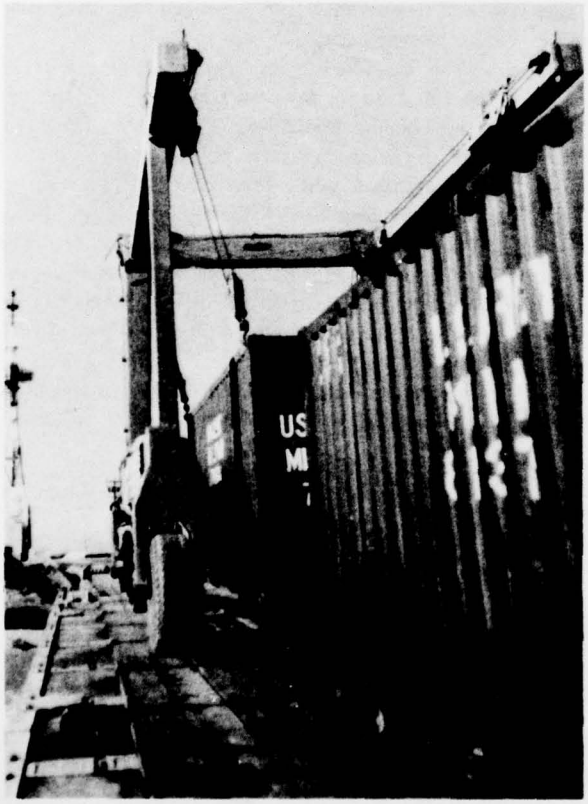


Figure B-2. Straddle-lift with container.

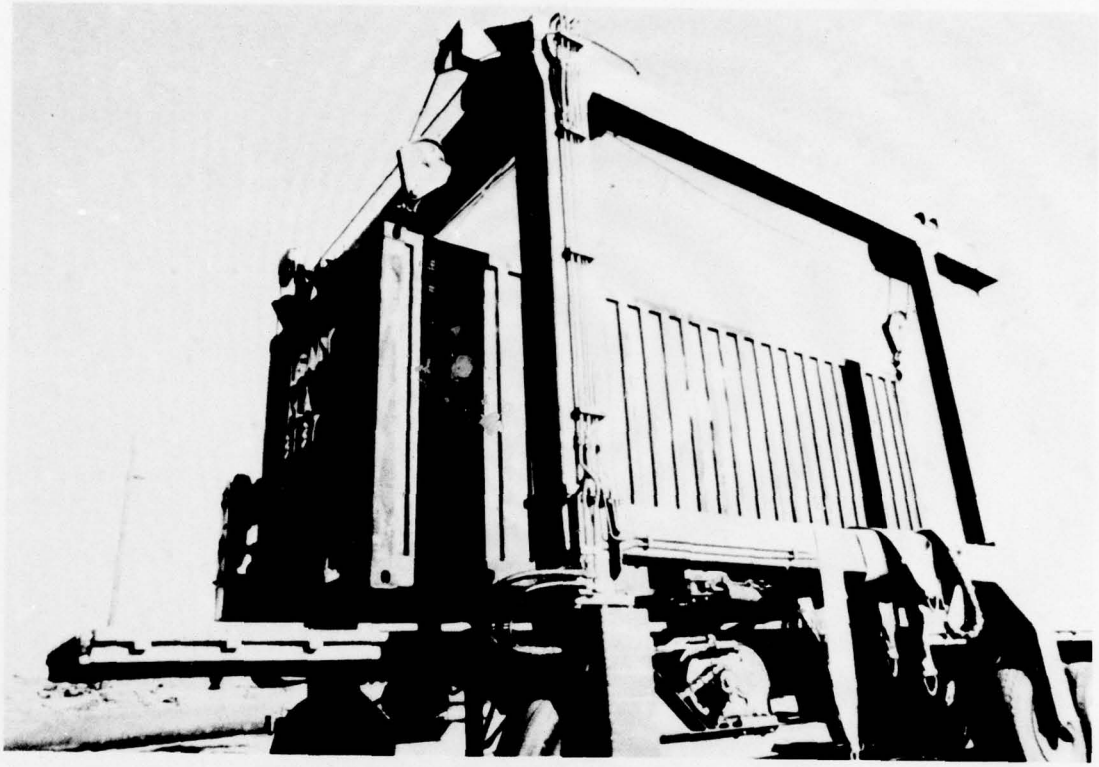


Figure B-3. Loading container on trailer with straddle-lift.

DISCUSSION

The straddle-lift evaluated did not have sufficient power to negotiate the causeway ramp; therefore, a graded sand ramp was required. The time required to construct this ramp for each causeway ferry would be excessive.

In general, the straddle-lift modular construction provides for easy transport to the site via breakbulk ship, and the relatively low module weights permit assembly at the site with relatively small equipment.

Appendix C

PEDESTAL CRANES FOR ELEVATED CAUSEWAY

An alternative for the mobile crane is the fixed crane with revolving superstructure and crane boom that is capable of rotating 360 degrees in either direction. Two commercial pedestal cranes, the P&H MC/50 marine crane and the Bucyrus-Erie MK-60 marine crane, were investigated. Both of these cranes were developed essentially for use on offshore oil drilling platforms and, therefore, have the required qualifications for use in the marine environment of the COTS Elevated Causeway System.

The MC/50 crane can be broken down into six major modules, the heaviest weighing about 8 tons (7.3 Mg). The crane is presently undergoing pre-production testing by P&H and will be in production in late 1976. The crane capacity versus operating radius is shown in Figure C-1. It can be seen that the MC/50 has the capability to reach and lift the 20-foot (6.1-m) containers at the more efficient operating radius of 50 feet (15 m).

The Bucyrus-Erie MK-60 pedestal crane is similar in construction to the MC/50, but it can be broken down into only about four modules for deployment. The heaviest module is the upper works and weighs approximately 53,000 pounds (24 Mg). The Bucyrus-Erie MK-60 crane has been in production and operation for several years; a lead time of under 12 months is required for procurement. The crane capacity versus operating radius is shown in Figure C-1. It also can lift a fully loaded 20-foot (6.1-m) container at a radius of 50 feet (15 m).

One distinct advantage of the pedestal crane over the mobile crane is the savings in weight. A pedestal crane (P&H Model MC/50) that is capable of lifting 25 tons (22.7 Mg) at a radius of 60 feet (18.3 m) has an operational weight of approximately 45 tons (40.8 Mg), including mounting base. A 140-to-150-ton (127-to-136-Mg) rated mobile crane (P&H Model 9125-TC) with a lift capacity of 25 tons (22.7 Mg) at 53 feet (16.2 m) has an operational weight of about 95 tons (86.2 Mg). This difference in weight, 50 tons (45.4 Mg), is found in the carrier and counterweights required by the mobile crane. Thus, the pedestal crane provides an equivalent lift capability at a greater radius with a considerable savings in weight.

The pedestal-type crane does have some disadvantages however. The lack of mobility is considered by many to be the major disadvantage. Discussions with personnel of PHIBCB-ONE, PHIBCB-TWO, and NAVCHAPGRU have indicated that the lack of mobility would be the primary cause for rejection by the Fleet. The pedestal crane also requires a special base or tub to be mounted on the causeway pierhead. The base supports the crane and transmits the loads resulting from container lifts into the causeway platform and supporting piling.

CEL has investigated a base that is nominally compatible with the two pedestal cranes. The preliminary design calls for six additional piles to support the crane and loads resulting from container lifts. Some minor modifications to the causeway structure are also indicated. The estimated weight of the base is 15,000 pounds (6.8 Mg), and the crane mounting ring is 1,700 pounds (772 Kg), thus offsetting approximately 8 tons (7.2 Mg) in the weight savings.

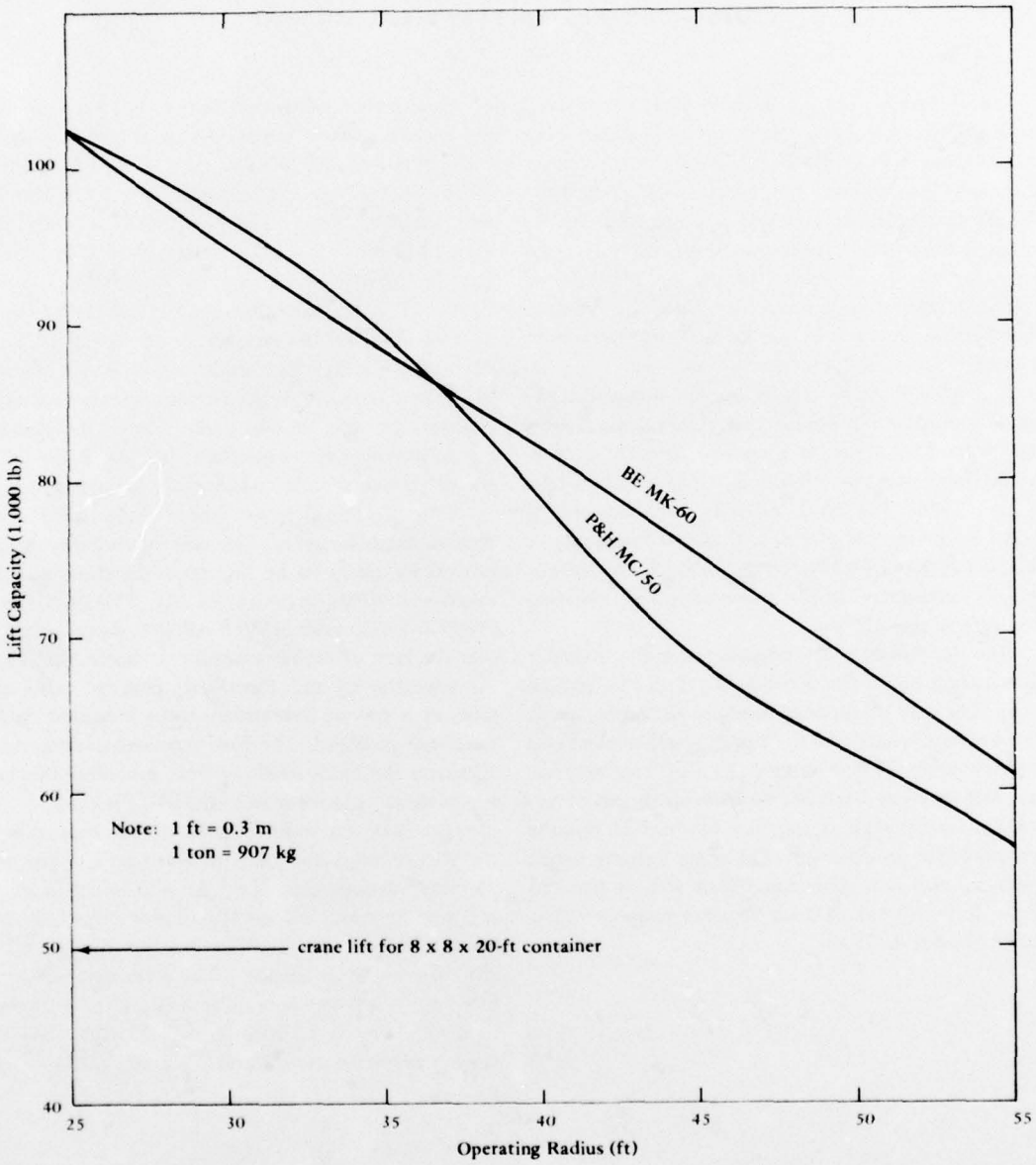


Figure C-1. Load versus operating radius for two pedestal cranes.

Appendix D

DEPLOYMENT OF CRANES

TYPE OF CRANE

Mobile Cranes

The deployment of mobile cranes presents problems because of their weight and size. A fully operational 140-ton (127-Mg) rated mobile truck crane (P&H 9125-TC) with two counterweights, a 70-foot (21.4-m) boom, and other miscellaneous equipment weighs approximately 95 tons (86.2 Mg). Fully assembled and with boom horizontal, the crane has an overall length of approximately 90 feet (27.5 m). This is too long and too heavy to transport in a fully operational configuration.

A sufficient reduction in size and weight can be obtained without removing the crane's upper works from the carrier. It can be disassembled into five main components: the carrier with upper works and boom butt section (tactical disassembly), two counterweights [30.5 tons (27.2 Mg)], and two boom sections [4 tons (3.6 Mg)]. The carrier with upperworks and boom butt section is the heaviest, weighing about 60 tons (54.4 Mg), and is approximately 38 feet (11.6 m) long.

Pedestal Cranes

The knockdown design of the P&H MC/50 crane facilitates deployment via breakbulk shipping, because the heaviest module is within the lift capability of the deployment system. It breaks down into six major modules, the heaviest weighing about 16,000 pounds (7.2 Mg). The modules can be preloaded onto trailers for loading into the hold of the breakbulk ship. Transport from ship to beach can be accomplished by causeway ferry, LCU, or LCM-8.

METHOD OF DEPLOYMENT

Breakbulk Ship

Breakbulk ship deployment requires the ship to have sufficient lifting capacity and stowage space to accommodate the outsized equipment found in a COTS operation. Any breakbulk ship considered for deployment of the 140-ton (127-Mg) mobile crane should have a boom or tandem-boom lift capability greater than 80 tons (72.6 Mg). Hatch size is also a primary consideration, because deck-loading of the crane is not the preferred method of transport. Overhead clearance problems can be alleviated by stowing it on the square of the hatch and leaving the above hatch square open. The hatch squares must be capable of accommodating the break-down dimensions of the crane, which are 38 feet (11.6 m) in length by 11 feet (3.4 m) in width.

Two ships, the TRANSCOLORADO and the TRANSCOLUMBIA, are best equipped for deploying the COTS equipment. They have the capability to load and unload the cranes [single boom lift of 120 tons (108.8 Mg) or tandem-boom lift of 240 tons (217.7 Mg)] and have hatch sizes of sufficient length and width to accommodate the 140-ton (127-Mg) mobile crane below deck.

The Army conducted tests in April 1976 at Fort Story, Virginia, in which a conventional breakbulk ship was used to deploy and off-load a P&H 6250-TC and a P&H 9125-TC mobile crane into lighters for transport to the beach. Problems with a sling arrangement precluded loading the 9125-TC mobile crane onto the breakbulk ship. The crane, complete with upperworks, carriage, and boom butt sections, was loaded into a LCU for the test. The crane was delivered to and assembled on the beach (Figures D-1 and D-2) from components delivered by other lighters.

Figure D-1. P&H 9125-TC crane (tactically disassembled) being delivered to beach in LCU.

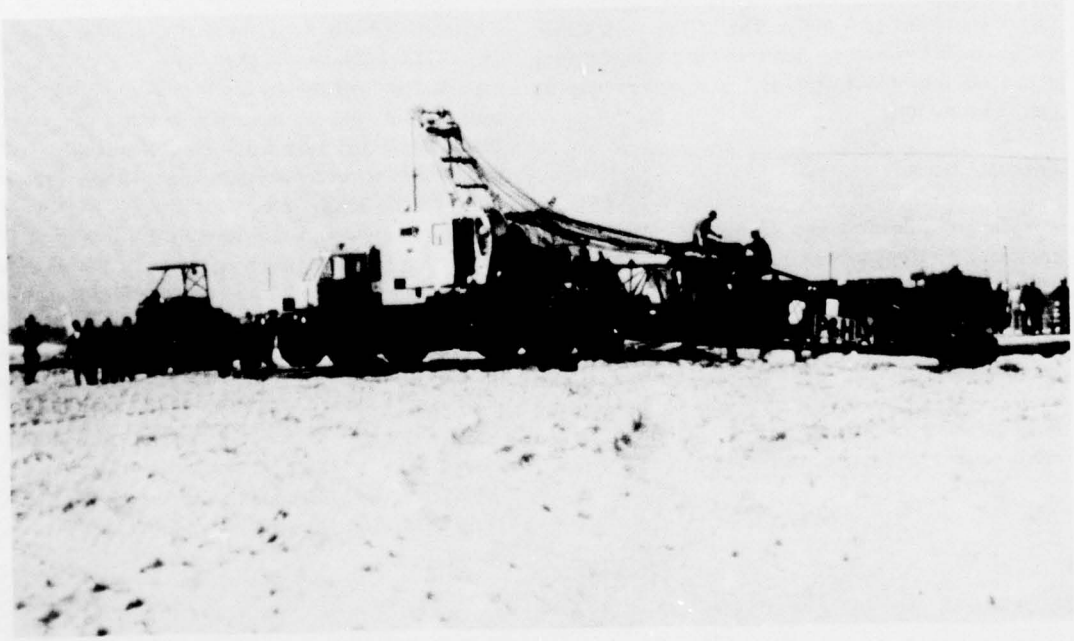


Figure D-2. P&H 9125-TC crane being assembled on beach by Army crew.

The 6250-TC crane had been disassembled into its administrative shipping configuration* for handling by the ship's cranes. Two lifts, the carrier [61 tons (55.3 Mg)] and the upper machinery [62 tons (56.2 Mg)], were off-loaded into LCM-8s and delivered to the beach. Other components, the boom sections and counterweights, were preloaded onto trailers for off-loading and transport to the beach in lighters. Figures D-3 and D-4 show the carrier and upper machinery being delivered to the beach in LCM-8s.

Once at the operational site, several lighterage options are available to transport the crane from the ship to the beach. These are the LCU or a causeway ferry. Both the LCU and a five-section causeway ferry have sufficient stability to carry the tactically disassembled crane from the ship to the shore. The causeway ferry is preferred because of the larger deck area on which to place the crane and the other components of the crane (counterweights and boom sections) for transfer to the beach. Also, the causeway ferry is more likely to have a dry ramp beaching than the LCM-8 or LCU. At the beach, the crane can be transferred from the causeway to the beach assembly area under its own power. The counterweights and boom sections, if not already preloaded onto truck/trailers, will have to be transferred separately. The boom can be assembled on the beach by the crane crew without the need of outside equipment. The counterweights can be delivered to the crane on the pierhead for assembly by the crane crew.

LASH Ship

The preferred means for deploying the COTS elevated causeway crane to the operational site would be in an assembled condition on the causeway pierhead section. The LASH ship provides a viable alternative for deployment of heavy equipment in support of the COTS mission. The gantry crane at the stern of the ship is capable of lifting and positioning on deck loads of up to 500 tons (453.5 Mg).

The results of a conceptual design analysis** indicate that when employing the recommended cantilever lift frame, the P&H 9125-TC crane on a 4x15 pontoon causeway section can be handled by any LASH-type ship. The 4x15 causeway section was used because of the marginal stability of a single 3x15 causeway section carrying a P&H 9125-TC crane. The conceptual design analysis also indicated that the pedestal crane mounted on a 3x15 pontoon causeway section can be satisfactorily handled by a LASH-type ship deployment. However, the offshore operation in an open seaway with the LASH system has yet to be established.

SEABEE Bargeship

Since the introduction of the SEABEE bargeship, the Army and Navy have studied its potential as a support vessel for a variety of military missions. One possible application is a post-assault amphibious vessel in support of a COTS operation.

The SEABEE system consists of a barge-carrying SEABEE vessel and SEABEE barges. The vessel is equipped with a barge-handling system that consists of a pair of self-propelled barge transporters of 1,000-long-ton (102-Mg) capacity each for moving barges fore and aft, and a 2,000-long-ton (204-Mg) capacity at the stern for raising and lowering barges.

The findings of a CEL special study*** indicated that the SEABEE barge-handling system together with the "container adapter" can easily be adapted for transporting the modular elevated pier facility, including mobile cranes mounted on NL pontoon causeway sections. However, the offshore operation in an open seaway with the SEABEE system has yet to be established.

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*Administrative disassembly of the 250-ton crane is defined as the detailed reduction of the crane into a state compatible for administrative movement. In this state the boom sections and counterweights are removed; the upper works are separated from the carrier; and the components, such as the outriggers, cable, and gantry, are removed. This reduces the largest component, the carrier, to 61 tons (55 Mg).

**LASH Amphibious Post-Assault Support (LAPS) Mission, Phase I – Conceptual Design Analysis, Contract No. N00600-72-0-0308, Task No. FD75, prepared by J. J. Henry Co., for DTNSRDC and DCEN, sponsored by NAVFAC.

***CEL Special Report 55-76-01: SEABEE lift of amphibious outsized cargo, by S. Wang and D. Davis, Sep 1975.

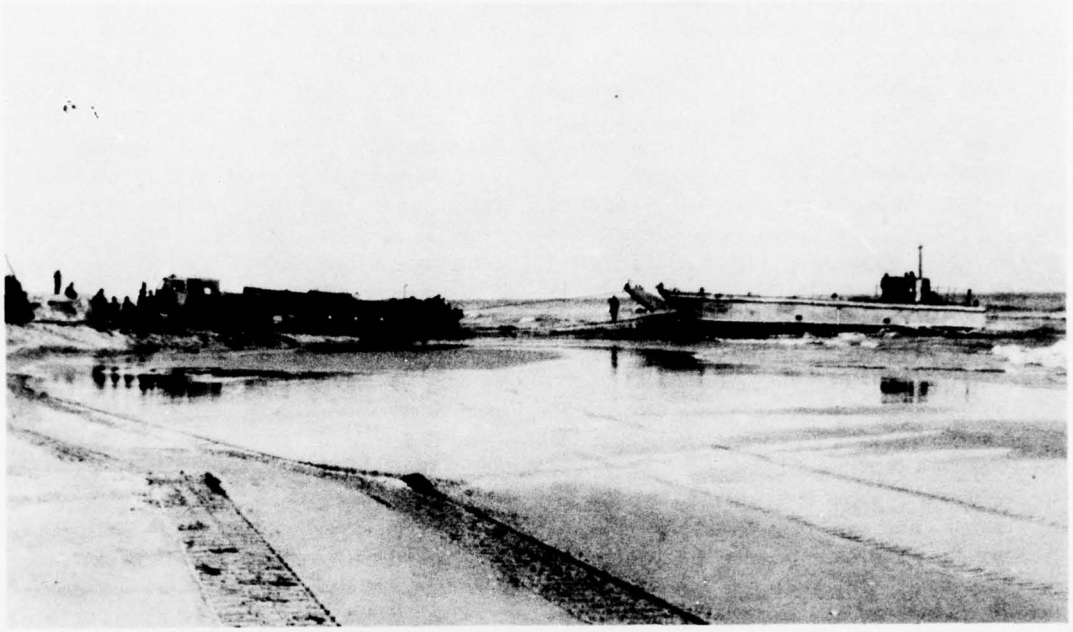

Figure D-3. P&H 6250-TC crane carrier being delivered to beach by LCM-8.

Figure D-4. P&H 6250-TC crane upper works on trailer being delivered to beach in LCM-8.

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