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Technical Report

BEACH MATERIALS HANDLING—ADVANCED CONCEPTS

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BEACH MATERIALS HANDLING—ADVANCED CONCEPTS

Technical Report R-722

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by

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ABSTRACT

This report considers means for improving the handling rate of palletized cargo at the craft–beach interface with reference to the advanced landing craft under development by the Amphibious Assault Landing Craft Program. A base-line unloading rate is established and components of the base-line system are studied to see if modifications to the equipment or off-loading methods can effect an increase in unloading rates. A number of advanced concepts are considered, the more promising of which include a multiple pallet transporter, sliding craft deck, causeway, and portable near-shore breakwater. While these concepts improve unloading rates in specific instances, they may be difficult to justify in terms of their cost and contribution to the overall efficiency of the general unloading phase of amphibious operations. A more desirable option may be to increase the number of rough terrain forklifts and/or develop a more efficient forklift.

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INTRODUCTION

The Naval Ship Research and Development Laboratory (NSRDL), Annapolis, Maryland, is participating in an advanced development program (Amphibious Assault Landing Craft Program) to define and develop a new generation of high-speed assault landing craft (air cushion vehicles and planing-hull craft) for future amphibious landings in the midrange period. If the ship-to-shore cargo-handling cycle is to be shortened, more effective interfaces with the new landing craft both at the ship and on the beach are required to improve the overall cargo-handling system. Thus, the investigation of the cargo-handling phase of the ship-to-shore operation is included as part of the craft-development program.

A portion of this cargo-handling investigation was conducted by the Naval Civil Engineering Laboratory (NCEL) during FY-69.[1] The specific task studied the concept of using a large pallet, with primary emphasis on the beach end of the system. The present task evolved as follow-on work to generate concepts for improving the unloading rate of palletized cargo from the landing craft in order to provide input for long-range planning. While the FY-69 work aimed at midrange improvement of handling amphibious assault material at the craft–beach interface, the current task addresses some concepts which are more applicable to the long-range period.

The objective of the present task is to formulate concepts that will improve the handling rate of palletized cargo at the craft–beach interface. This final report documents the work accomplished and provides a basis for future developmental efforts.

The approach used in the conduct of the study was to establish a base-line unloading rate. Components of the unloading cycle of present-day equipment were studied to see if modifications to the equipment or off-loading methods could effect an increase in unloading rates. Also a number of new concepts were explored to varying degrees, depending on the availability of information.

Although unloading rate may appear to be the best measure of effectiveness, it is often difficult to precisely quantify. It is a function of environmental conditions such as wave height or beach firmness for most handling equipment, but various adverse aspects of the environment may be more significant for different material-handling equipment. For example, cranes unloading in a stationary position are not generally affected by beach soil stability except when moving between unloading sites, while forklift trucks are more sensitive to this parameter. For this reason quantitative comparisons are done on an "ideal conditions" basis (that is, good beach, surf, and weather conditions). However, the amphibious operations most in need of improvement are those conducted under adverse conditions. Obviously, the spectrum of conditions under which an amphibious operation may be successfully executed must be broadened by improving the operating capability under adverse conditions. Consequently this study addresses the "adverse conditions" problem but in a less quantative manner than in the "ideal conditions" case.

The landing craft characteristics used are those which evolved from the preliminary design studies for the Amphibious Assault Landing Craft Program (AALCP). A 2% beach slope used in previous AALCP comparisons is assumed. With this slope, the water depth at the ramp for various beached, fully loaded landing craft ranges from 1.0 to 4.4 feet and the distance to shore from 50 to 220 feet.

BASE-LINE SYSTEM

The conventional off-loading method, a forklift conveying cargo between craft and a shoreside truck or dump, is used as the base-line system. In the case of air cushion vehicles (ACVs) the forklift is assumed to load cargo into a truck located adjacent to the ACV on firm ground. Unloading rates presented in Table 1 are computed as in Reference 1 for cargo consisting of large pallets 8 x 9 feet in area and weighing 4 tons each, which are transported from the landing craft across the 2% beach slope to a point 10 feet inland from the waterline and then loaded onto a truck. The unloading rates assumed are for forklifts working under the most ideal conditions possible; that is, good beach, sea, and weather conditions, and availability of experienced, highly efficient operators. As such, they represent the maximum rates obtainable, not those which one might record in a typical amphibious operation. But as explained in the Introduction, this is the most feasible way to compare alternatives. In establishing the base-line rate it is further assumed that two forklifts will offload each landing craft and thus double the rate computed for one forklift. Beach stabilization is assumed to be available when required for soft sand conditions.

The relative degradation in off-loading rate between various alternatives can best be handled in a subjective manner; that is, by the application of a reduction factor to the idealized unloading rate. The effect of the environment is particularly significant for the planing craft, for which an increase in wave height in the surf zone can cause a considerable reduction in operational capability. It has been reported[2] that landings can be safely accomplished in wave heights of 3 to 4 feet, but only marginal operation can take place in wave heights of 4 to 7 feet; with waves higher than 7 feet, operations become dangerous and inefficient. However, even in 3- to 4-foot waves a 25% reduction in cargo discharge rate can be expected, and in 4- to 5-foot waves the reduction in rate can reach 65%.

Other environmental factors influencing handling rates include beach composition and firmness, beach slope, and visibility. Beach materials vary greatly, but sand predominates. It is soft when dry but usually sufficiently firm for rough terrain vehicles when wet. Ninety percent of the world's accessible coasts are composed of sand, mud, pebbles, coral, or a combination of these.[3] Eighty percent of the beaches have a slope less than 10%, and 90% have slopes less than 15%.[3] These slopes are well within the ability of a rough terrain forklift except possibly under full load in soft sand. The application of suitable beach stabilization should eliminate degradation in handling rates due to soft sandy terrain whether sloping or level.

Under limited visibility conditions operations may take 50% to 100% longer. The significance as well as the resolution of this problem is beyond the scope of this investigation.

IMPROVEMENTS IN COMPONENTS OF BASE-LINE SYSTEM

Craft-to-Shore Travel

For the planing craft, which go aground at a relatively large distance from shore, a considerable portion of the ship-to-shore cycle time is consumed by forklift travel between craft and shore, even when two forklifts per craft are employed. Time would be saved if the trucks could enter the surf zone for loading. This of course assumes that a sufficient number of trucks are available to maintain the off-loading rate. If not, it would be more efficient to dump the cargo on the beach or use a combination of beach dump and trucks to minimize the total off-loading time for a given craft. Table 2 shows the best possible unloading times with trucks entering the surf zone to within 15 feet of the planing craft and at a sufficient rate to eliminate queuing by the rough terrain forklift.

An alternative to the above system would be to substitute a crane for the forklift. This case is similar to off-loading an ACV with a crane, for which the minimum time per pallet, as computed in Reference 1, is 1.4 minutes. However, greater fording depth and stability for the crane would be required than is currently available.

Table 1. Base-Line Unloading Rates

Craft Type	Designation[b]	Payload (lb)	Depth at Ramp (ft)[c]	Distance to Shore (ft)[c]	Unloading Time per Large Pallet Using Two Forklifts (min)[d]
Planing[a]	M&H P30-35	30,000	1.0	50	0.65
ACV	BELL C30-50B	30,000	–	–	0.48
ACV	AROJ C30-50B	30,000	–	–	0.48
Planing	S&S P125-20S	125,000	4.4	220	2.12
Planing	TRG P125-20	125,000	3.8	190	1.76
ACV	BELL C150-50B	150,000	–	–	0.52
ACV	AROJ C150-50A	150,000	–	–	0.52
Planing	BOWK P320-20	320,000	2.7	135	1.26
Planing	BOWK P320-35	320,000	3.0	150	1.36
Planing	TRG P320-20	320,000	3.1	155	1.39

[a] Assumed characteristics; design data not presently available.

[b] Craft characteristics based on Preliminary Design Studies for Amphibious Assault Landing Craft, July 1968.

[c] For beached, fully loaded craft.

[d] With one forklift the unloading time is doubled.

Table 2. Planing Craft Unloading Cycle Times Using One Forklift Loading Large Pallets Into a Truck Adjacent to the Craft

Item	Measurement	Craft[a]					
		M&H P30-35	S&S P125-20S	TRG P125-20	BOWK P320-20	BOWK P320-35	TRG P320-20
1	Depth at ramp (ft)	1.0	4.4	3.8	2.7	3.0	3.1
2	Average internal craft travel (ft)	38	46	55	112	115	115
3	Average internal travel time (sec)	7.6	9.2	11.0	22.4	23.0	23.0
4	Position and pickup time (sec)	7.0	7.0	7.0	7.0	7.0	7.0
5	Craft to truck time (sec)	10.0	10.0	10.0	10.0	10.0	10.0
6	Unload, maneuver, and position time (sec)	20.0	20.0	20.0	20.0	20.0	20.0
7	Unload, lower, and clear time (sec)	5.0	5.0	5.0	5.0	5.0	5.0
8	Maneuver for return time (sec)	10.0	10.0	10.0	10.0	10.0	10.0
9	Truck to craft time (sec)	8.5	8.5	8.5	8.5	8.5	8.5
10	Average time/pallet (min)[b]	1.14	1.16	1.19	1.38	1.39	1.39

[a] Craft characteristics based on Preliminary Design Studies for Amphibious Assault Landing Craft, July 1968.

[b] Average time/pallet (min) = sum of items 3 through 9 divided by 60.

A system whereby the craft unloading ramp is mated with the truck was also investigated. A forklift was assumed as the means of moving cargo from the craft deck to the truck. There are obvious operational disadvantages in such a method, but off-loading times are computed for comparison purposes in Table 3.

All of the above off-loading systems have a common problem—namely trucks tend to get stuck as the surf washes the sand around the tires. For this reason concepts requiring trucks to stand in the surf zone while loading do not appear to be practical. Modifications to the trucks, such as large high-flotation tires, might reduce the problem, but it is unlikely that specialized trucks could be justified for general cargo-unloading operations.

The only feasible alternative is simply to increase the number of forklifts used in the base-line system. A maximum of four forklifts could be utilized to off-load all of the 125,000-pound and 320,000-pound-capacity planing craft except for the BOWK P320-20, which could only use three forklifts without causing interference at loading and unloading points. Thus, the base-line unloading times could be halved for the 125,000-pound and 320,000-pound-capacity planing craft except for the BOWK P320-20 craft, for which the unloading time would be reduced by one-third.

Forklifts

Technological improvements in forklifts should follow forecasted improvements in motors and control systems[4] which will be available in the 1980-to-1990 time frame. It should be feasible to build a rough terrain forklift truck that will lift as much as its shipping weight. More rapid acceleration will be possible. Developments in control technology could be employed by forklifts to increase operator efficiency. Instead of the operator having to use two controls for speed and direction, for example, he could use a single "joystick" to control both speed and direction. Forced feedback systems such as used in boosted aircraft controls could be used to give the operator immediate input on what the equipment is doing. Automatic subroutines utilizing either fluidic or solid-state electrical logic could decrease the number of operator decisions. Such equipment could control the power output to meet demand, provide remote sensing of equipment conditions, and furnish safety interlocks and collision avoidance capabilities. The improved operator efficiency resulting from technological improvements in forklifts should be reflected in reduced cycle times for cargo handling.

Table 3. Computations for Planing Craft Unloading Cycle Time Using One Forklift Loading Large Pallets Into a Truck Mated With the Craft Ramp

Item	Measurement	Craft[a]					
		M&H P30-35	S&S P125-20S	TRG P125-20	BOWK P320-20	BOWK P320-35	TRG P320-20
1	Average internal craft travel (ft)	38	46	55	112	115	115
2	Average internal travel time (sec)	7.6	9.2	11.0	22.4	23.0	23.0
3	Maneuver and mate with ramp time (sec)	30.0	30.0	30.0	30.0	30.0	30.0
4	Release ramp and depart time (sec)	10.0	10.0	10.0	10.0	10.0	10.0
5	Maneuver forklift for unloading time (sec)	15.0	15.0	15.0	15.0	15.0	15.0
6	Unload, lower, and clear time (sec)	5.0	5.0	5.0	5.0	5.0	5.0
7	Maneuver forklift for return time (sec)	10.0	10.0	10.0	10.0	10.0	10.0
8	Average time/pallet (min)[b]	1.29	1.32	1.35	1.54	1.55	1.55

[a] Craft characteristics based on Preliminary Design Studies for Amphibious Assault Landing Craft, July 1968.

[b] Average time/pallet (min) = sum of items 2 through 7 divided by 60.

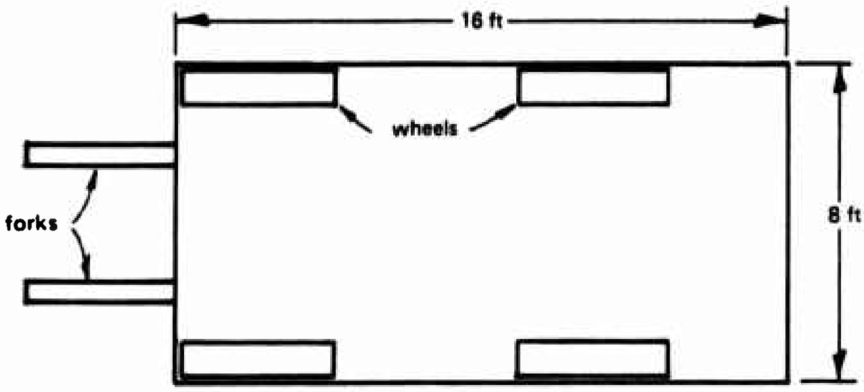
ADVANCED CONCEPTS

Air Cushion Forklift

A forklift supported on an air cushion would enhance the off-loading rates for planing craft, particularly under adverse environmental conditions. However, an investigation of this concept reveals it to be impractical as the following discussion will illustrate.

There are several methods of creating the air cushion, the most simple of which is the plenum chamber. Such a vehicle is supported on a cushion of air supplied from a high-volume, low-pressure axial fan. The lifting capability is a function of the base pressure and area (planform) while the lifting height depends on the base pressure and exit area. Given a planform of constant area, the power required varies as the load to the 3/2's power and linearly with the exit gap height. Such vehicles normally incorporate a flexible skirt made of neoprene-coated nylon to minimize the exit or gap area and thereby maximize the lift height for a given base pressure. This allows the ACV to pass over obstacles as high as the skirt depth.

Computations for a hypothetical air cushion forklift were made assuming the most favorable technological capabilities. It has been reported that by 1980-90 rough terrain forklifts capable of lifting as much as their own weight will be feasible. Hence a conservative payload-to-gross-weight ratio of 1/2 is assumed for the air cushion forklift. Other assumptions as well as the computations are given in Figure 1. The lifting power for a 10,000-pound-capacity air cushion forklift is estimated to be 790 hp for full-cushion support and 278 hp for 50% support. Over water or surf the wheels cannot be used as the ACV must operate under full-cushion support. On the beach some support on the wheels is necessary in order to avoid the maneuvering and stability problems characteristic of ACVs. When operating over rough terrain the air cushion avoids imposing high dynamic loads on the suspension system, thus permitting higher cross-country speed. For over-water operation full-cushion support is necessary, resulting in an impractically high power requirement of about 790 hp, exclusive of propulsion power. In the case of overland use, where 50% of the support is provided by the wheels, it is estimated that the total power requirement (lift plus propulsion) is approximately 400 hp, which is still a considerable amount in comparison with the 145-hp engine of a 10,000-pound-capacity rough terrain forklift.



Bottom Plan View of Forklift

$$\frac{\text{payload}}{\text{gross weight}} = 1/2$$

W (gross weight) = 20,000 pounds
A (effective support area) = 112 ft^2

$$P\,(\text{cushion pressure}) = \frac{W}{A} = \frac{20{,}000\ \text{lb}}{112\ \text{ft}^2} = 178.5\ \text{psf}$$

P = 178.5 psf with 100% cushion support
P = 89.2 psf with 50% cushion support and 50% wheel support

$$\text{power} = (P)^{3/2}\left(\frac{2}{\rho}\right)^{1/2} h\,L\,Dc$$

where L = perifery length = 48 ft
h = skirt gap = 0.1 ft
Dc = exit coefficient = 0.65
ρ = density of air = 0.002378

Power is 139 hp when P = 89.2 psf; assuming 50% efficiency, lift power for 50% weight on wheels is 278 hp

Power is 395 hp when P = 178.5 psf; assuming 50% efficiency, lift power for 100% cushion support is 790 hp

Figure 1. Sketch and computations for hypothetical air cushion forklift.

Air Cushion Bubble

Another use of the air cushion phenomenon is to completely enclose the load to be transported with a bubble as depicted in Figure 2. The air-cushion-supported load would be moved by a tracked or wheeled tractor unit, which would also carry the air cushion blower. Such a technique has been employed to move very heavy loads on land, but it is not particularly applicable to amphibious operations for a number of reasons, the most important of which is the considerable time anticipated to engage and disengage the load. This concept might be worthy of consideration for a substitute landing craft retriever (LCR), however. Reference 5 documents some developmental work done by the British on a vehicle recovery system shown in Figure 3.

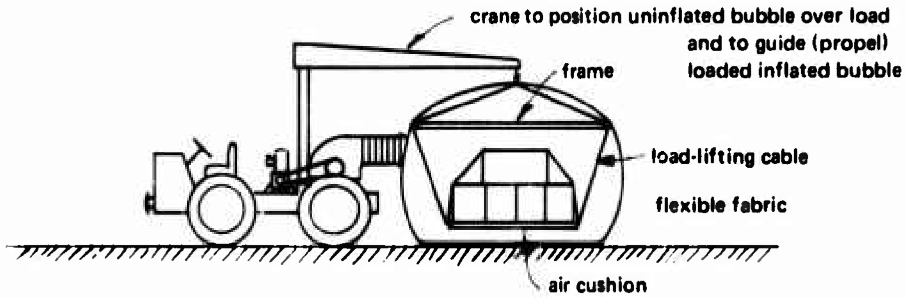


Figure 2. Air cushion bubble lifter.

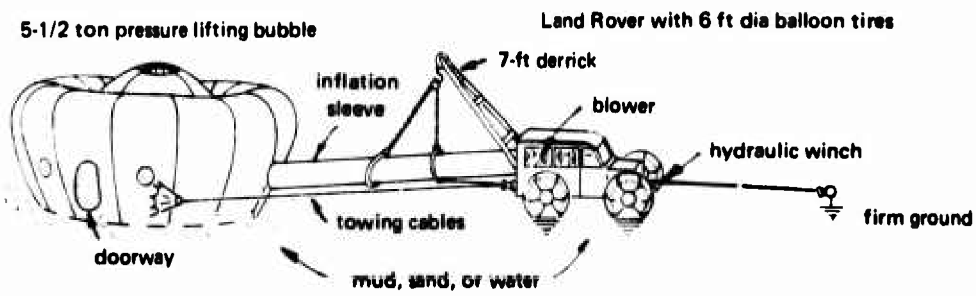


Figure 3. Land-Rover-powered recovery system.[5]

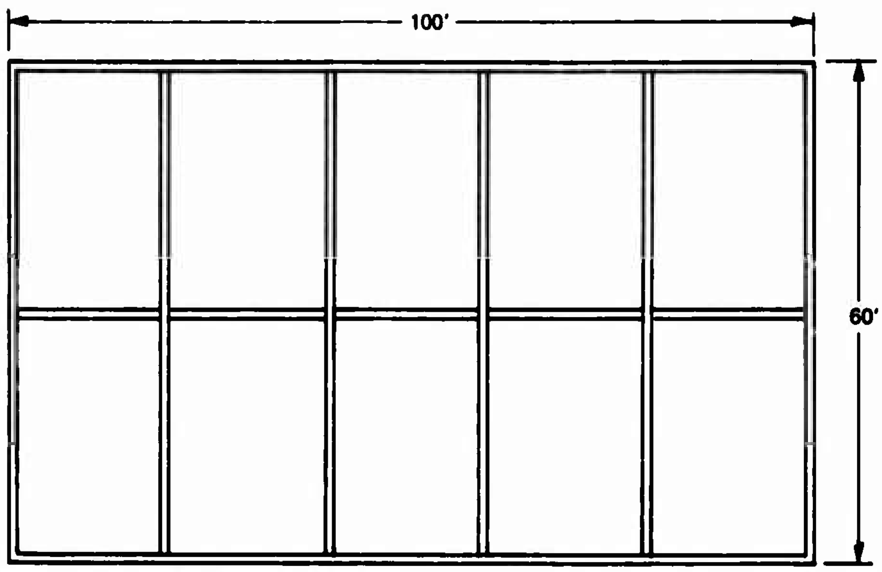
Portable Breakwater

A nearshore breakwater would minimize surf in the beach area utilized for off-loading landing craft. To provide sufficient space for craft maneuvering while minimizing the structural height, the breakwater should be 500 feet offshore at low tide; the water depth at this point would be 10 feet on a 1:50 bottom slope. The breakwater should be 1,000 feet long, serviceable in a depth range of 10 to 15 feet, and deployable in 10 to 15 feet of water in half a day under sea state 3 conditions. The breakwater should reduce the incoming waves by one sea state up to sea state 4 and survive a sea state 6. Deploying a breakwater in sea state 3 is a difficult task, but this is the very time when it is most needed.

Although there have been numerous attempts to develop a floating or other type of breakwater which is readily transported and deployed, which is effective for a broad range of wave conditions, and which can endure severe wave conditions, no significant successes have been reported.[6] However, most investigators have been interested in offshore breakwaters rather than the nearshore case. Several offshore concepts may prove practical when applied to the relatively small water depth of the nearshore environment.

Caissons, either concrete or steel, can be used to form a bottom-resting gravity structural barrier. Total elimination of waves on the leeward side is prevented only be diffraction around the ends and overtopping when the freeboard is insufficient. Mobility is a major problem for caissons. A steel caisson would be more mobile than a concrete caisson, especially without ballast, but it probably requires a ballasting material heavier than water if it is to be held in place by gravity only. In fact, the stability of gravity structures is a major problem if they are to remain in place at high sea states. Features to minimize this problem include inclination of the seaward face to obtain a downward component of the wave force and anchoring devices to resist sliding. Scour at gaps between modules and in front of the breakwater is also a problem.

To ascertain the practicality of caissons for the nearshore environment, a rough design of a concrete caisson breakwater was made using the basic criteria outlined above. Figure 4 shows one possible design consisting of modules 100 feet long by 60 feet wide by 22 feet high with a wall thickness of 8 inches and total weight of 1,100 tons. The draft is 5 feet 9 inches, making it deployable in a water depth as low as 10 feet. Design calculations were made for several water depths and sea states to determine the worst conditions. The low end of sea state 5 (8- or 9-foot waves) at low tide produces breaking waves at the structure. At high tide under sea state 6 conditions, waves will also break at the structure. These two cases present severe design conditions because of the high impact loads of breaking waves. Even with a structure as massive as the above design, a supplemental resisting force of 5 tons/foot is required for the low sea state 5 case and 12 to 30 tons/foot for the sea state 6 case. While it may be possible to develop an explosive anchor system on the bottom of the caisson with sufficient holding power for the former case, 30 tons/foot of supplemental anchoring force is considerably beyond the current state-of-the-art.



Note: All walls 8 inches thick.

Figure 4. Plan view of caisson nearshore breakwater.

The size of the proposed caisson breakwater module requires that it be towed to the site of deployment. Estimated power for a 4- to 5-knot speed in waves 5 to 6 feet high is 300 to 600 hp per module. For this breakwater design to be practical in amphibious warfare, caisson modules would have to be stored in strategic locations throughout the world, and even then the tow-age time might negate their usefulness. Deployment of the breakwater under sea state 3 conditions would be very difficult. Tugs would have to maneuver the caissons in 10 feet of water, if they were deployed at low tide, and contend with tide currents and 5-foot waves. Further study is required not only of the feasibility of deployment at sea state 3 conditions, but the survivability of the structure under breaking waves encountered in higher sea states.

An alternative to the caisson which may be more promising is an inclined pontoon breakwater shown in Figure 5. The concept consists of a series of pontoons 150 feet long by 50 feet wide by 5 feet deep weighing 180 tons each. Draft is about 9 inches. When deployed it would be held in place by anchors and the tendency of the toe to dig into the bottom. It could also be ballasted by flooding. Very little is known about the characteristics of such a breakwater, especially the mooring requirements. However, experimental results indicated that they may not be excessively high.[7] It is unlikely that such a breakwater could survive breaking waves; thus it must be deployed in deeper water (about 20 feet deep) in order to have sea state 6 waves break on the shoreside. Five-foot waves (sea state 3) would be reduced to 2 feet at this depth, but diffraction between modules and around the ends of the breakwater would give an average transmitted height of 3 feet.

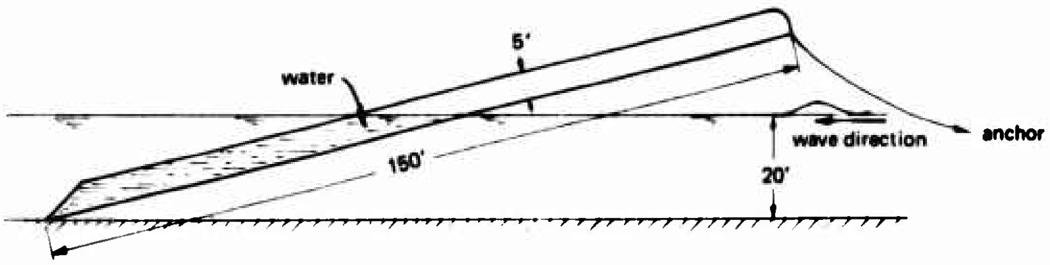


Figure 5. Vertical view of inclined pontoon nearshore breakwater.

An inclined pontoon breakwater has the advantage of being more readily maneuvered for deployment in sea state 3 than caissons; a more important advantage is that it may be possible to transport the pontoons aboard ship. Additional research is needed before the technical feasibility of this concept can be established. Topics needing further study include wave transmission for various configurations, rigid-body response in high sea states, mooring forces, and deployment procedures.

Anthropomorphic Devices

Anthropomorphic devices duplicate, with force feedback, some of the motions of the human operator, while multiplying the size of the motion and the magnitude of the force. Included in this category are robot and exoskeleton devices.

General Electric is currently developing an exoskeleton device for the Army and Navy called HardiMan (Figure 6).[8,9] The device will have two arms and two legs capable of mimicking the movements of its operator and lifting and manipulating loads up to 1,500 pounds. It will be worn as an external skeleton and will have its own power source. The operator will be connected to the structure at the arms and feet, and at a cross piece that links the left and right sides. As part of an exploratory development effort, the Army has also contracted with General Electric for the development of an exoskeleton boom with the goal of handling 7,500 pounds at 15 feet and 4,000 pounds at 25 feet.

Small anthropomorphic devices are most applicable for dump areas and inland points where the typical unit load is a standard pallet weighing 2,000 pounds. Such a device could be used for breaking down large pallet or standard pallet loads. It might be used for loading or unloading 2-1/2-ton trucks or sorting supplies in the dump. Another application might be to position pallets, particularly standard pallets, in landing craft during the loading or off-loading operation. Also the device could be used for loading standard pallets onto large pallets aboard ship. None of these uses is directly related to the improvement of unloading rates of landing craft, except for positioning pallets for off-loading in conjunction with another material handling unit such as the multiple pallet transporter described later in the report, or a conventional rough terrain forklift. The production cost of a small anthropomorphic device capable of lifting standard pallets weighing 2,500 pounds is estimated to be in the order of $150,000.[4]

Figure 6. Part of General Electric's exoskeleton device.

Because of the trend towards larger unit loads at the beach end of the ship-to-shore cycle, anthropomorphic devices of at least 10,000-pound capacity are of more interest for off-loading craft. There is insufficient information with which to evaluate the feasibility of a large exoskeleton boom suitable for moving loads of 10,000 pounds or more from landing craft. The results of the Army's exploratory development mentioned above should enable an assessment of the feasibility of exoskeleton devices for off-loading landing craft.

Remotely Controlled Helicopter

A remotely controlled helicopter specifically designed for lifting large pallets and containers would greatly increase mobility and flexibility of materials-handling operations while costing less than conventional helicopters. Reference 10 indicates this concept to be technologically feasible. The concept envisioned in Figure 7 is a material-handling aircraft with vertical take off and landing capability, a vacuum or magnetic coupling for picking up containers, and with lift provided by a counterrotating coaxial rotor system. The entire operation would be radio controlled by an operator in a remote location. The advantages and disadvantages of present-day manned helicopter operations would be inherent in such a system, but possibly on a reduced scale. Although it would be possible to off-load landing craft with a remotely controlled helicopter, it is certainly highly expensive in comparison to a forklift. Cargo of high enough priority to justify the expense of remotely controlled helicopter handling at the beach could probably equally justify ship-to-shore movement by conventional helicopter.

Sliding Craft Deck

A concept proposed in Reference 11 for handling packages in commercial trucking operations may be applicable to amphibious landing craft. The concept consists of a stainless steel sheet which slides on the truck floor by rolling or unrolling like a horizontal window shade (Figure 8). The cargo rides directly on the stainless steel sheet which has a traveling bulkhead attached to the loose end. As the sheet is pulled by the take-up roller, the entire cargo load is moved at a speed of about 1 fpm. A 1-hp motor coupled to a high reduction transmission was found sufficient to move the sheet over the oiled masonite-lined trailer floor even with a cargo load of parcels weighing 30,000 pounds.

The adaption of the above system to landing craft would require incorporation of tie downs on the sheets, a difficult problem if they must be recessed. The bulkhead could be deleted, a necessity on craft with both stern and bow ramps. It is estimated that a 10% to 20% reduction in cycle time, under ideal operating conditions, could be achieved by using such an unloading system. The percent reduction in cycle time from elimination of internal forklift travel increases as the craft size increases and as the craft-to-shore distance decreases. The percent improvement in unloading rate would be considerably less under adverse environmental conditions. The cost of incorporating such a deck in the advanced landing craft would depend on the size of the craft and the necessity of providing a separate power source to drive the deck.

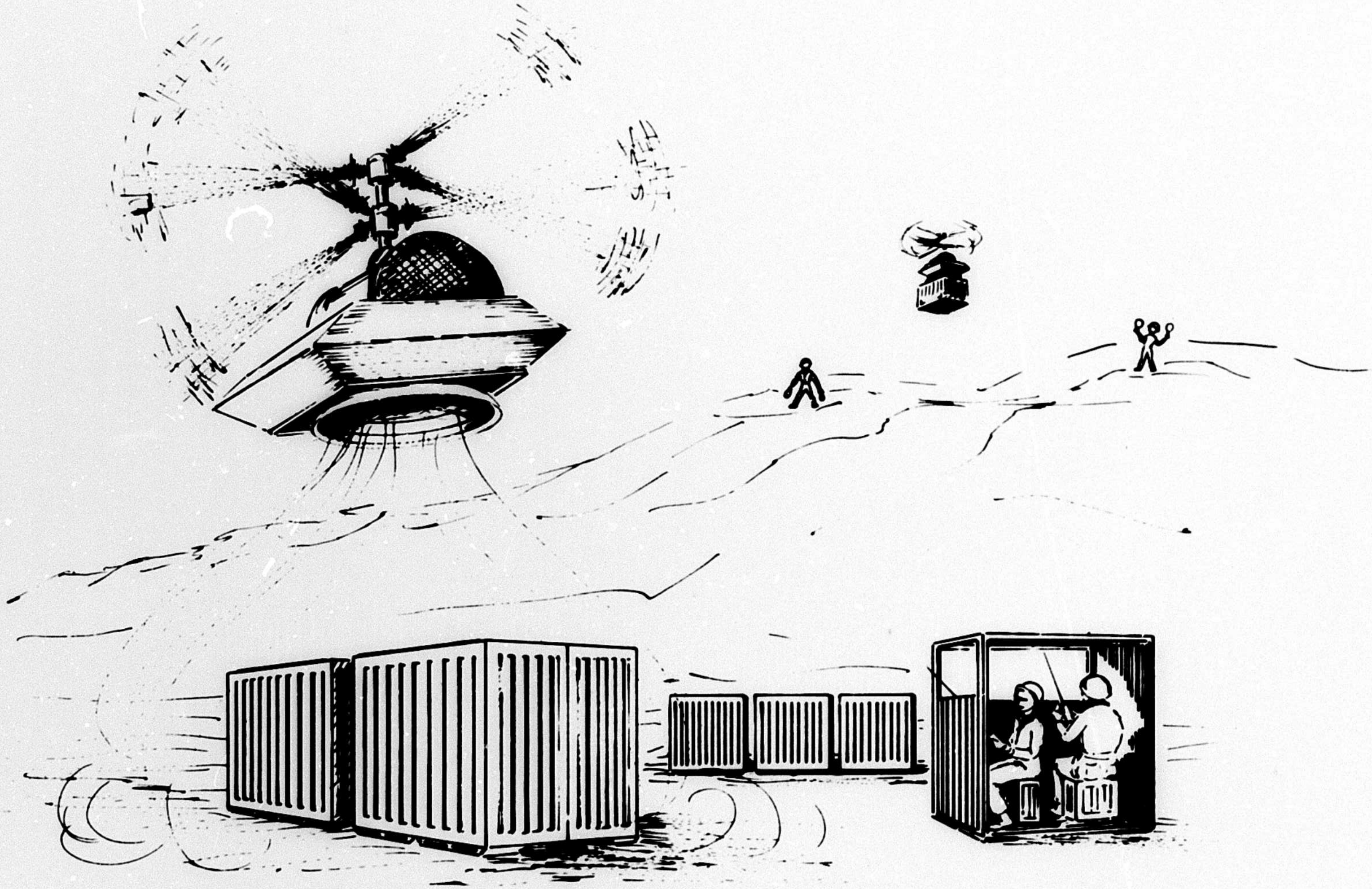


Figure 7. Remotely controlled helicopter. (Adapted from Army concept published in January-February, 1970 *Defense Transportation*. Used by permission.)

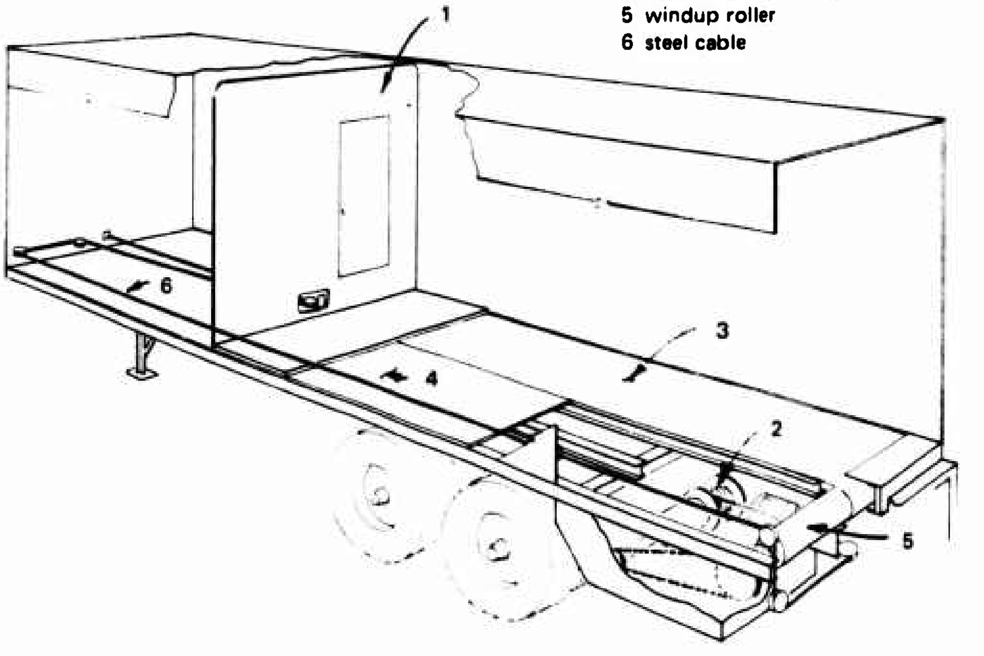
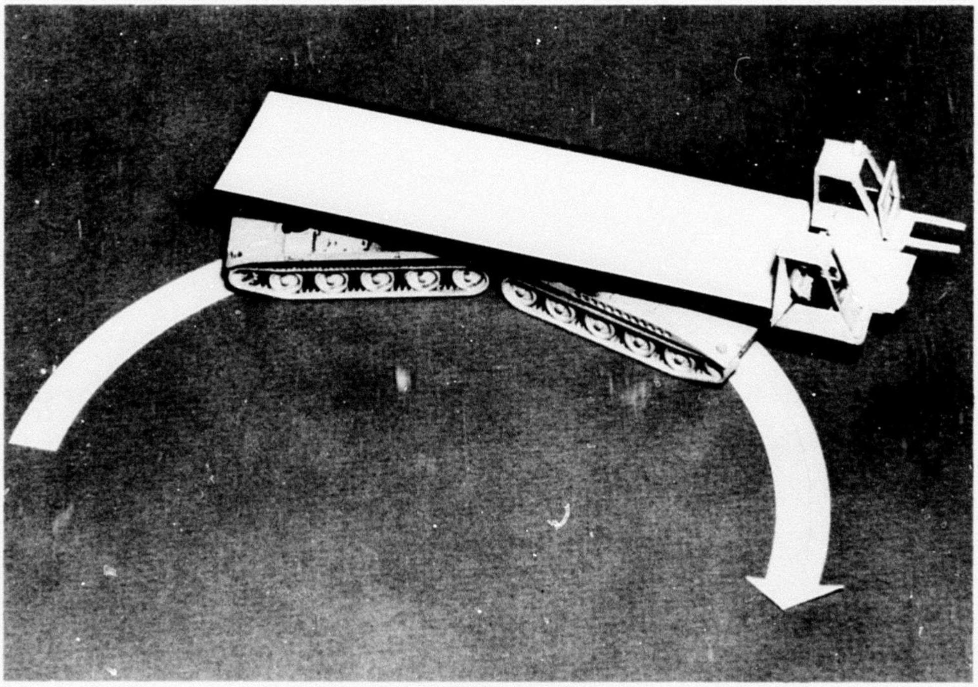


Figure 8. Sliding semitrailer deck.

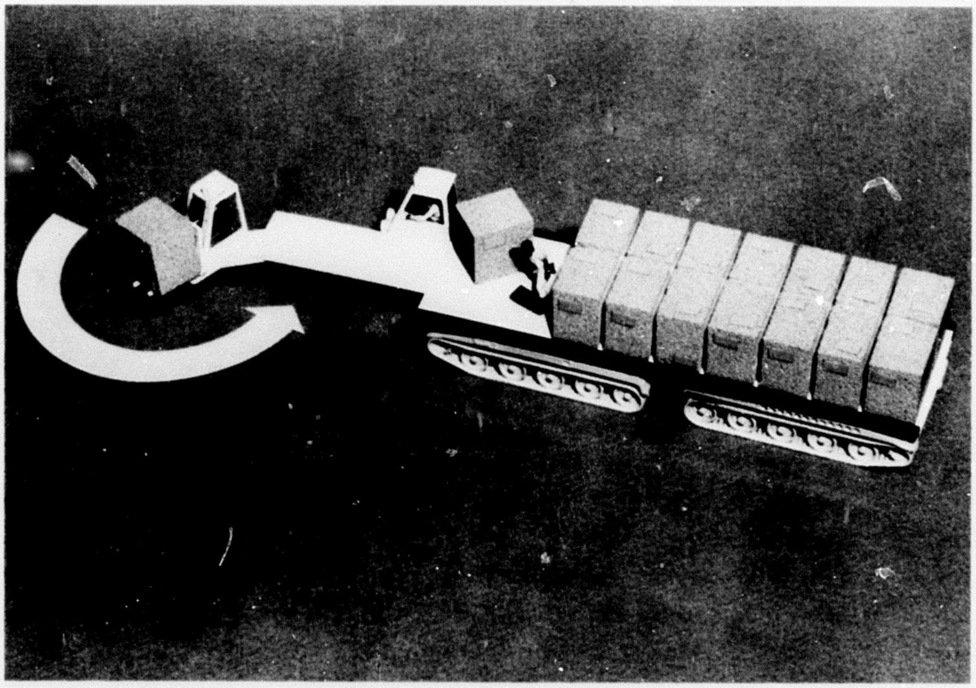
Multiple Pallet Transporter

An unloading equipment capable of handling all or at least a large portion of a craft payload could significantly improve off-loading rates, particularly for planing craft which beach with large craft-to-shore distances. Such a concept is proposed in the following discussion.

The transporter (Figure 9) would have a 50,000-pound capacity (five large pallets or 25 1-ton standard pallets), self-loading and unloading capability by means of an extendable conveyor with an articulated forklift at its end, 5-foot fording depth, and tracks for maximum mobility in the surf and on the beach. A retractable roller system or air conveyor on the transporter deck would be required for rapid deposit of the pallets as they come on the deck from the extendable conveyor. It might also be advisable to provide a self-leveling capability for the deck. In order for such a vehicle to be loaded, the cargo must be positioned near the bow of the craft. This can be accomplished by using a sliding deck as previously described, or in the case of standard pallets, a small forklift such as the electric stackers used aboard ships.



(a) Traveling configuration.



(b) Loading configuration.

Figure 9. Multiple pallet transporter.

An important advantage of the multiple pallet transporter is its ability to handle standard pallets at a high rate, thereby avoiding the shipboard disadvantages of large pallets. It is estimated that a cycle time for engaging and placing a standard pallet on the extendable conveyor as low as 10 seconds might be possible. This is equivalent to 6 standard pallets per minute or 1.5 large pallets per minute.

To maintain a constant high off-loading rate more than one transporter per craft would be required to eliminate queuing by the craft while the transporter deposits its load at a beach dump or into trucks. The production cost of the above transporter is estimated to be about $150,000.

A less sophisticated transporter would suffice for ACV off-loading. Since rollers are considered feasible for ACVs, an unloading concept similar to the Air Force 463L pallet system which incorporates K-loaders (comparable to the multiple pallet transporter) and rollers on both the K-loader and aircraft decks, can be envisioned. Unloading the small, 30,000-pound-capacity ACV could be accomplished in one operation by simply pushing the pallets from the ACV onto the mated deck of the transporter. An average cycle time of 1-1/3 minutes per large pallet (0.5 minute per pallet plus 2.0 minutes to mate transporter and craft plus 0.5 minute to disengage craft) can be anticipated. The corresponding cycle time for the 150,000-pound-capacity ACV is 1 minute per large pallet (assuming three matings of craft and transporter, five pallets per transporter).

Causeway

Pontoon causeways are commonly employed for off-loading roll-off cargo from LSTs. Because of the large craft-to-shore distances of some planing craft when beached, a causeway could be advantageous for off-loading these craft also. An end connection with a causeway such as used by LSTs has been tried with present day landing craft and found to be ineffective because of the smaller ramp and greater buoyancy of the craft. A beaching ramp alongside the causeway has been used successfully in calm water but found to be impractical as the sea state increases.

Two alternatives exist for off-loading landing craft onto a causeway: (1) beaching the craft parallel to the causeway and (2) drydocking the craft on a pontoon integral with the causeway. A possible concept for the latter method consists of floodable pontoons located on either side of, and integral with, the causeway near the seaward end. On the top of these drydocking pontoons would be an inflatable bladder to provide uniform lifting over the entire craft bottom as well as to minimize problems of cradling the craft while it and the pontoon are in relative motion (Figure 10).

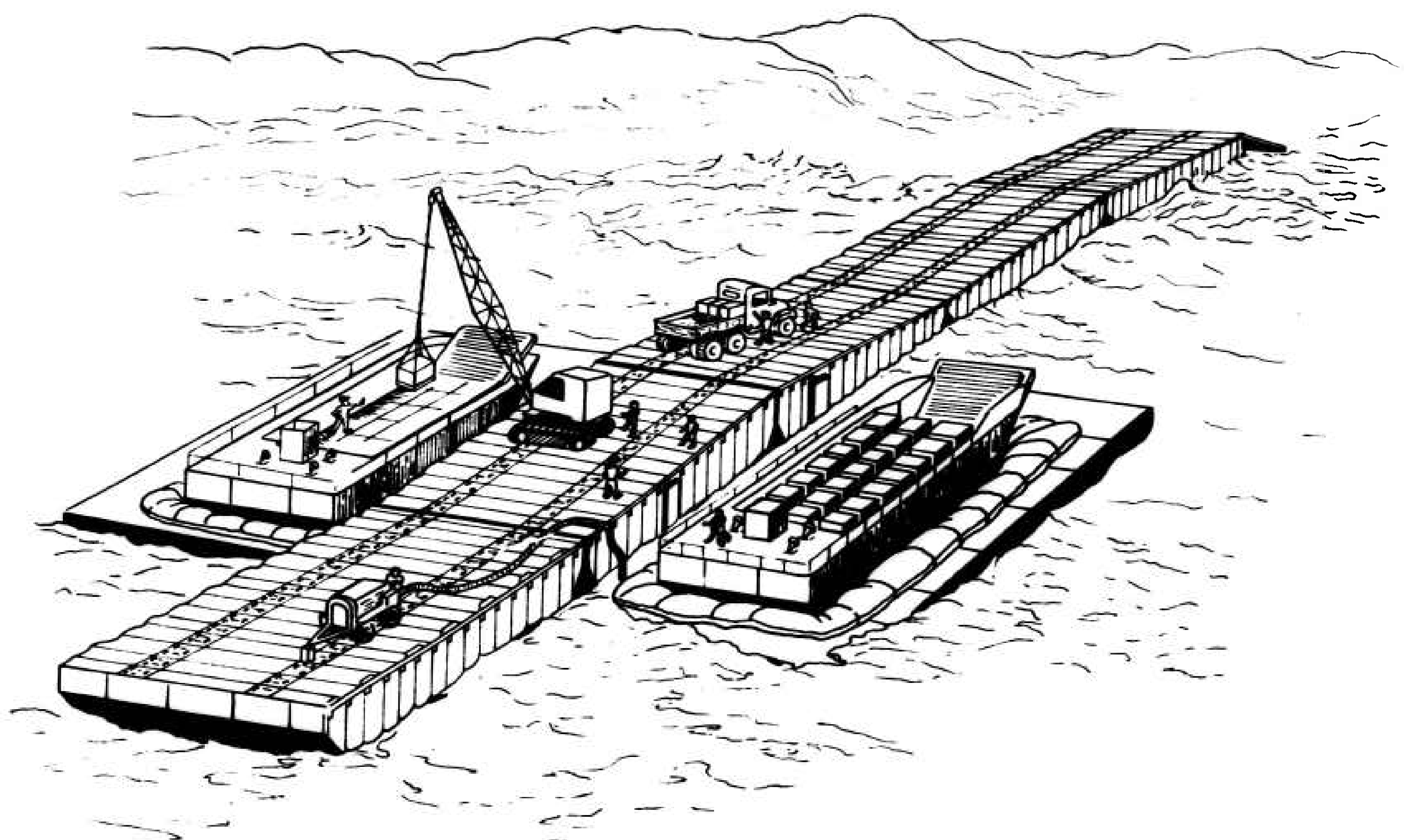


Figure 10. Pontoon drydock at causeway.

The foregoing system is not without its potential problems, however. The speed of the drydocking operation may be too slow for efficient use of the landing craft. At high sea states positioning the craft for cradling may be difficult or impossible. Unless the drydocking and unloading operations happen simultaneously on both sides of the causeway, the moment about the longitudinal axis of the causeway may be intolerable.

The alternative to the above system, beaching alongside the causeway, would result in greater relative motion during off-loading but would be considerably less complicated. Since it is doubtful that either method could be employed under high sea state conditions, it appears that beaching alongside the causeway would be the most cost-effective alternative. It is envisioned that a crane could load pallets directly into trucks which would travel in both directions on a widened causeway. The cycle time per large pallet is estimated to be 1.4 minutes (see page 36 of Reference 1). A P-series pontoon causeway 270 feet long and of sufficient width for two-way truck traffic costs about $160,000. It should be noted, however, that such a causeway may be wider than those employed in amphibious operations and could not be side-carried on an LST.

DISCUSSION

Some of the preceding concepts are obviously not feasible; however, four concepts may warrant further consideration for improving off-loading rates: *multiple pallet transporter, sliding craft deck, causeway,* and *portable breakwater.* Even these concepts appear difficult to justify without first determining if any improvement in off-loading rate beyond that possible in the base-line system (two rough terrain forklifts per landing craft) is required when viewed from an overall perspective of amphibious warfare in the future time frame. Questions such as the availability of trucks to match the inflow of cargo, the necessity of rapidly building up beach dumps, and the probability of craft being under enemy fire during general unloading should be addressed.

Unloading rates for the multiple pallet transporter, sliding craft deck, and causeway concepts are presented for advanced landing craft in Table 4 along with the base-line rate and a modified base-line rate. It is evident that the multiple pallet transporter improves off-loading rates with the larger planing craft—particularly those with large craft-to-shore distances, for which an improvement in off-loading rate as high as 50% is observed. The transporter offers no advantage for ACVs. The sliding craft deck, which might also be used in conjunction with the multiple pallet transporter, improves off-loading rates for all craft by eliminating forklift travel within the cargo holds. On a

Table 4. Comparison of Unloading Rates for Selected Advanced Concepts With Base-Line and Modified Base-Line Rates

Craft Type	Designation	Unloading Time For Base-Line System[a] (minutes/large pallet)	Modified Base-Line System[b]		Multiple Pallet Transporter		Sliding Craft Deck Plus Two Forklifts		Causeway Plus Crane[d]	
			Unloading Time (minutes/ pallet)	Change From Base-Line[c] (%)	Unloading Time (minutes/ pallet)	Change From Base-Line[c] (%)	Unloading Time (minutes/ pallet)	Change From Base-Line[c] (%)	Unloading Time (minutes/ pallet)	Change From Base-Line[c] (%)
Planing	M&H P30-35	0.65	–	–	1.33	+104	0.59	- 9	1.4	+115
ACV	BELL C30-50B	0.48	–	–	1.33	+177	0.41	-15	–	–
ACV	AROJ C30-50B	0.48	–	–	1.33	+177	0.41	-15	–	–
Planing	S&S P125-20S	2.12	1.06	-50	1.07	- 50	2.04	- 4	1.4	- 34
Planing	TRG P125-20	1.76	0.88	-50	1.07	- 39	1.67	- 5	1.4	- 20
ACV	BELL C150-50B	0.52	–	–	1.00	+ 92	0.42	-19	–	–
ACV	AROJ C150-50A	0.52	–	–	1.00	+ 92	0.42	-19	–	–
Planing	BOWK P320-20	1.26	0.84	-33	1.07	- 15	1.08	-14	1.4	+ 11
Planing	BOWK P320-35	1.36	0.68	-50	1.07	- 21	1.18	-13	1.4	+ 3
Planing	TRG P320-20	1.39	0.70	-50	1.07	- 23	1.20	-14	1.4	+ 1

[a] Two forklifts.

[b] Rates are indicated only for those craft which can accommodate more than two forklifts in their unloading cycle. Four forklifts are used for the S&S P125-20S, TRG P125-20, BOWK P320-35, and TRG P320-20 craft. Three forklifts are used with the BOWK P320-20 craft.

[c] Negative percentage indicates decrease in unloading time, positive percentage indicates increase.

[d] Applicable to planing craft only.

percentage basis the greatest improvement from this concept (19%) is in the 150,000-pound-capacity ACV off-loading rate. As one would expect, the causeway is most beneficial for the planing craft with high grounding depth. Only two planing craft, the S&S P125-20S and TRG P125-20, show an improvement over the base-line rate with this system.

The modified base-line system, which employs additional forklifts for those planing craft grounding at a large distance from shore, produces a significant improvement in off-loading rates. Table 4 shows the improvement to be 50% for four of the craft; this is equal to or greater than that calculated for the other alternatives. The forklift is clearly worthy of consideration as a material-handling unit, even in the long-range time frame. The forklift's high versatility and relatively rapid handling rate should not be overlooked. Improvements in forklift power and control systems should also be considered as a means for improving forklift handling rates.

A nearshore breakwater would improve cargo operations for planing craft under adverse sea conditions. The estimated improvement would range from 25% for 3- to 4-foot waves to 100% for 5-foot waves. The previously discussed difficulties of getting the breakwater to the site and deployment under adverse sea conditions (when it will normally be needed) must be recognized. More research on the inclined pontoon breakwater is warranted to ascertain its feasibility. Studies of its logistic burden as well as the trade-off between size and effectiveness (particularly survivability at high sea states) should also be conducted.

CONCLUSIONS

1. The following concepts show promise for improving the off-loading rate for some of the advanced landing craft: ***multiple pallet transporter, sliding craft deck, causeway***, and ***nearshore portable breakwater***.

2. Further research is needed to verify the technical feasibility of a nearshore portable breakwater. Development of the multiple pallet transporter, sliding craft deck, and causeway concepts could proceed without further technical research.

3. Increased numbers of rough terrain forklifts and/or the development of more efficient forklifts may be the most desirable means of increasing off-loading rates.

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13. ABSTRACT

This report considers means for improving the handling rate of palletized cargo at the craft–beach interface with reference to the advanced landing craft under development by the Amphibious Assault Landing Craft Program. A base-line unloading rate is established and components of the base-line system are studied to see if modifications to the equipment or off-loading methods can effect an increase in unloading rates. A number of advanced concepts are considered, the more promising of which include a multiple pallet transporter, sliding craft deck, causeway, and portable nearshore breakwater. While these concepts improve unloading rates in specific instances, they may be difficult to justify in terms of their cost and contribution to the overall efficiency of the general unloading phase of amphibious operations. A more desirable option may be to increase the number of rough terrain forklifts and/or develop a more efficient forklift.

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	ROLE	WT	ROLE	WT	ROLE	WT
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Amphibious operations						
Amphibious warfare						
Logistics--amphibious cargo handling						
Rough terrain forklift						
Air cushion vehicle						
Portable breakwater						
Remotely controlled helicopter						
Sliding deck cargo mover						
Pontoon causeway with floating drydock						

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