

AD 721 328

Technical Report

R 715

**AMPHIBIOUS ASSAULT LANDING CRAFT PROGRAM—
LARGE PALLET DEVELOPMENT**

March 1971



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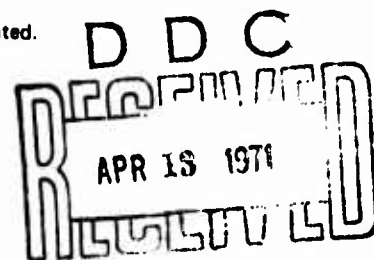


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**AMPHIBIOUS ASSAULT LANDING CRAFT PROGRAM—
LARGE PALLET DEVELOPMENT**

Technical Report R-715

55-013

by

Joseph A. Drelicharz and Robert W. Julian

ABSTRACT

To complement the high speed of the advanced craft being developed by the Amphibious Assault Landing Craft Program, a need exists to consolidate cargo into larger unit loads in order to improve the material handling rates at the terminals of the ship-to-shore cycle. This report documents the design, fabrication, test, and evaluation of four prototype large pallets, 8 x 9 feet in area, each capable of carrying four standard 40 x 48-inch pallets. The prototype pallets include a wooden, a folded-plate, an aluminum, and a strongback design. Each pallet functioned well with respect to its specific design criteria; however, no one pallet was clearly superior to the other three alternatives, and none fulfilled all the design criteria.

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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 (AALCP), Project S14-17, to define and develop a new generation of assault landing craft. A need exists to improve the material handling rate at the ends of the ship-to-shore cycle to complement the high speed of the advanced landing craft.

Utilizing a larger unit load is one way to increase cargo transfer rates—hence the large pallet concept. Since it is desirable to retain the standard 40 x 48-inch pallet size for inland transportation and subsequent handling, the large pallet must be designed to carry standard pallets. A previous investigation* reported that a large pallet having 8 x 9-foot (96 x 108-inch) dimensions and carrying four standard pallets, with a maximum payload of 10,000 pounds, would be most suitable for amphibious operations. The objective of the present task was to design, fabricate, test, and evaluate several prototype large pallets which met those basic criteria.

As a starting point for formulating the design of a large pallet, consideration was given to the Marine Corps 88 x 156-inch pallet and the Air Force 463L 108 x 88-inch and 54 x 88-inch pallets. The characteristics of these pallets (detailed in the previous investigation*) were studied to determine if simple modification would make them suitable for amphibious operations. Because the Marine Corps large pallet was designed for helicopter transport and the Air Force pallet for air freight, these rather specialized pallets are not suitable for amphibious operations without significant modification. It was concluded that an optimal design could best be achieved by an independent design for amphibious ship-to-shore operations.

Contact was made with organizations within the Defense Department engaged in material-handling development efforts to establish if any similar large pallet developments were in progress. It was determined that the only development effort is that of the Air Force to find an improved alternative to the current 463L pallets. This work is being carried out by the Equipment Development Branch, Aeronautical Systems Division, Wright-Patterson Air Force Base, Dayton, Ohio.

The Air Force has a continuing program for improving the 463L cargo-handling system. They have experimented with a large wooden pallet and a special pallet for handling mail, and are currently building

* Naval Civil Engineering Laboratory. Technical Note N-1039: Beach materials handling, by R. W. Julian. Port Hueneme, Calif., Sept. 1969. (AD 860411L)

an 88 x 108-inch prototype plastic pallet. The expected production cost of this latter pallet is \$235, which is less than the current \$300 procurement cost of the 463L large pallet. Some technical problems can be anticipated in adapting a plastic pallet to amphibious operations, as the Air Force pallet is not designed for forklift entry or crane hoisting. It was decided that the interests of the AALCP could best be served by concentrating the task effort on existing materials rather than expending resources on an effort paralleling that of the Air Force. The progress of the Air Force plastic pallet development should be monitored by the AALCP for possible consideration as a large pallet for amphibious use.

This report documents the design, fabrication, test, and evaluation of three Naval Civil Engineering Laboratory (NCEL) prototype large pallets. At the request of the task sponsor, tests were conducted on a fourth pallet, a strongback type, designed and fabricated by Hunters Point Naval Shipyard. Results of this test are also reported.

DESIGN REQUIREMENTS

General Criteria

The general design criteria call for a large pallet, 8 by 9 feet, capable of supporting a maximum payload of 10,000 pounds.* The pallet must be compatible with shipboard material-handling equipment, landing craft, forklifts, cranes, and trucks; thus its design must include four-way entry, lifting points for crane operation, and the availability of skids. The standard pallets, which will be the normal payload for the large pallet, are four-way-entry, 40 x 48-inch hardwood pallets; these weigh approximately 96 pounds, are capable of supporting a maximum payload of 2,500 pounds, and have a maximum payload height of 40 inches. The average payload is expected to be 2,000 pounds. A tare weight of 600 pounds or less is desired for the large pallet. In addition, loaded pallets must be capable of being stacked three high. Therefore, the bottom pallet must be able to sustain a maximum static loading of about 30,000 pounds.

Specific Criteria

Failure of standard wooden pallets can result from a variety of causes. From discussions with field personnel it was determined that such failures occurred when loaded pallets were dropped on objects, were impacted

* Ibid.

into hard surfaces, were driven over, or experienced a fastening failure. The design phase of the prototype pallet development attempted to take these failures into account.

No height restriction exists for the large pallet; however, it is logical to assume that minimum height is desirable. Each prototype was designed to try to minimize the pallet height.

Information was lacking on the design requirements for the tine openings; specifically, the size of the openings, their spacing, and design tine length. A survey of military specifications of forklifts and stackers produced the following tine opening requirement to enable handling of the pallet in most of the locations where it might be found. The design tine length was established at 60 inches, each tine a maximum of 10 inches in width and 3 inches in depth, spaced 48 inches on centers. This spacing is also compatible with the structural design of a well-proportioned large pallet.

DESCRIPTION OF LARGE PALLETS

Four different pallets, each having certain advantages, were designed, fabricated, and tested. Three were designed and built at NCEL; the fourth, a strongback pallet, was designed and built by Hunters Point Naval Shipyard.

The first, a wooden pallet, was designed to be low in cost and disposable. It was built with construction-grade 4 x 4's and 1/2-inch 32/16 unsanded plywood in accordance with the deck-loading criteria presented in the American Plywood Association booklet on pallet design.* Figure 1 shows the wooden pallet loaded and ready for testing. The approximate weight of the wooden pallet is 600 pounds, and the prototype cost was \$335. A drawing of details is presented in Figure A-1 of the Appendix.

The second, a folded-plate pallet, was developed for low-cost production, compact storage, and ease of handling. Four such pallets can be stacked in a space 9 inches high; the stack can be easily disassembled and the pallets loaded with a minimum amount of handling, since the stack is disassembled by sliding the pallets off the top and no time is wasted discriminating the top of the pallets from the bottom. This pallet weighs approximately 1,200 pounds, is built of 1/8-inch steel, and its prototype cost was approximately \$1,000. It was originally intended as an aluminum pallet weighing about 400 pounds. However, the high cost of hand fabrication involved in prototype construction of such an aluminum pallet was prohibitive, thereby justifying the use of a steel alternative for test purposes. Mass production of

* American Plywood Association. Form No. 68-2221 Plywood design manual: Pallets. Tacoma, Wash., Sept. 1968.

this folded-plate pallet in aluminum is anticipated to have low cost, since construction on a production basis is a two-step operation—punching out the tine opening and breaking (folding) the plate. A detail drawing of the folded-plate pallet is presented in Figure A-2 of the Appendix. Figure 2 illustrates the pallet loaded and ready for testing.

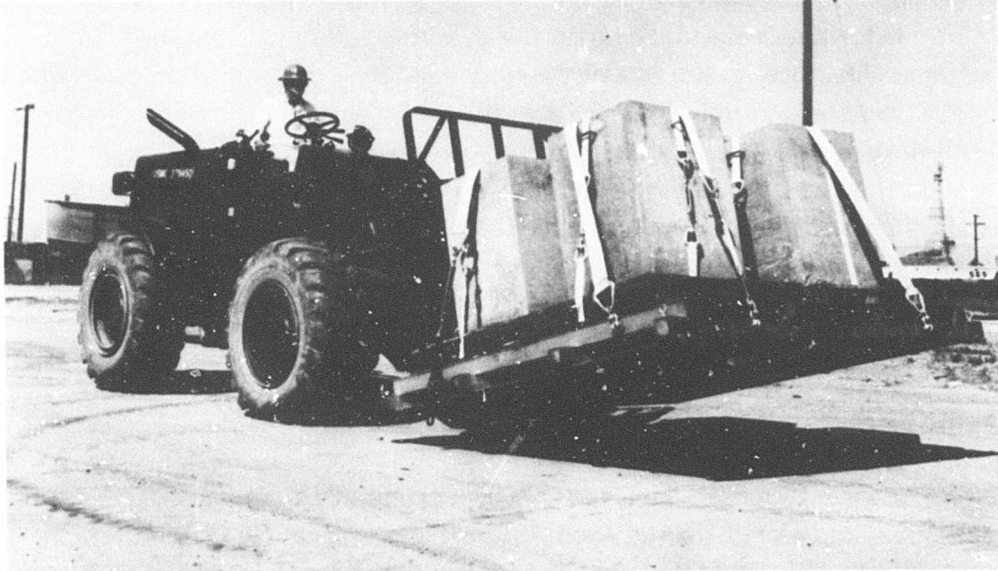


Figure 1. Wooden large pallet during initial forklift operations.

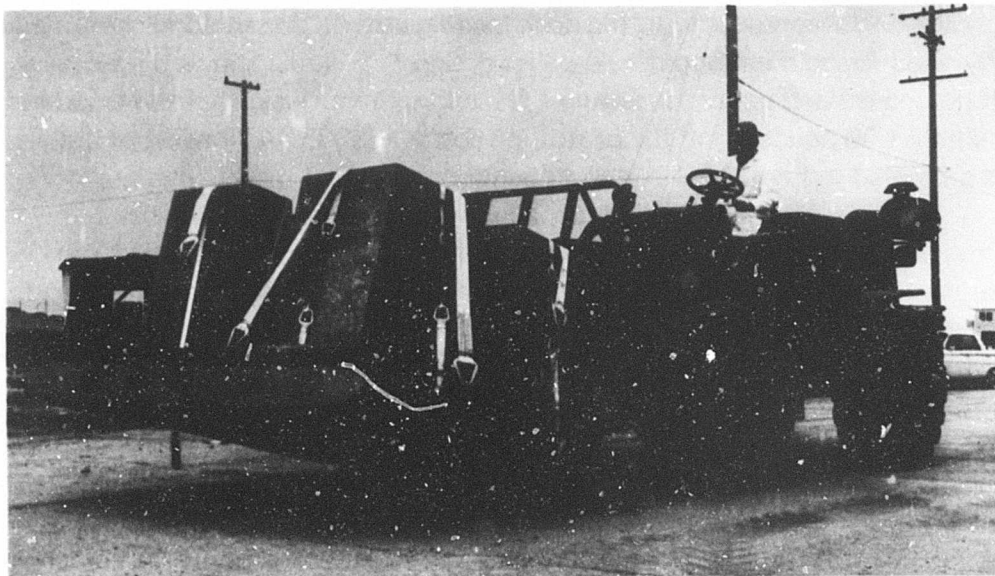


Figure 2. Folded-plate large pallet (steel construction) during initial forklift operations.

The third, an aluminum pallet, is of the conventional design to provide some comparison with known performance capabilities. The pallet was first designed for steel construction, but the weight requirement necessitated an alternative aluminum design. This pallet served a secondary function as a spreader for lifting the more pliable wooden and folded-plate pallets. Prototype cost for this 600-pound pallet was \$2,000. Figure 3 shows the loaded pallet positioned for testing. Details of the design are presented in Figure A-3 of the Appendix.

A fourth pallet was delivered to NCEL for testing from Hunters Point Naval Shipyard. This strongback pallet has been shown* to be the most compatible large pallet from the standpoint of shipboard handling. Figure 4 shows the pallet loaded and positioned for testing. Figure A-4 of the Appendix gives details of the design. Prototype cost for this 325-pound pallet was \$753. A summary of specific design criteria and general description of each pallet are presented in Table 1.

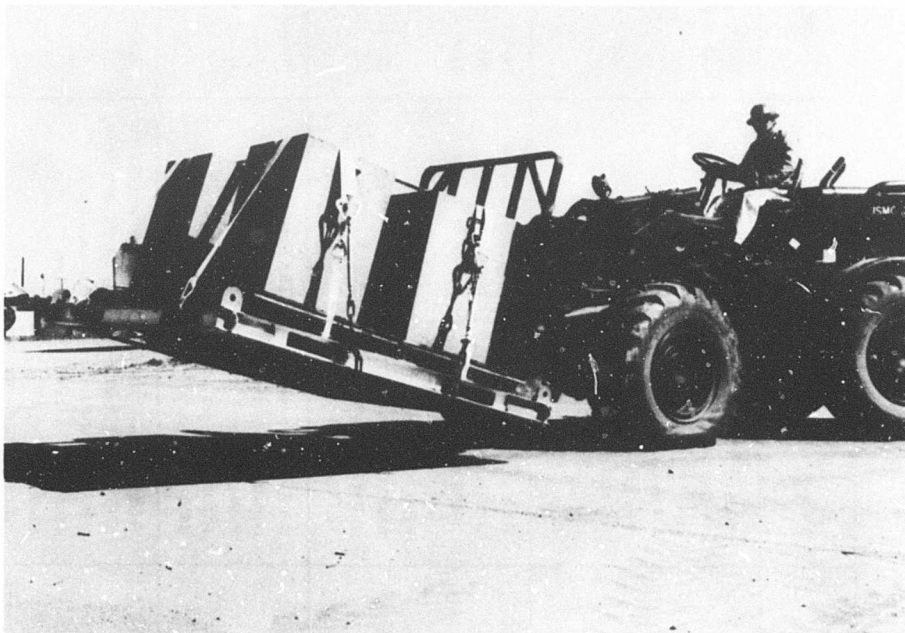


Figure 3. Aluminum large pallet during initial forklift operations. (Note wheel loading.)

* Hunters Point Naval Shipyard. Report No. Hunters PT-TR-2-70: Amphibious assault landing craft program (S14-17). Load consolidation test report, by R. R. Peterson. San Francisco, Calif., Feb. 1970. (AD 867108L)

Table 1. Large Pallet Description Summary

Type of Pallet	Prototype Cost (\$)	General Description	Principal Load-Bearing Members	Specific Features	Specific Design Criteria	Figure Reference in Report
Wooden	335	An 8 x 9-foot pallet constructed of two layers of crossed 4 x 4's construction grade timbers decked top and bottom with rough 1/2-inch plywood. 600 pounds.	The 4 x 4 frame-work and plywood skin	Lifting eyes; structural use of the outer skin	Low cost; disposable	1 6 7 8 9 A-1
Folded-plate	1,000	An 8 x 9-foot pallet constructed of a steel plate 1/8-inch thick, folded diagonally. Tine entry is made through cutouts in the structure. 1,200 pounds.	The 1/8-inch steel plate	No protrusions or attachments of any kind	Low-cost production; compact storage; handling ease	2 10 11 A-2
Aluminum	2,000	An 8 x 9-foot pallet constructed of 5-inch H-beams with 1/4-inch strapping for the upper deck. 400 pounds.	The 5-inch H-beam frame	None—a conventional design; adapted for use as a spreader	Lightweight; standard of comparison	3 12 A-3
Strongback	753	A 55 x 88-inch frame of 6 x 4 light beams of steel from which the four-pallet load is suspended by 3/8-inch wire rope. 325 pounds.	The framework, the wire rope, and the standard pallet edges	None	Shipboard superiority; concept adaptability to existing forklift tines without the frame-work, which would be left shipboard	4 A-4

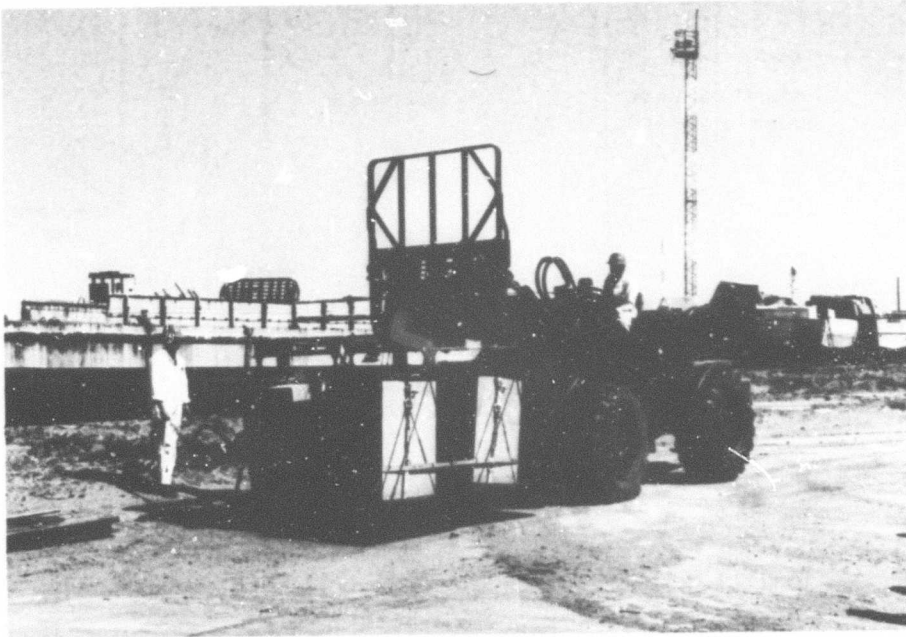


Figure 4. Typical forklift loading of strongback large pallet during initial rigging for test program. (Note standard pallet override.)

TEST PROGRAM

Test Sequence

As a result of the predetermined operational design criteria, an effort was made to investigate critical areas in each design.

A static test was required for the folded-plate pallet, because of the possibility that the folds would creep. The load consisted of four concrete weights, each weighing approximately 2,500 pounds. Each concrete weight was loaded on a standard pallet; a total weight of approximately 2,680 pounds, including the pallet, the payload, and the necessary rigging was obtained. No measurable movement of the folds was noted during a 1-week period of static testing. It is postulated that similar results would have been obtained with a 30,000-pound load, although the test was not actually performed.

The general test program, which was applied to all pallets except the strongback, is illustrated in Figure 5 and described as follows:

1. Lift the fully loaded large pallet with a forklift from the long side of the pallet (48-inch load center) and observe the prototype pallet for any malfunction or excess deformation.

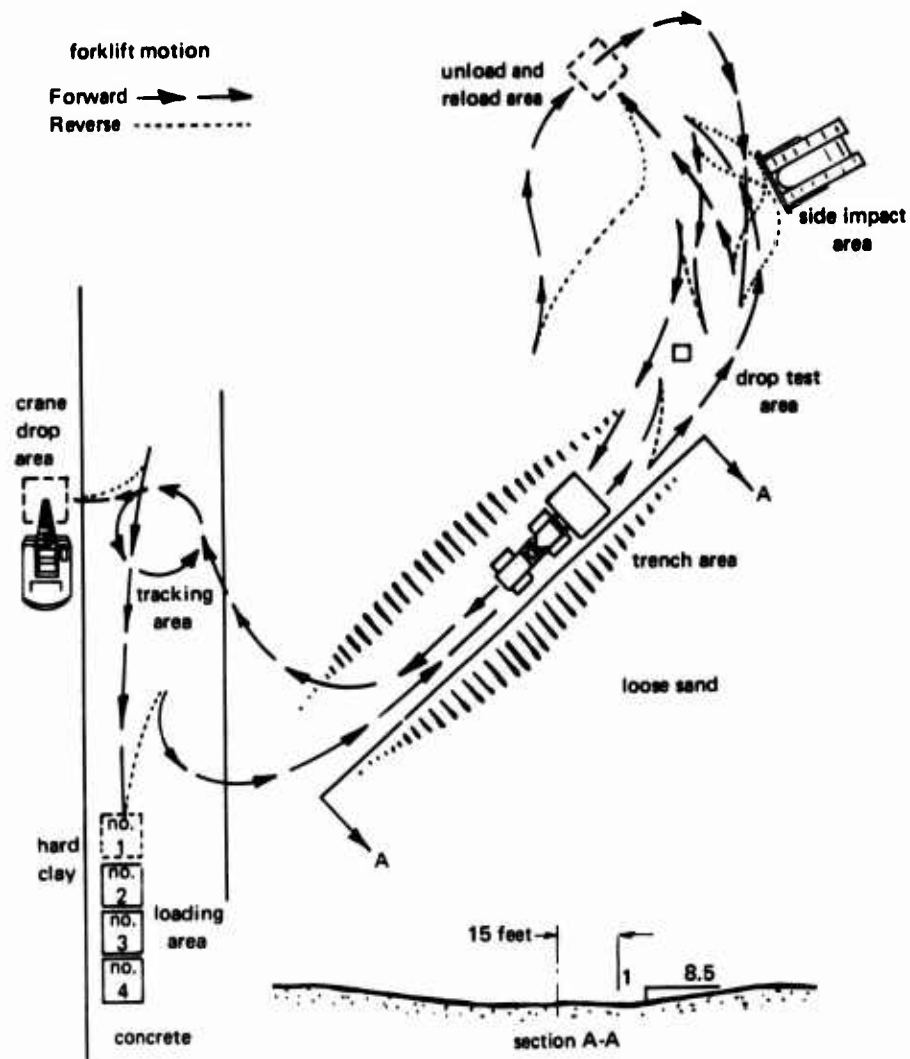


Figure 5. Forklift maneuvering procedure and site description. (Not to scale.)

2. Drive through a beach environment (the trench area) and observe the load, pallet, and forklift reactions.

3. Drop test (free fall) the extreme corner of the loaded pallet while still on the forklift onto a 12 x 12-inch wooden block in a typical beach environment—the block being supported on a concrete slab.

4. Impact the side of the pallet against a rigid body (a bulldozer blade) in an attempt to duplicate what might be typically anticipated when maneuvering in tight quarters.

5. Unload the pallet in a beach environment and reenter the pallet from the short side so that the load center would be in excess of 48 inches.

6. Recycle the previous sequence, one through four, in the reverse order.

7. Test tractability of the pallet by pushing it through a circle on the pavement.

8. Make a four-point lift with a crane to approximately a 5-foot elevation and free fall the load, interrupting the fall sharply before impact with the ground.

9. Repeat the lift to 4 or 5 feet and free fall the loaded pallet to the ground.

Site Description

The loading and tractability portions of the tests were performed on concrete pavement. Both crane operations were conducted on densely compacted clay and the remainder of the test procedure in loose sand. A general schematic of the area and test procedure are presented in Figure 5.

Test Equipment

Performance of the test program depended on two items of heavy equipment. The first of these was the Marine Corps' Adverse Terrain Forklift (shown in Figures 1 through 4), which has a 5-ton capacity at a 48-inch load center and is designated 72-13MP by the Marine Corps and 463L by the Air Force. This forklift, as used in the test program, is equipped with 72-inch tines. The second piece of heavy equipment was a 40-ton tracked crane with a 60-foot boom.

Test Observations

Wooden Pallet. The wooden pallet was tested first and in general performed well.

The lifting of the pallet showed no excessive deformations even though the poor quality of the 4 x 4 construction-grade timbers used in fabrication may have warranted a failure at this point.

Performance of the pallet during the maneuvering stages of the test, both on concrete and loose sand, was satisfactory, although the forklift maneuvered poorly because of the overload conditions (11,320 pounds) under which it operated.

The drop portion of the test was also satisfactory, although failure should have occurred as a result of the dynamic loading of the checked timbers.

The side impact test was poorly performed because of the poor maneuverability of the forklift in the loose sand, since the pallet could not be impacted squarely into the bulldozer blade nor accurately aimed. The forklift is normally steered by rotating the front structure (the portion of the forklift forward of a pivot used to secure it to the main frame of the vehicle), with respect to the main frame. Since most of the weight was on the front axle, little leverage from the main frame could be applied to rotate the front structure, resulting in poor steering capability. Consequently, a lifting eye which protruded beyond the plywood decking of the pallet was torn off. Future design developments of the large pallet should carefully avoid any protrusions.

Tractability of the pallet was excellent with no excessive wear.

Figure 6 illustrates damage to an exterior beam prior to the crane drop tests. This damage is an exaggeration of an initial flaw in the timber that was further developed during the drop tests performed by the forklift.

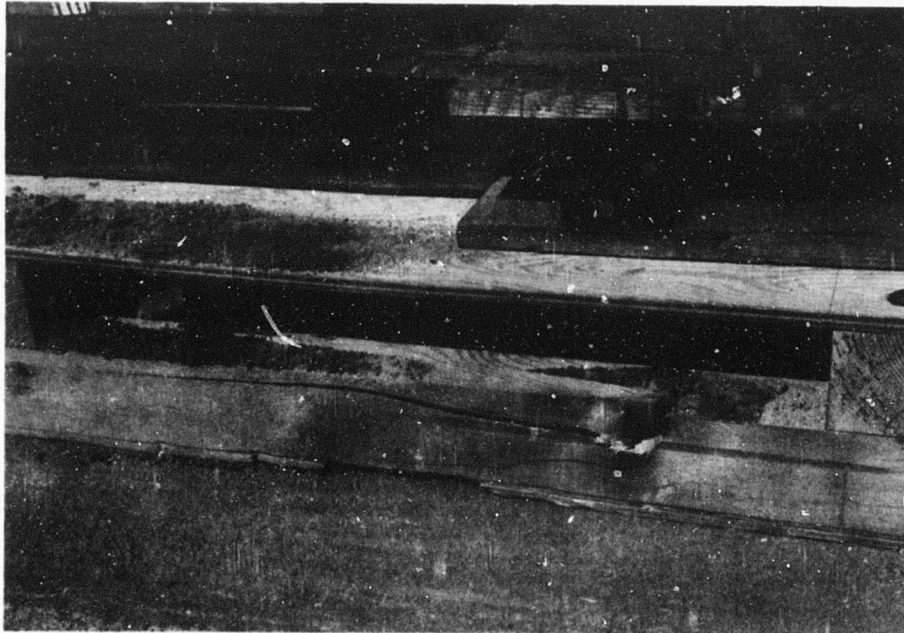


Figure 6. Damage to wooden large pallet prior to the crane drop tests (an exaggeration of initial checks).

The four-point lift test performed on the pallet resulted in excessive deformation in the 4 x 4 beams, although by this time checks were fully visible in the 4 x 4 framework. Lifting the pallet was possible; however, on the first drop the pallet nearly failed in that deflections were excessive. On the second drop failure occurred (see Figure 7). In all cases failure occurred at bolt joints and knots of the 4 x 4's (Figure 8). Several eye bolts failed during the destruction although the lifting eye assembly for the four-point lift performed satisfactorily with only slight indications of shear initiation in the timbers (Figure 9).

Folded-Plate Pallet. The folded-plate pallet was the second to be tested and performed satisfactorily throughout.

The pallet functioned well during the lifting and maneuvering portions of the test.

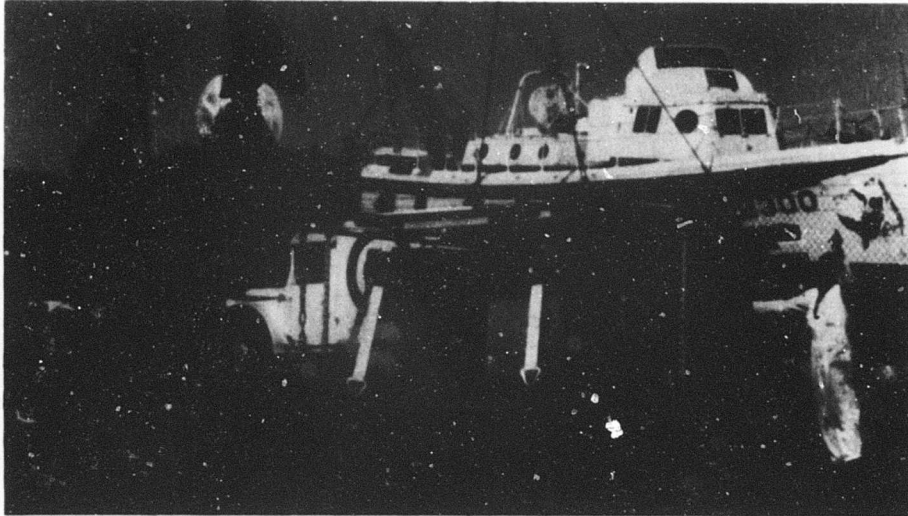
During the drop test its extreme flexibility proved an asset to its life expectancy, but the standard wooden pallets were destroyed (Figure 10a). Failure of the wooden standard pallets was primarily a bearing failure due to stress concentrations developed on the wooden pallet at the breaks (folds) of the folded plate. The extreme flexibility, however, required rigging the pallet several times in the performance of a test program, especially after the standard pallets failed, since the strapping would loosen excessively. Little damage occurred to the large pallet itself during any portion of the forklift operation, although the side gusset plates had buckled.

During the tractability portion of the test, the only problem experienced was the burning away of the paint in the breaks because of the frictional heat developed.

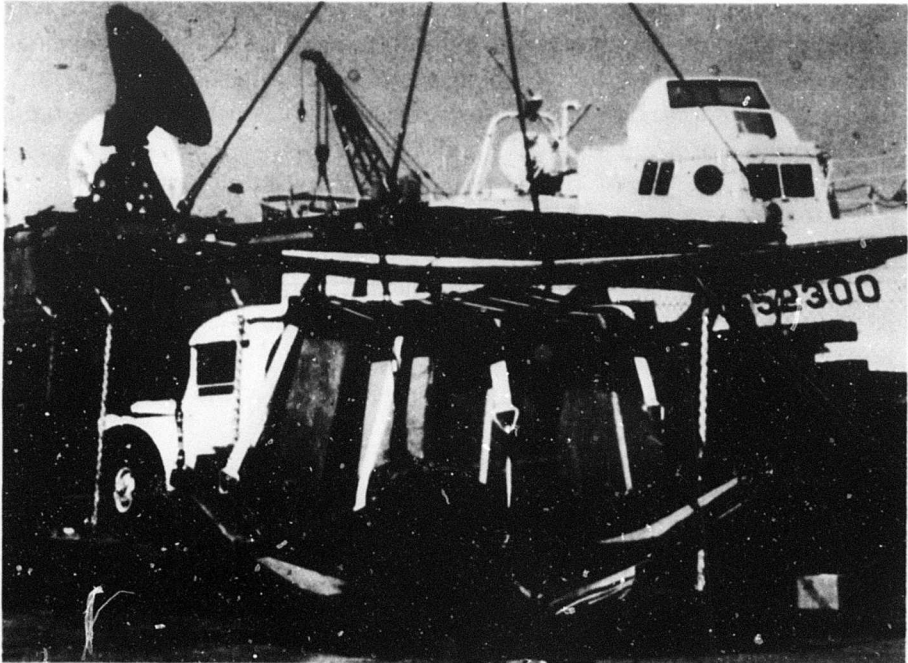
Crane operation with the folded-plate pallet was difficult because of its flexibility. Although it functioned satisfactorily through the series of free falls, damage to the standard pallets was again extensive. The grab-eye lifting points worked exceedingly well in this portion of the test; none failed (Figure 11).

At the completion of the test there was no difficulty in inserting the tines into the large pallet fully loaded for movement to the unloading area.

Aluminum Pallet. The aluminum pallet was the third tested and it performed exceptionally well throughout all portions of the scheduled test. No failure was initiated in any portion of the scheduled program. The pallet failed structurally, however, when a nonscheduled drop test on concrete pavement was performed at the suggestion of the sponsor. Although permanent deformation was evident (Figure 12), damage was neither sufficient to prevent tine insertion nor to deter any functional requirement of the large pallet.



(a) First drop.

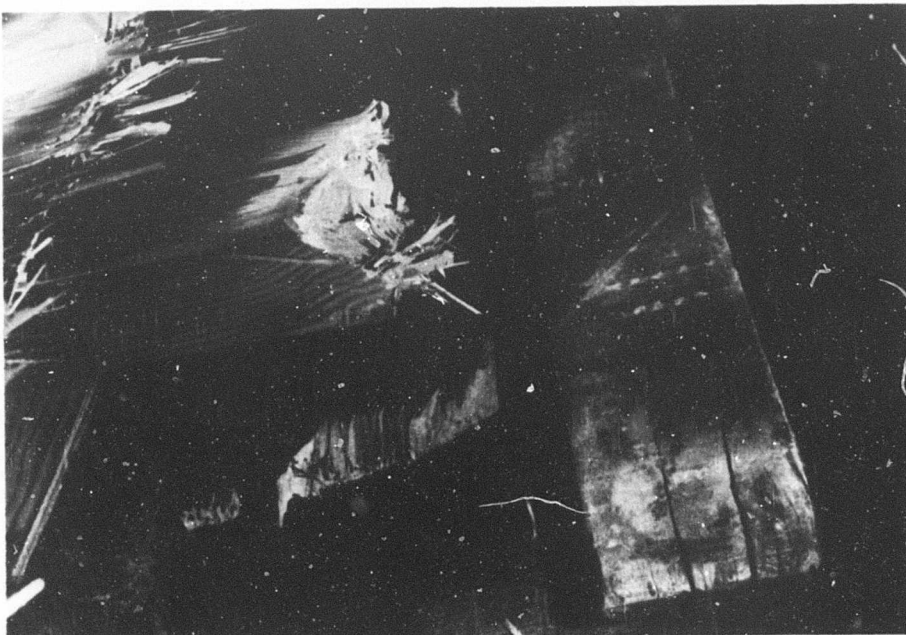


(b) Second drop.

Figure 7. Wooden large pallet during crane drop tests.



(a) At bolt connections.

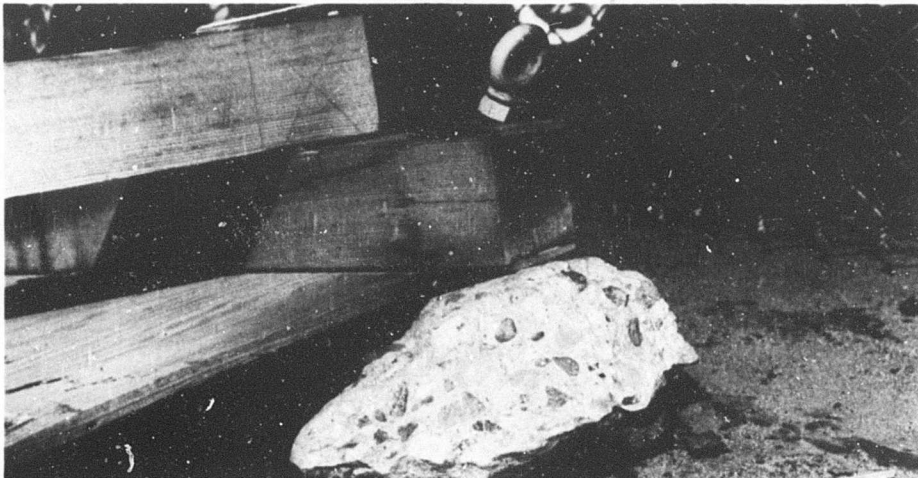


(b) At knots.

Figure 8. Wooden large pallet failures from crane drop tests.



(a) Typical tie-down.

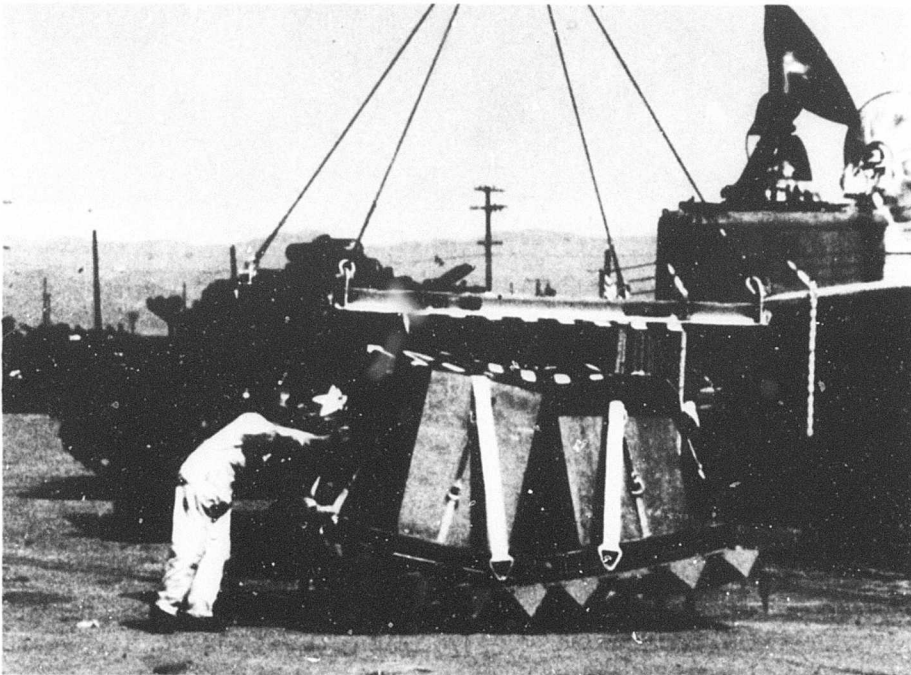


(b) Typical lifting eye.

Figure 9. Damage to tie-down and lifting points of wooden large pallet after crane drop tests.

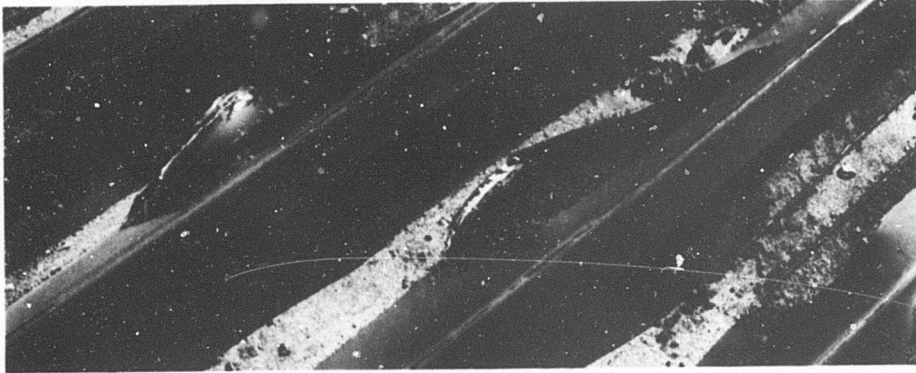


(a) Drop test.



(b) Four-point crane lift.

Figure 10. Flexibility of folded-plate pallet.



(a) Tine opening after first forklift operation.



(b) Grab-eye damage after crane drop tests.



(c) Gusset tear after crane drop tests.

Figure 11. Typical damage to folded-plate pallet.

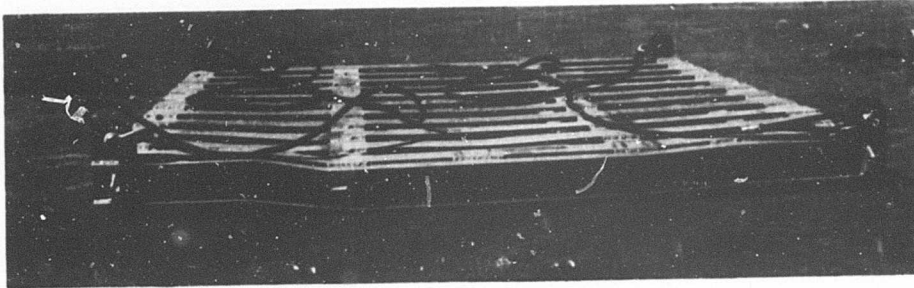


Figure 12. Damage to aluminum pallet after nonscheduled drop test onto 12 x 12-inch wooden block on concrete pavement.

Strongback Pallet. The fourth pallet tested was the Hunters Point Naval Shipyard strongback pallet. It proved to be difficult to rig and unwieldy during the maneuvering tests because of excessive sway. Since it was designed to carry its load in a suspended state with no bottom or side protection, it was not suited for the drop, impact, or sliding portions of the tests. The position of the tines necessary to raise the load off the ground minimizes the stability of the forklift, especially on descending grades. The strongback worked very well during the crane operations, but deformed excessively. Failure was again restricted to the standard wooden pallets, which failed during the rigging and maneuvering portions of the program by impact on each other or by riding onto each other thereby pulling the nails out of the decks.

Summary. A summary of the test results and observations is presented in Table 2. The subjective ratings are meant to show the relative performance of the individual pallets in a particular test rather than to evaluate the overall performance of a pallet during the test program.

DISCUSSION

In summary, the wooden large pallet, with careful quality control in timber selection and construction, may be useful during operations which anticipate no more than a half cycle of the pallet. It was by far the cheapest to produce on a prototype basis, but may be second cheapest in comparison to the folded-plate pallet produced in quantity.

The folded-plate pallet performed well and showed the least damage of all at the conclusion of the tests. It may well prove a useful concept, regardless of size, if its high flexibility can be tolerated or weighed against its compactness in shipping and low cost. It may be further stiffened to meet the user's requirements with little concession of cost, stackability, and

Table 2. Test Results and Observations

Tests	Performance of —				Remarks
	Wooden Pallet	Folded-Plate Pallet	Aluminum Pallet	Strongback Pallet ^a	
Initial lift with forklift	good	good	very good	poor	The rating is influenced to some degree by the operator's confidence in the pallet.
Traffic through sand	good	good	good	poor	The poor maneuverability of the forklift is reflected in the rating given to the swinging load.
Drop test	good	poor	very good	not applicable	—
Side impact	poor	good	good	not applicable	Poor forklift maneuverability is a definite factor in the ability to perform this test.
Unload and reenter pallet in a beach environment	very good	good	good	poor	—
Tractability on pavement	good	good	good	not applicable	—
Crane drop test and snatch before impact	poor	poor	good	good	—
Crane drop test to impact	not performed	poor	good	poor	The wooden pallet was destroyed in the second drop of the previous test.
Static loading (1-week duration)	not applicable	very good	not applicable	not applicable	—
Drop test performed on pavement (nonscheduled)	not applicable	not applicable	good	not applicable	Resulted in permanent deformation, yet pallet retained its functional abilities.

^a All principal load-carrying members were permanently deformed during the tests.

weight. Efforts should be made to optimize the fold number, position and angle of the folds in the horizontal and vertical planes, and the radii of the breaks. Such improvement may negate the problems of rigging and standard pallet failure encountered in this test program.

The aluminum pallet under overall conditions performed most favorably with little or no damage to it during the formal test program.

The strongback pallet has already proven itself superior to the bottom loading pallets for shipboard use but is extremely difficult to handle during forklift operations.

During the test, it was observed that the forklift operator could not easily discriminate between the 8- and 9-foot sides of the large pallet. Since there is only one way four standard 40 x 48-inch pallets can be loaded onto the 8 x 9-foot large pallet, the inability to discriminate the long dimension of the large pallet led to improper assembly, thus causing a delay while the load was reassembled properly. It may be necessary to include markings on the large pallets to assist in identification of the long and short sides.

In general, no pallet was expected to perform well during every phase of the test program. Each had its specific function, as outlined by its specific design criteria, which it performed well. Each illustrated the need for a second-generation prototype if its specific operational function is deemed primary to all others. All but the wooden large pallets exceeded the strength characteristics of their payloads—the standard wooden pallets.

FINDINGS AND CONCLUSIONS

All large pallets tested in this development program are workable. All operate well for their individual design objectives. All have advantages and disadvantages.

The wooden pallet is inexpensive, easily disposable, but requires close quality control in the selection of construction materials. It facilitates handling, since there is no significant distinction between top and bottom. It is very suitable for half-cycle operations.

The folded-plate pallet is inexpensive, easily produced, and highly flexible and resilient. It also has no distinct top or bottom and no protrusions, thus allowing for ease of handling and high-density stacking. In its present configuration it can be handled with a crane, although the high flexibility initiates a high percentage of standard pallet failures.

The aluminum pallet of conventional design is expensive and rigid with a definite top deck. It is easily handled by any piece of equipment normally expected to handle the large pallets.

The strongback pallet is an inexpensive system superior for handling four pallet loads shipboard. It is cumbersome to rig and maneuver with a forklift and is prone to minimize forklift stability.

It is the consumer's position to appraise these advantages and disadvantages at a time when selection criteria can be firmly established, to facilitate optimum utilization of the large pallet concept. To date the operational requirement for the large pallet is not sufficiently defined to establish criteria. Such an appraisal should include a comparison of these concepts with others which may be developed, including alternative means of load consolidation. Such efforts will converge on the most suitable alternative, which will require a second-generation large pallet before production would be warranted.

Appendix A

DETAIL DRAWINGS OF LARGE PALLETS

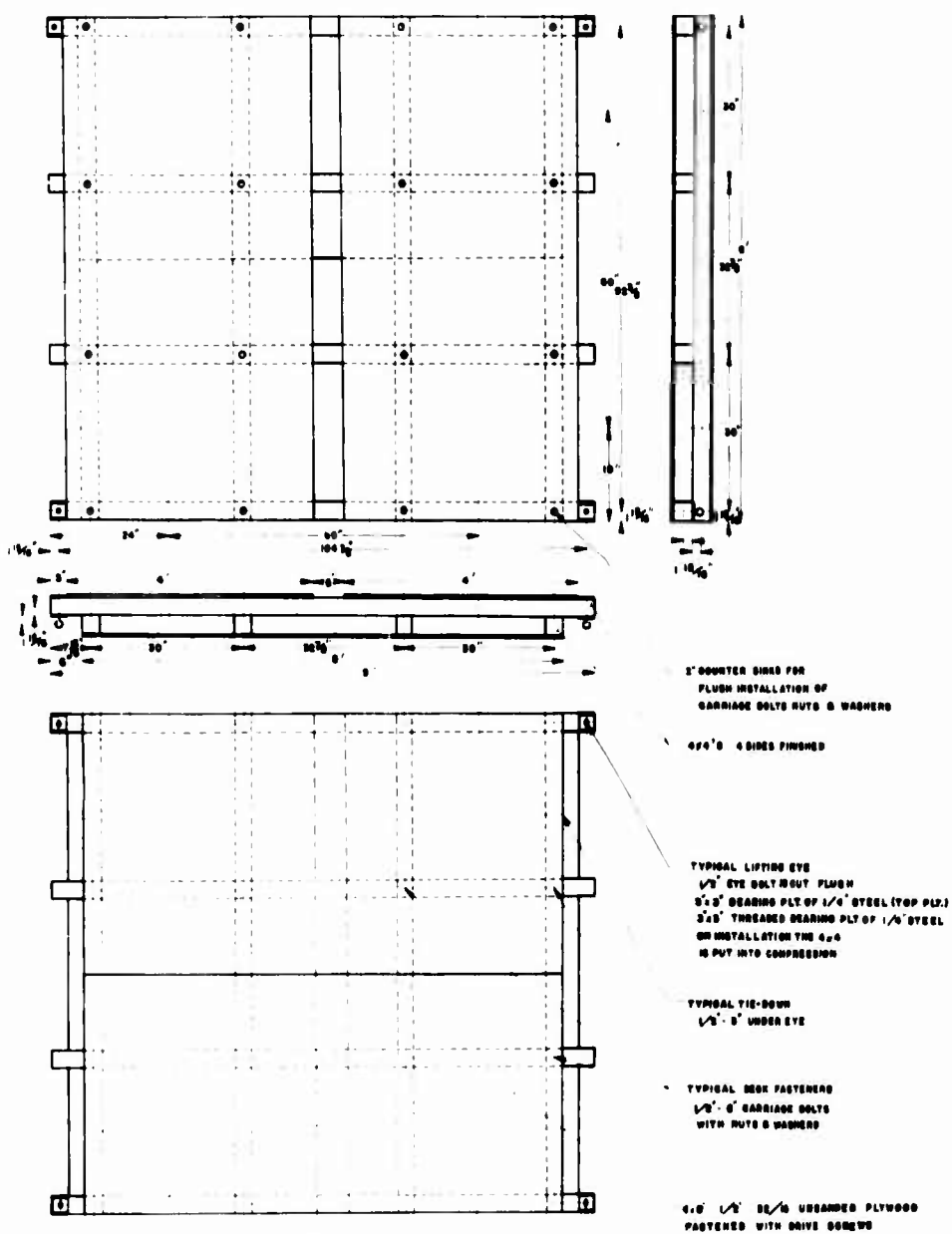


Figure A-1. Wooden large pallet.

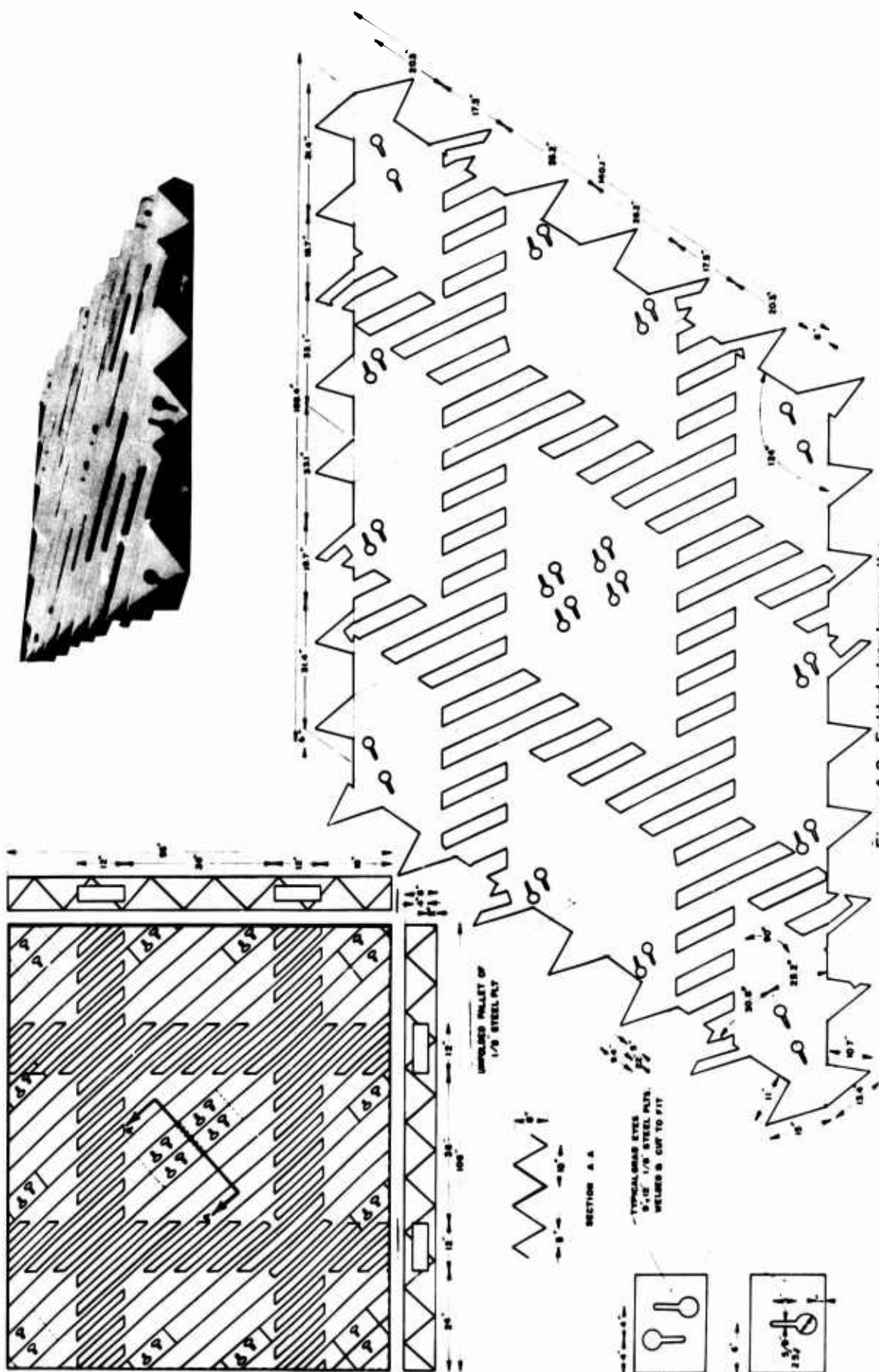


Figure A-2. Folded-plate large pallet.

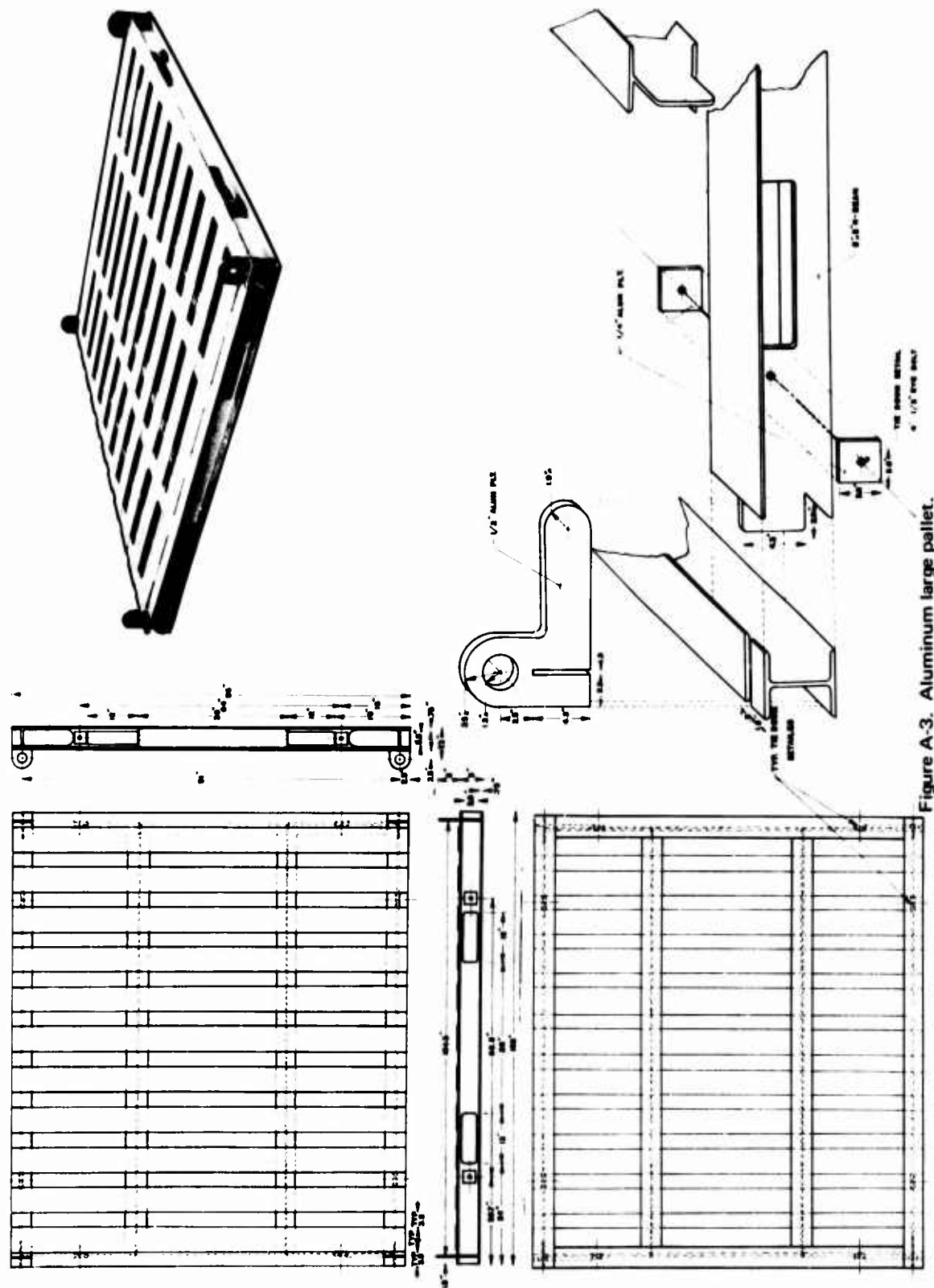
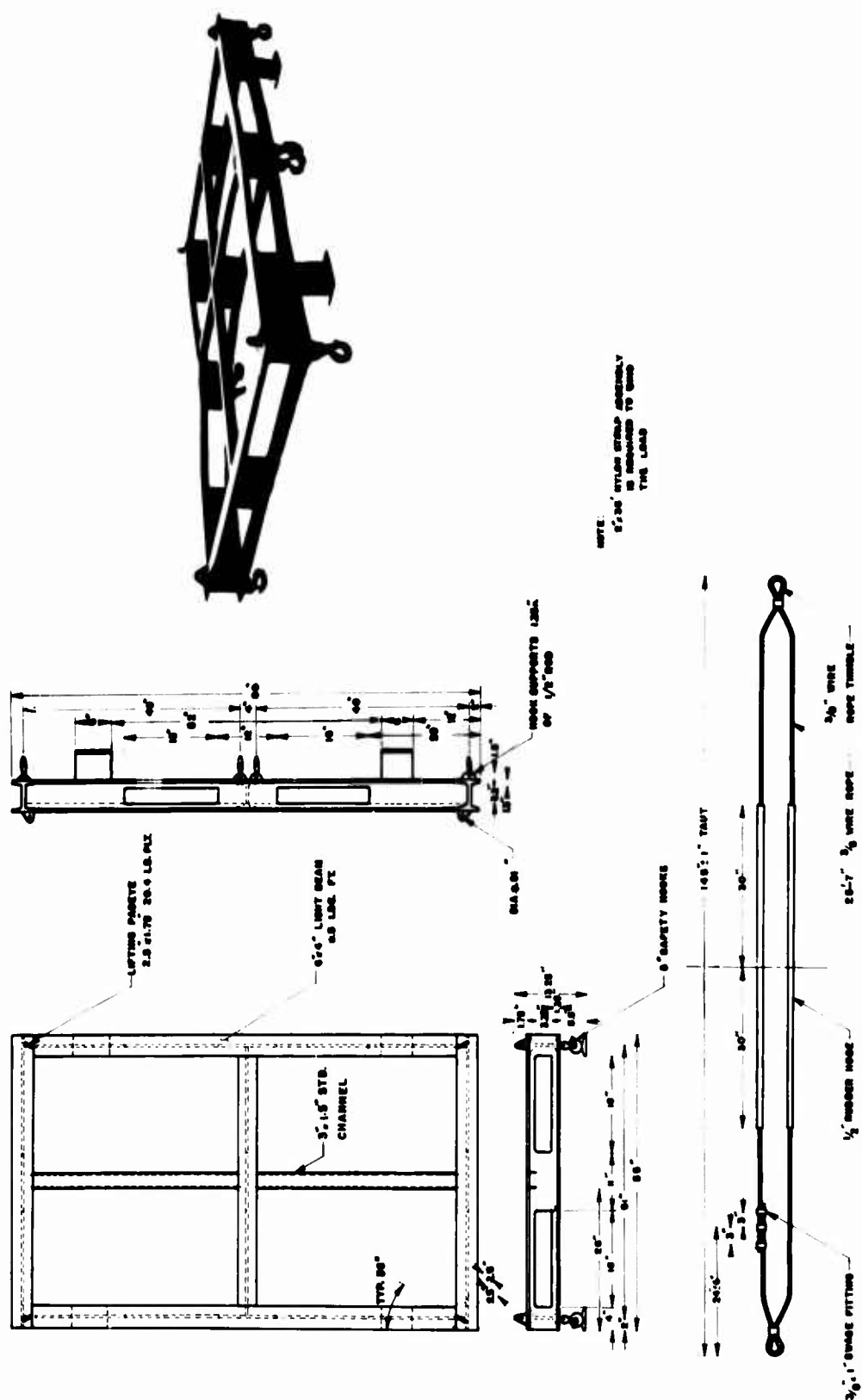


Figure A-3. Aluminum large pallet.



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13. ABSTRACT		
To complement the high speed of the advanced craft being developed by the Amphibious Assault Landing Craft Program, a need exists to consolidate cargo into larger unit loads in order to improve the material handling rates at the terminals of the ship-to-shore cycle. This report documents the design, fabrication, test, and evaluation of four prototype large pallets, 8 x 9 feet in area, each capable of carrying four standard 40 x 48-inch pallets. The prototype pallets include a wooden, a folded-plate, an aluminum, and a strongback design. Each pallet functioned well with respect to its specific design criteria; however, no one pallet was clearly superior to the other three alternatives, and none fulfilled all the design criteria.		

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