AD No. 436409

U. S. ARMY
TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

TRECOM TECHNICAL REPORT 63-41

LIGHTER, AMPHIBIOUS, RESUPPLY, CARGO, 15-TON
(LARC-XV)

ENGINEERING REPORT

Task 1D443012D25605
(Formerly Task 9R57-02-018-05)

August 1963

U.S. ARMY MOBILITY COMMAND

DISCLAIMER NOTICE

* * *

DDC AVAILABILITY NOTICE

Qualified requesters may obtain copies of this report from

Defense Documentation Center
Arlington Hall Station
Arlington 12, Virginia

* * *

This report has been released to the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., for sale to the general public.

* * *

The information contained herein will not be used for advertising purposes.

* * *

The findings and recommendations contained in this report are those of the preparing agency and do not necessarily reflect the views of the U. S. Army Mobility Command, the U. S. Army Materiel Command, or the Department of the Army.

ENGINEERING REPORT

(17) Task 1D443012D25605
~~(Formerly Task 9R57-02-018-05)~~

(19)
(18) ATRECOM Technical Report 63-41

(11) August ~~1~~963

(6) LIGHTER, AMPHIBIOUS, RESUPPLY, CARGO, 15-TON (LARC-XV)

(12) Prepared by

JOHN F. SARGENT, ~~Project Engineer~~
JOHN W. SOBCZAK, Test Engineer

~~U. S.~~ ARMY TRANSPORTATION RESEARCH COMMAND

Fort Eustis, V~~irgini~~a.

CONTENTS

APPENDIXES

ILLUSTRATIONS

Figure Page

Figure Page

TABLES

Table Page

SUMMARY

This report contains the results of engineering tests conducted on the LARC-XV-IX. The objective of the tests was twofold: (1) to determine the adequacy of modifications incorporated after completion of the original engineering tests performed by the contractor and (2) to determine whether the modifications comply with the military and technical characteristics, which are included in Appendix I.

The tests conducted on the LARC-XV-IX were divided into three main categories: static, performance in water, and performance on land. In addition, supplemental tests were conducted to determine (1) the LARC's dynamic stability, (2) the adequacy of the hydraulic system, (3) the degree of torsional vibration, and (4) the engine horsepower. Testing was not as complete as was desired because of weather and lack of time.

The variety of tests conducted necessitated a wide dispersal of test sites. These were located in Bloomington and Crane, Indiana; Yuma, Arizona; and Coronado and Camp Pendleton, California.

The modifications to the LARC-XV prior to the supplemental tests proved satisfactory. Also, subsequent modifications for stability and for hydraulic-system reliability appeared satisfactory (although the usual 1,000-hour test was not completed). Therefore, it is concluded that the production design for the LARC-XV, based on these modifications, will meet most of the military and technical characteristics.

CONCLUSIONS

It is concluded that the LARC-XV as redesigned will meet the military and technical characteristics with the following exceptions:

1. The maximum water speed with the LARC loaded will be approximately 8.5 miles per hour. (The 9.5 miles per hour specified in the military and technical characteristics implies the speed desired when the lighter is loaded.)

2. Transportability of the lighter and overseas shipment will be difficult, even under favorable conditions, with the widened beam of 14 feet 7 inches.*

3. The cooling systems can operate at an ambient temperature of 95° F. without producing any adverse effects. (The capability of the cooling systems to operate in ambients of 115° F. is unknown.)

4. A cold-weather starting kit for each LARC-XV-IX is a distinct requirement according to design calculations.

5. Smaller capacity engines could be used to power the LARC-XV if engine life is ignored.

6. The suppression of radio interference did not meet military requirements in the conductance phase at very low frequencies; however, this will not affect the LARC's communication equipment.

---

* 14 feet 7 inches--true overall width on land, including tire bulge; 14 feet 6 inches--true overall width in water, over rub rails; 14 feet--dimension of modified molded beam ("14-foot beam" has been used as nomenclature, in general, throughout this report).

BACKGROUND

Task 9R57-02-018-05 (subsequently designated Task 1D443012D25605) was initiated by the U. S. Army Transportation Research Command (USATRECOM) to meet a requirement of the Department of the Army for the design and construction of amphibious lighters for over-the-shore operations (see Appendix II). In June 1958, Contract DA 44-177-TC-479 was awarded to Ingersol Kalamazoo Division of Borg-Warner Corporation, Kalamazoo, Michigan, for the construction of a 5-ton and a 15-ton lighter (the LARC-V and the LARC-XV). The contract was later amended to include the construction of two additional LARC-XVs. A fourth LARC-XV was constructed under a separate contract with the same company for the Federal Republic of Germany.

The LARC-XV-IX (the first LARC that was constructed) was completed in late December 1959. The contractor's engineering tests, excluding stability and surf tests, were completed in October 1960. The Jennerstown brake tests were conducted on the LARC-XV-2X in May and June of 1960, and the LARC-XV-3X crossed Lake Michigan under its own power on 6 July 1960.

The LARC-XV-IX suffered damages during a rail shipment and consequently was deadlined until January 1961 while awaiting adjudication and repair. In February 1961, the original contract was modified to authorize changes determined to be necessary as a result of field usage. Contractual entanglements involving the LARC-XV-IX with the LARC-XV-4X slowed progress somewhat. In April 1961, a contract was awarded to Cummins Engine Company for the installation of its diesel engines in the LARC-XV-1X. Upon completion of work at Ingersol Kalamazoo Division in August 1961, the LARC-XV-1X was trucked to Cummins Engine Company, where the engine installations were completed in October 1961. Run-in tests were conducted at nearby Bloomington, Indiana, where transmission failures delayed schedules. Next, the LARC-XV-1X was shipped by rail from Crane, Indiana, to Yuma, Arizona. Severe storms caused sand drifts, which hindered land-gradient tests; the relatively mild temperatures caused by the storms prevented hot-weather tests; and the combination of storms and cool weather hardened the land dynamometer course to the extent that mobility tests had to be canceled. By the time the lighter arrived on the California coast, the surf season had abated to a point where 12-foot plunging breakers, a condition required by the military characteristics, were not forecast. Following limited testing at this site, a decision was made to assign the LARC-XV-1X to a missile recovery mission at Cape Canaveral, Florida, and not to wait for surf trials. In May 1962, the LARC-XV-1X was shiploaded for Florida, where tests were later resumed.

Modifications that were performed after completion of the initial engineering tests included the following: dieselizing and the associated relocating of components for trim adjustment, replacing double disc-type brakes operating off a master cylinder static system with a spot disc-type brake operating off a power boost system, strengthening drive shafts and universal joints, matching the dieselized power train to the performance requirements, and redesigning the cab and associated controls.

Upon arrival of the LARC-XV-1X at Cape Canaveral, Florida, the beam was widened from 12 feet 7 inches to 14 feet 7 inches (overall), and the open-center hydraulic system was changed to a closed-center system with a variable-stroke piston pump. Results of an abbreviated test on the modification to the beam are reported in Determination One of Supplemental Tests, page 111 in this report, but insufficient data were available to report on the modifications to the hydraulic system.

DESCRIPTION OF LARC-XV-1X

The LARC-XV-1X is shown in Figures 1 through 6. A detailed description of the lighter itself (with the original beam), its components, and the various systems used in the LARC-XV-1X follows the illustrations.

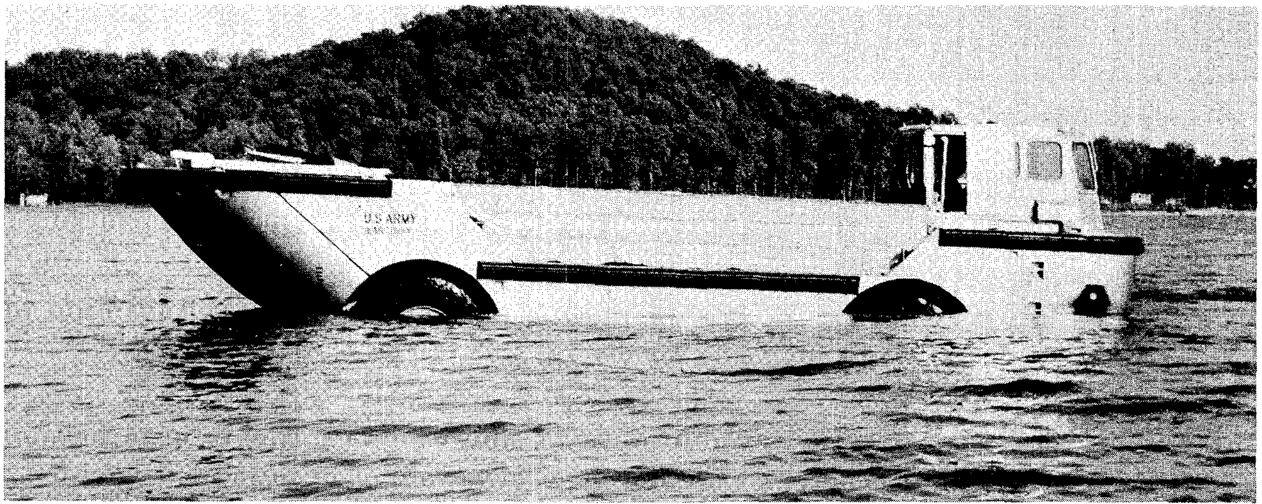


Figure 1. Side View of LARC-XV-1X in Water.

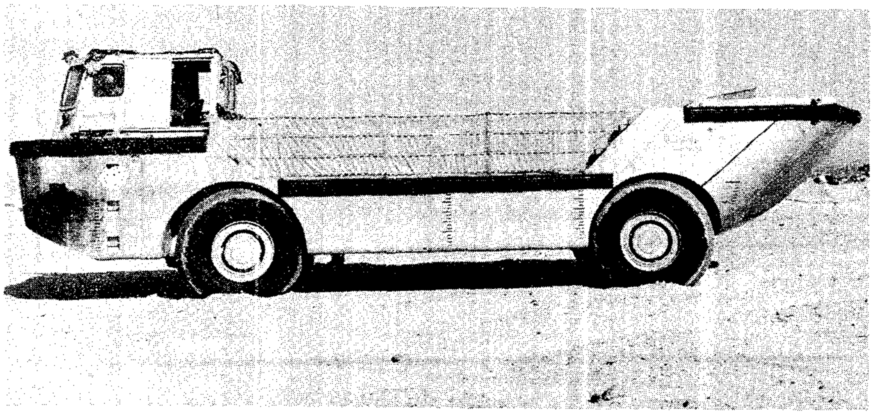


Figure 2. Side View of LARC-XV-1X on Land.

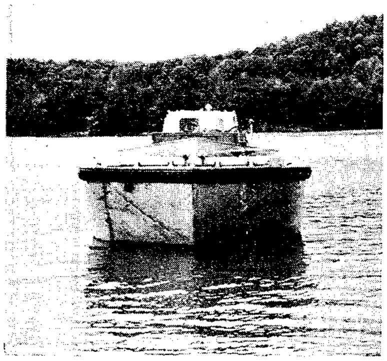


Figure 3. Bow View of LARC-XV-1X in Marine Operations.

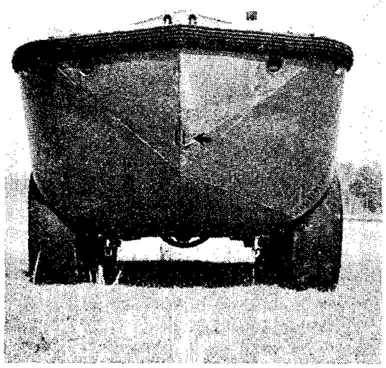


Figure 4. Rear View of LARC-XV-1X in Land Operations. (Bow of lighter in marine operations. Arrow indicates drainage slots at exposed cavity for ramp extension cylinders.)

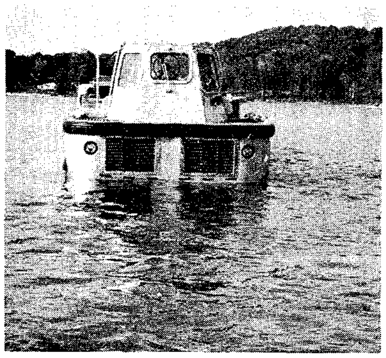


Figure 5. Stern of LARC-XV-1X in Marine Operations.

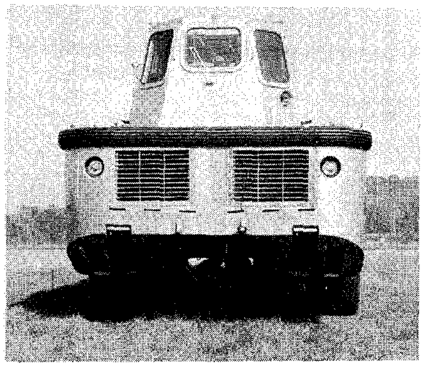


Figure 6. Front View of LARC-XV-1X in Normal Land Operations. (Stern of lighter in marine operations.)

DESCRIPTION OF LIGHTER

Overall Dimensions*

Length	45 feet
Width	12 feet 7 inches**
Height	13 feet 7 inches

Dimensions of Cargo Space*

Height of cargo deck	6 feet 2 inches
Unobstructed length	23 feet 11 inches
Width inside flex bulwarks	10 feet
Depth to top of flex bulwarks	3 feet 3 inches
Unobstructed volume	780 cubic feet (approximately)
Total available volume	840 cubic feet (approximately)

Ground Clearance Necessary

At propeller shroud	16 inches
At hull bottom	2 feet 5 inches
Angle of approach (cab end)	25 degrees
Angle of departure (ramp end)	34 degrees

---

* When tire pressure equals 25 psi aft and 15 psi forward.

** 12 feet 7 inches--true overall width on land, including tire bulge; 12 feet 6 inches--true overall width in water, over rub rails (as specified in military characteristics); 12 feet--dimension of molded beam ("12-foot beam" has been used as nomenclature, in general, throughout this report).

Weight Capacity

Net (curb)	44,600 pounds
Payload	30,000 pounds

Speed

Land	31.7 miles per hour (maximum)
Water	10 miles per hour (maximum)

Miscellaneous

Hull	Welded aluminum, type 5086 and 5083
Wheels	4
Tires	24:00 x 29 (16-ply rating)
Crew	3
Propeller	4-blade, 36-inch diameter by 34-inch pitch

DESCRIPTION OF LIGHTER COMPONENTS

Engines (two)

Manufacturer	Cummins Engine Company
Model	VINE
Displacement	785 cubic inches
Type	Diesel, 4-cycle, V-8, naturally aspirated
Rating	300 horsepower at 3,000 rpm
Weight	1,775 pounds (excluding alternator, exhaust manifold, lube filter, fan and fan hub, and flywheel dampener)

Transmissions

Forward-Reverse Transmission and Torque Converter

Manufacturer	Borg-Warner Corporation
Torque-converter stall ratio	3.50:1
Forward and reverse ratio	1.00:1

Transfer Transmission

Low-range ratio	1.679:1
High-range ratio	.667:1
Marine-drive ratio	3.384:1

Differential Transmission

Differential	Spicer Model Power-Lok
Drive ratio	1.658:1

Final Drives

Wheel Angle Drive

Ratio	3.545:1

Wheel Planetary

Manufacturer	Clark Equipment Company
Ratio	4.667:1

DESCRIPTION OF SYSTEMS

Electrical System

Voltage alternators (two)	24 volts
Manufacturer	Curtiss-Wright Corporation
Rating	125 amperes each

Hydraulic System (Actuates steering, braking, ramp, and bilge system)

Pressure	2,250 psi (maximum)
Flow available	70 gpm (maximum)

Steering System

Land

Hydraulic
Selective 2-wheel (cab end)
4-wheel track, or 4-wheel oblique

Water

Combined rudder and wheels

Braking System

Service Brakes

Hydraulic
Spot disc
Power boost off hydraulic system pressure

Parking Brakes

Mechanical

Armament System	None
Suspension System	Rigid

CAPACITIES OF SYSTEMS

Fuel (diesel oil)

Usable	435 gallons (approximately)
Total	476 gallons (approximately)

Hydraulic Oil

Reservoir	35 gallons (approximately)
Total	50 gallons (approximately)

Lube Oil

Engine	4-1/2 gallons
FNR transmission	8 gallons
Transfer transmission and differential	6-1/2 gallons
Differential ends	1 gallon each
Wheel angle drive	3 gallons each
Wheel planetary	3.5 gallons each

Cooling System	32-1/2 gallons of water, each engine

TEST PROCEDURES AND RESULTS

The LARC-XV Test Team was organized to conduct a combination of tests at the following sites for the periods specified:

Lake Lemon, Bloomington, Indiana	5 Oct - 25 Oct 1961
Crane Naval Depot, Crane, Indiana	25 Oct - 5 Nov 1961
Yuma Test Station, Yuma, Arizona	9 Nov - 14 Dec 1961
Coronado, California	2 Jan - 28 Feb 1962
Camp Pendleton, California	28 Feb - 14 May 1962

Equipment and instruments used to record the test data are shown in Figures 7 through 14.

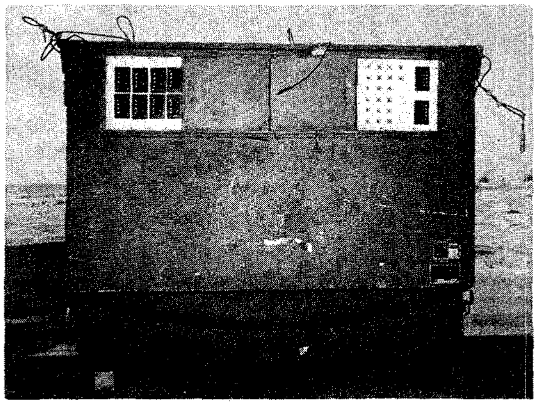


Figure 7. Instrument Shelter Used During Tests.

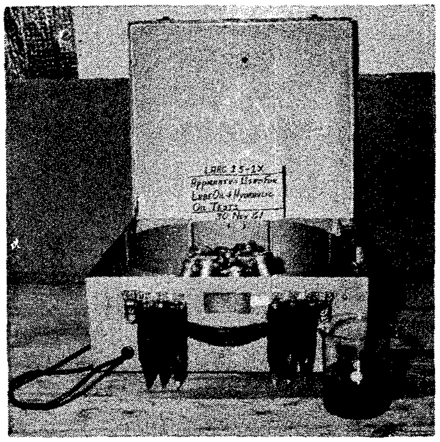


Figure 8. Centrifuge Used To Determine Contamination of Lube and Hydraulic Oils.

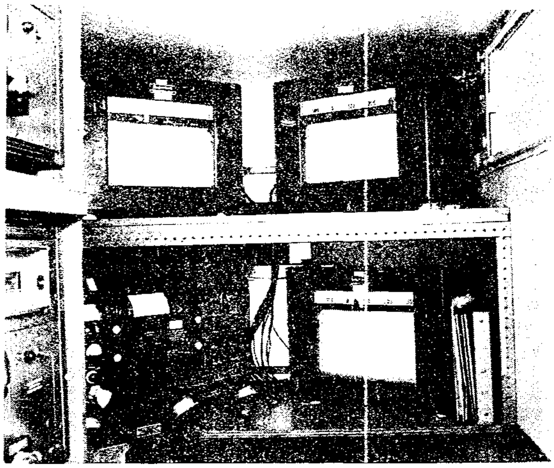
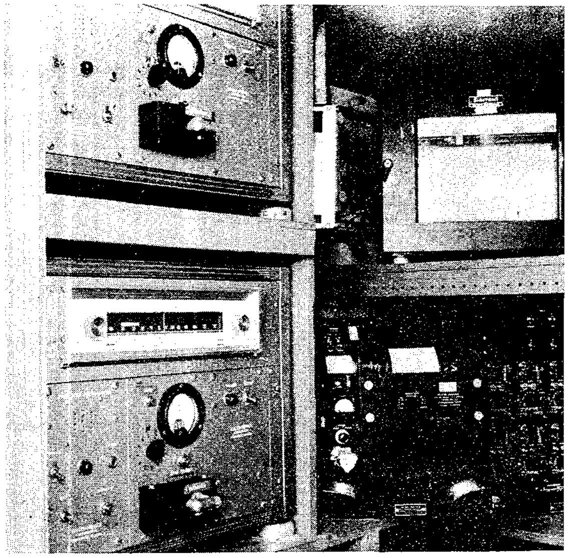


Figure 9. Interior of Instrument Shelter. (The three similar recorders are temperature measurement units.)

Figure 10. Interior of Instrument Shelter. (The two units on left are receivers for torque signals and were used in conjunction with unit in lower right corner.)



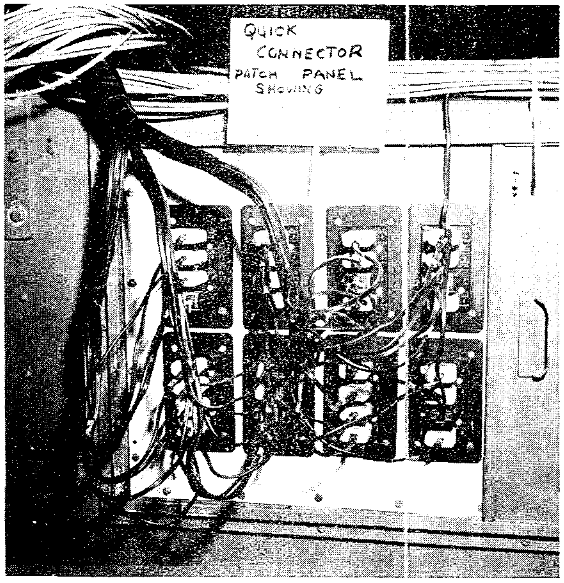


Figure 11. Patch Panel for Thermocouples on Instrument Shelter.

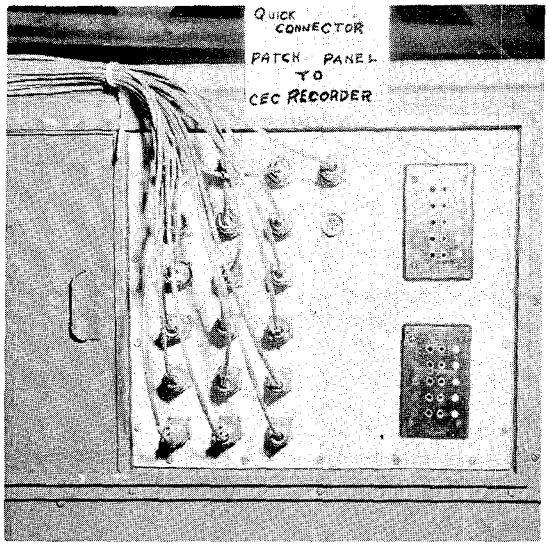
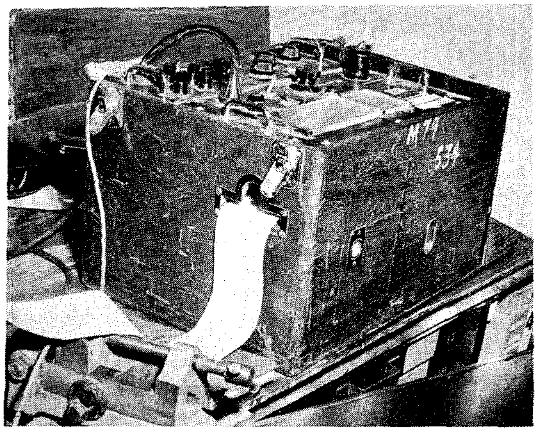


Figure 12. Patch Panel Showing Pickups for Various Temperatures Recorded on Oscillograph in Shelter.

Figure 13. Recorder Used for Measuring Loads During Weight, Pull, and Stability Tests.



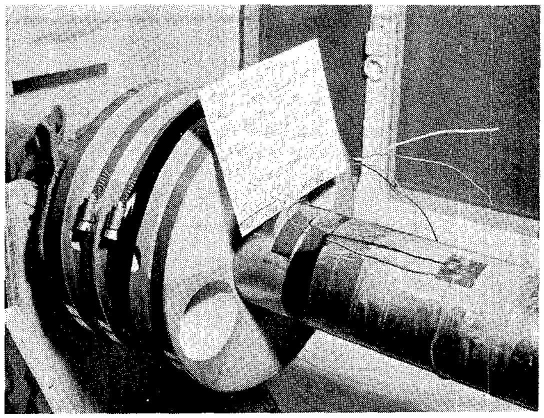


Figure 14. Installation of Sending Unit Used for Torque Measurements. (Engine drive shaft shown with transmitter and battery installed in wooden block.)

PHASE I - STATIC TESTS

DETERMINATION ONE. Overall Measurements

Procedure

The LARC, at curb weight (tanks topped), was parked on a hardstand at Columbus, Indiana, so that measurements of the lighter could be made. The tires were inflated to 15 psi at the ramp end and to 25 psi on the cab end. The measurements obtained are as follows:

Overall length	45 feet
Overall width	12 feet 7 inches
Overall height	13 feet 7 inches
Height to cab deck	8 feet 5-3/4 inches
Height to cargo well deck	6 feet 2 inches
Width of ramp opening	9 feet
Ground clearances	
At propeller shroud	16 inches
At hull bottom	29 inches
Angle of approach (cab end)	25 degrees
Angle of departure (ramp end)	34 degrees

DETERMINATION TWO. Weights of LARC-XVs

Procedure

Weight tests of the LARC XVs were conducted at the U. S. Naval Repair Facility in San Diego, California. The net weight was determined with all tanks and systems filled to capacity. A 100-ton traveling gantry was used to lift the lighter; the lift was made at the four lifting eyes. A 50,000-pound load cell was inserted at the junction of the lifting cables. Load-cell calibration was checked with known shipyard weights. The crane lifted the lighter three times; each time, the lighter was placed on the ground before it was reweighed. The weight was then recorded when the lighter was free of the ground and in a steady position (see Figure 15). At Cape Canaveral, Florida, the LARC-XV-1X, with its beam widened from 12 feet to 14 feet for increased stability, was weighed. For comparative purposes, the LARC-XV-2X (12-foot beam) was also weighed with and without the installed crane for missile recovery.

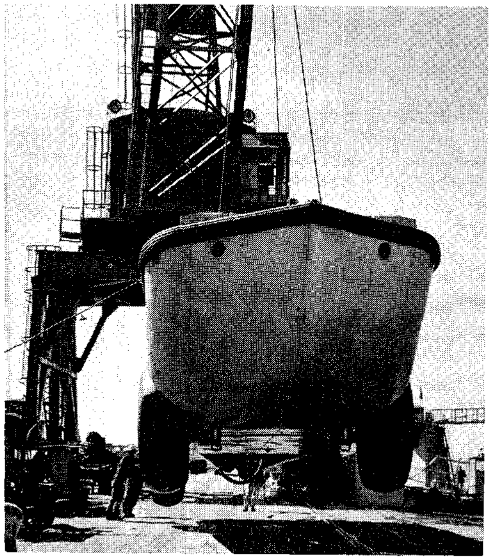


Figure 15. LARC-XV-IX Being Weighed at U. S. Naval Repair Facility, San Diego, California.

Results

The weights of the LARC-XVs are shown in Table 1.

TABLE 1
NET WEIGHT WITH TANKS AND SYSTEMS FILLED

Item Weighed	Weight (lb.)	Remarks
LARC-XV-1X	44,600	12-ft. beam
LARC-XV-1X	46,800	14-ft. beam
LARC-XV-2X	43,475	12-ft. beam, without crane
LARC-XV-2X	45,100	12-ft. beam, with crane

Procedure

Tests to determine axle weights were conducted at Coronado, California. One axle was placed on a concrete hardstand approximately 10 inches above ground level, and the lighter was then lifted to a level condition; thereupon, the weight was recorded by a load cell inserted in the lifting cable. The configuration of the lighter necessitated extreme caution in handling the lighter at extreme angles of lift to prevent damage to stern and cab windows. The degree of levelness was measured by plumb bobs and carpenter's levels. Weights were recorded for angles greater and less than level. These weights are recorded in Table 2.

TABLE 2
AXLE WEIGHTS

Trial No.	Lifting Force (lb.) Recorded	Lifting Force (lb.) Corrected	Lifting Angle (deg.) Plumb Bob	Lifting Angle (deg.) Carpenter's Level	Remarks
1	15,500	16,000	0	0	Lifted bow end
2	15,000	15,500	8.5	8.3	" " "
3*	14,500	15,000	18.7	18.5	" " "
4	16,000	16,500	-1.2	-1.0	" " "
5	28,000	29,000	-1.2	-.75	Lifted stern end
6	26,400	27,400	6.4	6.5	" " "
7**	26,200	27,100	8.9	8.5	" " "
8	27,500	28,500	0	0	" " "
9	16,500	16,800	-1.2	-.75	Confirming run; lifted bow end
10	43,000	44,600	-	-	LARC lifted clear of ground

*Maximum angle of lift due to limited clearance (4-7/16 inches) of stern from ground.
**Maximum angle of lift due to limited clearance (approximately 3 inches) of lifting cables from cab windows.

Procedure

Certain components, including the engines, were weighed at Columbus, Indiana, prior to installation. These were weighed in the dry condition by a balance scale.

Results

The weights are recorded in Table 3.

TABLE 3
WEIGHTS OF COMPONENTS IN DRY CONDITION

Description	Weight (lb.)	Remarks
Fuel cell, original	9	
Fuel cell, new	14	
Radiator, original	135	Without top tank
Radiator, new	126	Without top tank
Radiator fan, original (steel)	9	
Radiator fan, new (steel)	19-1/2	Steel type was subsequently replaced with aluminum type weighing 7 pounds
Curtiss-Wright alternator, model 14Y05, 100 amperes	14	
Curtiss-Wright alternator, model 14Y11, 125 amperes	25	
Flexible coupling, complete	68	
Stearnes magnetic clutch	26	In-line type
Exhaust pipe and muffler	57	Port side only
Exhaust muffler	21	
Cummins engine, main coolant pumps	30	With connections
Heat exchanger		
Hydrotarder	38	
Main engine lube	18	
Torque converter	58	
Hydraulic oil	18	

TABLE 3 - contd.

Description	Weight (lb.)	Remarks
Fuel oil flow tank	7-1/2	
Secondary oil filter	25	
Fuel oil filter	11-1/2	
Corrosion inhibitor for coolant	4-1/2	
Engine lube oil filter	15	
Regulator and condenser	6-1/2	With bracket
Tire and rim only	1,440	
Cab	1,400	
Cummins diesel engine, 300 hp at 3,000 rpm	1,723	Excludes alternator, 25 engine mounts, 25 lb.; water-jacketed exhaust manifold, 25 lb.; lube filter, 25 lb.

DETERMINATION THREE. Center of Gravity

Procedure

The suspension method of determining the center of gravity, which is based upon the fact that a vertical line through the point of suspension will pass through the center of gravity of a freely suspended mass, was rejected because of the difficulty of obtaining adequate lifting gear for an item the size of the LARC-XV. Instead, the reaction method was employed; this system is based upon the fact that the sum of moments about an axis of rotation is zero as long as the body is in static equilibrium. By knowing the horizontal center of gravity, an equation can be established. By defining an equation involving the inclined center of gravity, a second equation is established. The intersection of curves defined by these two equations establishes the center-of-gravity point.

Data for the second equation were obtained as follows: The lighter was raised to an arbitrary height at one axle, and the load on the grounded axle was measured. (See preceding Determination Two.) With this measurement, a line perpendicular to the ground through the center of gravity could be defined by taking moments about the point of lift. Simultaneous solution of the two equations located the center of gravity. As with any tests for determining center of gravity, minor uncontrollable errors were introduced; in this case, the main error was the shift of fluids when the lighter was elevated. This was minimized by quickly elevating the LARC and noting the initial load-cell reading and then by closely watching the oscillograph for a slow deviation from that reading which would be indicative of drainage away from the elevated end; this made possible the selection of the highest true value.

Figures 16 and 17 show the lighter being lifted during tests for determining the center of gravity. The sketches in Figures 18, 19, 20, and 21 illustrate the test setups and the data on which the equations are based.

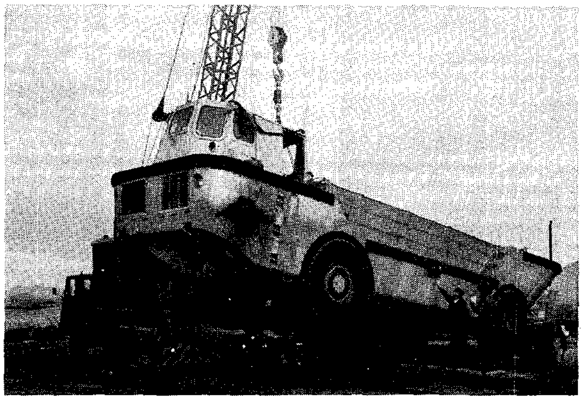


Figure 16. Aft End of Lighter Being Lifted During Determination of Longitudinal Center of Gravity.

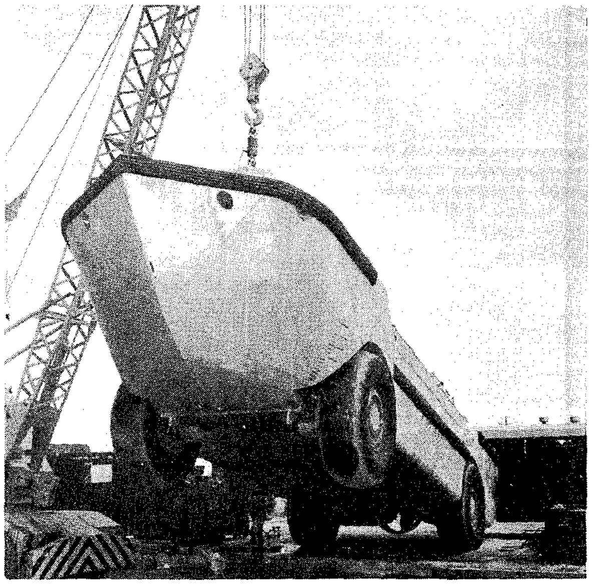


Figure 17. Forward End of Lighter Being Lifted During Determination of Longitudinal Center of Gravity.

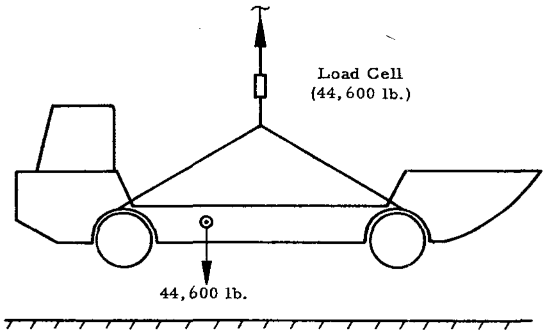


Figure 18. Test Setup for Weighing Entire Vehicle.

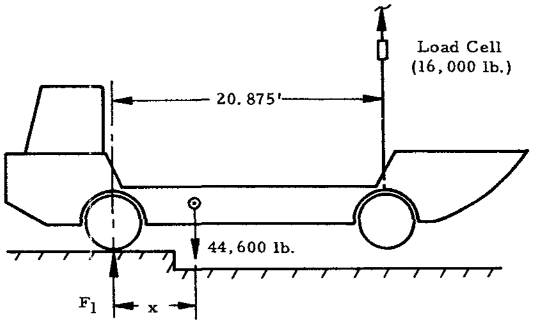


Figure 19. Test Setup for Determining Weight on Front Axle.

Horizontal Center of Gravity

Moments about A:

$$\Sigma M_A = 16,000(20.875) - 44,600(x) = 0$$

$$x = \frac{16,000(20.875)}{44,600} = 7.506 = 7 \text{ ft. } 6 \text{ in.}$$

Summation of forces in vertical direction:

$$\Sigma F_V = 44,600 - 16,000 - F_1 = 0$$

$$F_1 = 44,600 - 16,000 = 28,500 \text{ lb.}$$

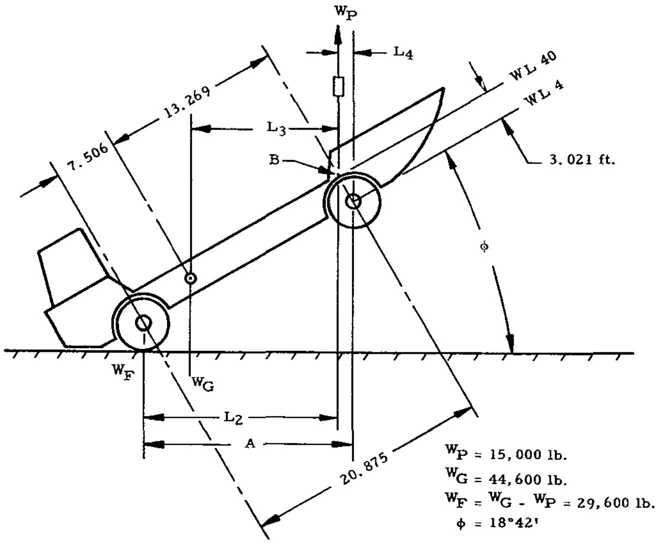


Figure 20. Test Setup for Determining Vertical Center of Gravity.

Vertical Center of Gravity

$$\Sigma M_B = W_G(L_3) - W_F(L_2) = 0 \qquad (1)$$

where

$$L_3 = \frac{W_F(L_2)}{W_G} \qquad (2)$$

From the geometry of Figure 20,

$$L_4 = 3.021 \sin 18^{\circ}42' = 3.021(0.32062) = .9685 \text{ ft.}$$

$$A = 20.875 \cos 18^{\circ}42' = 20.875(0.94721) = 19.773 \text{ ft.}$$

$$L_2 = A - L_4 = 18.805 \text{ ft.}$$

From equation (2),

$$L_3 = \frac{29,600(18.805)}{44,600} = 12.4804$$

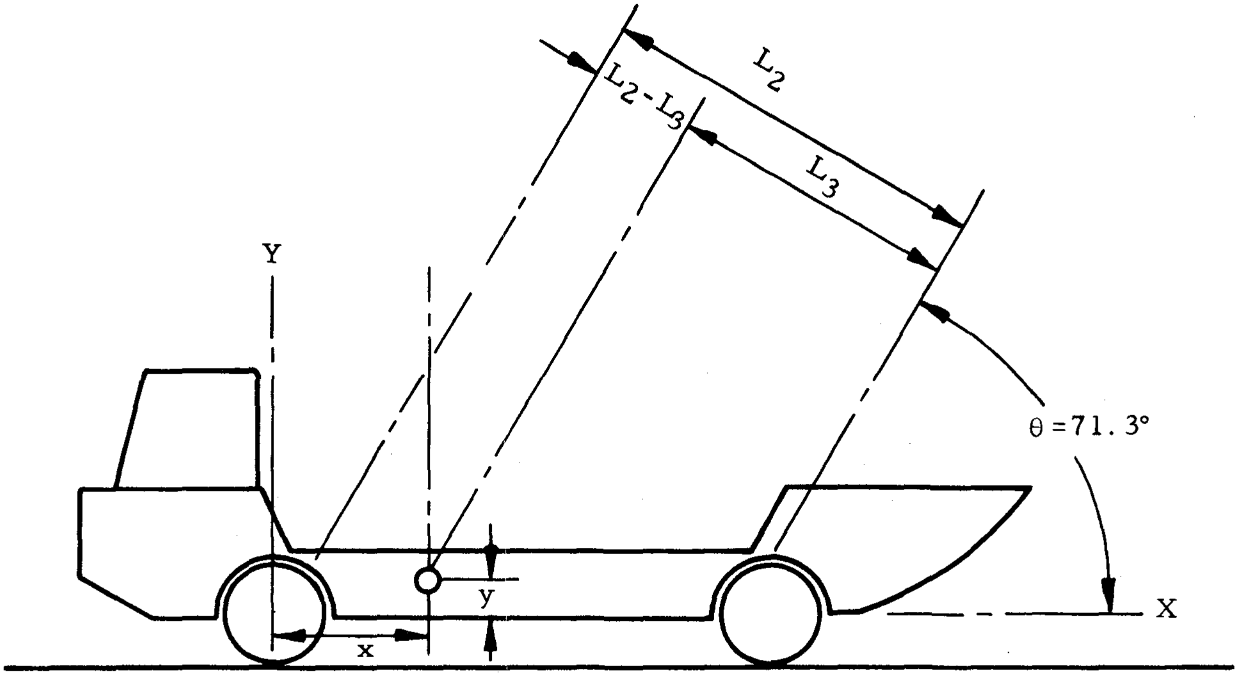


Figure 21. Test Setup for Determining Vertical Center of Gravity, Resolved Into Horizontal Plane.

$L_2 - L_3 = 18.805 - 12.4804 = 6.325$

$$x = \frac{6.325}{\cos 18.7^{\circ}} = \frac{6.325}{0.94721} = 6.673$$

$m = \tan 71.3 = 2.954$ = slope of all force lines

By substituting the above values in the general equation for the line W_G,

$$m = \frac{y - y_1}{x - x_1} ,$$

the following equation is obtained:

$$m = 2.954 = \frac{y - 0}{x - 6.673}$$

or

$$y = 2.954x - 19.715.$$

At $x = 7.506$, y has a value of 2.495 ft. = 2 ft. - 5-1/2 in.

The preceding center-of-gravity determinations were made by using the 4-inch water line between the forward and aft wheels as a reference. Therefore, the vertical center of gravity has a value of 2 ft. 5-1/2 in. + 4 in. = 2 ft. 9-1/2 in. from the hull bottom.

Results

The center of gravity of the LARC-XV-1X with tanks and systems filled was found to be 2 feet 9-1/2 inches above the hull bottom and 7.506 feet forward of the cab-end-wheels center line.

DETERMINATION FOUR. Structural Strength

Procedure

The towing eyes were tested on land and in the water, with the LARC fully loaded. (The maximum forces are recorded under land drawbar pull tests in Table 51.)

Results

An inspection of support structure after repeated tests revealed no indications of weakness.

Procedure

The mooring bitts were subjected to full side thrust from the lighter during the bollard pull tests and the towing tests. Forces involved are recorded under those tests.

Results

No indication of yield was observed during inspection after tests were completed.

Observations

Scheduled tests of highly stressed areas with the use of strain gages and "stress coating" were canceled because of lack of time.

Testing of the hull lifting eyes was not repeated, since the contractor had originally tested with a 51,000-pound load (a gross load of 87,000 pounds).

DETERMINATION FIVE. Watertight Integrity

Procedure

Hatches and seals were hosed with water at an approximate 10-psi pressure to determine whether leakage occurred at these locations.

Results

The FNR transmission hatch seal and the outboard engine hatch seals leaked. After a softer gasket was installed on the FNR transmission hatch seal coaming and after the outboard engine latches that secure the hatch were strengthened, no further leakage was revealed.

Observations

Drainage for the ramp at the exposed cavity for ramp extension cylinders (see Figure 4) was excellent, and the drainage slots did not clog.

Drains at the lifting eyes frequently became clogged with sand and debris; as a result, they were continually being filled with sea water. Since this condition is typical of field situations, no attempt was made to correct it. A careful inspection of the lighter before it was shipped to Cape Canaveral revealed no indications of corrosion or electrolysis where the high-strength steel pin and eyes were adjacent to the aluminum hull.

Because of the low location of the bilge-pump overboard discharges, leakage occurred during hard turns when the LARC was fully loaded. To avoid leakage, the discharges were moved to a higher position.

DETERMINATION SIX. Adequacy of Systems

Procedure

The electrical system was checked to determine the adequacy of the entire system.

Results

In general, the system was satisfactory. Instrumentation showed that the voltage was regulated within the permissible limits of 26.5 to 28 volts.

Observation

Diode failures in the alternators occurred frequently; the failures were believed to be caused by the inadequate capacity of the diodes. (The manufacturer is investigating this matter.)

Procedure

The fuel system was operationally checked during run-in tests.

Results

The system proved to be adequate.

Procedure

The bilge ventilation system (which consisted of electrically powered blowers and belt-driven fans off the engine) was checked, since production economics and successful scavenging by the engine-driven high-mount fan had dictated deletion of the electric blowers.

Results

The belt-driven fans were capable of changing the air approximately 2-1/2 times per minute, which kept the engine-room ambient temperature at an acceptable level.

Procedure

The hydraulic system piping was hydrostatically tested to 3,000 psi, which is approximately 1-1/2 times operating pressure.

Results

No leakage was evident. The system relieved at the specified 2,250 psi, and the bilge pumps operated at 1,000 psi. The ramp extension system was later modified to relieve at 900 psi to prevent damage to the ramp extension control arms.

Procedure

Releases were tripped on the CO_2 fire extinguishers to ascertain functional operation.

Results

The system was found to be adequate; engine-room coverage was ample.

Procedure

The engine exhaust system was checked during initial run-in tests for sensible heat and flow. The muffler in the radiator well was cooled by the radiator fan during land travel, and by water when the lighter was afloat.

Results

Although the exhaust outlet was at the level of a man's head, no adverse effect was experienced during tests. At no time were toxic fumes detected in or around the cab or cargo well deck except when the lighter was alongside ship and unfavorable winds prevailed, thus permitting exhaust fumes to recirculate back to the LARC.

Observations

Thermocouple probes at the engine exhaust ports read as high as 1,400° F. at full load. In high ambients, this may result in damage to engine exhaust valves because of the higher intake air temperature, so the matter has been referred to the engine manufacturer.

The engine cooling systems were not subjected to the extreme ambient conditions specified in the military characteristics; therefore, no valid conclusions could be drawn regarding the adequacy of the system in any abnormal environment. Functionally, no difficulty was experienced (see Phase II, Determination Ten, Heat Measurements).

DETERMINATION SEVEN. Transverse Stability on Land

Procedure

The lighter (with a full load having a 20-inch center of gravity) was driven over a tank course at Camp Pendleton, California. The slope was recorded by an inclinometer and a bubble level.

Results

The lighter progressively negotiated a 29-percent slope.

Observation

It is believed that the lighter could have negotiated a steeper grade, but the uneven terrain would have made performance dangerous.

DETERMINATION EIGHT. Marine Characteristics

Procedure - Metacentric Height

The classical inclining experiment to determine metacentric height was conducted at the U. S. Naval Repair Facility in San Diego, California. The lighter, with all tanks topped and the fuel systems filled, was placed in a protected slip, where pendulums were installed fore and aft (see Figures 22 through 25). Sea conditions were relatively calm. Two 500-pound weights (rather than a single 1,000-pound weight, for convenience in handling) were centered aboard; both were simultaneously moved outboard, port and starboard, in turn, for two different distances while the angles of heel were recorded. The data obtained are recorded in Table 4.

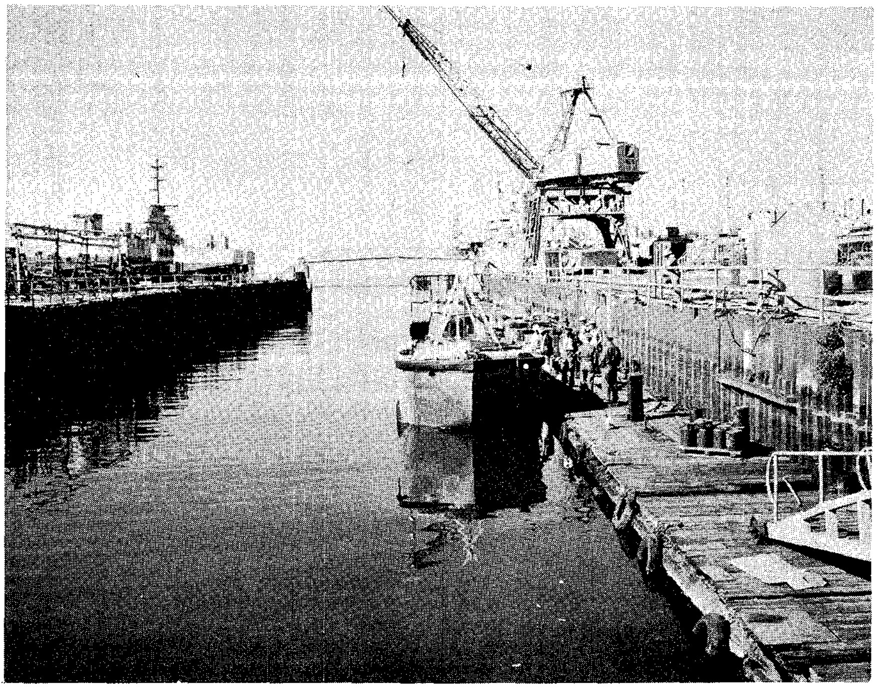
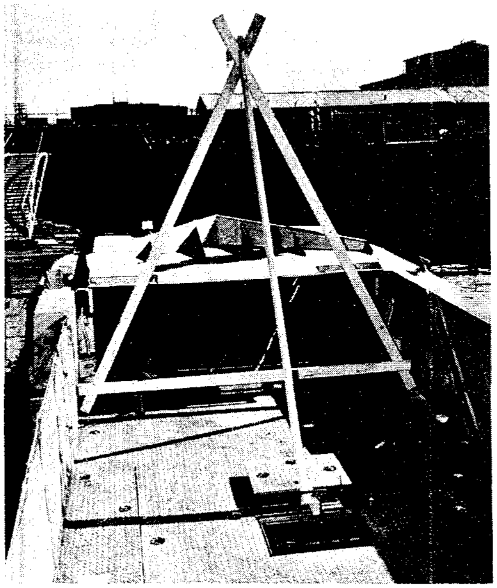


Figure 22. Lighter at U. S. Naval Repair Facility, San Diego, California, Before Inclining Test for Determining Metacentric Height.



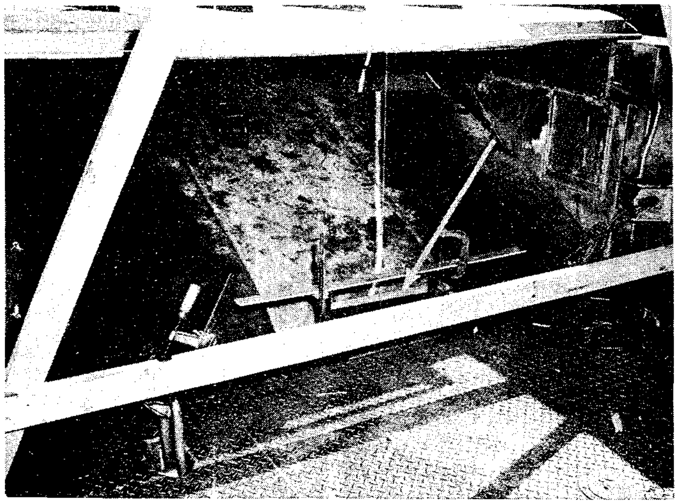


Figure 24. View of Pendulum. (Arrow indicates oil bath used to dampen pendulum swing.)

Figure 23. Pendulum Secured to Bow of Lighter for Determining Metacentric Height.

Figure 25. Pendulum Secured to Stern of Lighter for Determining Metacentric Height.

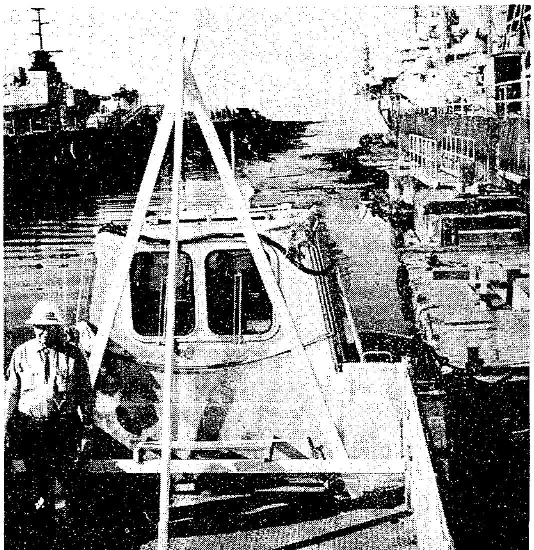


TABLE 4
INCLINING EXPERIMENT WITH 1,000-POUND LOAD[1]

Run	Distance Loads Moved (ft.)	Direction Loads Moved	Moment (ft.-tons[2])	Tangent of Angle of Heel (deg.)		
				Forward	Aft	Average
1	4.25	Port	.94775	.01158	.01116	.01137[5]
2[3]	8.5	Port	1.8955	.02433	.02340	.023865[6]
3	centered	-	0	-	negligible	-
4	4.25	Starboard	.94775	.01129	.01116	.011225
5	8.5	Starboard	1.8955	.02317	.02286	.023015
6[4]	centered	-	0	.00057	-	-

[1] Two 500-lb. lead blocks
[2] Long ton (2,240 lb.)
[3] Confirming run
[4] Confirming run; slight list to starboard; list ignored
[5] $\tan^{-1} .01137 = 0^\circ 39'$
[6] $\tan^{-1} .023865 = 1^\circ 22'$

Results - Metacentric Height

The metacentric height was determined from the following calculations, which are based on the data in Table 4:

$$GM = \frac{\text{(distance weight moved) (weight)}}{\text{displacement (tangent of angle of heel)}}$$

$$GM_1 = \frac{4.25\ (1,000)}{44,600\ (.01137)} = 8.3809 \text{ feet}$$

$$GM_2 = \frac{8.5\ (1,000)}{44,600\ (.023865)} = 7.9859 \text{ feet}$$

$$GM_4 = \frac{4.25\ (1,000)}{44,600\ (.011225)} = 8.489 \text{ feet}$$

$$GM_5 = \frac{8.5\ (1,000)}{44,600\ (.023015)} = 8.281 \text{ feet}$$

$$GM_{AV} = \frac{\Sigma GM}{4} = \frac{33.1368}{4} = 8.284 \text{ feet}$$

Procedure - Stability at High Angles of Heel

Static stability tests were conducted at the U. S. Naval Repair Facility in San Diego to determine the righting moment of the lighter under various loads and with various vertical centers of gravity.

The lighter was rigged in a floating dry dock so that a known pull could be applied to cause the LARC to heel to some desired angle (see Figures 26 through 29).

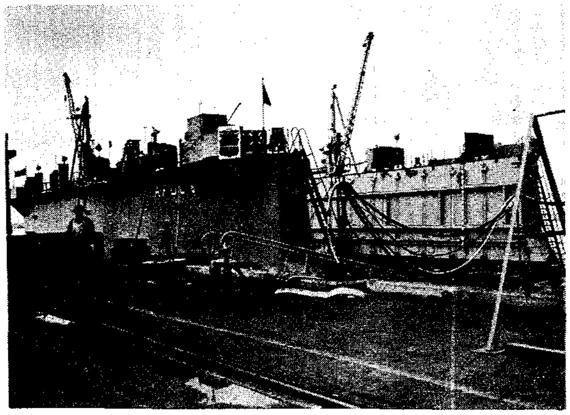


Figure 26. Floating Dry Dock Used for Static Stability Tests at U. S. Naval Repair Facility, San Diego, California.

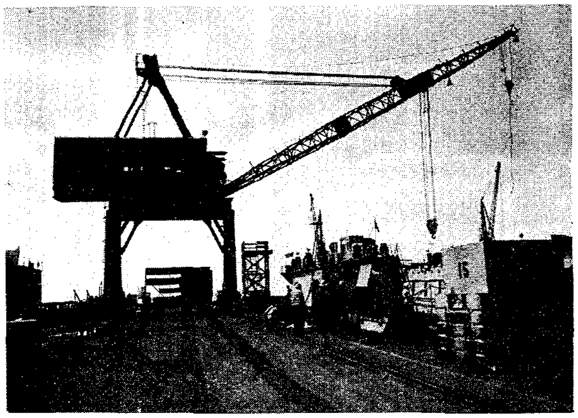


Figure 27. Dock Facilities Used for Static Stability Tests.

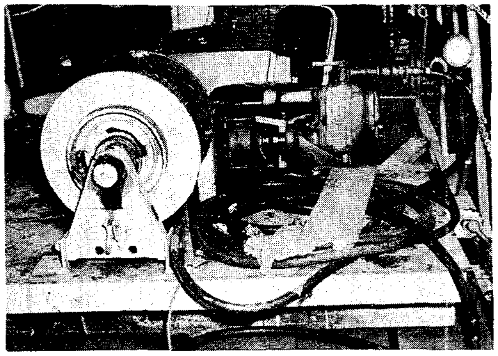


Figure 28. Pneumatic Winch Used To Tilt Lighter During Static Stability Tests.

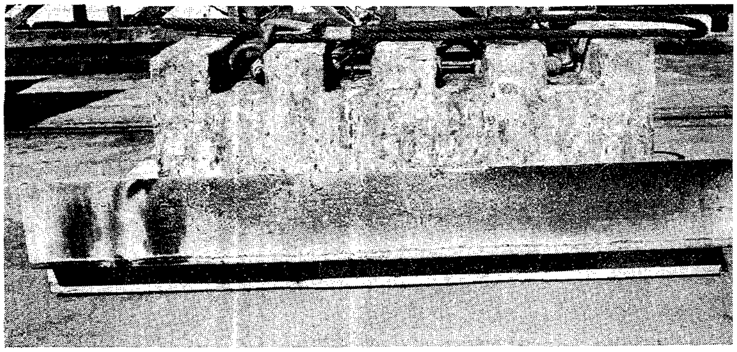


Figure 29. 10-Ton Lead Block Used To Load Lighter During Static Stability Tests.

The angle of heel was recorded from a pendulum attached to the aft end of the operator's cab. The applied heeling force was measured by a load cell inserted in the pulling cable.

The theory used to resolve final stability characteristics is as follows: In order to determine the righting moment for the lighter, it is necessary to know the magnitude of the couple which tends to capsize the craft. For a condition of equilibrium, the righting moment is equal in magnitude but opposite in direction in relation to this couple. The magnitude of the couple is determined by resolving the applied force (P) into its horizontal component (P_H) and obtaining the product of the perpendicular distance (d) between it and the horizontal component of the restraining force (R_H) (see Figure 30). The horizontal components mentioned are equal in magnitude and opposite in direction and form the capsizing couple.

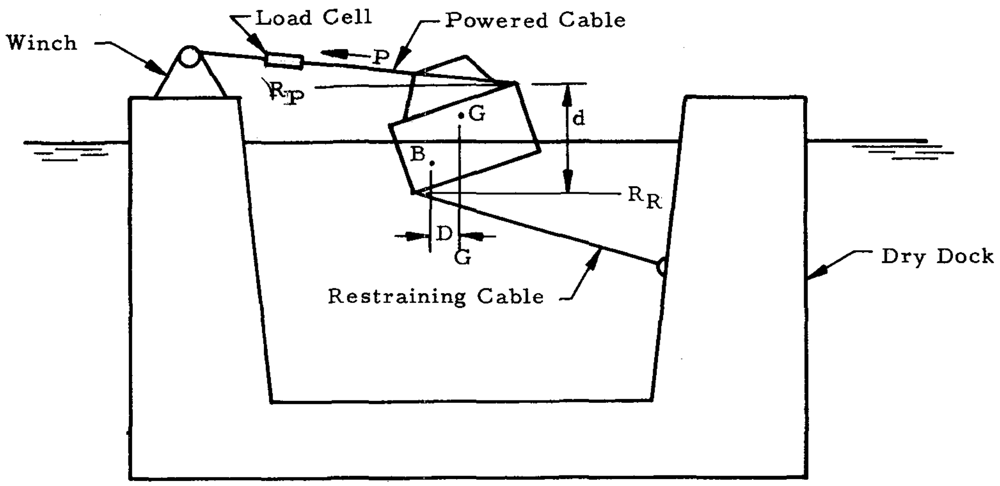


Figure 30. Test Setup for Static Stability Tests.

The moment resisting the couple is the righting moment comprised by the couple of the buoyant force of the water and the weight force of the lighter and cargo. As the lighter is heeled over, the righting moment increases until it reaches a maximum value and then gradually recedes to zero. The factor which determines the magnitude of the righting moment is the perpendicular distance between the buoyant force of the water and the total weight of the test vehicle. When the lighter is at rest, the weight and buoyant forces lie in the same vertical line, and the righting moment is zero. As the lighter is heeled, the forces move out of this line and are separated by the distance (d) shown in Figure 30. This distance increases to a maximum value and then decreases gradually to zero. Beyond this point, the craft will capsize. A typical righting-moment versus angle-of-heel curve is shown in Figure 31.

Results - Stability at High Angles of Heel

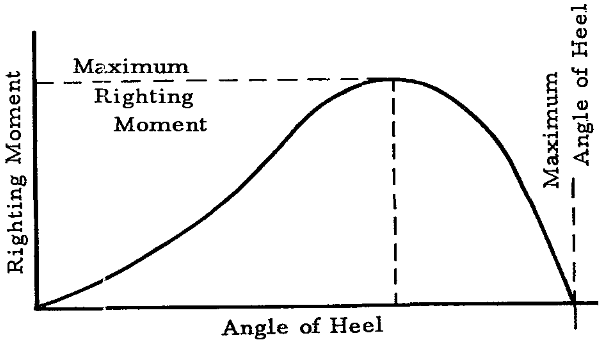


Figure 31. Typical Stability Curve.

The following test data are summarized in Tables 5 through 12. In the light condition, the righting moment was 102,000 foot-pounds; with the 5-ton, 40-inch-center-of-gravity load, the maximum righting moment was 76,000 foot-pounds; with the 10-ton, 40-inch-center-of-gravity load, the maximum righting moment was 40,000 foot-pounds; but with the 15-ton, 40-inch-center-of-gravity load, the maximum righting moment was 6,600 foot-pounds. Figures 32 through 38 show a comparison of the angles of heel for the various combinations of weight and center of gravity; Figures 39 through 61 further illustrate static stability test conditions. The lack of symmetry of the fully loaded lighter stability curves compared with those of other curves initially raised doubts as to the accuracy of procedure for determining the maximum righting moment of the LARC with a 15-ton, 40-inch-center-of-gravity load. However, later runs substantiated the initial data. The placement of a 20-ton load aboard the LARC forced the cargo well deck slightly under water. Further substantiating runs were conducted on the LARC-XV-2X at Cape Canaveral, Florida, with almost identical results. As a result of these data and of dynamic stability tests (see Supplemental Tests), the beam of the LARC-XV-1X was widened by 2 feet and retested. The righting moment for the 14-ton, 40-inch-center-of-gravity load with the broader beam was 63,000 foot-pounds. This was 57-1/2 percent greater then the righting moment for the 10-ton, 40-inch-center-of-gravity load with the 12-foot beam, which proved to be adequate in dynamic tests. A subsequent dynamic test of the 14-foot-beam lighter, fully loaded, proved the stability to be quite adequate (see Supplemental Tests, Determination One). The righting-moment versus angle-of-heel curves are shown graphically in Figures 62 through 69.

TABLE 5
NO-LOAD STATIC STABILITY TESTS

Angle of Heel (deg.)	Pull (lb.)	Angle of Pull (deg.)	Cosine Angle of Pull	Horizontal Component of Pull (lb.)	Lever Arm (ft.)	Righting Moment (ft.-lb.)
5.0	4,000	6.5	.99357	3,974	4.620	18,356
10.0	6,800	5.0	.99619	6,774	5.375	36,410
15.0	9,000	4.5	.99692	8,973	6.090	54,646
20.0	10,800	3.5	.99813	10,779	6.760	72,866
25.0	12,000	3.0	.99863	11,983	7.375	88,375
30.0	12,200	2.5	.99905	12,188	7.935	96,712
33.0	12,100	2.0	.99939	12,093	8.243	99,683
36.0	12,000	1.5	.99966	11,996	8.528	102,302
38.0	11,300	1.5	.99966	11,296	8.705	98,332
40.0	11,000	1.0	.99985	10,998	8.871	97,563
42.0	10,800	1.0	.99985	10,798	9.027	97,474
44.0	10,000	1.0	.99985	9,999	9.172	91,711
46.5	9,500	1.0	.99985	9,499	9.305	88,388

TABLE 6
STATIC STABILITY TESTS
WITH 5-TON, 40-INCH-CENTER-OF-GRAVITY LOAD

Angle of Heel (deg.)	Pull (lb.)	Angle of Pull (deg.)	Cosine Angle of Pull	Horizontal Component of Pull (lb.)	Lever Arm (ft.)	Righting Moment (ft.-lb.)
5.0	500	8.5	.98901	494	4.620	2,282
10.0	3,000	6.5	.99357	2,981	5.375	16,023
15.0	5,000	5.5	.99540	4,977	6.090	30,310
20.0	7,300	5.0	.99619	7,272	6.758	49,144
25.0	8,200	4.5	.99692	8,175	7.375	60,291
30.0	8,800	4.0	.99756	8,779	7.935	69,661
35.0	9,000	3.5	.99813	8,983	8.435	75,772
37.5	8,800	3.5	.99813	8,784	8.662	76,087
40.0	8,300	3.0	.99863	8,289	8.871	73,522
43.0	7,800	3.0	.99863	7,789	9.101	70,888
45.0	6,800	3.0	.99863	6,791	9.240	62,749
47.0	5,700	3.0	.99863	5,692	9.368	53,323

TABLE 7
STATIC STABILITY TESTS
WITH 5-TON, 20-INCH-CENTER-OF-GRAVITY LOAD

Angle of Heel (deg.)	Pull (lb.)	Angle of Pull (deg.)	Cosine Angle of Pull	Horizontal Component of Pull (lb.)	Lever Arm (ft.)	Righting Moment (ft.-lb.)
5.0	1,900	6.5	.99357	1,888	4.620	8,723
10.0	3,850	5.5	.99540	3,832	5.375	20,597
15.0	6,650	5.0	.99619	6,625	6.090	40,346
20.0	8,500	5.0	.99619	8,468	6.758	57,227
23.0	9,200	4.5	.99692	9,172	7.134	65,433
26.0	9,800	4.5	.99692	9,770	7.491	73,187
29.0	10,000	4.0	.99756	9,976	7.828	78,092
31.0	9,800	4.0	.99756	9,776	8.040	78,599
33.0	9,800	3.5	.99813	9,782	8.243	80,633
35.0	9,800	3.5	.99813	9,782	8.435	82,511
36.0	9,600	3.5	.99813	9,582	8.528	81,715
37.5	9,400	3.5	.99813	9,382	8.705	81,670

TABLE 8
STATIC STABILITY TESTS
WITH 10-TON, 30-INCH-CENTER-OF-GRAVITY LOAD

Angle of Heel (deg.)	Pull (lb.)	Angle of Pull (deg.)	Cosine Angle of Pull	Horizontal Component of Pull (lb.)	Lever Arm (ft.)	Righting Moment (ft.-lb.)
5	1,250	11.0	.98163	1,227	4.620	5,867
10	3,150	10.5	.98325	3,097	5.375	16,646
15	6,050	10.5	.98325	5,949	6.090	36,229
20	5,600	8.5	.98901	5,538	6.758	37,426
25	6,050	7.5	.99144	5,998	7.375	44,235
28	6,250	7.0	.99255	6,203	7.718	47,875
30	5,850	7.0	.99255	5,806	7.935	46,071
33	5,850	6.5	.99357	5,812	8.243	47,908
35	5,200	6.5	.99357	5,167	8.435	43,584
37	5,200	7.0	.99255	5,161	8.705	44,927
40	5,200	7.0	.99255	5,161	8.871	45,783

TABLE 9
STATIC STABILITY TESTS
WITH 10-TON, 40-INCH-CENTER-OF-GRAVITY LOAD

Angle of Heel (deg.)	Pull (lb.)	Angle of Pull (deg.)	Cosine Angle of Pull	Horizontal Component of Pull (lb.)	Lever Arm (ft.)	Righting Moment (ft.-lb.)
5	1,400	10.5	.98325	1,377	4.620	6,362
10	3,150	9.0	.98769	3,111	5.375	16,722
15	4,200	8.0	.99027	4,159	6.090	25,328
20	4,900	7.5	.99144	4,858	6.758	32,830
25	5,200	7.0	.99255	5,161	7.375	38,062
27	5,300	7.0	.99255	5,261	7.606	40,015
29	5,200	6.5	.99357	5,167	7.828	40,447
32	4,500	7.0	.99255	4,466	8.143	36,367
35	4,200	7.5	.99144	4,164	8.435	35,123
37	3,750	7.5	.99144	3,718	8.662	32,205

TABLE 10
STATIC STABILITY TESTS
WITH 15-TON, 20-INCH-CENTER-OF-GRAVITY LOAD

Angle of Heel (deg.)	Pull (lb.)	Angle of Pull (deg.)	Cosine Angle of Pull	Horizontal Component of Pull (lb.)	Lever Arm (ft.)	Righting Moment (ft.-lb.)
5.0	700	11.5	.97992	686	4.620	3,169
10.0	2,000	10.5	.98325	1,967	5.375	10,573
15.0	2,800	9.5	.98628	2,762	6.090	16,821
20.0	3,000	9.0	.98769	2,963	6.758	20,024
25.0	3,700	8.5	.98901	3,659	7.375	36,985
27.5	4,000	8.5	.98901	3,956	7.606	30,089
30.0	4,300	8.5	.98901	4,253	7.935	33,748
33.0	3,600	9.0	.98769	3,556	8.243	29,312
35.0	3,100	9.5	.98628	3,057	8.435	25,786
36.5	3,700	9.5	.98628	3,649	8.573	31,283
39.0	3,000	10.0	.98481	2,954	8.790	25,966
41.0	3,000	10.0	.98481	2,954	8.950	26,438

TABLE 11
STATIC STABILITY TESTS
WITH 15-TON, 30-INCH-CENTER-OF-GRAVITY LOAD

Angle of Heel (deg.)	Pull (lb.)	Angle of Pull (deg.)	Cosine Angle of Pull	Horizontal Component of Pull (lb.)	Lever Arm (ft.)	Righting Moment (ft.-lb.)
5.0	1,500	10.5	.98325	1,475	4.620	6,815
10.0	2,600	10.0	.98418	2,559	5.375	13,746
15.0	3,050	9.5	.98628	3,008	6.090	18,319
20.0	3,350	9.0	.98769	3,309	6.758	22,362
25.0	3,250	9.0	.98769	3,210	7.375	23,674
27.5	2,950	9.0	.98769	2,914	7.606	22,164
30.0	2,500	9.5	.98628	2,466	7.935	19,568
32.0	2,300	10.0	.98418	2,264	8.143	18,436
35.0	1,900	11.0	.98163	1,865	8.435	15,731
37.0	1,400	11.0	.98163	1,374	8.705	11,961
40.0	1,250	12.0	.97815	1,223	8.871	10,849

TABLE 12
STATIC STABILITY TESTS
WITH 15-TON, 40-INCH-CENTER-OF-GRAVITY LOAD

Angle of Heel (deg.)	Pull (lb.)	Angle of Pull (deg.)	Cosine Angle of Pull	Horizontal Component of Pull (lb.)	Lever Arm (ft.)	Righting Moment (ft.-lb.)
3	360	12.5	.97630	351	4.310	1,513
6	900	11.5	.97992	882	4.474	3,946
10	1,250	10.5	.98325	1,229	5.375	6,606
13	1,100	10.0	.98481	1,083	5.809	6,291
15	1,100	10.0	.98481	1,083	6.090	6,595
17	900	10.0	.98491	886	6.363	5,638
19	750	11.0	.98101	736	6.628	4,878

LIGHTER HEELED OVER DURING STATIC STABILITY TESTS

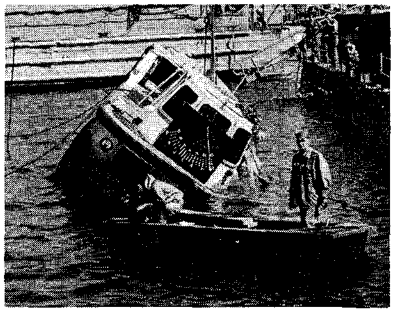


Figure 32. 5-Ton, 20-Inch-Center-of-Gravity Load.

Figure 33. 5-Ton, 40-Inch-Center-of-Gravity Load.

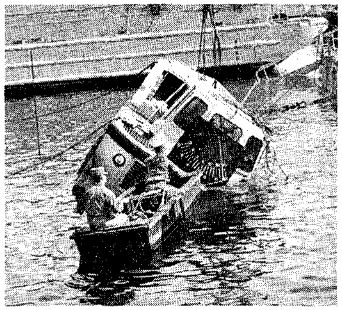


Figure 34. 10-Ton, 30-Inch-Center-of-Gravity Load.

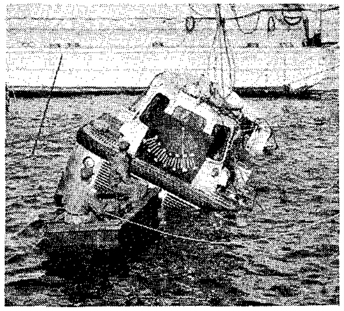


Figure 35. 10-Ton, 40-Inch-Center-of-Gravity Load.

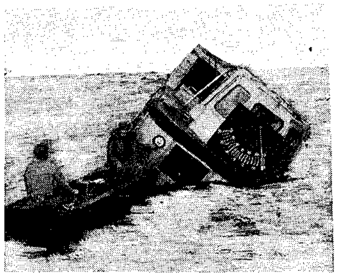


Figure 36. 15-Ton, 20-Inch-Center-of Gravity Load.

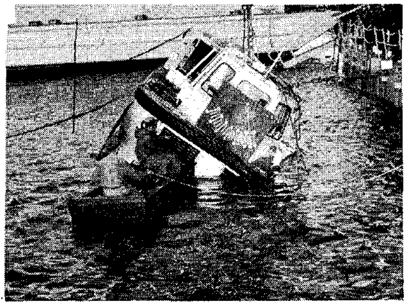


Figure 37. 15-Ton, 30-Inch-Center-of-Gravity Load.

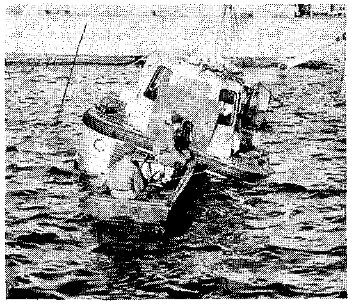


Figure 38. 15-Ton, 40-Inch-Center-of-Gravity Load.

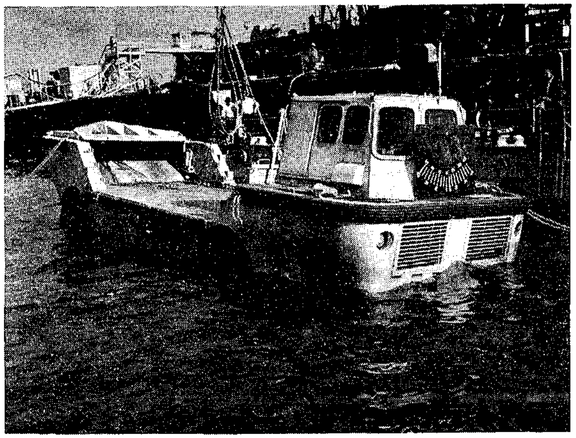


Figure 39. Lighter Prior to No-Load Static Stability Tests. (Note restraining cables hooked to port lifting eyes to prevent capsizing.)

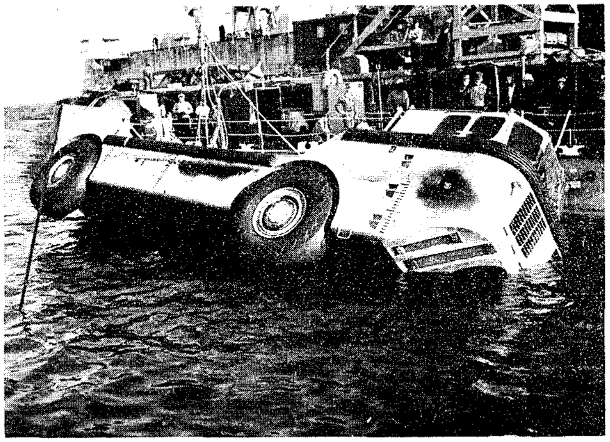


Figure 40. Lighter Heeled Over During No-Load Static Stability Tests. (Note port wheels in relation to water surface.)

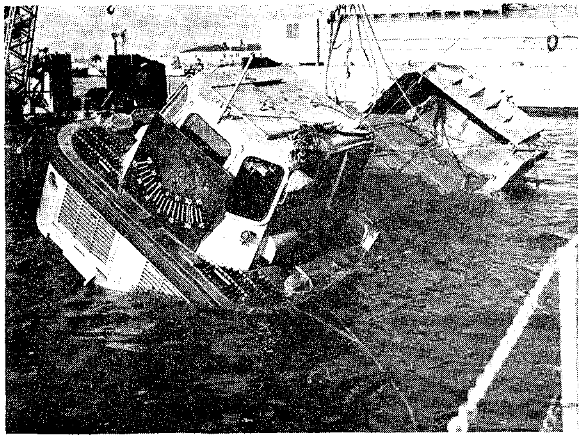


Figure 41. Lighter Heeled Over During No-Load Static Stability Tests.

Figure 42. Lighter Heeled Over During No-Load Static Stability Tests--Maximum Angle of Yield. (Water had entered operator's cab.)

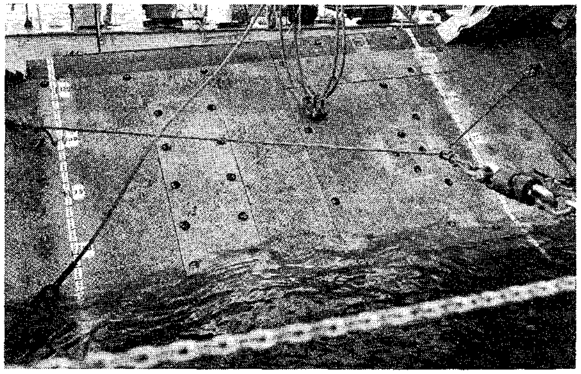


Figure 43. No-Load Static Stability Tests. (Note load cell at right center.)

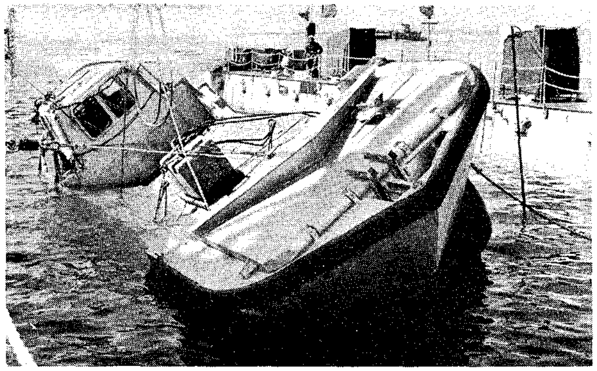


Figure 44. Lighter Heeled Over During Static Stability Tests With 5-Ton, 20-Inch-Center-of-Gravity Load.

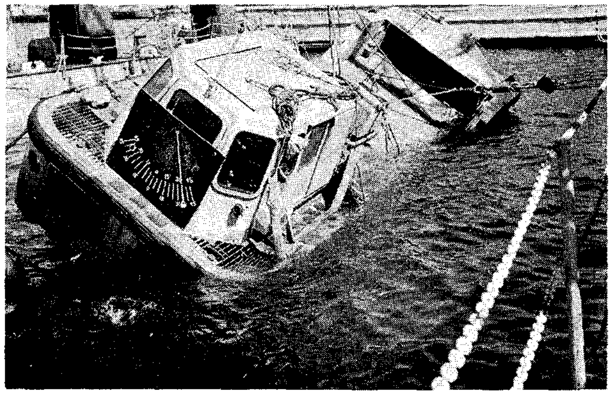


Figure 45. Lighter Heeled Over During Static Stability Tests With 5-Ton, 20-Inch-Center-of-Gravity Load.

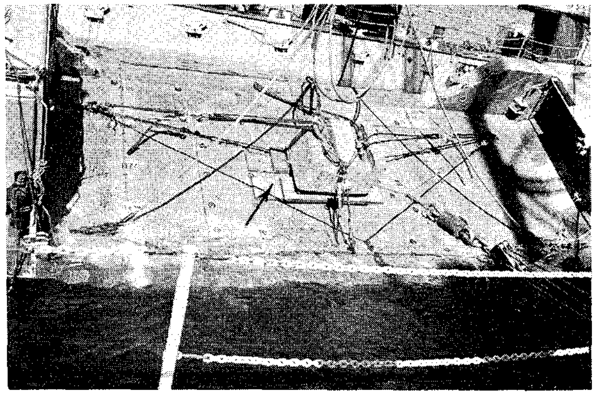


Figure 46. Lighter Heeled Over During Static Stability Tests With 5-Ton, 20-Inch-Center-of-Gravity Load. (Arrow points to dunnage used to bring load to desired center of gravity.)

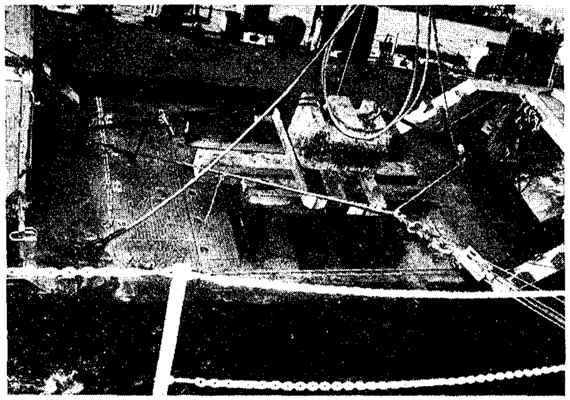


Figure 47. Lighter Heeled Over During Static Stability Tests With 5-Ton, 40-Inch-Center-of-Gravity Load.

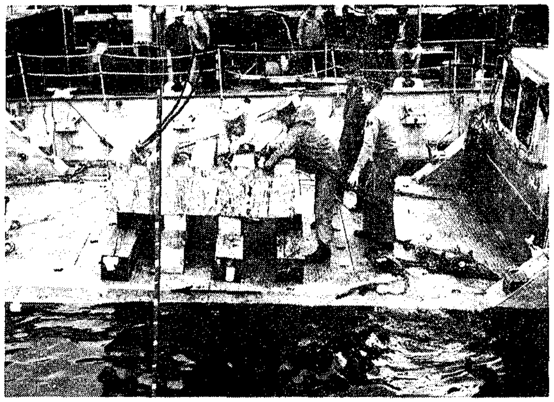


Figure 48. Securing 10-Ton Lead Block Before Static Stability Tests With 30-Inch-Center-of-Gravity Load. (Yardstick used to measure distance between restraining and pulling forces.)

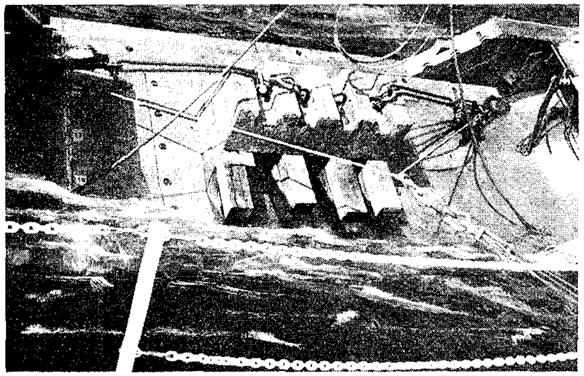


Figure 49. Lighter Heeled Over During Static Stability Tests With 10-Ton, 30-Inch-Center-of-Gra

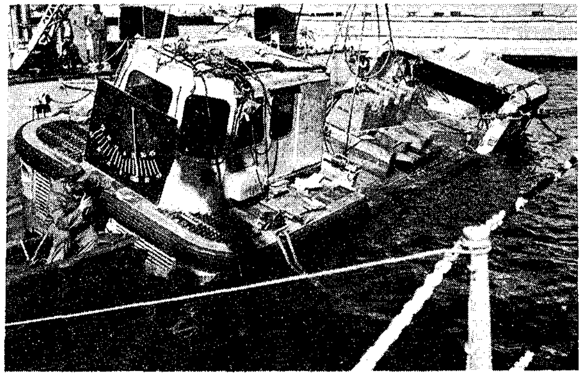


Figure 50. Submergence of Cargo Well Deck at 22-Degree (approximately) Angle of Heel During Static Stability Tests With 10-Ton, 30-

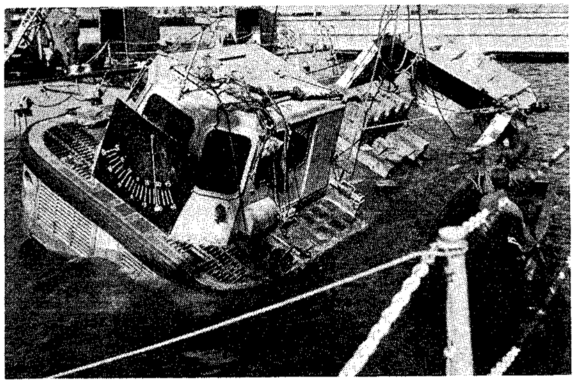


Figure 51. Submergence of Cab Deck at 27-Degree (approximately) Angle of Heel During Static Stability Tests With 10-Ton, 30-Inch-Center-of-Gravity Load.

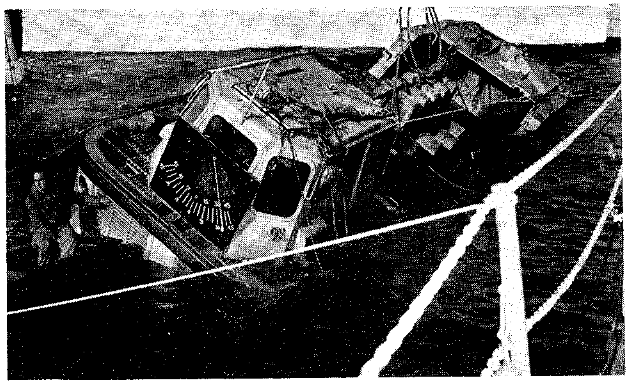


Figure 52. Lighter Heeled Over During Static Stability Tests With 10-Ton, 40-Inch-Center-of-Gravity Load.

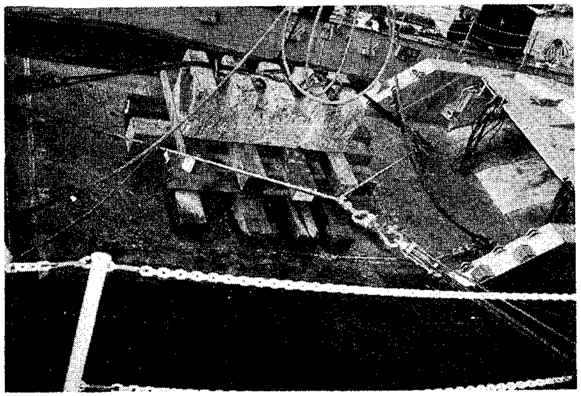


Figure 53. Lighter Heeled Over During Static Stability Tests With 10-Ton, 40-Inch-Center-of-Gravity Load.

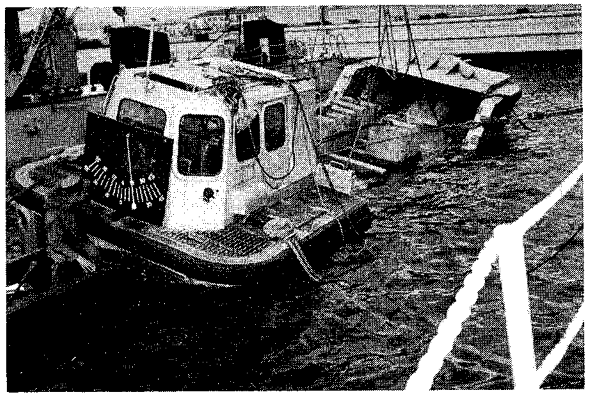


Figure 54. Cargo Well Deck at 15-Degree (approximately) Angle of Heel During Static Stability Tests With 15-Ton, 20-Inch-Center-of-Gravity Load.

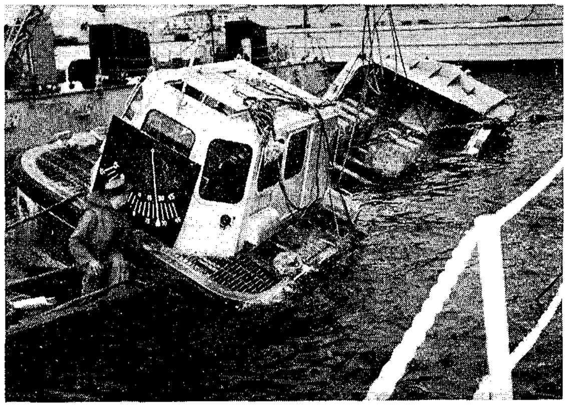


Figure 55. Cab Deck Submergence at 25-Degree (approximately) Angle of Heel During Static Stability Tests With 15-Ton, 20-Inch-Center-of-Gravity Load.

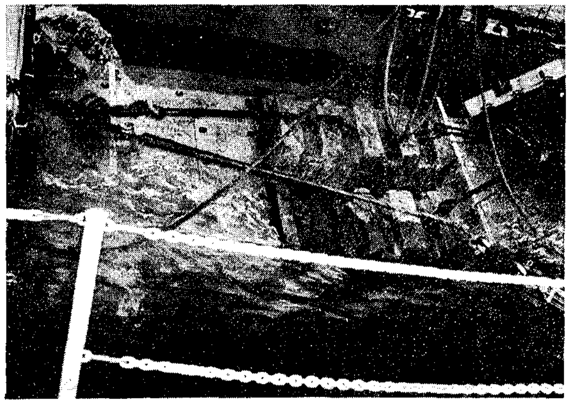


Figure 56. Lighter Heeled Over During Static Stability Tests With 15-Ton, 20-Inch-Center-of-Gravity Load. (Note water in upper left corner being pumped from engine room by electric bilge pump.)

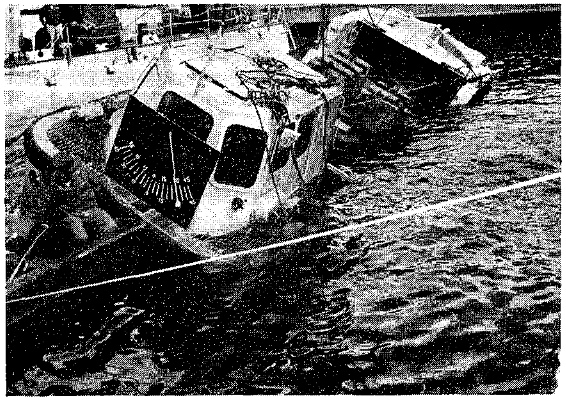


Figure 57. Lighter Heeled Over During Static Stability Tests With 15-Ton, 30-Inch-Center-of-Gravity Load.

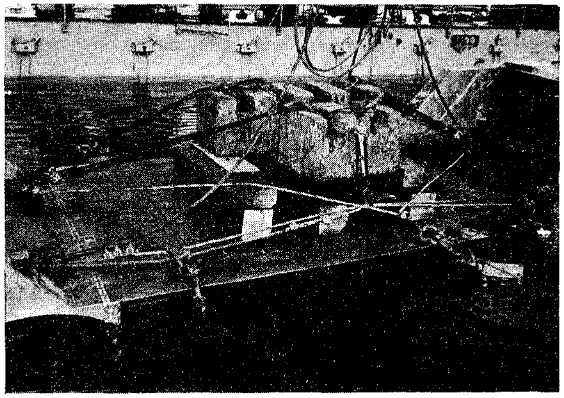


Figure 58. Lighter Loaded Before Static Stability Tests With 15-Ton, 30-Inch-Center-of-Gravity Load.

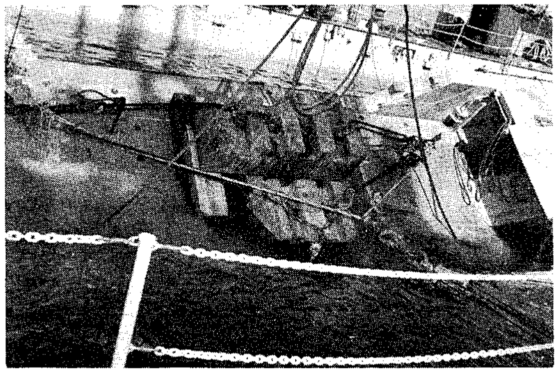


Figure 59. Lighter Heeled Over During Static Stability Tests With 15-Ton, 30-Inch-Center-of-Gravity Load. (Water at upper left corner is being pumped from engine room by electric bilge pump.)

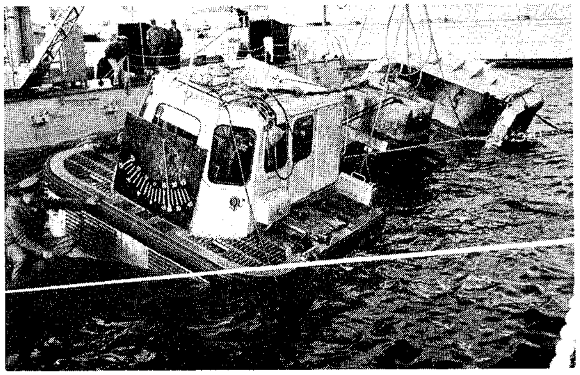


Figure 60. Lighter Heeled Over During Static Stability Tests With 15-Ton, 40-Inch-Center-of-Gravity Load.

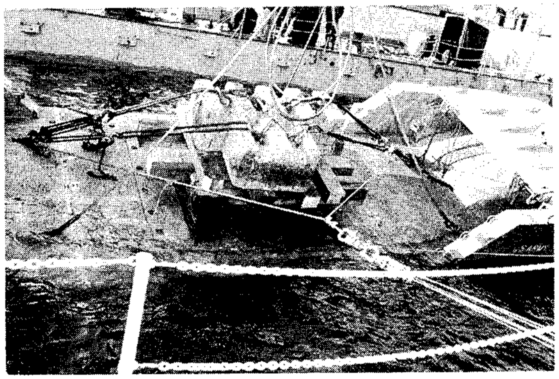


Figure 61. Lighter Heeled Over During Static Stability Tests With 15-Ton, 40-Inch-Center-of-Gravity Load.

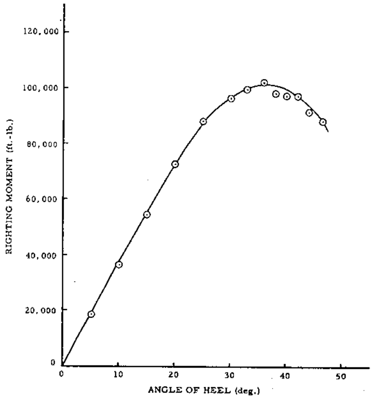


Figure 62. Righting Moment Versus Angle of Heel for No-Load Static Stability Tests.

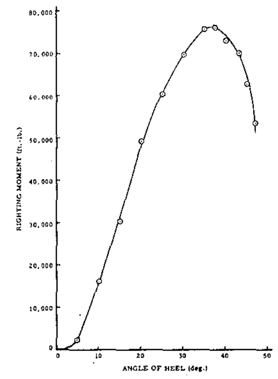


Figure 63. Righting Moment Versus Angle of Heel for 5-Ton, 40-Inch-Center-of-Gravity Load During Static Stability Tests.

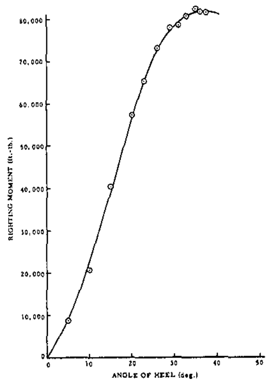


Figure 64. Righting Moment Versus Angle of Heel for 5-Ton, 20-Inch-Center-of-Gravity Load During Static Stability Tests.

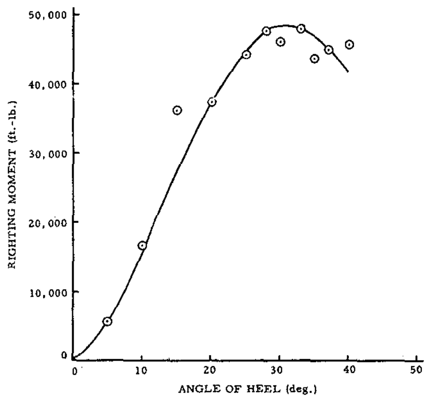


Figure 65. Righting Moment Versus Angle of Heel for 10-Ton, 30-Inch-Center-of-Gravity Load During Static Stability Tests.

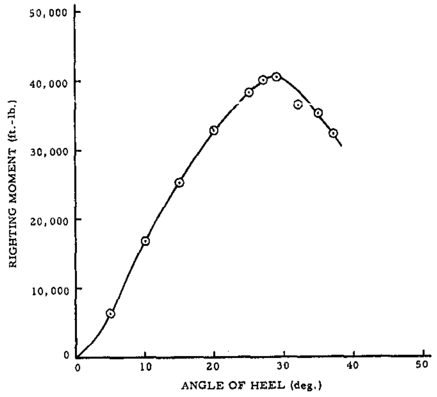


Figure 66. Righting Moment Versus Angle of Heel for 10-Ton, 40-Inch-Center-of-Gravity Load During Static Stability Tests.

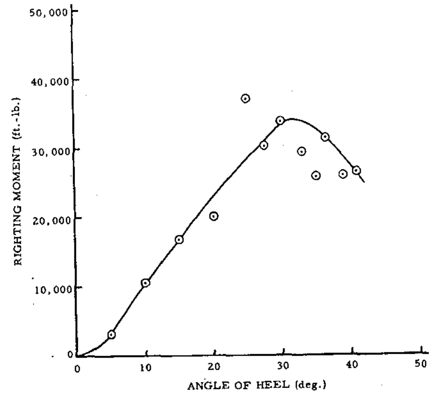


Figure 67. Righting Moment Versus Angle of Heel for 15-Ton, 20-Inch-Center-of-Gravity Load During Static Stability Tests.

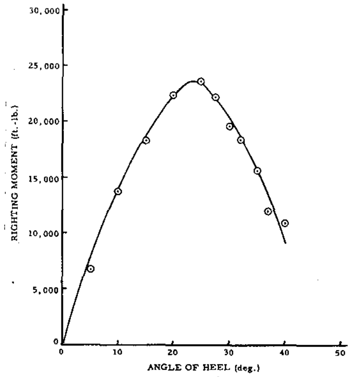


Figure 68. Righting Moment Versus Angle of Heel for 15-Ton, 30-Inch-Center-of-Gravity Load During Static Stability Tests.

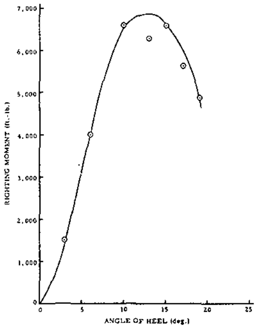


Figure 69. Righting Moment Versus Angle of Heel for 15-Ton, 40-Inch-Center-of-Gravity Load During Static Stability Tests.

Procedure - Period of Roll

The period of roll of the lighter was determined in calm water at Camp Del Mar, Oceanside, California. The LARC was artificially rolled in the unloaded condition by men shifting their weights off the longitudinal center line of the vessel. When the largest angle of heel was reached, all personnel stood on the center line while the vessel went through the rolling cycles. The angular displacement was measured by a pitch-and-roll recorder from which the frequency of roll could be determined.

Results - Period of Roll

The angular displacements and times were measured from the permanent record of the pitch and roll recorder (see Figure 70). The results (see Table 13) were plotted, and the frequency rate was determined over a period of 24.7 seconds. The average frequency was determined to be 0.326 cycle per second for an average period of 3.065 seconds.

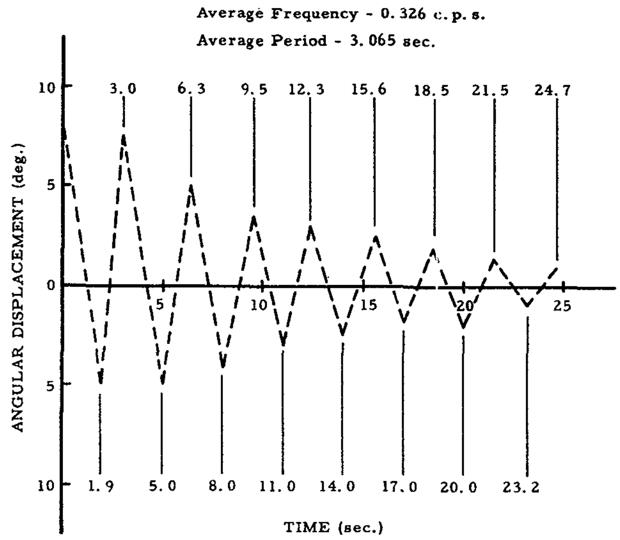


Figure 70. Angular Displacement Versus Time for Period of Roll.

TABLE 13
PERIOD OF ROLL

Cycle	Angular Displacement (deg.)	Elapsed Time (sec.)	Period (sec.)	Frequency (c.p.s.)
1	+8.0	0.0	3.0	0.333
	-5.0	1.9		
	+7.5	3.0		
2	+7.5	3.0	3.0	0.303
	-5.0	5.0		
	+5.0	6.3		
3	+5.0	6.3	3.2	0.313
	-4.0	8.0		
	+3.5	9.5		
4	+3.5	9.5	2.8	0.358
	-3.0	11.0		
	+3.0	12.3		
5	+3.0	12.3	3.3	0.303
	-2.5	14.0		
	+2.5	15.6		
6	+2.5	15.6	2.9	0.345
	-2.0	17.0		
	+2.0	18.5		
7	+2.0	18.5	3.0	0.333
	-2.0	20.0		
	+1.5	21.5		
8	+1.5	21.5	3.2	0.313
	-1.0	23.2		
	+1.0	24.7		

Procedure - Wheel Flotation

To determine the buoyant effect of the wheels on the lighter, a weight and immersion test was performed. A wheel was weighed and lowered into the salt-water basin where it was allowed to float freely.

Results - Wheel Flotation

The weight of the tire and rim was 1,440 pounds. After the tire floated free in the water, the submerged portion was measured upon extraction and found to be 11 inches (see Figure 71). A buoyant effect of approximately 1,500 pounds was realized from the assemblage.

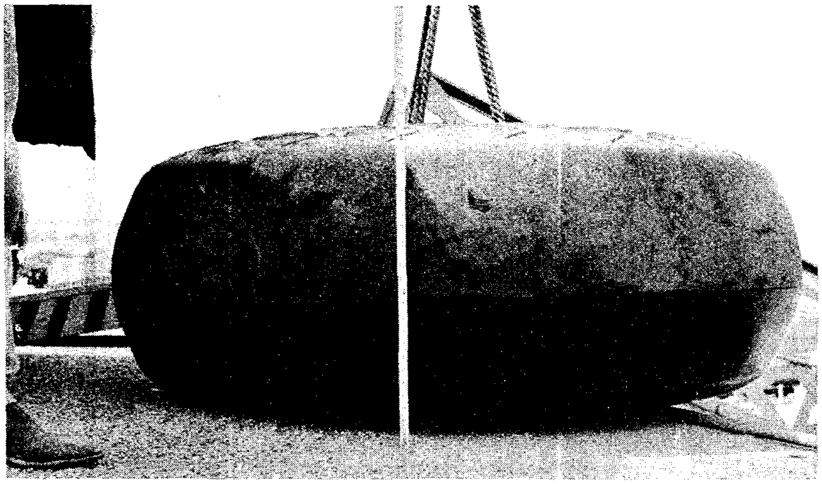


Figure 71. Tire After Being Withdrawn From Basin. (Rule shows 11-inch portion of tire (dark) that was submerged in basin.)

Procedure - Inch Trim Moment (M. T. I.)

A load of 10,000 pounds was centered on the LARC cargo deck, and the trim was recorded. The load was then moved aft, and the trim and the distance moved were recorded. The load was then moved forward, and the trim and the distance moved were again recorded. The test was conducted in salt water under slightly choppy conditions. Testing was repeated with a 20,000-pound load.

Results - Inch Trim Moment

Reults of the M. T. I. tests are shown in Table 14 and in the equations following the table.

TABLE 14
CHANGE IN TRIM RESULTING FROM CARGO-LOAD MOVEMENT

Weight (lb.)	Location	Station (in. from bow)	Trim (in.)		Shift of Weight (in.)	Change in Trim (in.)	M. T. I. (ft.-lb.)
			Fwd.	Aft			
10,000	Centered	277.5	24.0	33.0	-	-	-
"	Aft	397.5	19.0	39.0	120.0	11.0	9,090
"	Forward	151.5	27.0	27.0	126.0	9.0	7,000
20,000	Centered	277.5	26.5	35.0	-	-	-
"	Aft	369.0	23.0	46.0	91.5	14.0	10,173
"	Forward	170.5	35.0	25.0	107.0	18.5	9,911

$$\text{M.T.I.} = \frac{\text{load (load displacement)}}{\text{change in trim}}$$

For a 10,000-pound load,

$$\text{M.T.I.} = \frac{10,000\ (10\ \text{ft.})}{11} = 9,090\ \text{ft.-lb./in. of trim} \qquad \text{(Aft)}$$

$$\text{M.T.I.} = \frac{10,000\ (10\text{-}1/2\ \text{ft.})}{9} = 11,667\ \text{ft.-lb./in. of trim} \qquad \text{(Forward)}$$

For a 20,000-pound load,

$$\text{M.T.I.} = \frac{20,000\ (7.63\ \text{ft.})}{14} = 10,900\ \text{ft.-lb./in. of trim} \qquad \text{(Aft)}$$

$$\text{M.T.I.} = \frac{20,000\ (8.92\ \text{ft.})}{18\text{-}1/2} = 9,643\ \text{ft.-lb./in. of trim} \qquad \text{(Forward)}$$

Procedure - Pounds-Per-Inch Displacement

By progressively centering heavier loads in the cargo well and by measuring trim after each new load, an approximate curve can be drawn from the data to record the load sustained for each inch of displacement. The test was conducted in relatively calm salt water.

Results - Pounds-Per-Inch Displacement

Results of the displacement tests (see Table 15) are correct to within 10 percent. The discrepancy was caused by wave action, which varied trim readings by 1/2 inch.

TABLE 15
POUNDS-PER-INCH DISPLACEMENT

Load (lb.)	Trim (in.) Fwd.	Trim (in.) Aft	Average Immersion (in.)	Pounds per Inch Immersion
0	18-1/2	29-1/2	-	-
10,000	24	32	4	2,500
20,000	26-1/2	35	6-3/4	2,963
30,000	30	37	9-1/2	3,158

DETERMINATION NINE. Freeboard

Procedure

The freeboard of the LARC-XV-1X was measured for the light condition and with 5-ton, 10-ton, and 15-ton loads, in turn. Tanks were topped and weights were calibrated (see Figures 72 and 73). The trim was measured at a point approximately 6 inches forward of the forward wheel well cutout and 6 inches aft of the aft wheel well cutout and hull bottom.

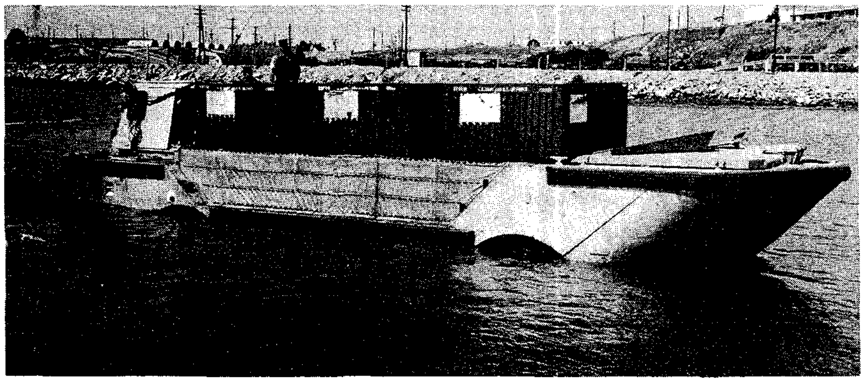


Figure 72. Bow View Showing Trim of Lighter Loaded to 15-Ton Capacity.

Figure 73. Stern View Showing Trim of Lighter Loaded to 15-Ton Capacity.

Results

Results are shown in Table 16.

TABLE 16
FREEBOARD OF LARC-XV-1X

Lighter Condition	Fwd. (in.)	Aft (in.)
Light condition	18-1/2	29-1/2
10,000-lb. load	24	32
20,000-lb. load	26-1/2	35
30,000-lb. load	30	37

DETERMINATION TEN. Capacities of Components

Procedure

The capacities of the following components were measured during initial fill: engine crankcase (including filter), transmissions, engine cooling system, right-angle drive, and planetary drive of wheel end.

Results

The results are included in "Description of LARC-XV-1X" of this report.

DETERMINATION ELEVEN. Radio Suppression

Procedure

Radio suppression tests were conducted for USATRECOM by the U. S. Army Signal Research and Development Laboratory in Milwaukee, Wisconsin (see Appendix IV).

Tests for radiated interference and conducted interference were performed. Permissible limits of interference allowed by Military Specification MIL-S-10379A were used throughout the tests. It was not possible to reduce interference at 1.8 and 3.0 megacycles during conduction tests when both alternators were operating simultaneously, although some reduction was realized when one alternator was operated independently. Radiated interference tests were passed. Since the conduction interference occurred at frequencies that do not affect LARC communication equipment, the electrical system was acceptable.

PHASE II - WATER PERFORMANCE TESTS

DETERMINATION ONE. Optimum Propeller

Procedure

The following three propellers were tested to determine which would provide the greatest speed and offer the best engine-loading capability: a 36-inch-diameter by 33-inch-pitch 4-blade standard; a 36-inch-diameter by 34-inch-pitch 3-blade standard; and a 36-inch-diameter by 34-inch-pitch 4-blade clipped. (The clipped propeller is a 38-inch-diameter unit faired into a 36-inch-diameter unit for tip strength.)

A 0.1-mile course in the Camp Del Mar water basin at Oceanside, California, was selected as a test course. Two transits were placed on the extremities of the course, and each transit operator had a stop watch to time the LARC as it came into the transit's line of sight. The LARC was run at three predetermined rpm's with each test propeller. During this test, the LARC was run in an unloaded condition. All runs were made in two directions to eliminate error which could be caused by wind or tide action. The average time was then used in final speed calculations. Engine rail pressures, which were correlated to engine horsepower, were recorded for each run to determine the load induced on the engines by the various propellers. Ambient temperatures were between 65° F. and 75° F.

Results

On the basis of best speeds and propeller loading, the 36-inch-diameter by 34-inch-pitch 4-blade clipped propeller was chosen as the optimum. This propeller produced a top speed of 9.97 miles per hour. The 3-blade propeller produced a speed of 9.89 miles per hour, and the 4-blade 33-inch-pitch propeller produced a speed of 9.4 miles per hour. Detailed data are presented in Tables 17 through 19 and are shown graphically in Figure 74.

TABLE 17

36-INCH-DIAMETER BY 33-INCH-PITCH 4-BLADE STANDARD PROPELLER

Engine Speed (rpm)	Direction	Time 1st Run (sec.)	Time 2nd Run (sec.)	Avg. Time (sec.)	Speed (mph)	Engine Rail Pressure (psi) Port	Engine Rail Pressure (psi) Stbd.
2,000	North	52.0	52.7	52.7	6.83	40	0
2,000	South	52.5	53.7				
2,000	North	52.8	52.2				
2,500	South	44.6	45.0	44.2	8.15	100	45
2,500	North	45.6	44.8				
2,500	South	42.7	42.4				
3,000	North	36.8	-	38.3	9.40	190	190
3,000	South	40.4	39.2				
3,000	North	38.8	37.7				
3,000	South	36.8	37.8				
3,000	North	39.0	38.1				
3,000	South	38.5	38.0				

TABLE 18

36-INCH-DIAMETER BY 34-INCH-PITCH 3-BLADE STANDARD PROPELLER

Engine Speed (rpm) Port	Engine Speed (rpm) Stbd	Direction	Time 1st Run (sec.)	Time 2nd Run (sec.)	Avg. Time (sec.)	Speed (mph)	Engine Rail Pressure (psi) Port	Engine Rail Pressure (psi) Stbd.
2,000	2,000	North	48.4	49.2	48.0	7.50	40	0
2,000	2,000	South	47.6	46.9				
2,500	2,500	North	40.6	41.2	41.4	8.69	80	35
2,500	2,500	South	42.5	41.2				
2,975	2,950	North	36.2	36.2	36.4	9.89	190	190
2,975	2,950	South	37.2	36.2				
2,950	2,950	North	35.8	36.1				
2,950	2,950	South	37.6	36.3				

TABLE 19

36-INCH-DIAMETER BY 34-INCH-PITCH 4-BLADE CLIPPED PROPELLER

Engine Speed (rpm)	Direction	Time 1st Run (sec.)	Time 2nd Run (sec.)	Avg. Time (sec.)	Speed (mph)	Engine Rail Pressure (psi) Port	Engine Rail Pressure (psi) Stbd.
2,000	North	49.6	49.2	48.5	7.43	40	0
2,000	South	47.2	47.9				
2,500	North	41.5	40.7	40.7	8.84	110	50
2,500	South	40.2	40.4				
2,975	North	36.4	36.0	36.1	9.97	210	190
2,975	South	36.0	36.2				
2,975	North	36.0	36.2				

Note: Because this propeller gave the highest water speeds and rail pressures, it was chosen as the optimum propeller.

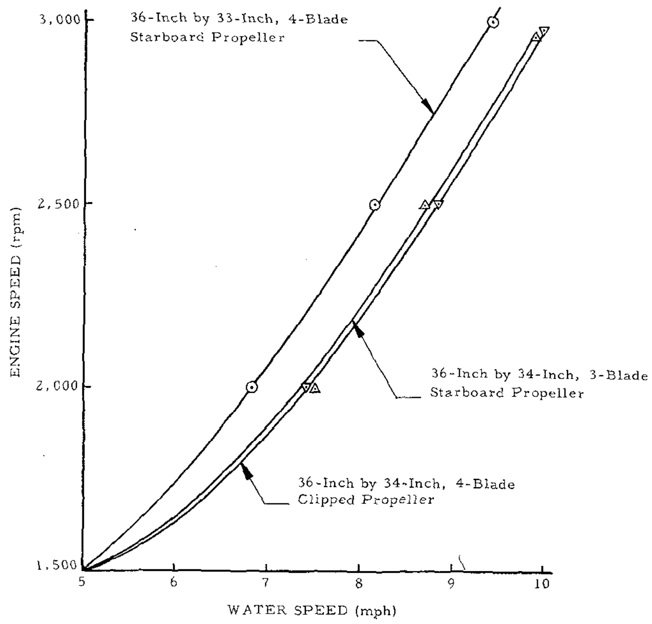


Figure 74. Engine Speed Versus Water Speed for Determination of Optimum Propeller.

DETERMINATION TWO. Steering Characteristics

Procedure

Turning radius tests were performed to determine the effectiveness of the various steering possibilities of the lighter. Aiming stakes were centered on the lighter bow and stern. As the LARC circled in the basin, its path was traced by two transits on the shore by measuring the angle at which the aiming stakes were aligned (see Figure 75). Each test was performed at varying engine speeds for both the forward and reverse conditions.

Wind and current were negligible at the time of tests. The steering conditions tested were as follows:

Four-wheel steering with rudder.
Four-wheel steering without rudder.
Two-wheel steering with rudder.
Two-wheel steering without rudder.
Rudder without wheels.

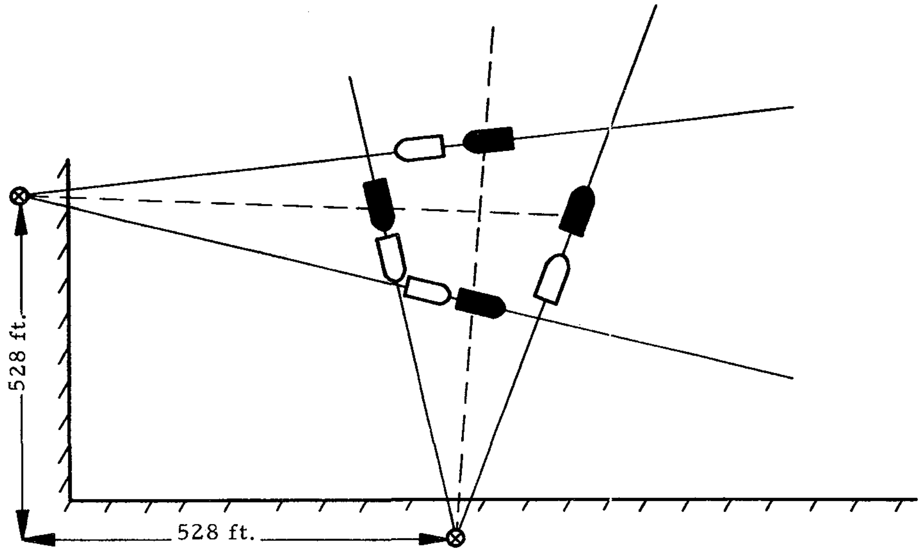


Figure 75. Test Setup To Measure Turning Radius.

A graphical layout of the sightings was made during the test. The intersections of the sightings taken perpendicular to the lighter were used as the center of rotation of the vehicle. From this point, perpendicular lines were drawn to the line of sights which describe the outer boundaries of the turning path. These lines were measured and the corresponding major and minor axes were determined.

Results

For the following conditions, the lighter was not able to negotiate a turn within the limits of the basin:

Two-wheel steering without rudder, port turn, forward.
Two-wheel steering without rudder, starboard turn, reverse.
Rudder without wheels, starboard turn, reverse.

Generally, the turning radius for any condition increases as the engine speed increases. The best turning conditions, in either the port or the starboard direction, were found to be with the four-wheel steering with rudder, which at full speed was a 50-foot radius in a starboard turn and a 71-foot radius in a port turn (see Tables 20 through 25 and Figures 76 and 77). Because of instability, turning-circle tests for loaded conditions were not conducted.

TABLE 20
TURNING RADIUS WITH FOUR-WHEEL STEERING--FORWARD DIRECTION

Steering Condition	Engine Speed (rpm)	Direction of Turn	Major Radius (ft.)	Minor Radius (ft.)
With Rudder	1,500	Port	56	54
"	2,000	"	61	57
"	2,500	"	71	67
"	3,000	"	71	65
"	1,500	Starboard	45	40
"	2,000	"	46	44
"	2,500	"	51	48
"	3,000	"	50	47
Without Rudder	1,500	Port	145	55
"	2,000	"	190	70
"	2,500	"	193	78
"	3,000	"	240	103
"	1,500	Starboard	66	60
"	2,000	"	77	72
"	2,500	"	75	69
"	3,000	"	81	78

TABLE 21
TURNING RADIUS WITH FOUR-WHEEL STEERING--REVERSE DIRECTION

Steering Condition	Engine Speed (rpm)	Direction of Turn	Major Radius (ft.)	Minor Radius (ft.)
With Rudder	1,500	Port	51	43
"	2,000	"	55	50
"	2,500	"	57	57
"	3,000	"	59	54
"	1,500	Starboard	44	36

TABLE 21 - contd.

Steering Condition	Engine Speed (rpm)	Direction of Turn	Major Radius (ft.)	Minor Radius (ft.)
With Rudder	2,000	Starboard	46	36
"	2,500	"	42	36
"	3,000	"	42	35
Without Rudder	1,500	Port	54	52
"	2,000	"	59	55
"	2,500	"	85	68
"	3,000	"	76	70
"	1,500	Starboard	85	60
"	2,000	"	78	61
"	2,500	"	77	72
"	3,000	"	90	88

TABLE 22
TURNING RADIUS WITH TWO-WHEEL STEERING--FORWARD DIRECTION

Steering Condition	Engine Speed (rpm)	Direction of Turn	Major Radius (ft.)	Minor Radi (ft.)
With Rudder	1,500	Port	66	58
"	2,000	"	89	64
"	2,500	"	91	56
"	3,000	"	110	71
"	1,500	Starboard	78	63
"	2,000	"	78	58
"	2,500	"	94	60
"	3,000	"	94	86
Without Rudder	-	Port	Could not negotiate turns within limits of basin	
"	1,500	Starboard	138	125
"	2,000	"	128	115
"	2,500	"	165	158
"	3,000	"	228	190

TABLE 23
TURNING RADIUS WITH TWO-WHEEL STEERING--REVERSE DIRECTION

Steering Condition	Engine Speed (rpm)	Direction of Turn	Major Radius (ft.)	Minor Radius (ft.)
With Rudder	1,500	Port	84	65
"	2,000	"	105	100
"	2,500	"	153	143
"	3,000	"	173	155
"	1,500	Starboard	70	60
"	2,000	"	93	83
"	2,500	"	108	90
"	3,000	"	345	328
Without Rudder	-	"	Could not be negotiated within limits of basin	
"	1,500	Port	44	40
"	2,000	"	39	37
"	2,500	"	57	52
"	3,000	"	70	64

TABLE 24
TURNING RADIUS WITH RUDDER AND NO WHEELS--FORWARD DIRECTION

Engine Speed (rpm)	Direction of Turn	Major Radius (ft.)	Minor Radius (ft.)
1,500	Port	195	190
2,000	"	194	173
2,500	"	235	215
3,000	"	250	238
1,500	Starboard	87	75
2,000	"	103	75
2,500	"	95	93
3,000	"	95	93

TABLE 25
TURNING RADIUS WITH RUDDER AND NO WHEELS--REVERSE DIRECTION

Engine Speed (rpm)	Direction of Turn	Major Radius (ft.)	Minor Radius (ft.)
1,500	Port	175	170
2,000	"	223	210
2,500	"	268	255
3,000	"	278	268

Figure 76. Transit Used To Trace Path of Lighter During Marine Turning Radius Tests.

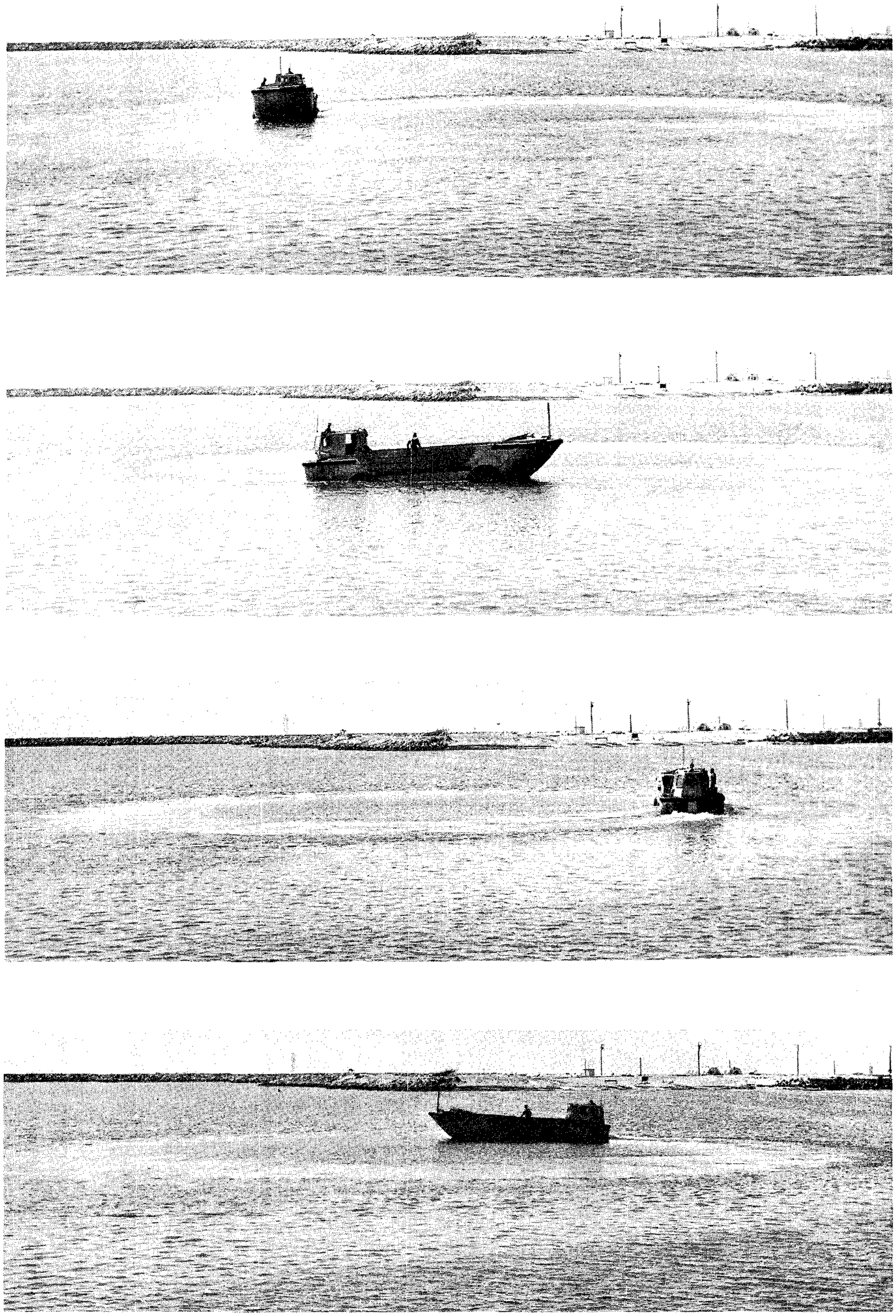


Figure 77. Marine Turning Radius Tests--Lighter at 90-Degree Intervals in a Port Turn.

DETERMINATION THREE. Water Speed

Procedure - Optimum Propeller

Speed runs were conducted with the optimum propeller. The same procedure was used as was described in Determination One of Phase II for the selection of the optimum propeller. The load was restricted to 10 tons because of the stability consideration and the maneuvering required for the narrow basin. For single-engine operation, one engine drive was disconnected. The following speed runs were conducted:

Reverse, two engines, 10-ton load
Reverse, two engines, no load
Forward, two engines, 10-ton load
Forward, one engine, no load

(For horsepower , see Determination Three of Supplemental Tests, page 123, and Appendix III.)

Results - Optimum Propeller

Maximum speeds were 8.89 miles per hour with a 10-ton load and 9.97 miles per hour in the light condition (see Tables 26 through 29 and Figures 78 through 81). With single-engine operation, a speed of 8 miles per hour was realized in the unloaded condition. The maximum power output was 575 horsepower for both engines (310 horsepower for the port engine), measured at the engine output shafts. Difficulty experienced in protecting the instrumented marine propeller shaft nullified horsepower test results at the propeller. (The proximity of the shaft to the hull exposed the instrumentation to bilge water and oil.)

When the speed runs were initiated, the LARC showed a tendency to porpoise; the porpoising eventually subsided. No directional instability was observed at any speeds. Slight propeller cavitation occurred at engine speeds of 2,500 to 3,000 rpm in the forward direction, and quite severe cavitation occurred in the reverse direction. No shaft whip was observed at any speeds, but a slight vibration was felt at the deck at engine speeds of approximately 2,000 rpm, which was indicative of a torsional vibration.

TABLE 26
SPEED RUNS WITH TWO ENGINES, 10-TON LOAD--REVERSE DIRECTION

Engine Speed (rpm)	Distance (mi.)	Time (sec.)					Water Speed (mph)
		1st Run	2nd Run	3rd Run	4th Run	Average	
1,000	0.1	159.2	149.8	-	150.2	153.1	2.35
2,000	0.1	76.3	74.2	75.4	74.8	75.2	4.79
3,000	0.1	52.2	52.3	51.3	52.6	52.1	6.91

TABLE 27
SPEED RUNS WITH TWO ENGINES, 10-TON LOAD--FORWARD DIRECTION

Engine Speed (rpm)	Distance (mi.)	Time (sec.)					Water Speed (mph)
		1st Run	2nd Run	3rd Run	4th Run	Average	
1,000	0.1	129.8	-	129.2	129.0	129.3	2.78
2,000	0.1	58.0	57.0	57.0	57.5	57.4	6.27
3,000	0.1	41.3	40.0	40.2	40.4	40.5	8.89

TABLE 28
SPEED RUNS WITH TWO ENGINES, NO LOAD--REVERSE DIRECTION

Engine Speed (rpm)	Distance (mi.)	Time (sec.)					Water Speed (mph)
		1st Run	2nd Run	3rd Run	4th Run	Average	
1,000	0.1	111.4	129.3	114.2	128.8	120.9	2.98
2,000	0.1	71.8	70.5	72.7	70.3	71.3	5.05
3,000	0.1	49.4	49.4	50.0	48.7	49.4	7.29

TABLE 29

SPEED RUNS WITH ONE ENGINE, NO LOAD--FORWARD DIRECTION

Engine Speed (rpm)	Distance (mi.)	Engine	Time (sec.) 1st Run	2nd Run	Average	Water Speed (mph)	Rail Pressures (psi) Port	Stbd.
2,000	0.1	Port	47.8	48.3	48.9	7.37	60	-
2,000	0.1		50.0	49.4				
2,250	0.1	Port	44.2	44.5	44.9	8.02	130	-
2,250	0.1		46.0	45.2				
2,300	0.1	Stbd.	44.0	44.1	44.5	8.09	-	130
2,300	0.1		45.4	44.7				

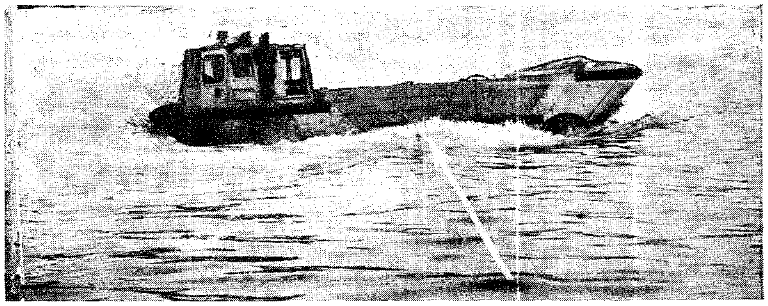


Figure 78. Speed Run With Lighter Fully Loaded. (Note secondary bow wave.)

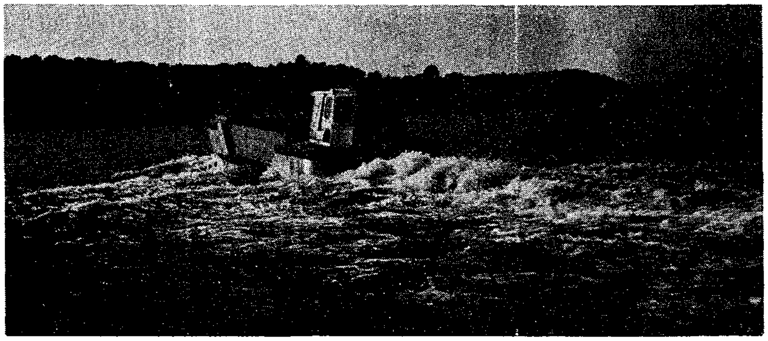


Figure 79. Speed Run With Lighter in Unloaded Condition--Wake and Bow Wave Shown.

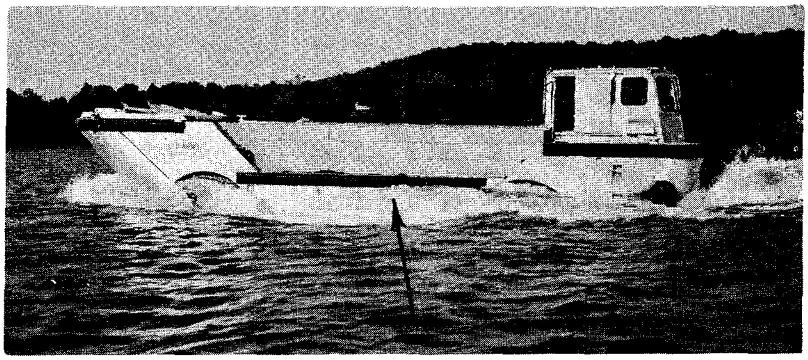


Figure 80. Speed Run With Lighter in Unloaded Condition. (Note secondary wave shown, indicated by arrow.)

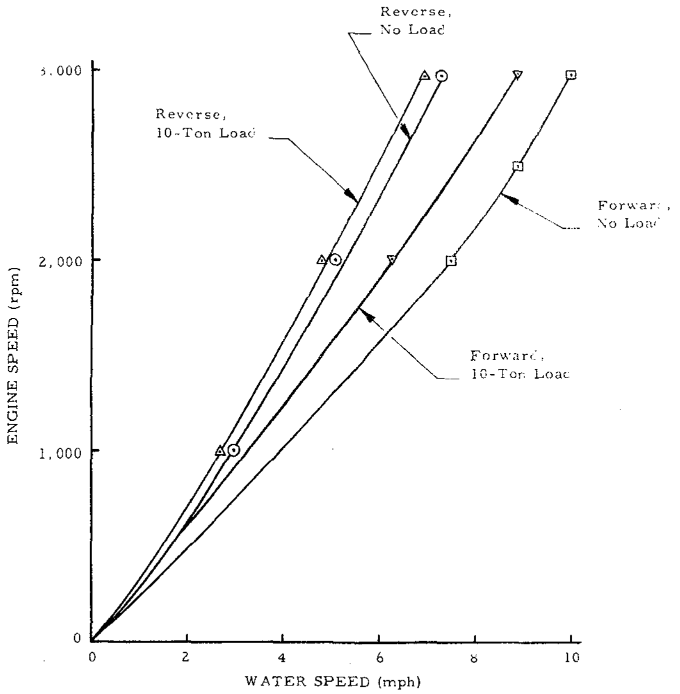


Figure 81. Engine Speed Versus Water Speed for Test Runs With Optimum Propeller.

Procedure - Wheels for Propulsion

Water speed tests were run at Camp Del Mar water basin, Oceanside, California, with the wheels alone being used for propulsion. The same test procedure was used as was described for speed runs with the optimum propeller (see Figure 82).

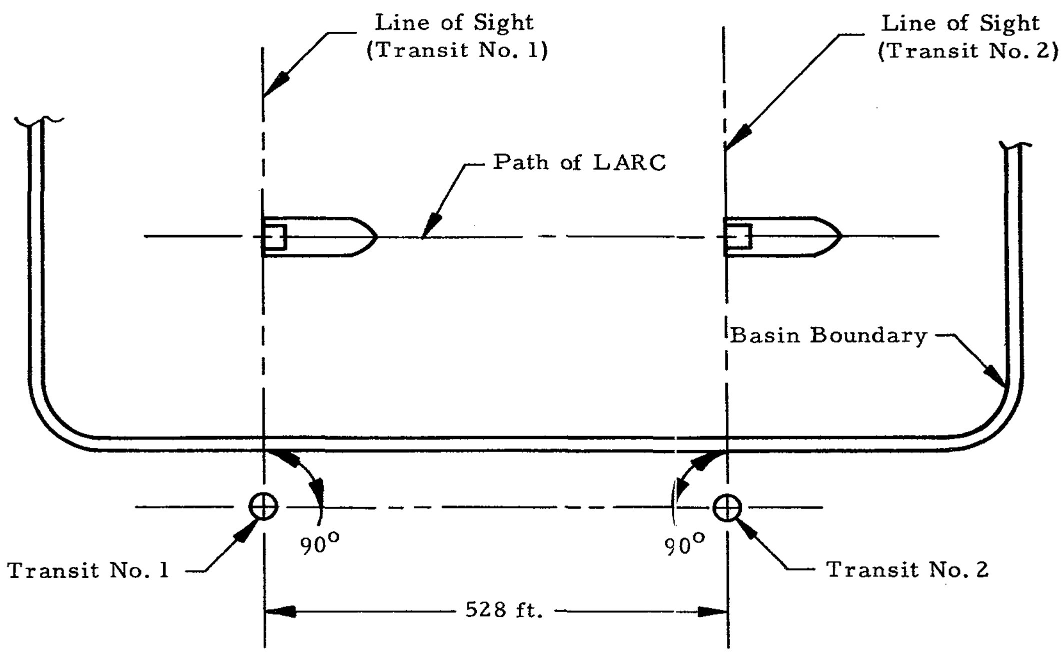


Figure 82. Test Setup To Determine Speed--Wheels for Propulsion.

Results - Wheels for Propulsion

The maximum forward speed was 2.72 miles per hour.

DETERMINATION FOUR. Head Reach

Procedure

The lighter was tested in the Camp Del Mar water basin to check the distance required to coast to a complete stop from full speed. This was accomplished by stopping both engines as soon as the vessel had reached full speed. Testing was conducted in forward and reverse directions and in loaded and unloaded conditions. The path of the lighter was traced by marking a point on the LARC at engine cutoff and again when the vehicle had come to a complete stop. These points were traced with two transits, and the distance was recorded from the resulting plot. (The load was limited to 10 tons for stability purposes.)

Results

For this type of test, it is difficult to determine where the lighter loses the inertia that it derives from the propeller and where it picks up forward motion due to wind and water action. For this reason, a question is raised as to when the exact moment arrives at which forward motion ceases. This point should be kept in mind upon consideration of the results shown in Table 30. See Figures 83 and 84 for graphical solution of test results.

TABLE 30
HEAD-REACH TESTS AT ENGINE SPEED OF 3, 000 RPM

Trial	Transit No. 1		Transit No. 2		Test Condition		Head Reach
	θ_1	θ_2	Φ_1	Φ_2	Direction	Load	(ft.)
1	90°00'	58°46'	35°30'	44°15'	Forward	None	205
2	90°00'	59°32'	38°00'	49°00'	Forward	None	220
1	90°00'	59°30'	36°00'	49°20'	Forward	10 Tons	217
2	90°00'	60°30'	37°00'	52°00'	Forward	10 Tons	223
3*	90°00'	59°15'	33°55'	44°25'	Reverse	None	196
4*	90°00'	65°30'	37°19'	49°30'	Reverse	10 Tons	183

* Time did not permit confirming runs.

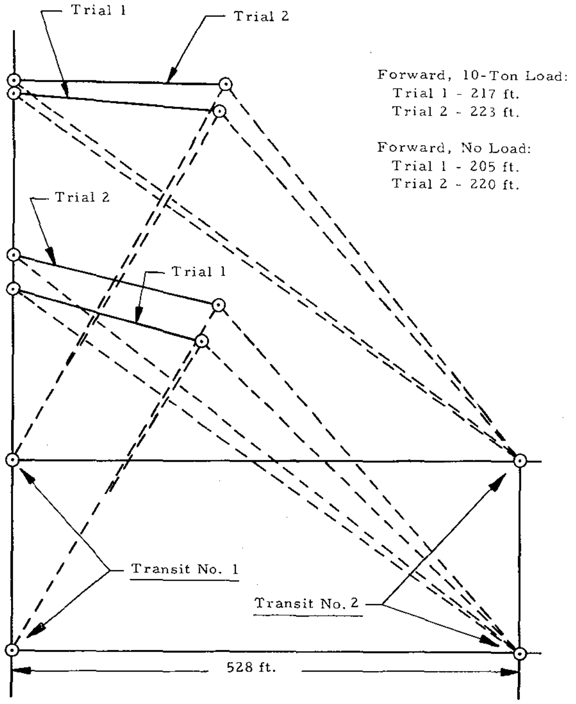


Figure 83. Graphical Solution of Head-Reach Tests--Forward Direction.

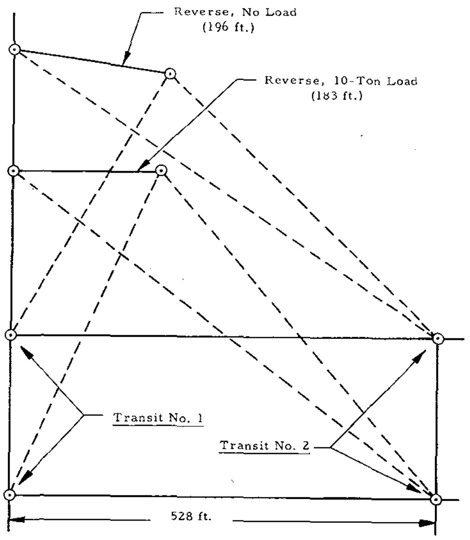


Figure 84. Graphical Solution of Head-Reach Tests--Reverse Direction.

DETERMINATION FIVE. Fuel Consumption

Procedure

Fuel consumption tests for both land and marine operations, with various engine rpm's, were conducted at the Naval Amphibious Base, Coronado, California. Auxiliary fuel tanks were substituted for the designed fuel supply and recirculating system (see Figure 85). The substitute fuel supply was weighed before and after each run, and the difference in weight represented the fuel consumed. The runs were timed to give a rate of consumption.

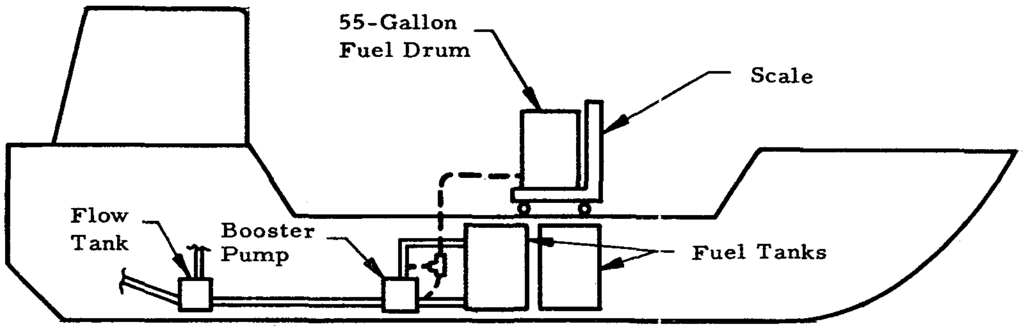


Figure 85. Test Setup To Determine Fuel Consumption. (Solid lines indicate actual fuel lines. Dotted lines indicate test fuel lines.)

Diesel oil no. 2 with a 44-cetane rating was used; it conformed to Specification MIL-F-896. Flow meters were not used because of the recirculation of a portion of the injector pump discharge for cooling purposes. (Multifuel tests were canceled because the LARC was shipped to Cape Canaveral for reassignment.)

Results

Results of the fuel consumption tests are shown in Tables 31 and 32 and graphically in Figure 86.

TABLE 31
MARINE FUEL CONSUMPTION

Engine Speed (rpm)	Fuel Weight at Start (lb.)		Fuel Weight at End (lb.)		Fuel Consumed (lb.)		Total Fuel Consumed by Two Engines (lb.)	Time (min.)	Consumption of Two Engines (lb. /min.)	Consumption of Two Engines (gal. /hr.)
	Port Tank	Stbd. Tank	Port Tank	Stbd. Tank	Port Engine	Stbd. Engine				
1,000	379.0	358.0	372.5	353.5	6.5	4.5	11.0	30	0.37	2.96
1,500	372.5	353.5	361.0	344.0	11.5	9.5	21.0	30	0.70	5.60
2,000	356.0	344.0	334.0	324.0	22.0	20.0	42.0	30	1.40	11.20
2,500	339.0	324.0	313.0	299.0	26.0	25.0	51.0	20	2.55	20.40
3,000	313.0	299.0	272.5	251.5	40.5	47.5	88.0	25	3.52	28.16

TABLE 32
LAND FUEL CONSUMPTION

Engine Speed (rpm)	Fuel Weight at Start (lb.)		Fuel Weight at End (lb.)		Fuel Consumed (lb.)		Total Fuel Consumed by Two Engines (lb.)	Time (min.)	Consumption of Two Engines (lb. /min.)	Consumption of Two Engines (gal. /hr.)
	Port Tank	Stbd. Tank	Port Tank	Stbd. Tank	Port Engine	Stbd. Engine				
1,000	440.5	432.5	434.0	425.5	6.5	7.0	13.5	30.0	0.45	3.60
1,500	434.0	425.5	428.5	419.0	5.5	6.5	12.0	17.0	0.71	5.68
2,000	423.5	413.0	410.5	402.5	13.0	10.5	23.5	22.5	1.04	8.32
2,500	410.5	402.5	397.5	388.0	13.0	14.5	27.5	16.8	1.64	13.12
3,000	397.5	388.0	387.0	370.0	10.5	18.0	28.0	13.8	2.04	16.32

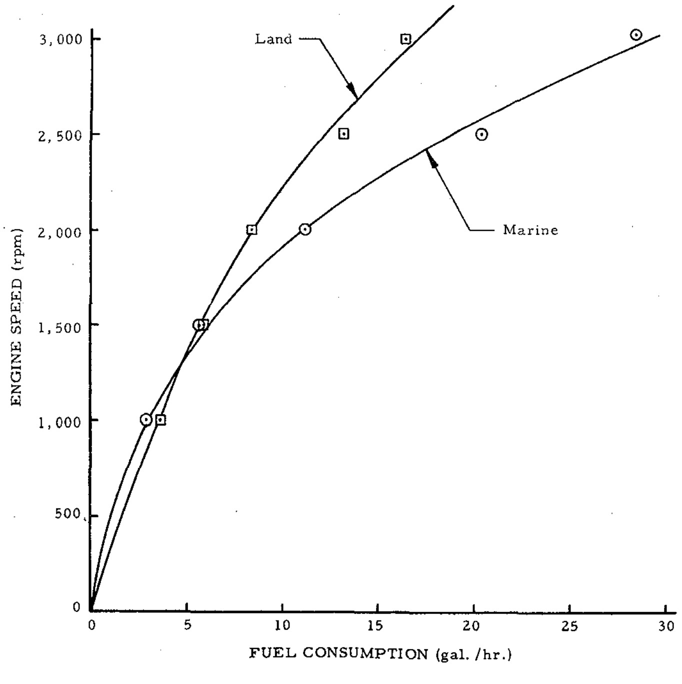


Figure 86. Engine RPM Versus Land and Marine Fuel Consumption.

DETERMINATION SIX. Thrust and Drag

Procedure - Thrust

Bollard-pull tests were conducted to determine the thrust developed under various engine rpm's. The LARC was tested in both the forward and reverse directions with the vehicle in the loaded and unloaded conditions. The maximum tension in the securing cable was measured by a load cell located in the towing cable between the LARC and a stationary vehicle on the shore. The towing cable was 60 feet long to allow the LARC to pull in water 12 to 15 feet deep (see Figure 87).

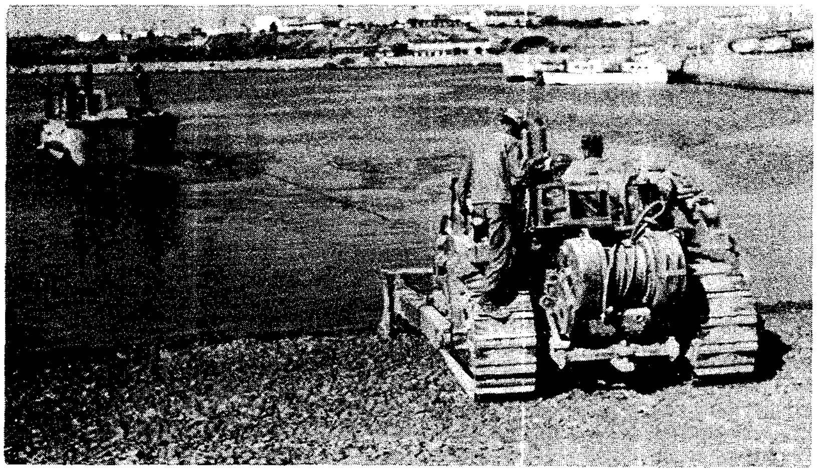


Figure 87. Marine Bollard-Pull Test With Lighter Running in Reverse.

Results - Thrust

The maximum thrusts developed for the test conditions stated are shown on the last line of Table 33. Figure 88 shows the thrusts developed in the lower rpm range.

TABLE 33
BOLLARD PULL

Engine Speed (rpm)	Forward Direction No Load (lb.)	Forward Direction 10-Ton Load (lb.)	Reverse Direction No Load (lb.)	Reverse Direction 10-Ton Load (lb.)
600	300	200	200	100
1,000	600	700	300	400

TABLE 33 - contd.

Engine Speed (rpm)	Forward Direction No Load (lb.)	Forward Direction 10-Ton Load (lb.)	Reverse Direction No Load (lb.)	Reverse Direction 10-Ton Load (lb.)
1,500	1,000	1,400	1,400	1,200
2,000	3,500	3,200	2,300	2,200
2,500	5,500	5,500	3,400	3,400
3,000	7,100	7,400	5,500	5,600

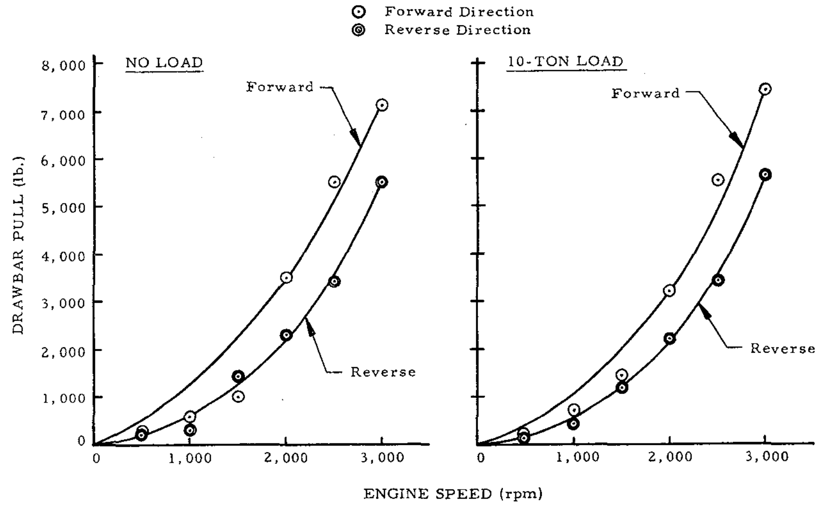


Figure 88. Bollard Pull Versus Engine Speed.

Procedure - Drag

The LARC was towed by a DUKW in the Camp Del Mar water basin to determine towing resistance (see Figure 89). The highest water speed that the DUKW could attain when towing the LARC was 3.57 miles per hour. Speeds of up to 15 miles per hour had been desired, but no towing vehicle could be obtained to pull the lighter at greater speeds. For this reason, the test was run only three times. The force was measured by inserting a load cell in the towing cable. The lighter was towed and timed through the 0.1-mile course. In order to minimize wake effect, a tow tope having a minimum length of 100 feet was used.

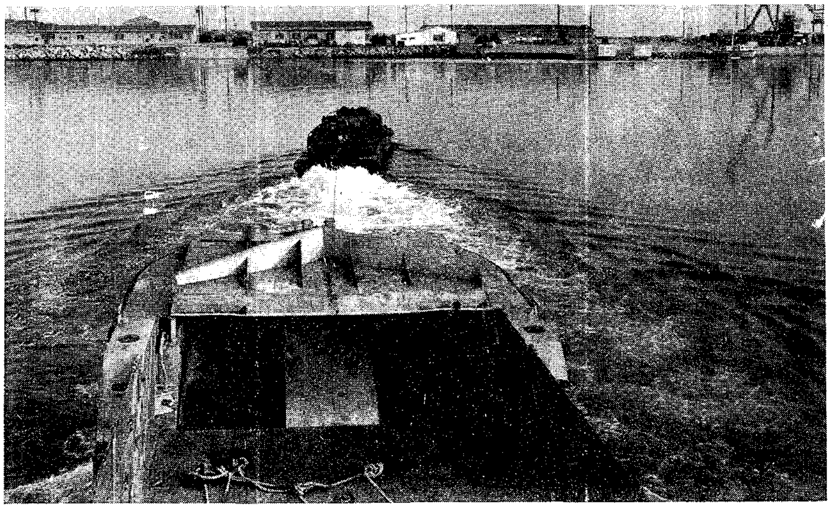


Figure 89. Lighter Being Towed by DUKW During Towing Resistance Tests.

Results - Drag

For the maximum speed attained (3.57 miles per hour), a pull of 950 pounds was recorded; at this low speed, there was no porpoising or directional instability. There also was no evidence of damage to welds or to support structure as a result of the tow on the port and starboard bitts. (See data in Table 34 and Figure 90.)

TABLE 34
TOWING RESISTANCE
FOR LARC PULLED BY DUKW

Time (sec.)	Distance (mi.)	Speed (mph)	Pull (lb.)
171.8	0.1	2.11	350
123.4	0.1	2.92	625
101.0	0.1	3.57	950

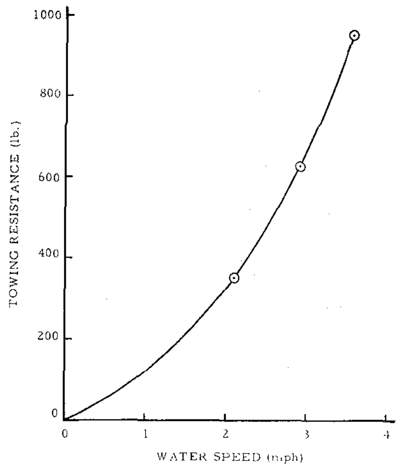


Figure 90. Towing Resistance Versus Water Speed for LARC Being Towed by DUKW.

Procedure - Side Thrust With Lighter Moored

Side-thrust tests with the lighter moored were simulated at Camp Del Mar water basin, Oceanside, California. A dock was used to simulate a ship to which the LARC would be moored. The vehicle was tied to the dock from the forward mooring bitts and from the steps on the forward cheeks in order to determine which position gave the largest side thrust (see Figures 91 and 92). The test was conducted for both port and starboard moorings at various engine rpm's. The side thrust was measured by means of a load cell that was inserted between the lighter and the dock (see Figure 93); the vehicle was propelled in the forward and reverse directions.

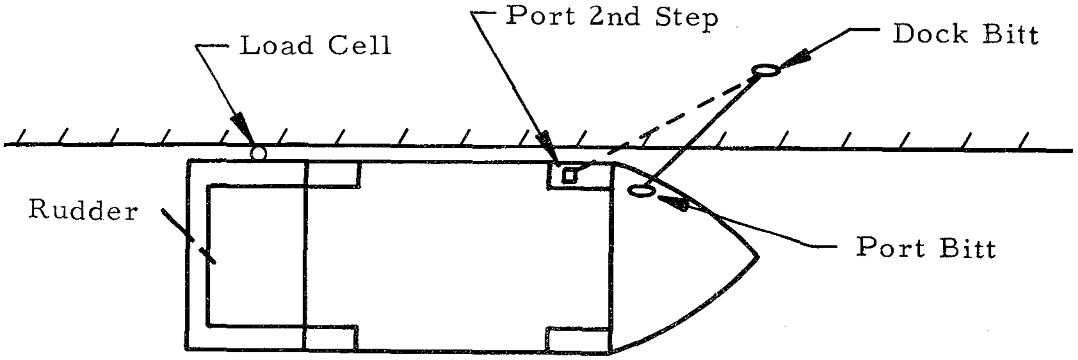


Figure 91. Side-Thrust Test--Port Mooring.

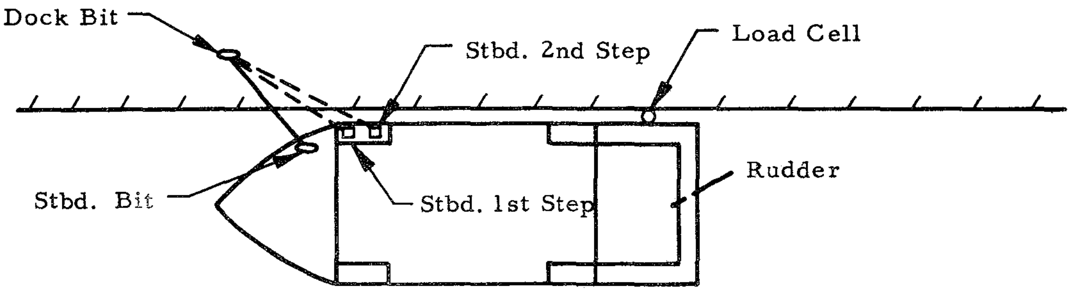
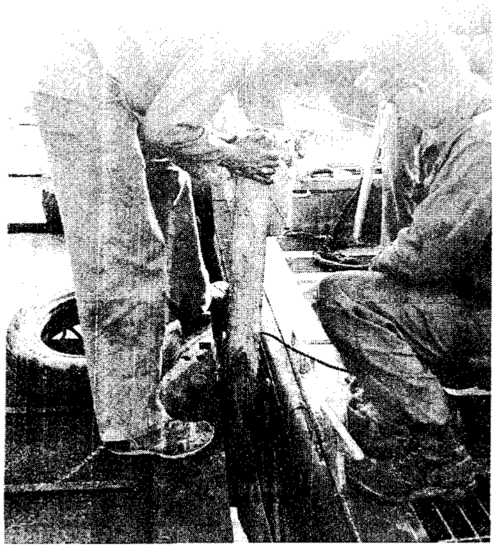


Figure 92. Side-Thrust Test--Starboard Mooring.

Figure 93. Measuring Side Thrust of Lighter During Mooring Test. (Thrust was measured by load cell inserted in timber held by man on left.)



Results - Side Thrust With Lighter Moored

Driven in the forward direction, the LARC did not develop sufficient side thrust to hold it against the dock. This was true of both port and starboard moorings. In reverse, the maximum side thrust of 600 pounds occurred with the vehicle tied on the most forward step on the starboard cheek. Subsequent inspection revealed no indication of damage either to the welds or to the support structure as a result of the forces on the bitts. Detailed test results are shown in Table 35 and Figure 94.

TABLE 35
SIDE THRUST OF LARC

Engine Speed (rpm)	Stbd. Bitt (lb.)	Stbd. 1st Step (lb.)	Stbd. 2nd Step (lb.)	Port Bitt (lb.)	Port 2nd Step (lb.)
Idle	60	30	80	20	75
1,000	100	160	140	75	120
1,500	280	330	280	220	290
2,000	450	600	500	480	500

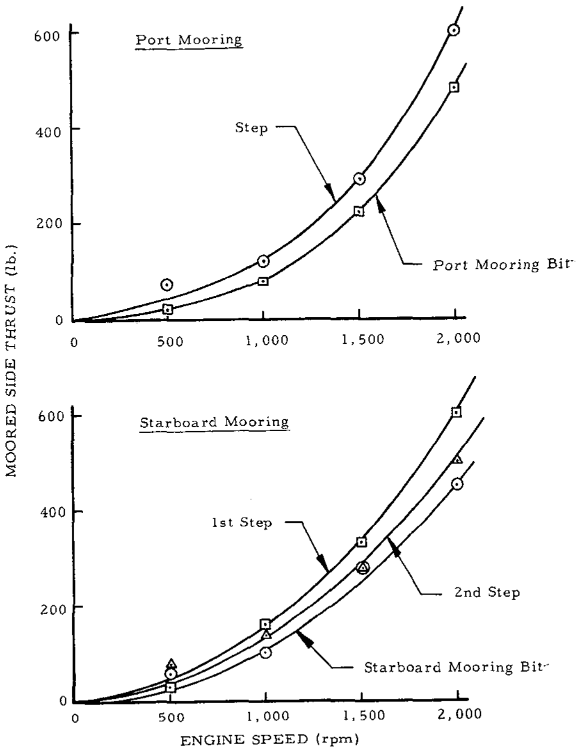


Figure 94. Side Thrust Versus Engine Speed When Running Astern During Mooring Tests.

DETERMINATION SEVEN. Rudder Override

Procedure

Rudder override tests were performed to see if control could be maintained if the rudder were damaged and locked hard over in either the port or starboard direction. The rudder control link was disengaged, and the rudder was secured in the port or the starboard hard-over position. The wheels were then the only controls left for marine steering. The speed of the lighter was varied, and the path of the lighter was traced by means of two transits on the shore, each transit sighting on a common point on the LARC and marking this point upon a signal given at intervals from the vehicle. The test was conducted for four-wheel steering only.

Results

When the rudder was locked for a hard-over starboard turn, the wheels did not override the rudder for an engine-speed range of from 1,000 to 3,000 rpm (see Table 36 and Figures 95 and 96).

TABLE 36
OVERRIDE TESTS*

	Engine	Sighting Point 1		Sighting Point 2		Sighting Point 3		Sighting Point 4	
Trial	Speed (rpm)	Transit No. 1	Transit No. 2	Transit No. 1	Transit No. 2	Transit No. 1	Transit No. 2	Transit No. 1	Transit No. 2
				RUDDER LOCKED IN STARBOARD TURN					
1	1,000	93°45'	46°45'	85°00'	48°45'	79°45'	49°50'	-	-
2	2,000	87°15'	46°00'	81°00'	49°30'	76°00'	51°30'	-	-
3	3,000	89°45'	44°45'	81°45'	49°00'	75°45'	52°30'	68°00'	55°30'
				RUDDER LOCKED IN PORT TURN					
1	3,000	91°30'	44°00'	78°15'	48°45'	67°30'	52°00'	67°30'	52°00'
2	3,000	95°00'	42°30'	86°15'	45°45'	75°30'	50°15'	62°15'	52°15'

* Four-wheel steering to overcome locked rudder.

With the rudder locked for a hard-over port turn, the wheels overrode the rudder. (This test was run at 3,000 rpm only, since the higher rpm would be the most critical as seen from the starboard condition.)

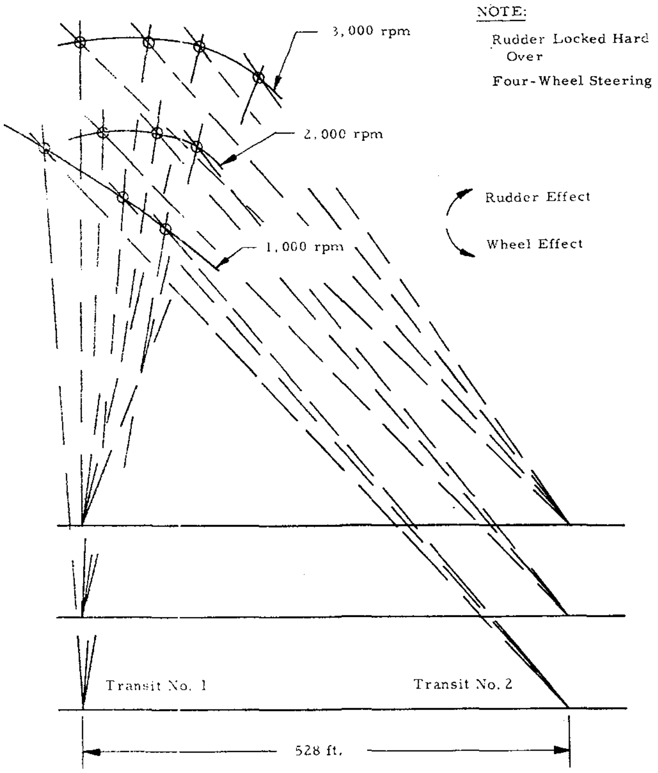


Figure 95. Rudder Override Path Characteristics for Various Engine RPMs--Starboard Turn.

Observation

At the lower rpm range, the path of the LARC approached a straight line, so it is possible that the lighter could override the rudder at speeds of less than 1,000 rpm. Although overriding may be possible, the radius of the turn would be so large that it would be more practical to assume that overriding was not possible.

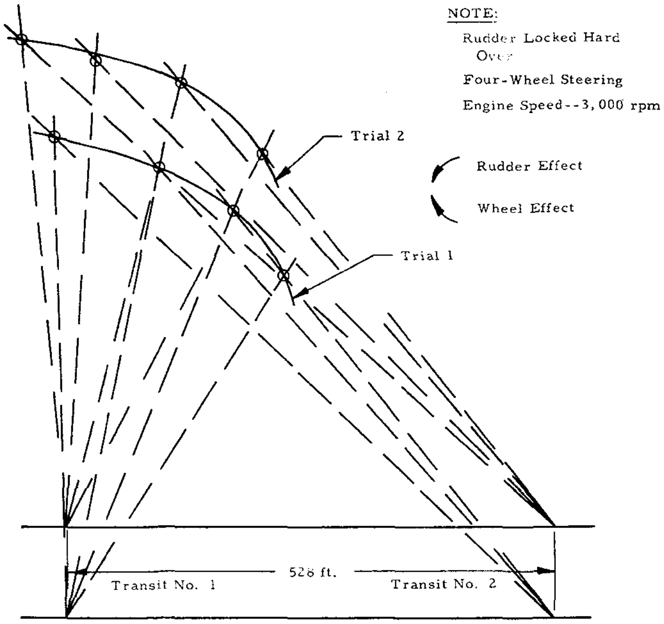


Figure 96. Rudder Override Path Characteristics for Various Engine RPMs--Port Turn.

DETERMINATION EIGHT. Effort Required by Operator To Steer

Procedure

Tests were conducted at Camp Del Mar, Oceanside, California, to determine the force an operator must exert to put the lighter in either a port or a starboard turn for marine operation. The force was measured by a spring scale attached to the outside rim of the steering wheel. The scale was held perpendicular to the radius of the wheel to assure that the pull was tangential and that it could easily be resolved into the torque required. The measurements were performed on the land operator's steering wheel to ensure that the stand-by operator had complete control of the vessel during the test. With the diameters of both steering wheels being know, the torque could then be resolved to the marine steering control. The pull required on the marine steering wheel was calculated from the torque values by dividing by the radius of the marine steering wheel (10.5 inches). The torque values were determined from the product of the pulls required on the land steering wheel and its radius (8.5 inches). The test was performed at various engine rpm's.

Results

The largest pull required was found in a starboard turn at an engine speed of 2,500 rpm. The initial pull required to put the vessel in the turn using the land-drive wheel was 19 pounds, which would be equivalent to a pull of 15.4 pounds on the marine steering wheel (see Table 37).

TABLE 37
MARINE STEERING TESTS

		Pull Required				Torque Required for Land and Marine Steering Wheels	
		Land Steering Wheel		Marine Steering Wheel			
Engine Speed (rpm)	Direction of Motion	Stbd. Turn (lb.)	Port Turn (lb.)	Stbd. Turn (lb.)	Port Turn (lb.)	Stbd. Turn (in.-lb.)	Port Turn (in.-lb.)
600	Forward	6	5	4.86	4.05	51.0	42.5
1,000	"	8	6	6.48	4.86	68.0	51.0
1,500	"	8	5	6.48	4.05	68.0	42.5
2,000	"	14	6	11.33	4.86	119.0	51.0
2,500	"	19	5	15.38	4.05	161.5	42.5
3,000	"	18	5	14.57	4.05	153.0	42.5
600	Reverse	5	4	4.05	3.24	42.5	34.0
1,000	"	5	6	4.05	4.86	42.5	51.0
1,500	"	7	5	5.67	4.05	59.5	42.5
2,000	"	7	5	5.67	4.05	59.5	42.5
2,500	"	6	4	4.86	3.24	51.0	34.0
3,000	"	5	7	4.05	5.67	42.5	59.5

DETERMINATION NINE. Torsional Vibrations

Procedure

The Cummins Engine Company conducted torsiograph tests to ascertain severity of torsional vibration of drive shafts at different engine speeds in the water.

Results

The torsional characteristics of the entire engine system were considered to be satisfactory. Appendix V contains the report of test submitted by the Cummins Engine Company.

DETERMINATION TEN. Heat Measurements

Procedure - Engine Cooling System

Each engine cooling system consisted of two parallel branches collecting in a common radiator and branching from the radiator back into the two parallel systems (see Figure 97). (It is important to note that each engine cooling system is independent of the other.) The branches were crossed within the

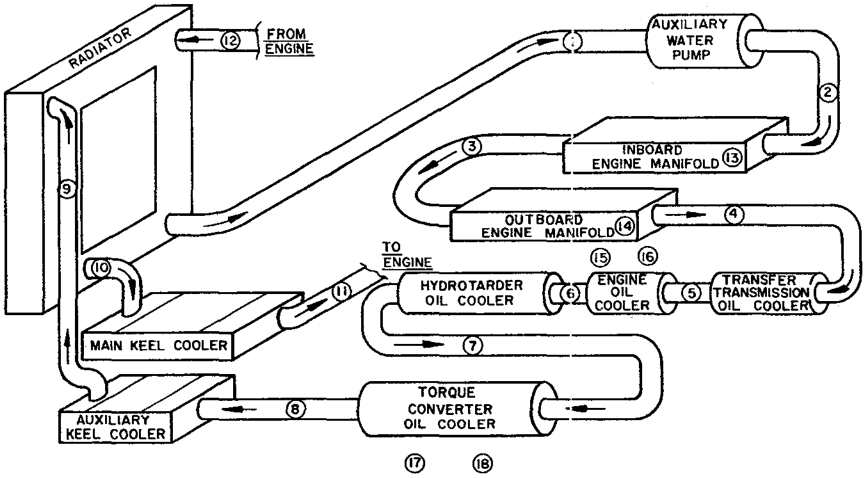


Figure 97. Thermocouple Locations in Starboard Engine Room. (Numbers 15, 16, 17, and 18 represent oil thermocouples.)

radiator by reversing outlets in order to ensure a coolant mixture by cross-flow. The coolant of the main branch flowed from the engine to the radiator and then through the keel cooler to the engine-mounted water pump (98 gallons per minute at 3,000 rpm). The coolant of the auxiliary branch picked up heat loads from the inboard and outboard water-cooled exhaust manifolds and from the heat changers and discharged these loads to the auxiliary keel cooler and/or common radiator; the flow was provided by the auxiliary cooling water pump (80 gallons per minute at 3,000 rpm). Since there were two hydrotarder heat exchangers for the single hydrotarder (hydraulic brake or retarder), the heat load sharing was ensured by sizing the feeder lines to split the flow equally to the two heat exchangers.

With the use of thermocouples, the starboard engine cooling system was prepared for recording temperatures during a continuous 1-hour full-speed land test and a 2-hour full-speed water test. (Table 38 shows where the thermocouples were located.) The LARC was operated with no load both

TABLE 38
THERMOCOUPLE IDENTIFICATION

Thermo-couple No.	Thermocouple Location
1	Coolant: From Radiator to Auxiliary Water Pump, Starboard Engine
2	Coolant: From Auxiliary Water Pump to Inboard Manifold, Starboard Engine
3	Coolant: From Inboard to Outboard Manifold, Starboard Engine
4	Coolant: From Outboard Manifold to Transfer Transmission Oil Cooler, Starboard Engine
5	Coolant: From Transfer Transmission Oil Cooler to Engine Oil Cooler, Starboard Engine
6	Coolant: From Engine Oil Cooler to Hydrotarder Oil Cooler, Starboard Engine
7	Coolant: From Hydrotarder Oil Cooler to Torque Converter Oil Cooler, Starboard Engine
8	Coolant: From Torque Converter Oil Cooler to Auxiliary Keel Cooler, Starboard Engine
9	Coolant: From Auxiliary Keel Cooler to Radiator, Starboard Engine
10	Coolant: From Radiator to Main Keel Cooler, Starboard Engine
11	Coolant: From Main Keel Cooler to Engine, Starboard Engine
12	Coolant: From Engine to Radiator, Starboard Engine
13	Surface Temperature: Inboard Manifold, Starboard Engine
14	Surface Temperature: Outboard Manifold, Starboard Engine
15	Oil: From Engine Oil Cooler to Engine, Starboard Engine
16	Oil: From Engine to Engine Oil Cooler, Starboard Engine
17	Oil: From Torque Converter Oil Cooler to Torque Converter, Starboard Engine
18	Oil: From Torque Converter to Torque Converter Oil Cooler, Starboard Engine
19	Surface Temperature: Transfer Transmission Ear Seal, Port
20	Surface Temperature: Transfer Transmission Ear Seal, Starboard
21	Surface Temperature: Transfer Transmission Ear Top, Port
22	Surface Temperature: Transfer Transmission Ear Top, Starboard
23	Air: Air Cleaner, Starboard
24	Air: Air Cleaner, Port
25	Air: Air Out of Grill, Starboard
26	Air: Air Out of Radiator, Starboard
27	Oil: Hydraulic Tank
28	Air: Outlet Exhaust, Starboard
29	Air: Ambient
30	Oil: Transfer Transmission Sump
31	Coolant: From Radiator to Main Keel Cooler, Port Engine
32	Coolant: From Engine to Radiator, Port Engine

over a relatively flat beach and in relatively calm water. Thermocouples were also installed at arbitrary check points on the port engine to provide a correlation between the two systems.

Superimposed on the engine cooling system was the heat load from the torque converter; in addition, on the starboard side only, a heat exchanger was installed for the transfer transmission oil. (Original hydrotarder heat exchangers provided in the port and starboard cooling systems for the purpose of dissipating the heat load created by hydraulic braking action were disconnected because of inactivation of the hydrotarder.)

Temperatures were continuously recorded by a multichannel oscillograph. All thermocouples had previously been calibrated. Simultaneously with the recording of coolant temperatures, the following were recorded: surface temperatures of salient components, air temperatures, and hydraulic oil and lube oil temperatures.

Results - Engine Cooling System, Land Operations

After 1 hour of operation, the cooling system temperatures stabilized. The peak temperature occurring in the auxiliary branch was 151° F. at the outlet of the second exhaust manifold; the peak temperature occurring in the main branch was 170° F. A temperature rise of approximately 50° F. was observed from ambient to engine air intake. The hydraulic oil temperature rose to 200° F. maximum, and the transfer transmission oil temperature rose to 140° F. maximum. Ambient temperatures ranged from 80° F. to 90° F.

Table 39 shows the temperatures recorded during the 1-hour land test for the thermocouples identified in Table 38, and Figure 98 is a graphic presentation of the heat transfer.

TABLE 39

TEMPERATURES

AFTER 1-HOUR LAND HEAT BALANCE TEST (°F.)

Thermo-couple	Elapsed Time (min.)							
No.*	0	8	16	24	32	40	48	56
1	-	-	-	-	-	-	-	-
2	88	92	120	122	119	118	125	122
3	136	170	121	122	120	118	128	174
4	121	120	151	149	144	146	147	-

TABLE 39 - contd.

Thermocouple No. *	Elapsed Time (min.)							
	0	8	16	24	32	40	48	56
5	94	110	129	128	128	121	137	132
6	109	109	140	145	144	141	142	-
7	106	100	92	113	130	137	136	-
8	110	118	142	143	141	140	141	-
9	110	123	143	144	140	139	142	-
10	93	89	122	126	119	122	122	-
11	117	124	128	142	151	155	160	-
12	160	157	170	162	166	161	163	-
13	181	-	-	197	186	188	230	248
14	126	109	123	122	122	120	130	130
15	96	103	123	132	134	135	147	191
16	178	183	216	226	222	218	225	206
17	67	58	77	92	103	102	119	110
18	115	134	161	138	138	140	146	158
19	89	92	106	115	117	119	125	125
20	94	105	115	121	125	126	140	144
21	94	100	109	114	124	118	132	136
22	98	106	117	126	142	136	146	143
23	108	101	109	129	128	130	139	144
24	106	108	117	128	129	132	139	144
25	88	84	101	102	99	99	99	120
26	91	94	104	104	102	104	103	123
27	106	128	152	173	183	187	200	190
28	300	300	300	300	300	300	300	300
29	80	74	85	68	75	88	88	67
30	96	109	127	137	139	140	126	124
31	-	-	-	-	-	-	-	-
32	151	140	142	146	156	165	176	182

* See Table 38 for thermocouple identification.
Thermocouples 1 through 12 located in water cooling system.
Thermocouples 13 through 32 installed in miscellaneous locations.

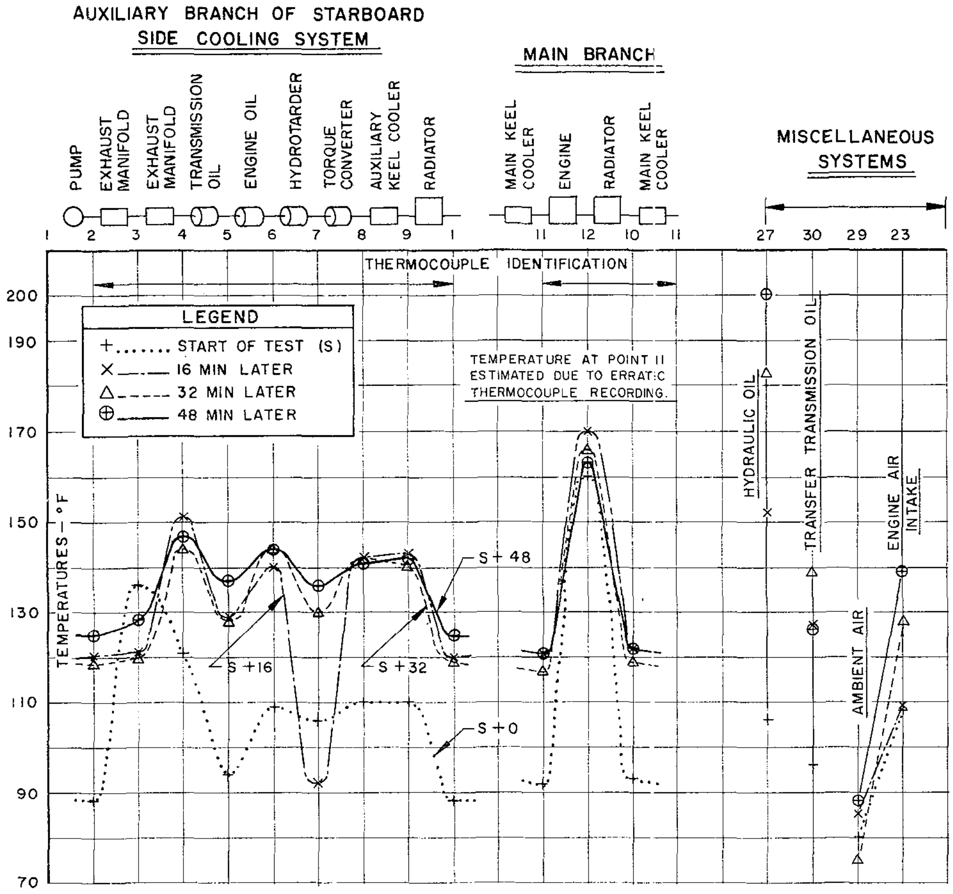


Figure 98. Starboard Engine Cooling System--
Land Operations.

Results - Engine Cooling System, Marine Operations

After 2 hours of operation, the cooling system temperatures stabilized. The peak temperature occurring in the auxiliary branch was 197° F. at the outlet of the second exhaust manifold; this cooled down to 176° F. within 30 minutes, and the cause was unknown. The peak temperature occurring within the main branch was 184° F. A temperature rise of approximately 35° F. was observed from ambient to engine air intake. The hydraulic oil temperature rose to 212° F. and then cooled to 200° F. The cause of the rise was believed to be due to maneuvering during that time. The transfer transmission oil temperature rose to 176° F. The ambient temperature ranged from 65° F. to 78° F. During water operation, the radiator provided a considerably greater cooling effect than did the keel coolers, which is indicative of their uselessness.

Table 40 shows the temperatures recorded for the 2-hour marine test, and Figure 99 is a graphic presentation of the heat transfer.

TABLE 40
TEMPERATURES
AFTER 2-HOUR MARINE HEAT BALANCE TEST (°F.)

Thermocouple No.*	Elapsed Time (min.)													
	0	8	16	24	32	40	48	56	64	72	80	88	96	104
1	114	-	-	-	-	-	120	-	-	-	118	114	-	-
2	-	123	119	95	103	106	-	-	100	110	118	-	113	109
3	143	148	-	162	151	161	160	156	160	158	153	156	150	156
4	176	176	-	-	-	-	-	-	-	-	-	-	-	179
5	146	147	-	156	159	154	154	154	152	156	148	144	146	150
6	176	175	185	191	190	193	191	193	188	197	185	187	181	176
7	81	118	153	166	170	167	170	170	184	184	178	187	162	177
8	174	174	194	188	190	191	192	188	185	185	185	181	178	166
9	162	164	177	176	184	183	191	180	183	180	183	171	170	156
10	150	149	155	157	155	158	160	158	152	161	150	152	144	149
11	168	174	-	-	-	-	-	-	-	-	-	-	-	-
12	165	172	175	176	177	182	184	180	179	181	175	177	177	173
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	146	152	172	164	160	-	166	161	163	154	-	159	156
15	-	141	147	154	158	161	-	172	162	164	159	-	163	165
16	-	231	230	206	204	227	-	228	207	217	218	-	207	210
17	68	81	-	110	110	113	123	118	115	118	123	122	123	122
18	171	179	-	190	193	191	190	193	188	186	188	183	179	187
19	-	109	110	96	104	106	-	-	100	103	112	-	105	103
20	-	109	116	124	125	126	-	119	125	125	122	-	112	109
21	-	96	95	102	98	99	-	100	102	101	101	-	93	89
22	-	98	127	115	119	118	-	114	112	116	116	-	108	108
23	-	111	77	58	88	98	-	113	101	101	94	-	90	-
24	-	110	88	83	97	107	-	114	108	105	103	-	104	104
25	-	163	151	167	170	142	-	-	162	165	172	-	168	168
26	-	102	119	133	140	129	-	150	135	145	138	-	139	128
27	-	182	192	201	208	212	-	211	205	204	200	-	198	200
28	-	300	300	300	300	300	-	300	300	300	300	-	300	300
29	-	70	78	76	71	72	-	71	68	67	68	-	65	70
30	156	164	-	174	177	174	176	176	172	174	175	172	167	170
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	152	159	-	172	171	166	169	167	169	172	164	165	167	166

* See Table 38 for thermocouple identification.
Thermocouples 1 through 12 located in water cooling system.
Thermocouples 13 through 32 installed in miscellaneous locations.

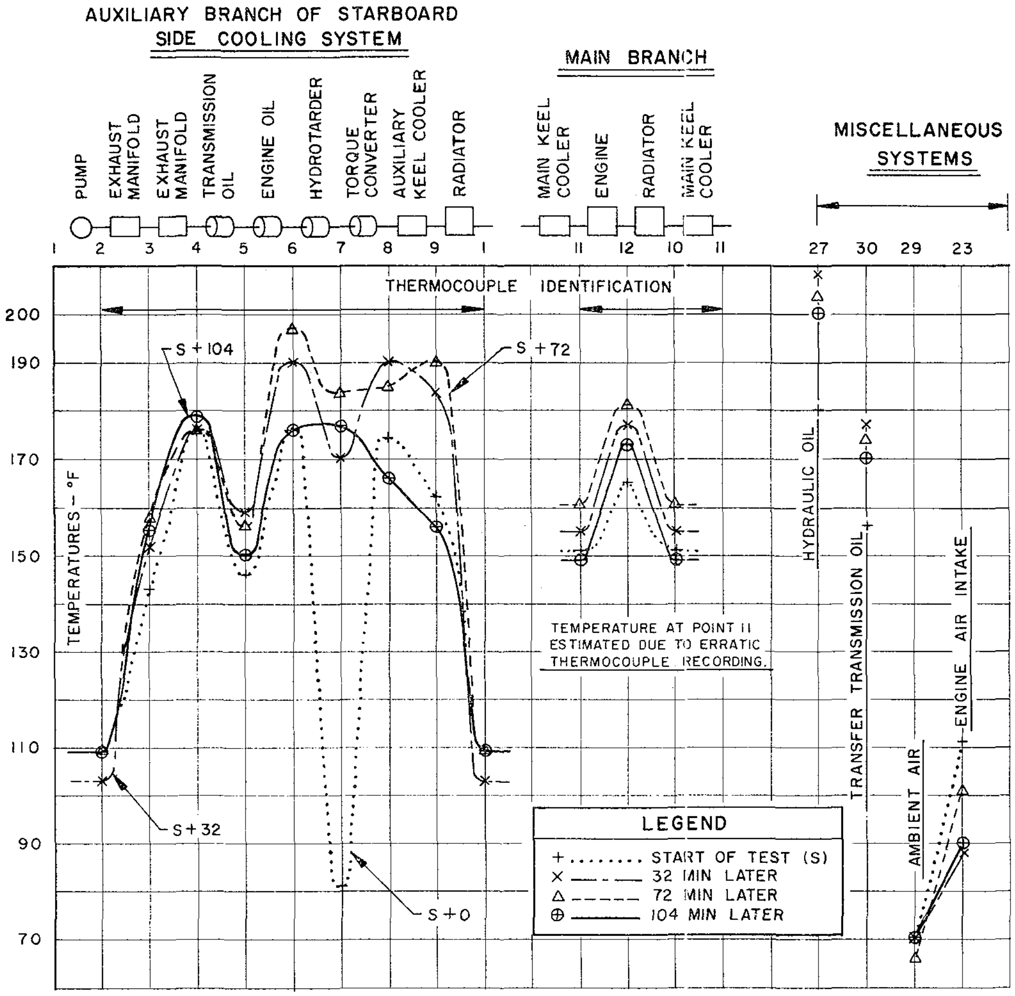


Figure 99. Starboard Engine Cooling System--Marine Operations.

Observations - Engine Cooling System

At the ambient test temperatures of from 70° F. to 90° F. and at the water test temperature of 65° F., the cooling systems were most satisfactory. It is recognized that the land tests were conducted under optimum conditions; that is, without load and on a level beach, due to the schedule. However, it is planned to conduct hot-weather tests at Cape Canaveral, Florida. The water tests were conducted under more realistic conditions.

Procedure - Engine Compartment Ventilating System

During the 2-hour full-speed marine endurance run, the air discharge velocity was measured with an air meter at the compartment outlet. The outlet was segmented into 2-inch squares, and velocity measurements were taken at the corners of each square (see Figure 100). The average of the four readings was then assumed to be the air velocity of this particular 4-square-inch section. The total outlet area was 0.75 square foot. The mass air flow was then calculated for each segment. The test was run at an engine speed of 3,000 rpm.

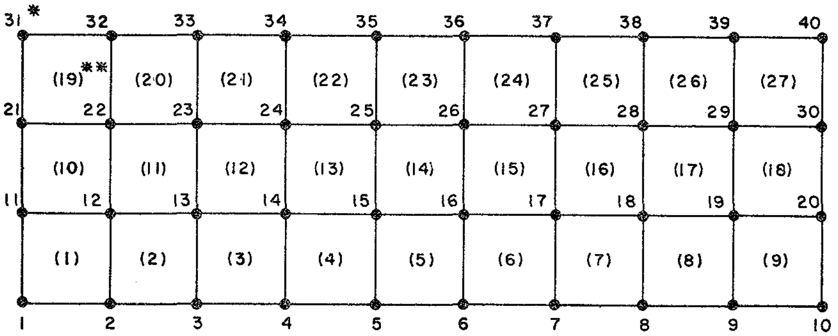


Figure 100. Points of Velocity Measurements for Engine Compartment Air Outlet. (*Points where actual velocity measurements were made; **points where average velocity measurements were made and mass flows were calculated; results shown in Table 42.)

Results - Engine Compartment Ventilating System

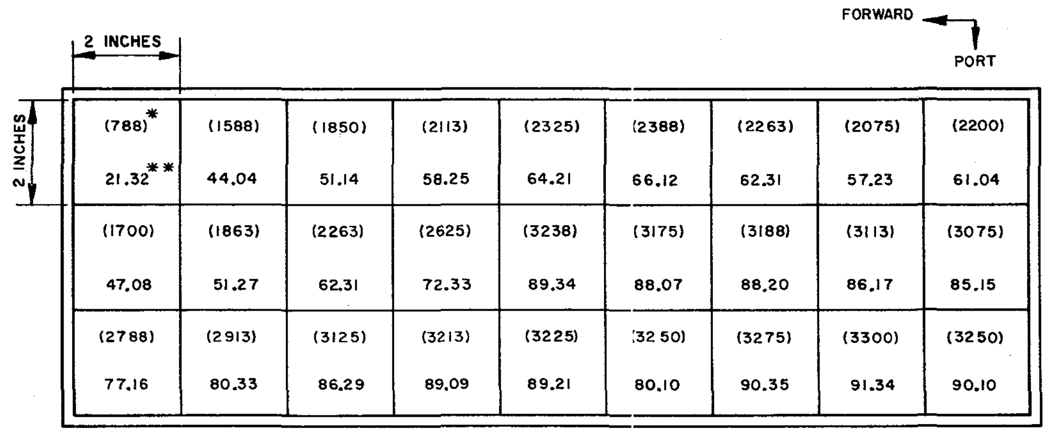
The maximum measured air velocity was 3,300 feet per minute (see Table 41). For the 4-square-inch segment where this velocity occurred, the calculated mass flow was 91.39 cubic feet per minute. The average velocity over the 0.75 square foot is 2,600 feet per minute (see Table 42). For the total area, this is comparable to a mass flow of 1,949.1 cubic feet per minute for the outlet on the starboard side (see Figure 101). Inasmuch as the systems are identical, the flow can be assumed to be doubled, or approximately 3,900 cubic feet per minute (2 × 1,949 cfm).

TABLE 41
ACTUAL VELOCITY MEASUREMENTS FROM ENGINE COMPARTMENT AIR OUTLET TEST

Point	Velocity (ft. /min.)	Point	Velocity (ft. /min.)	Point	Velocity (ft. /min.)	Point	Velocity (ft. /min.)
1	3,400	11	2,200	21	1,350	31	1,150
2	3,400	12	2,150	22	1,100	32	1,850
3	3,400	13	2,700	23	1,500	33	1,900
4	3,400	14	3,000	24	1,850	34	2,150
5	3,300	15	3,150	25	2,500	35	1,950
6	3,250	16	3,200	26	3,100	36	1,750
7	3,300	17	3,250	27	3,150	37	1,550
8	3,300	18	3,250	28	3,100	38	1,250
9	3,350	19	3,300	29	2,800	39	1,150
10	3,250	20	3,100	30	3,100	40	1,750

TABLE 42
AVERAGE VELOCITY MEASUREMENTS FROM ENGINE COMPARTMENT AIR OUTLET TEST

Point	Average Velocity (ft. /min.)	Mass Flow (cu. ft. /min.)	Point	Average Velocity (ft. /min.)	Mass Flow (cu. ft. /min.)	Point	Average Velocity (ft. /min.)	Mass Flow (cu. ft. /min.)
1	2,788	77.16	10	1,700	47.08	19	788	21.32
2	2,913	80.33	11	1,863	51.27	20	1,588	44.04
3	3,125	86.29	12	2,263	62.31	21	1,850	51.14
4	3,213	89.09	13	2,625	72.33	22	2,113	58.25
5	3,225	89.21	14	3,238	89.34	23	2,325	64.21
6	3,250	80.10	15	3,175	88.07	24	2,388	66.12
7	3,275	90.35	16	3,188	88.20	25	2,263	62.31
8	3,300	91.34	17	3,113	86.17	26	2,075	57.23
9	3,250	90.10	18	3,075	85.15	27	2,200	61.04



(788)* 21.32**	(1588) 44.04	(1850) 51.14	(2113) 58.25	(2325) 64.21	(2388) 66.12	(2263) 62.31	(2075) 57.23	(2200) 61.04
(1700) 47.08	(1863) 51.27	(2263) 62.31	(2625) 72.33	(3238) 89.34	(3175) 88.07	(3188) 88.20	(3113) 86.17	(3075) 85.15
(2788) 77.16	(2913) 80.33	(3125) 86.29	(3213) 89.09	(3225) 89.21	(3250) 80.10	(3275) 90.35	(3300) 91.34	(3250) 90.10

Figure 101. View of Engine Compartment Air Outlet From Above. (*Velocities in feet per minute measured at corners of 2-inch squares; **mass flows in cubic feet per minute, per square.)

Procedure - Temperatures in Engine Exhaust Valve Apertures

Thermocouples were installed on the inboard bank of the starboard engine in the exhaust valve orifices leading from the cylinders to the water-cooled manifold. The temperatures in the apertures were observed and recorded at various engine rpm's before the marine endurance run, and periodic checks were also made during the run.

Results - Temperatures in Engine Exhaust Valve Apertures

A peak temperature of 1,650° F. of short duration was observed on the no. 3 cylinder approximately 1/2 hour after the start of the marine endurance run. The average temperature readings are recorded in Table 43.

The thermocouple in cylinder no. 1 vibrated loose during the run at 3,000 rpm. Since the temperatures for this cylinder were lower than those of the other three cylinders, it can be assumed that a poor connection was the cause; therefore, the data for this cylinder should be considered erroneous. (See Figure 102 for temperatures under various engine rpm's.)

TABLE 43
ENGINE EXHAUST PORT TEMPERATURES (°F.)

Engine Speed (rpm)	Cylinder No. 1	2	3	4
600	191	191	191	191
1,000	207	219	228	216
1,500	271	310	310	262
2,000	453	459	459	360
2,500	705	744	786	504
3,000	1,284	1,359	1,410	-

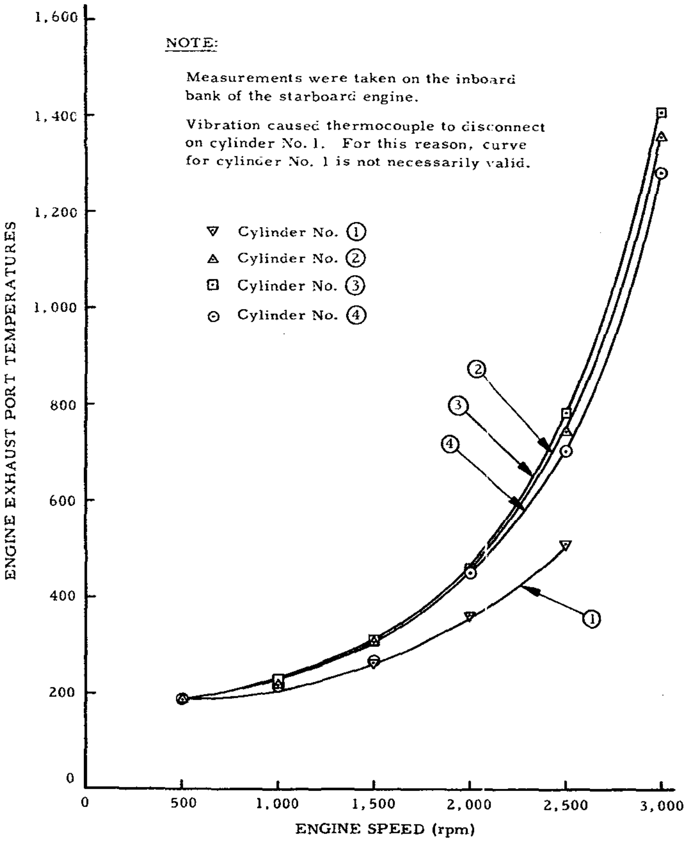


Figure 102. Temperatures in Engine Exhaust Valve Apertures Versus Engine Speed.

PHASE III - LAND PERFORMANCE TESTS*

DETERMINATION ONE. Steering Time

Procedure

Land and marine static wheel steering tests were conducted at Camp Del Mar, Oceanside, California. The lighter was tested in an unloaded condition on sand and asphalt and in the water to determine the time required for the wheels to swing hard over to hard over (30 degrees) from the moment the operator activated the control. The test was conducted for both two- and four-wheel steering at various engine rpm's.

Results

Below 800 rpm, the pump pressure was not sufficient to turn the wheels the full 30-degree swing. The times are recorded in Tables 44 and 45 and pertain to the length of time required for the wheels to come to a complete stop. Time required for hard-over-to-hard-over turns averaged approximately 9.1 seconds with two-wheel steering and 16.23 seconds with four-wheel steering (see Figures 103 through 105).

TABLE 44
TURNING TIME WITH TWO-WHEEL STEERING--STATIC TESTS

Engine Speed (rpm)	In Sand		On Asphalt		In Water	
	Left to Right (sec.)	Right to Left (sec.)	Left to Right (sec.)	Right to Left (sec.)	Left to Right (sec.)	Right to Left (sec.)
1,000	8.5	8.5	8.0*	8.0*	5.0	4.7
1,500	8.2	6.3	9.0	7.2	4.9	4.8
2,000	5.1	4.8	5.7	5.8	4.8	4.8
2,500	4.1	4.3	5.3	5.2	4.7	4.5
3,000	4.0	4.1	5.1	5.0	4.7	4.3

* Wheel did not turn full 30-degree swing.

---

* Determination Ten of Phase II includes data for heat measurements that were recorded during land operations.

TABLE 45
TURNING TIME WITH FOUR-WHEEL STEERING--STATIC TESTS

Engine Speed (rpm)	In Sand Left to Right (sec.)	In Sand Right to Left (sec.)	On Asphalt Left to Right (sec.)	On Asphalt Right to Left (sec.)	In Water Left to Right (sec.)	In Water Right to Left (sec.)
1,000	15.5	29.0*	12.2*	15.0*	9.2	9.4
1,500	10.9	13.1	11.6	10.2	9.2	9.2
2,000	9.9	8.9	9.2	7.8	9.2	8.8
2,500	9.4	8.0	8.4	8.0	8.8	8.2
3,000	8.7	7.6	7.7	7.8	8.7	8.2

* Wheel did not turn full 30-degree swing.

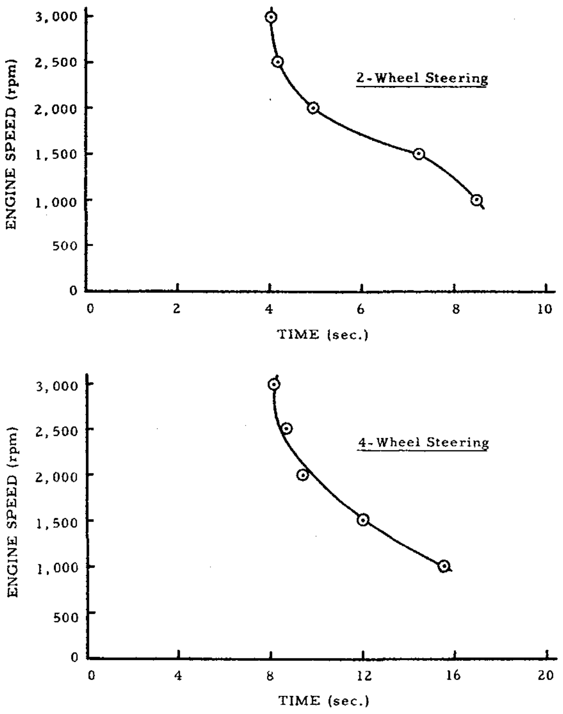


Figure 103. Engine Speed Versus Time for Full-Wheel Swing (30°) on Sand.

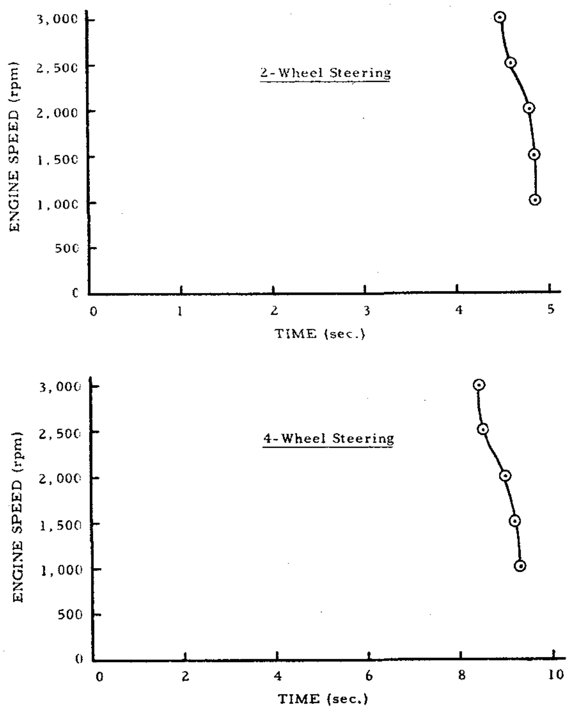


Figure 104. Engine Speed Versus Time for Full-wheel Swing (30°) in Water.

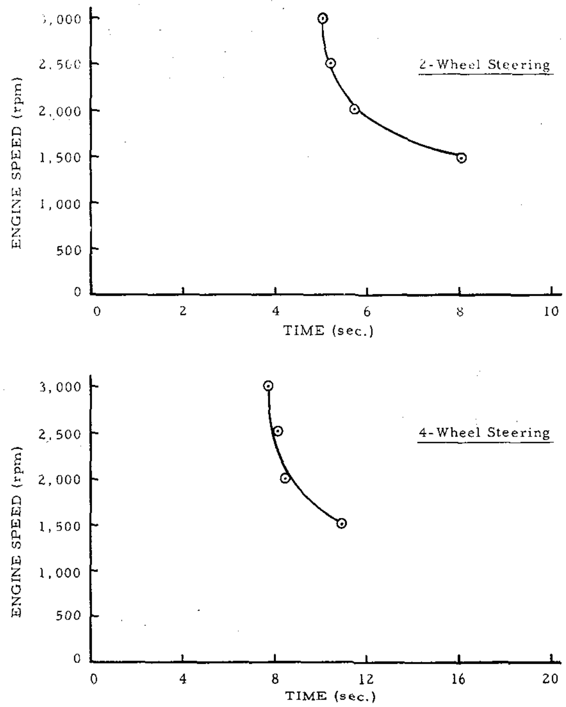


Figure 105. Engine Speed Versus Time for Full-Wheel Swing (30°) on Asphalt.

DETERMINATION TWO. Effectiveness of Brakes

Procedure - Crash Stops

Emergency crash-stop tests were conducted at the Naval Ammunition Depot, Crane, Indiana. The lighter was run at various speeds, the maximum of which was 30 miles per hour. At a predetermined point on the test road, the driver was signaled by hand to apply maximum pressure on the brakes. The time required for a complete stop was measured from the time of the hand signal until the lighter came to a dead halt; the overall stopping distances and skid marks were measured on the ground. After each run, the brake-line maximum pressure was recorded.

Results - Crash Stops

The maximum stopping distance obtained was 44 feet. This figure includes a skid distance of 37.6 inches. These results were obtained at the maximum road speed of 30 miles per hour with an elapsed braking and stopping time of 2.4 seconds, which resulted in approximately 12.5 feet/second deceleration.

Tables 46 and 47 show detailed test results, and Figure 106 shows a collapsed tire resulting from a hard stop.

TABLE 46
STOP TIME FROM ARM SIGNAL TO COMPLETE STOP

Speed	Brake Pressure	Stop Time	Stop Distance	
(mph)	(psi)	(sec.)	(ft.)	(in.)
5	500	1.0	4	3.00
5	500	1.0	5	3.25
10	1,200	2.2	8	.50
15	1,200	2.0	16	5.00
20	1,200	1.6	22	-
25	1,200	2.2	32	7.50
30	1,200	2.4	44	-

TABLE 47
STOP TIME FROM BRAKE LOCK TO COMPLETE STOP

Speed	Brake Pressure	Stop Time	Skid Distance	
(mph)	(psi)	(sec.)	(ft.)	(in.)
5	500	0.5	-	-
5	500	0.5	-	-
10	1,200	0.8	-	-
15	1,200	1.0	-	10.8
20	1,200	1.5	1	5.8
25	1,200	1.6	2	3.6
30	1,200	2.4	3	1.6

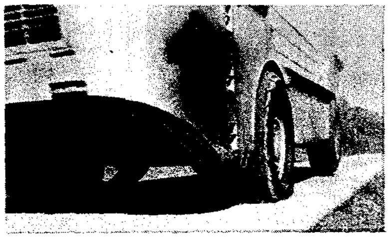


Figure 106. Collapsed Tire From Emergency Crash-Stop Brake Test.

Procedure - Static Brake System Test

A test was also performed on the brake system when the lighter was stationary. A spring scale was used to determine the force on the brake pedal. The resultant brake-line pressure for each pedal loading with and without power boost was recorded.

Results - Static Brake System Test

The maximum brake-line pressure for a stationary vehicle with power boost was 1,225 psi; without power boost, the maximum pressure was 400 psi (see Table 48 and Figure 107).

TABLE 48
BRAKE-LINE PRESSURE FOR STATIONARY VEHICLE

Pedal Force (lb.)	Brake Pressure (psi) Run No. 1	Run No. 2
10 - 13.5	0	0
15	100	100
20	175	175
25	225	250
30	290	300
35	375	375
40	445	450
45	500	525
50	600	600
55	675	700
60	775	780
65	850	850

Note: Maximum brake pressure with power boost for stationary vehicle, 1,225 psi.

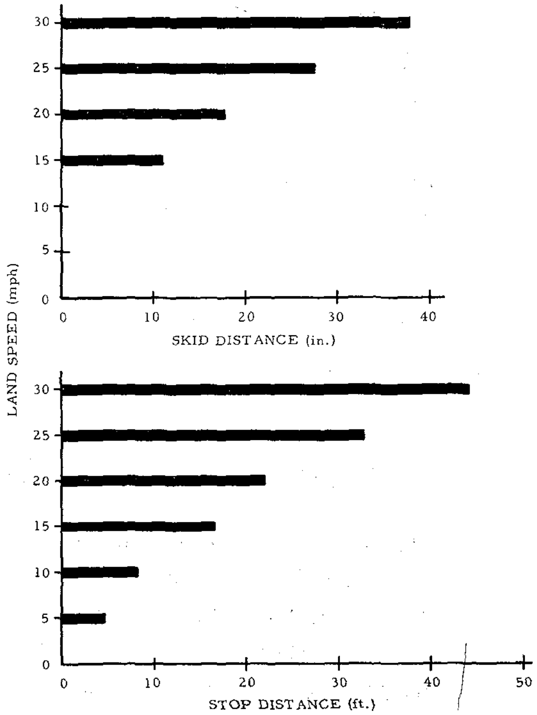


Figure 107. Land Speed Versus Stop and Skid Distances for Crash-Stop Tests.

Procedure - Adequacy of Parking Brakes

The lighter was parked on a 40-percent concrete grade at Yuma, Arizona. The parking brakes were applied to determine their effectiveness.

Results - Adequacy of Parking Brakes

After take-up was effected in the parking brake, the brakes were adequate on a 40-percent slope, although a slight brake drag was experienced with the taut heavy cable pulling on the brake arm. The heavy and bulky actuating cables were subsequently replaced with controllex cable, which eliminated drag on the brakes and required little take-up.

Procedure - Service Brakes, Emergency Application

Since the service brakes were dependent on the hydraulic system pressure for power-boost brake application, a qualitative evaluation was made of the alternate means of energizing the brakes in the event of engine failure. The first of four evaluation tests, which were performed in the open country at Yuma, Arizona, was conducted as follows: The lighter was accelerated to full speed; the engines were cut off, and the brakes were applied immediately afterwards. The test was repeated except that there was a 10-second pause between engine cutoff and brake application.

Results - Service Brakes, Emergency Application

In both cases, full power braking was realized.

Observations

It was concluded that at the higher speeds, with dead engines, sufficient power boost is generated by the pump's being driven by the rolling wheels back through the power train.

Procedure - Service Brakes, Mechanical Override

The mechanical override feature of the brake valve was tested by parking the LARC on an approximate 15-percent grade with the engines secured and by attempting to hold the LARC on that grade with engines secured. (The mechanical override feature of the brake valve is one which permits braking by conventional closed-system means should the power boost fail; the mechanical override is actuated by further physical pressure on the brake pedal.)

Results - Service Brakes, Mechanical Override

Efforts to hold the LARC with the mechanical override feature were completely unsuccessful; consequently, no further consideration was given to this feature as an emergency means of braking.

Procedure - Service Brakes, Emergency Hydraulic Steer Pump

To determine the capability of the emergency, electrically driven, hydraulic steer pump to provide sufficient power boost for satisfactory brake operation, this pump was energized when brakes were applied while the LARC was free-wheeling down a 15-percent incline at a creep speed.

Results - Service Brakes, Emergency Hydraulic Steer Pump

Full power-brake application was realized.

Procedure - Hydrotarder

As a result of overheating experienced with the hydrotarder as installed, but not operated, during overland operations, tests were conducted to ascertain the location of heat build-up. Thermometers were placed in the filling line to the fill cylinder, in the hydrotarder inlet, and in the hydrotarder outlet. The LARC was operated at speeds in increments of 5 miles per hour up to 25 miles per hour, and temperatures were recorded while braking. Following this, the LARC was operated for approximately an hour while temperatures were monitored.

Results - Hydrotarder

Temperatures recorded during the hydrotarder braking tests (see Table 49) did not indicate abnormal temperature rises, although there was a 4- to 5-second lapse noted before deceleration could be sensed at the higher speeds. The cause of the heat build-up was not determined.

TABLE 49

HYDROTARDER CIRCUITY--TEMPERATURE CHECKS

LARC Speed (mph)	Temperatures Oil Inlet Into Fill Cylinder (deg.)	Oil Inlet Into Retarder (deg.)	Oil Outlet From Retarder (deg.)
5	50	30	25
10	40	40	20
15	55	60	30
20	60	100	35
25	100	150	40

Observations

Since these tests were inconclusive regarding the heat build-up, a sustained operation without braking was conducted. It was then determined that the heat build-up was contained in the hydrotarder. Consequently, it was believed that this problem stemmed from a valve loading in the hydrotarder hydraulic circuit. Therefore, the hydrotarder was prevented from dumping its entire charge of oil, thus permitting a sizeable amount of oil to be carried within the hydrotarder and allowing this partial charge to be recirculated within and to become overheated. Subsequently, modifications to the hydraulic circuity were made, but an abbreviated test schedule and inadequate test facilities prevented further tests. As a result, the hydrotarder was disconnected and not used again.

DETERMINATION THREE. Drawbar Pull

Procedure

To determine the drawbar pull of the LARC, a stationary vehicle (a D8 tractor crawler) was pulled by the LARC, and the resultant force was recorded by a load cell inserted in a line between the two vehicles (see Figure 108).

The test was conducted on sand and concrete at various engine rpm's (see Figures 109 and 110). The maximum engine speed occurred at stall rpm (2,150 rpm).

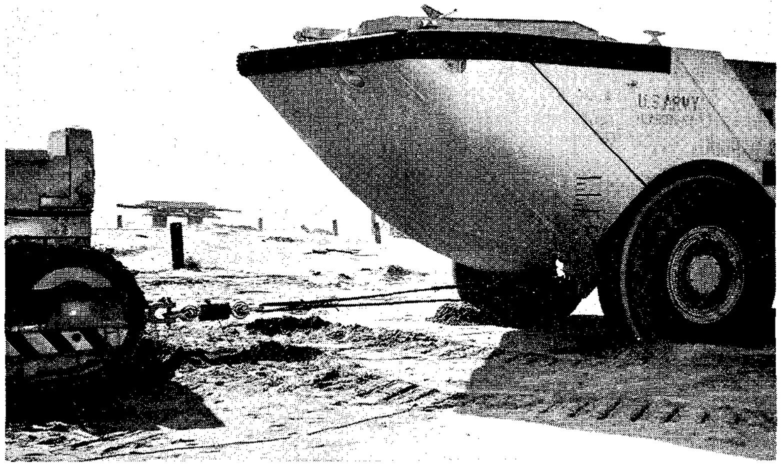


Figure 108. Load Cell Between LARC and Tractor Crawler During Drawbar-Pull Test on Sand.

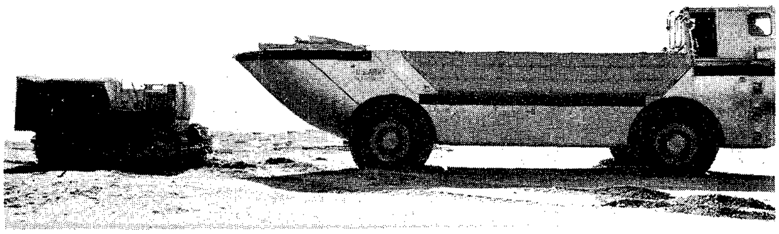


Figure 109. Drawbar-Pull Test With Lighter on Sand.

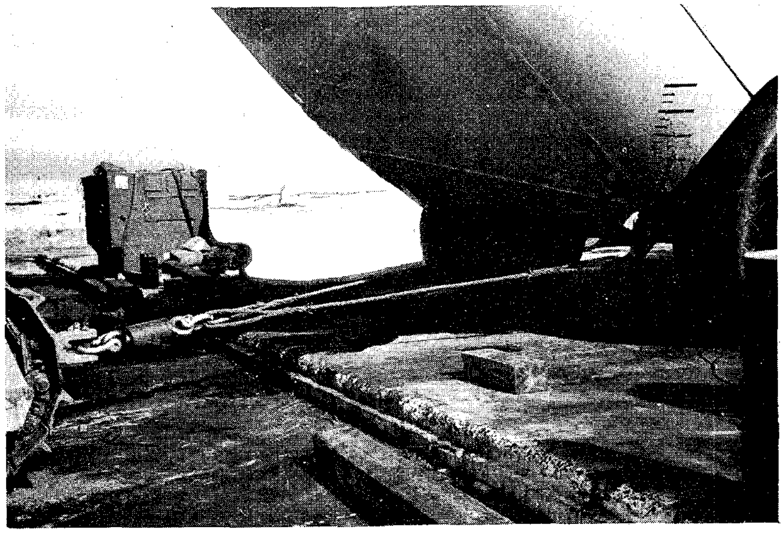


Figure 110. Drawbar-Pull Test With Lighter on Concrete.

Both high- and low-range transmission runs were conducted. The tire pressures were varied. One-engine runs were also conducted.

Results

The maximum pulls are shown in Table 50. Detailed results of tests conducted on sand and concrete are recorded in Tables 51 and 52 and are shown graphically in Figures 111 through 115.

TABLE 50
MAXIMUM DRAWBAR PULL

Testbed Surface	Pull (lb.)	Transmission Range	Number of Engines	Tire Pressure (psi)
Concrete	33,400	Low	2	12 and 24
Concrete	19,000	Low	1	18 and 30
Sand*	19,000	Low	2	18 and 30
Sand	19,000	Low	1	12 and 24

*Higher pull would have been attained if the wheels had not slipped at the maximum rpm. The curve of engine speed versus pull indicates that a value approaching 30,000 pounds may have been attained.

TABLE 51
DRAWBAR-PULL TESTS ON CONCRETE

Engine Speed* (rpm)	No. of Engines	Range	Tire Pressure (psi) Forward Axle	Tire Pressure (psi) Aft Axle	Rail Pressure (psi) Port Engine	Rail Pressure (psi) Starboard Engine	Pull (lb.)
1,000	2	High	18	30	10	12	2,500
1,500					32	34	6,900
2,000					100	90	11,700
1,000	2	Low	18	30	10	12	7,700
1,500					30	32	17,500
2,000					100	80	30,800
1,000	1	High	18	30	100	-	500
1,500					32	-	2,800
2,150					12	-	6,800

TABLE 51 - contd.

Engine Speed* (rpm)	No. of Engines	Range	Tire Pressure (psi) Forward Axle	Tire Pressure (psi) Aft Axle	Rail Pressure (psi) Port Engine	Rail Pressure (psi) Starboard Engine	Pull (lb.)
1,000	1	High	18	30	-	85	1,000
1,500						34	2,900
1,850						12	4,800
2,150P 1,750S	2	High	12	24	102	80	13,000
2,150P 1,750S	2	Low	12	24	100	80	33,400
2,150	1	High	12	24	102	-	7,600
2,150	1	Low	12	24	102	-	18,500
1,875	1	Low	18	30	-	80	13,500
2,150	1	Low	18	30	100	-	19,000

* Engine speed for both port and starboard engines unless specified.

TABLE 52
DRAWBAR-PULL TESTS ON SAND

Engine Speed* (rpm)	No. of Engines	Range	Tire Pressure (psi) Forward Axle	Tire Pressure (psi) Aft Axle	Rail Pressure (psi) Port Engine	Rail Pressure (psi) Starboard Engine	Pull (lb.)
1,000	2	High	18	30	10	12	1,600
1,500					32	34	4,300
2,000					105	90	9,200
1,000	2	Low	18	30	10	12	7,500
1,500					32	38	19,000
2,000					95	80	18,500
1,500	1	Low	18	30	105	-	4,700
2,000					75		10,500
2,200					30		12,200

TABLE 52 - contd.

Engine Speed* (rpm)	No. of Engines	Range	Tire Pressure (psi)		Rail Pressure (psi)		Pull (lb.)
			Forward Axle	Aft Axle	Port Engine	Starboard Engine	
2,000P 1,750S	2	Low	12	24	92	78	16,900
2,150P 1,750S	2	High	12	24	102	80	12,100
2,150	1	Low	12	24	102	-	19,000
2,150	1	High	12	24	102	-	7,000

* Engine speed for both port and starboard engines unless specified.

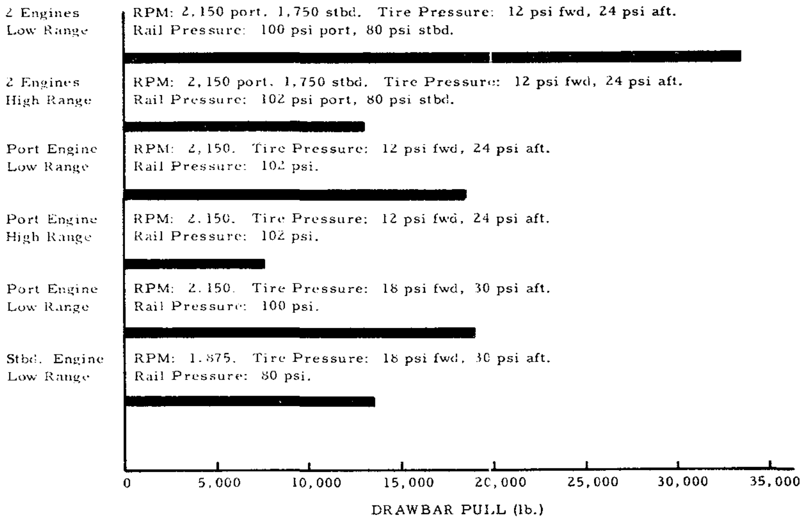


Figure 111. Drawbar-Pull Test Under Various Power Conditions--Lighter on Concrete.

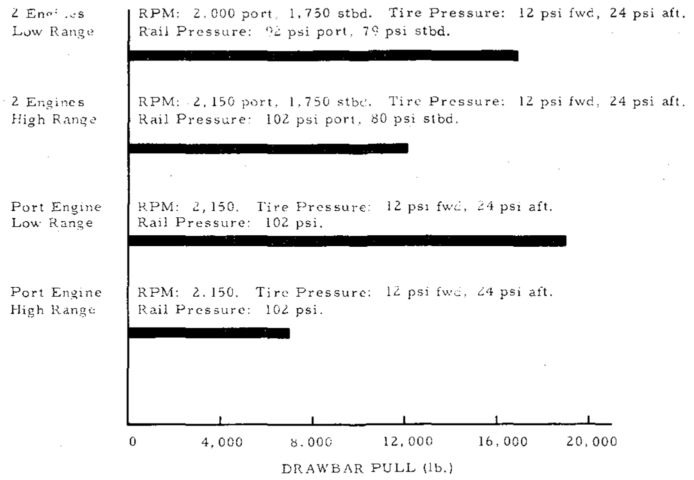


Figure 112. Drawbar-Pull Test Under Various Power Conditions--Lighter on Sand.

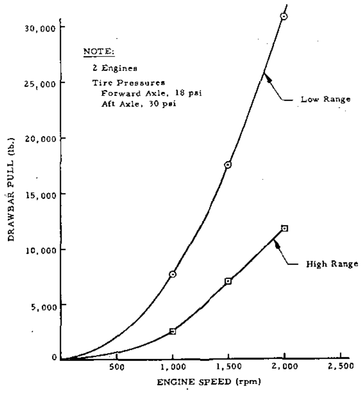


Figure 113. Drawbar Pull Versus Engine Speed With Two Engines Operating Simultaneously--Lighter on Concrete.

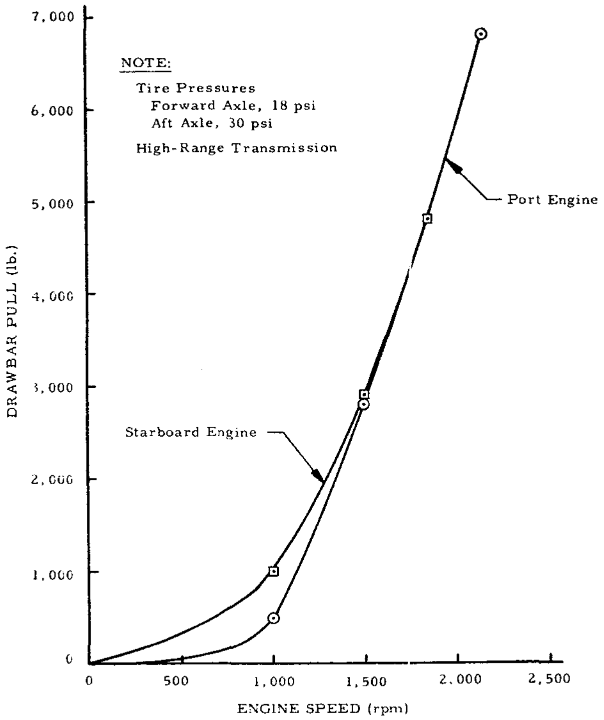


Figure 114. Drawbar Pull Versus Engine Speed During Port- and Starboard-Engine Runs--Lighter on Concrete.

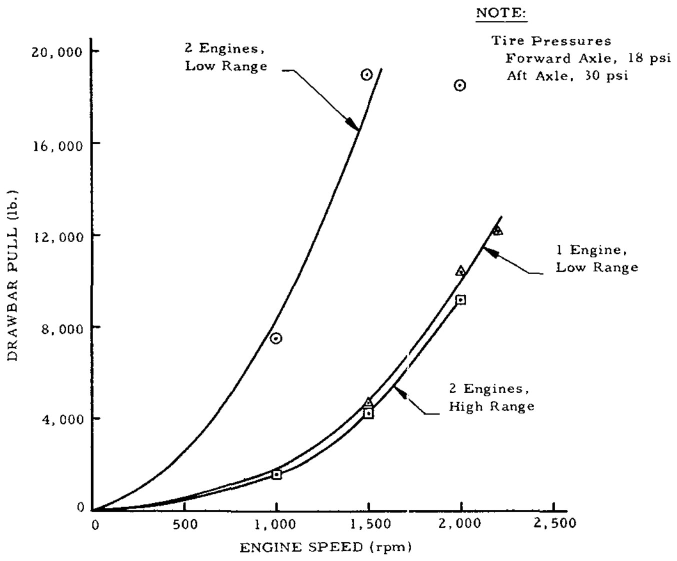


Figure 115. Drawbar Pull Versus Engine Speed Under Various Power Conditions--Lighter on Sand.

DETERMINATION FOUR. Gradeability

Procedure

The LARC was tested in a fully loaded condition at the Yuma Test Station, Yuma, Arizona, on 20-, 30-, and 40-percent sand slopes and on 40-percent and 60-percent concrete slopes (see Figures 116 through 119). In all cases, the LARC was driven from the halted position on the grade.

Figure 116. Lighter Negotiating 40-Percent Paved Grade--Normal Land Drive.

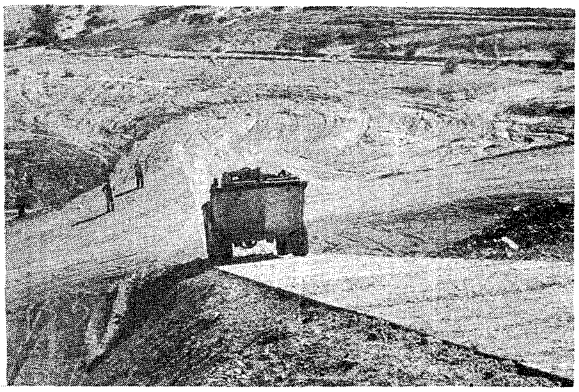


Figure 117. Lighter Negotiating 40-Percent Paved Grade--Reverse Land Drive.

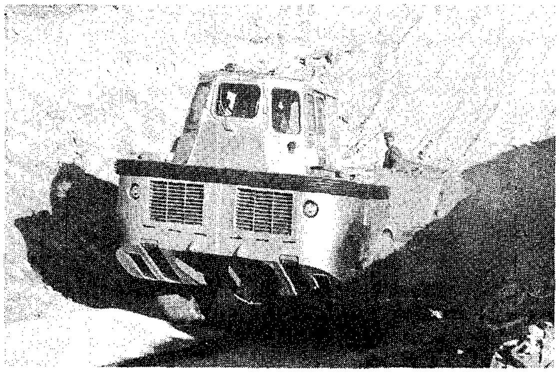


Figure 118. Lighter Negotiating 60-Percent Paved Grade.

Figure 119. Lighter Negotiating 30-Percent Sand Grade.

Results

The lighter successfully negotiated all slopes of up to (and including) 40-percent grade; the maximum required slope (40 percent) was negotiated at approximately 4 miles per hour. The sand-slope surfaces had been hardened by prior storms and rains to the point where the test was nonconclusive for mobility determinations. When the 60-percent concrete slope was attempted, a large depression at the bottom of the grade caused the LARC to ground on its approach. After the depression had been filled, the LARC negotiated the 60-percent grade.

DETERMINATION FIVE. Maximum Land Speed

Procedure

Speed runs of the lighter were conducted over a measured mile course at Crane Naval Depot, Crane, Indiana. The speed was recorded with the lighter both light and fully loaded, at full engine speeds, on a macadamized road surface, and with tire pressures at 15 psi at the bow end and 25 psi at the cab end.

Results

Maximum speeds of 31.7 miles per hour empty and 30.8 miles per hour loaded were recorded.

DETERMINATION SIX. Fuel Consumption

Procedure

The procedure for determining fuel consumption of the LARC during land operations is included with marine operations under Determination Five of Phase II.

Results

The maximum fuel consumption with both engines operating at 3,000 rpm was recorded as 16.32 gallons per hour. (See Figure 86 for fuel consumption curve.)

Observation

Multifuel tests were scheduled as the last of all tests. However, because of reassignment of the LARC to Cape Canaveral, Florida, these tests were canceled.

DETERMINATION SEVEN. Ramp Cycling

Procedure

With the lighter stationary, the total cycling times of the ramp and of the ramp extension were recorded at various engine speeds for both elevating and lowering. Hydraulic actuating pressures were recorded both during cycling and after grounding. Both ramp controls were also actuated simultaneously to observe results. (These tests were conducted after the ramp extension hydraulic circuit had been modified by adding a relief valve and by replacing the control valves to reduce the pressures and flow acting on the cylinders. The relief valve, which protects the previously unrelieved ramp extension system only, was set at approximately 900 psi; the flow control valves, set at 7-1/2 gallons per minute, replaced the original 15-gallon-per-minute units.)

Results

At full engine speed, the ramp was raised in 15.6 seconds and lowered in 14.7 seconds (see Table 53 and Figure 120). A minimum engine speed of 1,200 rpm was determined to be necessary for adequate hydraulic system pressure to raise the ramp, and, of course, the ramp could be lowered without pump power. The ramp extension was raised in approximately 6.5 seconds and was lowered in approximately 7.1 seconds.

With simultaneous actuation of both the ramp and the ramp-extension controls during elevating, the ramp did not act until the ramp extension had reached its raised position. During lowering operations, both the ramp and ramp extension dropped simultaneously. With the ramp-extension hydraulic-system relief valve set at 900 psi, a load of 705 pounds acting at the outermost end of the ramp extension, while in the horizontal position, was required to overcome the relief valve. The maximum hydraulic pressure during a ramp-extension lift was 600 psi; during lowering, it was 500 psi.

TABLE 53
RAMP CYCLING TESTS

Engine Speed (rpm)	Ramp Direction of Motion	Time Required for Test (sec.)
1,200	Raising	39.0
1,200	Lowering	14.1
1,400	Raising	31.8
1,400	Lowering	14.5
2,000	Raising	20.4
2,000	Lowering	15.7
3,000	Raising	15.6
3,000	Lowering	14.7

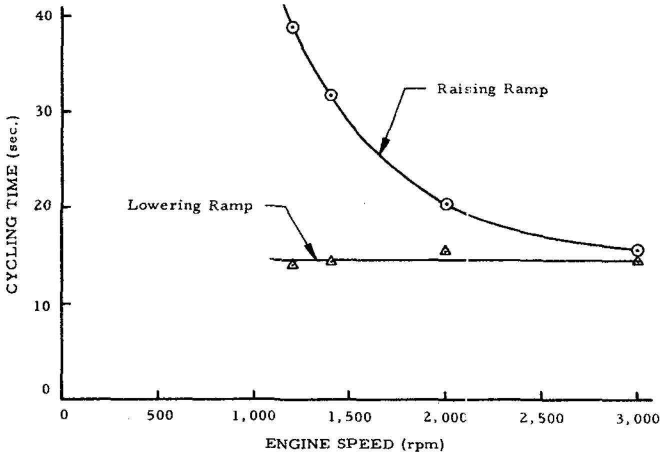


Figure 120. Ramp Cycling Time Versus Engine Speed.

DETERMINATION EIGHT. Land Turning Radius

Procedure

Minimum land turning radii were determined for the lighter for both two- and four-wheel steering conditions. The test was performed on packed sand with the lighter running at minimum rpm to prevent side slippage. The tire impressions left in the sand were measured for each condition.

Results

Figure 121 shows track patterns. All distances shown are measurements to the center lines of the tire tracks.

The minimum turning radii were as follows:

Two-Wheel Steering

Outer track	89 feet 11.5 inches
Inner track	76 feet 5.5 inches

Four-Wheel Steering

Outer track	44 feet 10 inches
Inner track	34 feet 4 inches

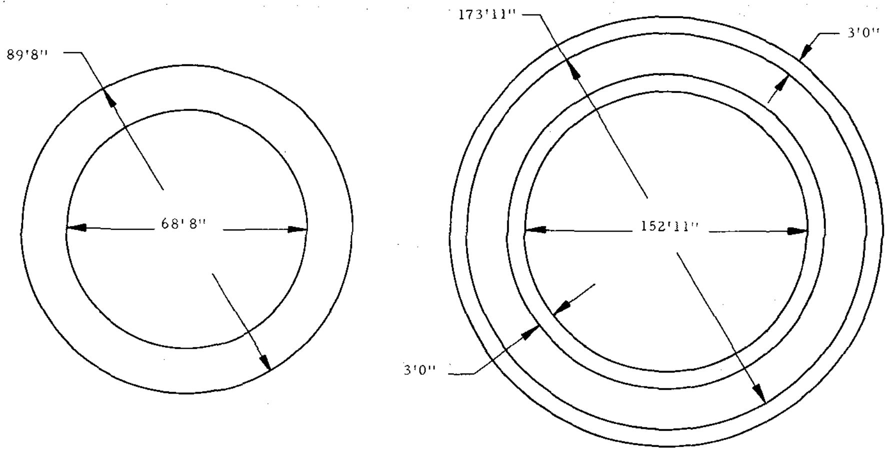


Figure 121. Graphical Layout of Tire Impressions From Land Turning Radius Tests.

DETERMINATION NINE. Mobility

Procedure - On Sand

Environmental conditions resulting from storms and cold weather coupled with lack of time prevented quantitative testing. Qualitative testing was performed by operating in the sand dunes near Ogilby, Arizona, with the lighter in the loaded and unloaded conditions. Figures 122, 123, and 124 show CONEX containers being prepared for the test.

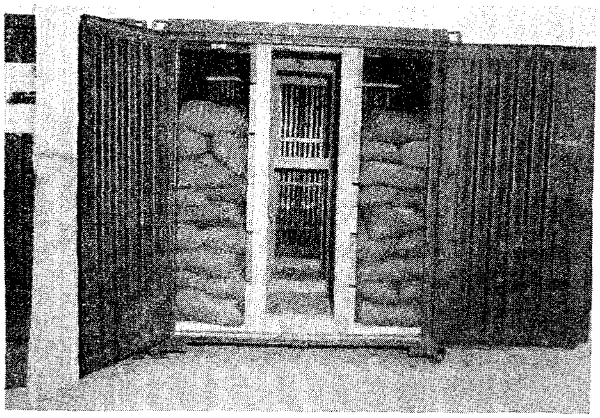


Figure 122. CONEX Container Loaded To Meet Specific Conditions of Weight and Center of Gravity.

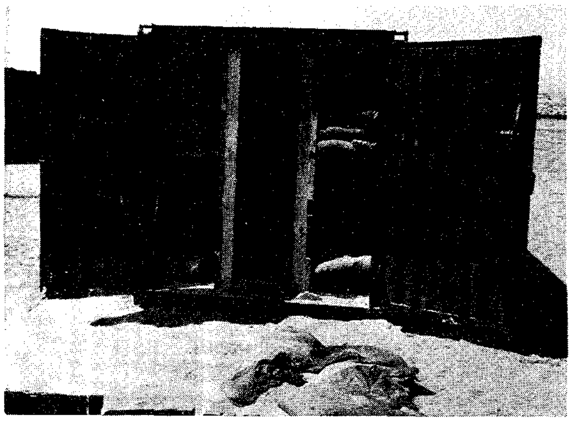


Figure 123. CONEX Container Loaded With Sand Bags. (Shelf used to raise center of gravity to desired location.)

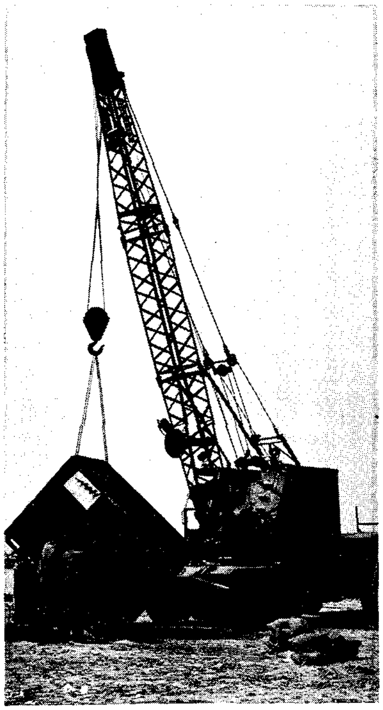


Figure 124. Determining Center of Gravity of Loaded CONEX Container.

Results - On Sand

The lighter did not negotiate the entire course that was laid out in the dunes because of the difficulty of extricating equipment of this size if it becomes immobilized deep in the course. The LARC maneuvered well through the dunes on sand inclines of up to 30 percent. Grounding amidships while traversing the crests of dunes had been feared; however, the momentum of the lighter allowed it to skid over the top. During this type of operation with the LARC in the unloaded condition, the outer-end housing supporting the port cab-end wheel failed, shearing off adjacent to the hull. * Following replacement of the housing, tests were conducted with a 15-ton load, having a 40-inch center of gravity--without repetition of the failure. At no time did the LARC become immobilized in negotiating sandy terrain. (This was also true during tests on sand beaches.) Figures 125 through 130 show the LARC negotiating sand dunes.

---

* See TRECOM Technical Report 63-6, the LARC-XV Endurance Test Report, page 66.

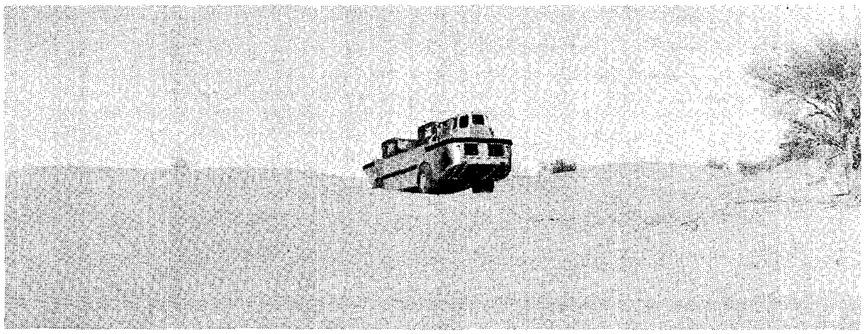


Figure 125. Lighter Operating With Full Load During Desert Tests. (Note open terrain.)

Figure 126. Lighter Operating With Full Load During Desert Tests.

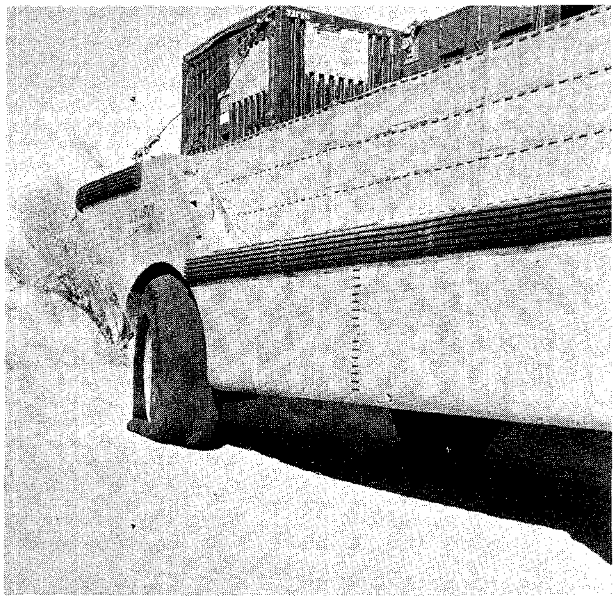


Figure 127. One Wheel Taking Greater Portion of Load Because of Uneven Terrain.

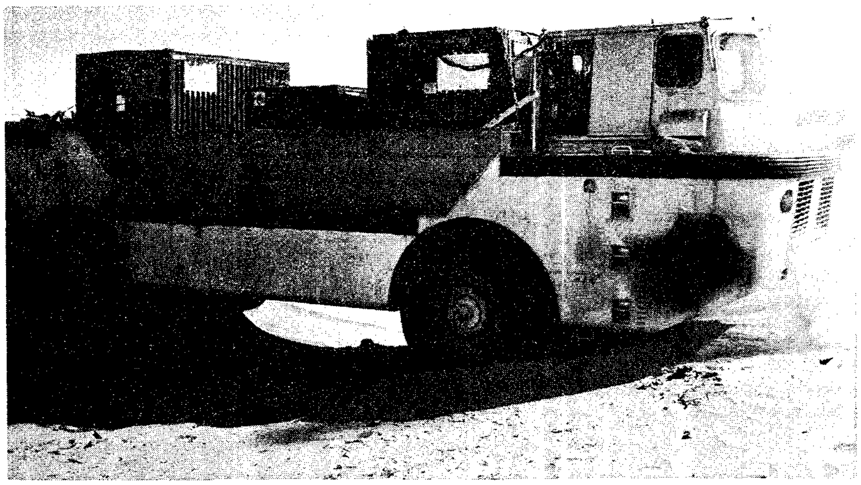


Figure 128. Lighter Manipulating Depression Between Two Sand Dunes.

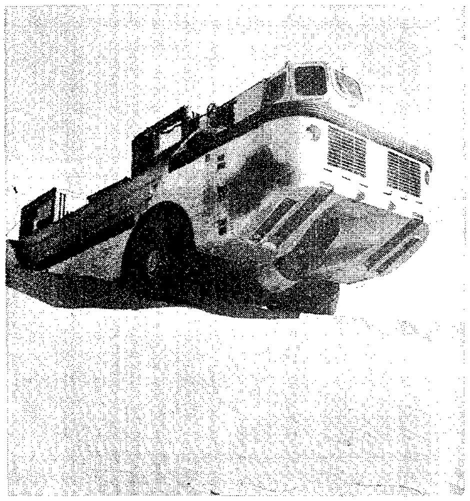


Figure 129. Lighter Coming Over Crest of Sand Dune With 15-Ton Load.

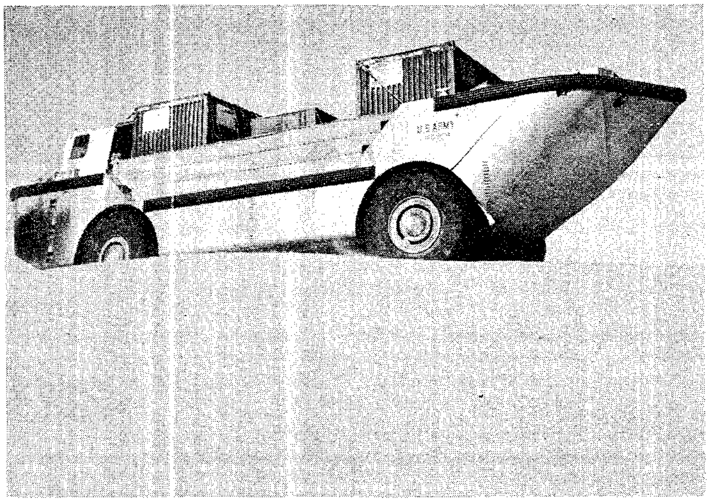


Figure 130. Lighter Riding Crest of Sand Dune.

Observation

It was believed initially that the failure in the unloaded condition was caused by excessive impact loads, but subsequent failure at Camp Pendleton, California,* proved that the trouble was due to corrosion fatigue.

Procedure - On Mud Flats

Mud flats at Coronado, California, were deliberately selected to ascertain the ability of the lighter to cross such beaches. This tidal flat consisted of silt and gumbo much imbedded with large rocks and concrete blocks.

Results - On Mud Flats

While proceeding to shore through this footing, the stern of the LARC hung on either rock or concrete, and insufficient traction with the bow-end wheels caused the lighter to become immobilized.

---

* Ibid., p. 95

SUPPLEMENTAL TESTS

DETERMINATION ONE. Dynamic Stability

Procedure - 12-Foot-Beam Lighter

Since a comparison of the LARC's stability with that of other amphibians could not be made because of the LARC's size and configuration, dynamic stability tests were conducted to verify the static stability results. The tests were also run to determine the additional moments exerted by inertia forces caused by cargo of various weights and vertical centers of gravity. These tests were conducted by running the 12-foot-beam lighter (12 feet 6 inches over the tires and rub rails) at various engine rpm's and throwing it into hard port and starboard turns. The angle of heel was measured by an oil-damped pendulum mounted on top of the operator's cab. The runs were conducted in a calm water basin at Oceanside, California, adjacent to a beach shelf where the LARC could quickly be grounded should unstable limits be surpassed.

The maximum engine speed (3,000 rpm) was not necessarily reached for all runs. The highest engine speed to be used was determined from where the angle of heel corresponded to the critical angle of heel found in the static stability tests. Runs were discontinued when the lighter stability was marginal because of lurching that commenced when water flooded the deck and then impinged on the bulkhead which forms the forward portion of the operator's cab. When the maximum angle of heel realized during calm-water tests was at least 10 degrees below the static stability curve peak, the lighter was taken through the surf zone into the open sea.

Results - 12-Foot-Beam Lighter

Results of the dynamic stability tests are shown in Tables 54 and 55. Significant facts that were revealed by the tests are as follows:

1. Water building up on the deck during the turn and impinging on the aft deck bulkhead caused added heel.
2. Loaded CONEX containers skidded off center during operations when not secured.
3. Additional momentary heel was caused when the steering force was removed by bringing the helm back to center when correcting for a critical heel caused by a turn.

4. A greater angle of heel occurred during a starboard turn because of propeller rotation.

Because of the present hull configuration of the LARC and if it is loaded, any one or any combination of the aforementioned circumstances could cause dangerous instability, especially if the LARC were in the open sea. The starboard turns were found to be the most critical for any of the tests and were therefore the only turns directed. If the vehicle could safely maneuver a starboard turn through the entire rpm range, it definitely would be able to make the corresponding port turns.

Cargo not secured skidded to the low side of the LARC at angles of from 22 to 23 degrees, regardless of the cargo material (wood, steel, or rubber). This is contrary to results of prior tests which were conducted by statically raising a wetted deck until a CONEX container shifted 30 degrees. (Because of the possibility of the LARC's capsizing, cargo was not secured to the lighter in order to facilitate recovery if the lighter rolled and sank. The low angle of skid forced the use of timbers at the deck to block the cargo.)

The maximum safe load which the lighter was capable of carrying under these conditions was 10 tons, with a 40-inch center of gravity. The maximum righting moment for this loading was approximately 40,000 foot-pounds at a 29-degree angle of heel.

Each loaded CONEX container weighed 5 tons, and three of the containers were loaded on the LARC. The first container was placed next to the cab; the second, at the aft end of the cargo well; and the third, at the center of the well between the first two containers. Figure 131 shows the LARC after the first two containers have been loaded (each is carrying 7-1/2 tons of cargo). Figures 132 through 137 show dynamic stability tests being conducted, and data from the tests are shown graphically in Figures 138 through 145.

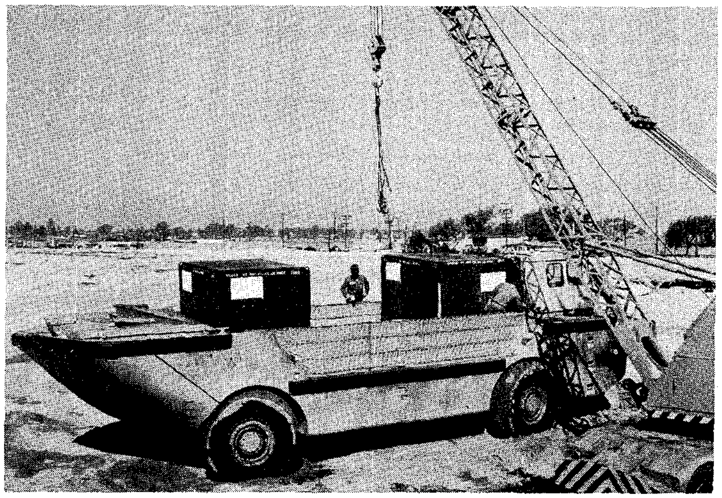


Figure 131. Method of Loading Lighter. (Two CONEX containers in place. Figure 72 shows three containers in place. Each container loaded with 5 tons of sand bags.)

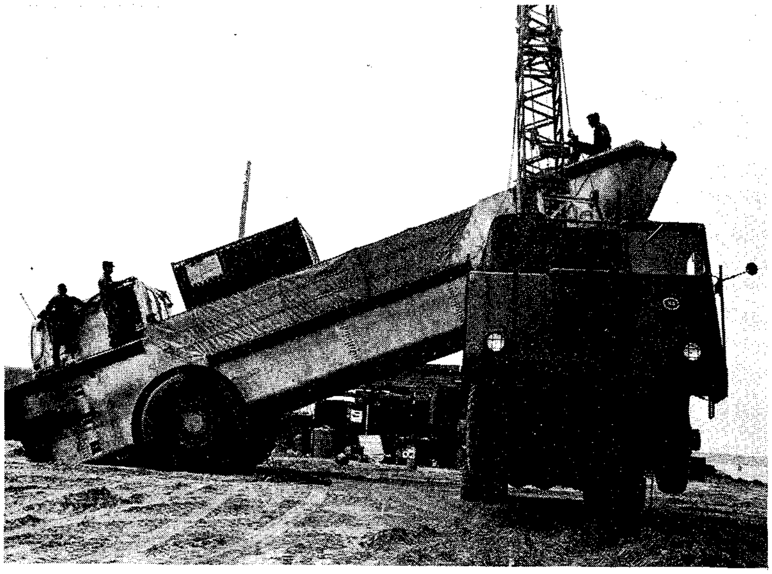


Figure 132. Lighter Being Lifted To Determine Angle at Which Unsecured CONEX Container Will Slide.

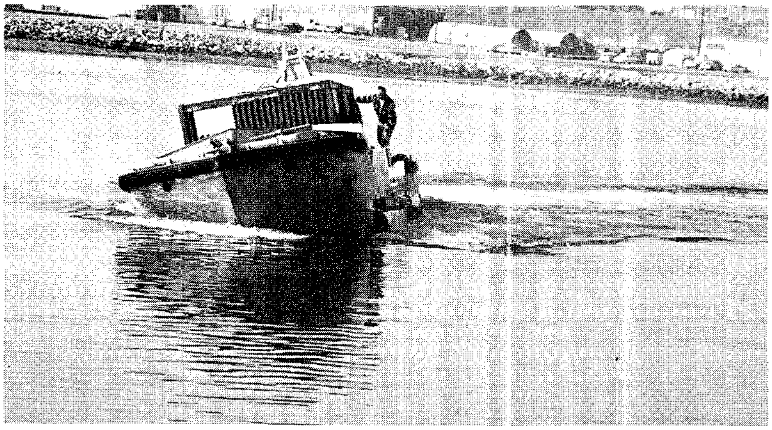


Figure 133. Lighter in Hard-Over Port Turn With 15-Ton, 40-Inch-Center-of-Gravity Load and 2,000 Engine RPM.

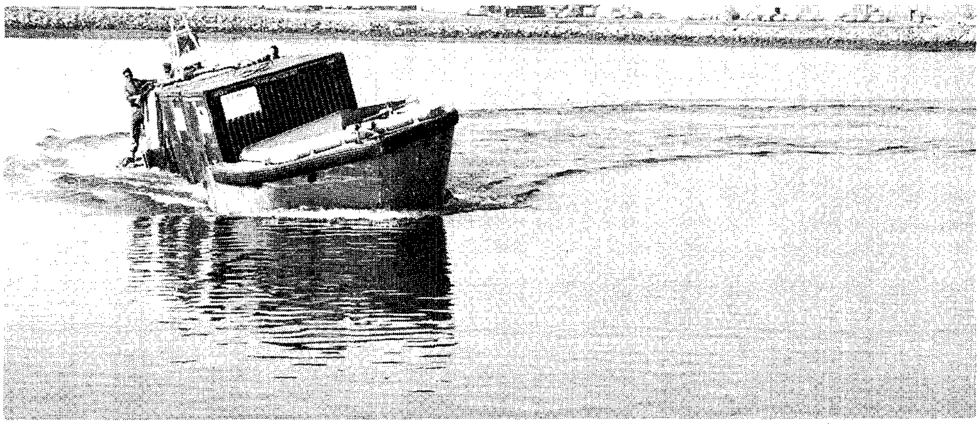


Figure 134. Lighter in Hard-Over Port Turn With 15-Ton, 40-Inch-Center-of-Gravity Load and 1,500 Engine RPM.

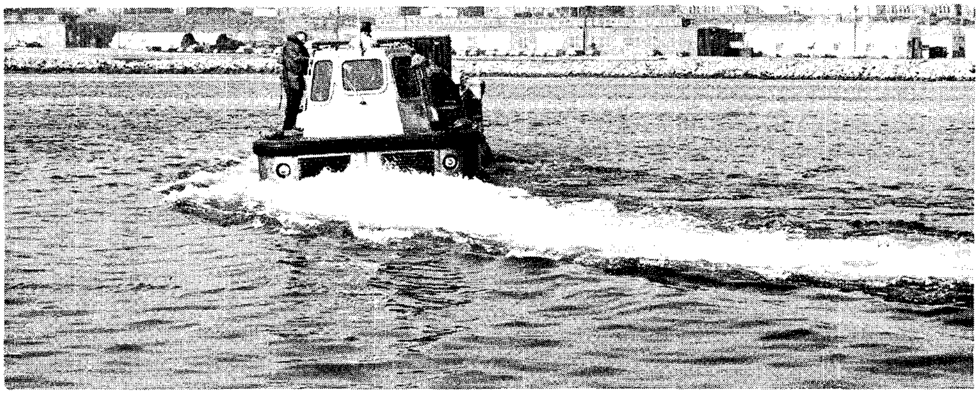


Figure 135. Lighter in Hard-Over Starboard Turn With 10-Ton, 40-Inch-Center-of-Gravity Load and 2,000 Engine RPM.

Figure 136. Lighter in Hard-Over Starboard Turn With 10-Ton, 40-Inch-Center-of-Gravity Load and 3,000 Engine RPM.

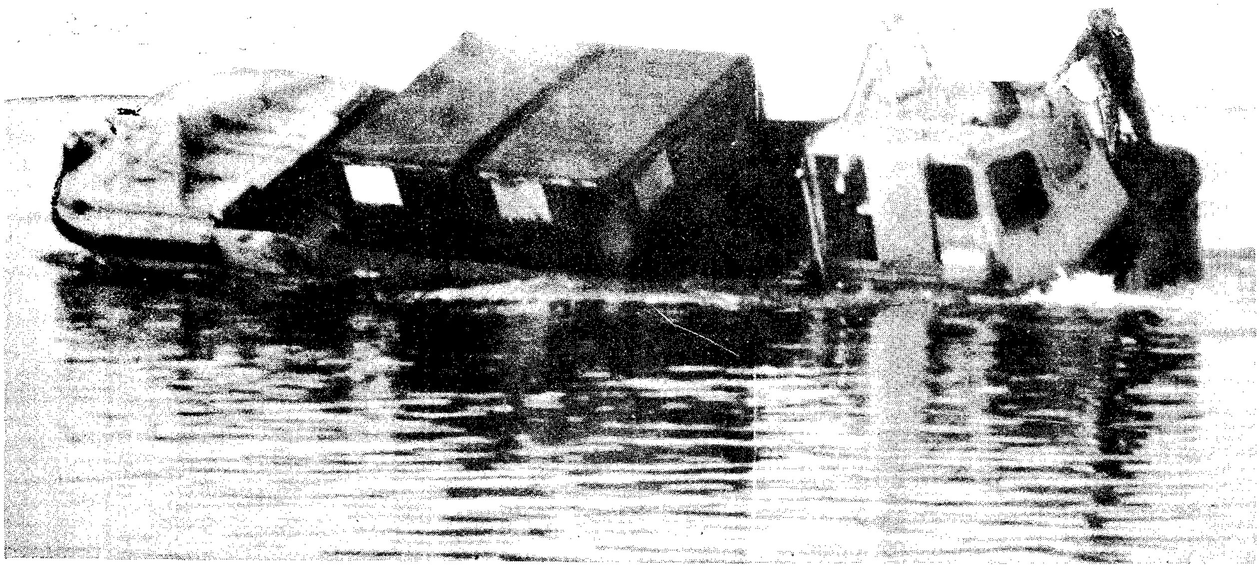


Figure 137. Lighter in Hard-Over Starboard Turn With 15-Ton, 30-Inch-Center-of-Gravity Load and 3,000 Engine RPM.

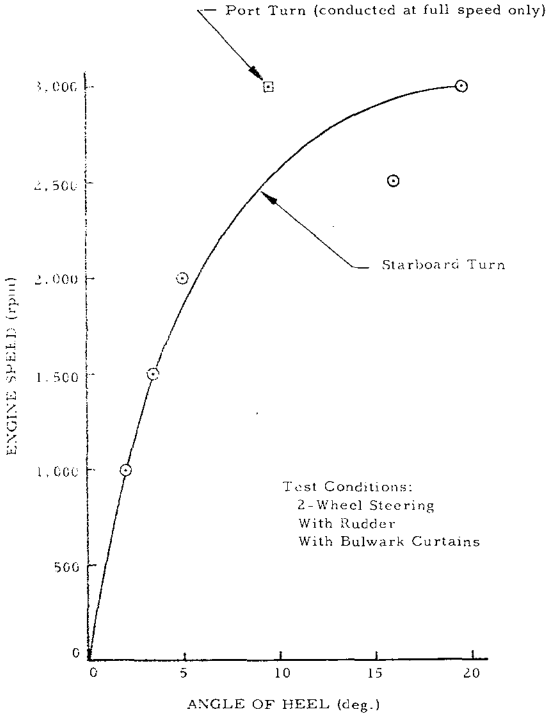


Figure 138. Engine Speed Versus Angle of Heel for 9-Ton, 43-Inch-Center-of-Gravity Load During Dynamic Stability Tests.

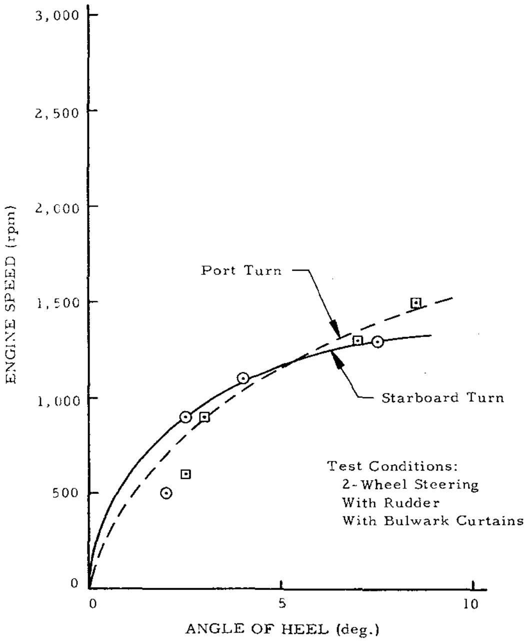


Figure 139. Engine Speed Versus Angle of Heel for 15-Ton, 40-Inch-Center-of-Gravity Load During Dynamic Stability Tests.

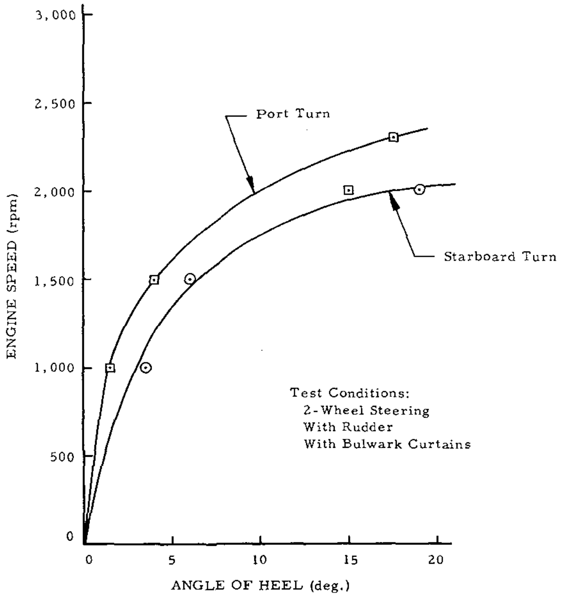


Figure 140. Engine Speed Versus Angle of Heel for 15-Ton, 30-Inch-Center-of-Gravity Load During Dynamic Stability Tests.

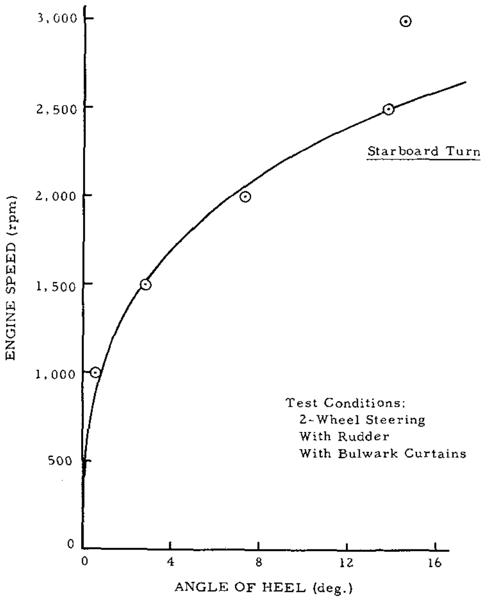


Figure 141. Engine Speed Versus Angle of Heel for 13.5-Ton, 40-Inch-Center-of-Gravity Load During Dynamic Stability Tests.

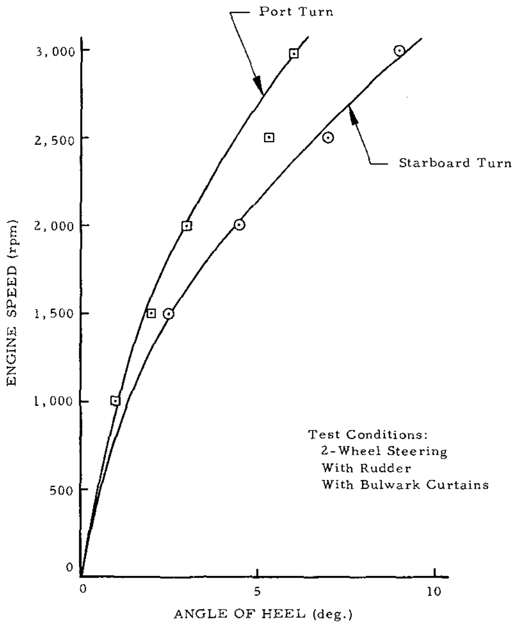


Figure 142. Engine Speed Versus Angle of Heel for No-Load Condition During Dynamic Stability Tests.

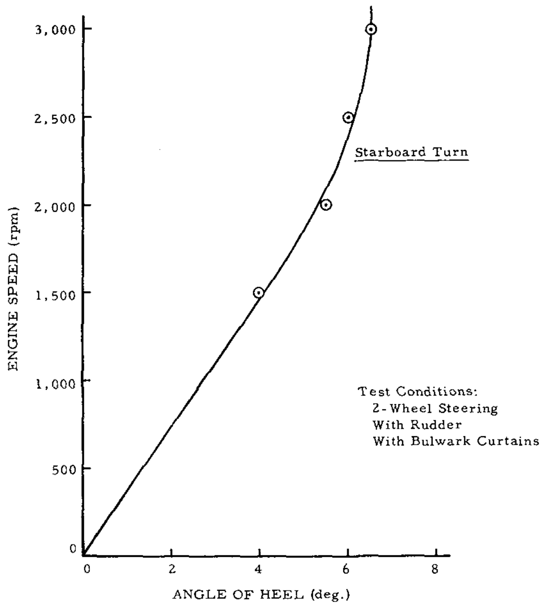


Figure 143. Engine Speed Versus Angle of Heel for 7.5-Ton, 40-Inch-Center-of-Gravity Load During Dynamic Stability Tests.

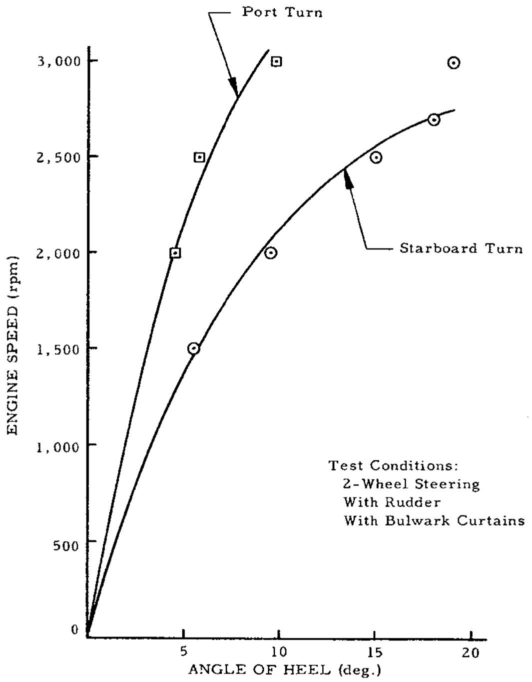


Figure 144. Engine Speed Versus Angle of Heel for 10-Ton, 40-Inch-Center-of-Gravity Load During Dynamic Stability Tests.

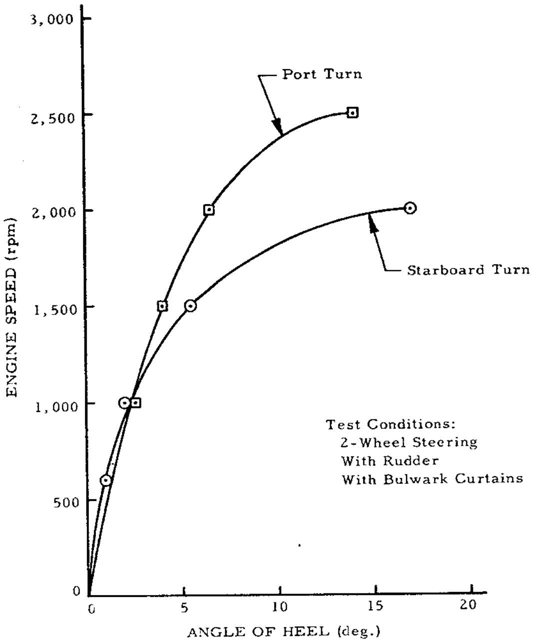


Figure 145. Engine Speed Versus Angle of Heel for 12-Ton, 40-Inch-Center-of-Gravity Load During Dynamic Stability Tests.

Procedure - 14-Foot-Beam Lighter

As a result of the preceding tests, it was decided to increase the beam of the lighter rather than to derate the load capacity from 15 to 10 tons. When the LARC-XV-1X was at Cape Canaveral, Florida, the beam was widened from 12 feet to 14 feet (14 feet 6 inches over the tires and rub rails). The lighter was retested, and the same procedure used during the tests with the 12-foot beam was repeated. All stability tests were conducted with wheels located in the original position, but the speed runs were conducted with the wheels relocated outboard 1 foot, port and starboard, to simulate the production design.

Results - 14-Foot-Beam Lighter

The maximum righting moment determined from a static test was found to be 63,000 foot-pounds at a 30-degree angle of heel. The trim when the lighter was loaded was 34-1/2 inches at the aft end of the aft wheel well and 33-1/8 inches at the aft end of the forward wheel well; with no load, the trim was

26-1/2 inches aft and 17-1/2 inches forward. Maximum speeds were approximately 10 miles per hour in an unloaded condition and 8.6 miles per hour with the lighter loaded. The final lighter lifting weight with tanks topped was 46,800 pounds. In dynamic stability tests, the maximum angle of heel experienced in a hard starboard turn at full speed, with a 30,000-pound load having a 40-inch center of gravity, was 13-1/2 degrees. The increased beam (14 feet, molded) was ample even with the wheels in the original position. Figures 146 and 147 show the completed fabrication of the 2-foot widened area, and Figures 148 and 149 show the LARC during static stability tests conducted after the beam was widened. Figure 150 shows the LARC during the full-speed maneuvering test; the beam had been widened, and the wheels had been temporarily moved outboard to simulate the production design. In the production design, the wheels will be relocated outboard by approximately 10 inches; the added width will provide greater stability than was realized during the dynamic stability tests, when the wheels were retained in the original position.

Figure 151 shows righting moment curves for the LARC-XV-1X original and modified beams, and Figure 152 shows a comparison of the dynamic stability of the lighter before and after widening the beam. Predicated on the static stability curve for the widened beam, which indicates a safe margin of stability, dynamic stability tests were conducted to ascertain maximum angles of heel in hard turns with the lighter fully loaded.

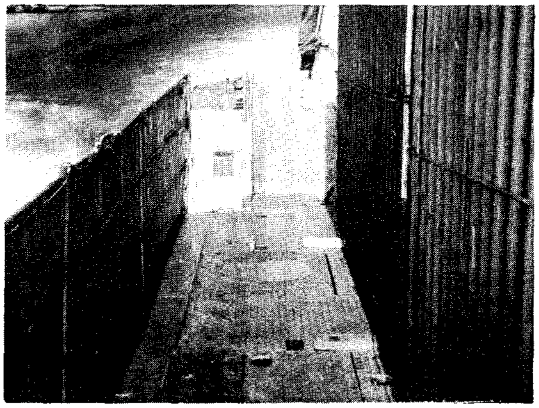


Figure 146. 1-Foot Extension to Beam of LARC-XV-1X.

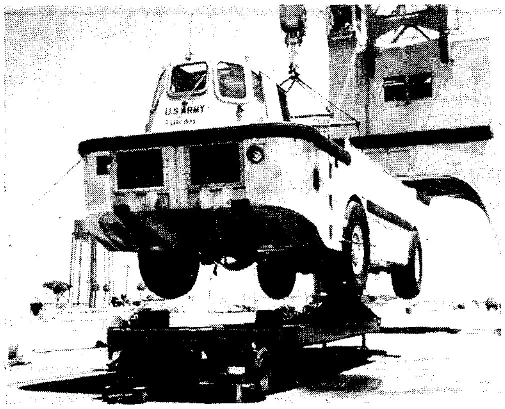


Figure 147. Completed Fabrication; 1-Foot Extension Port and Starboard.

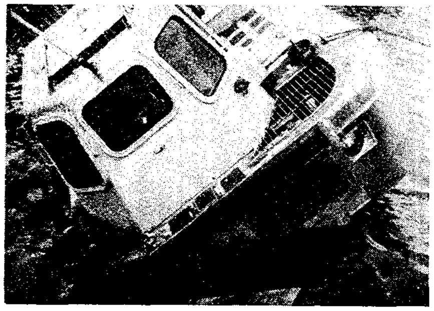


Figure 148. Stern of Lighter Heeled Over During Static Stability Tests. *

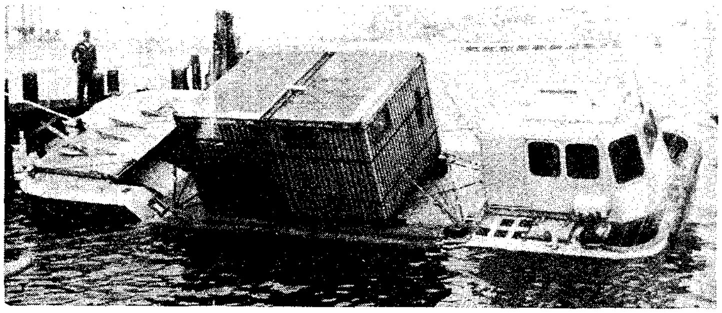


Figure 149. Lighter With Modified Beam Heeled Over During Static Stability Tests--15-Ton, 40-Inch-Center-of-Gravity Load

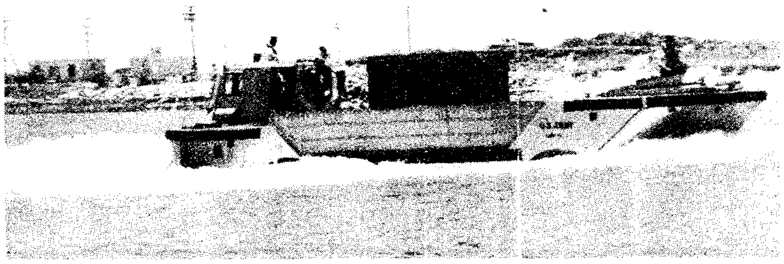


Figure 150. Water Maneuvering Tests. *

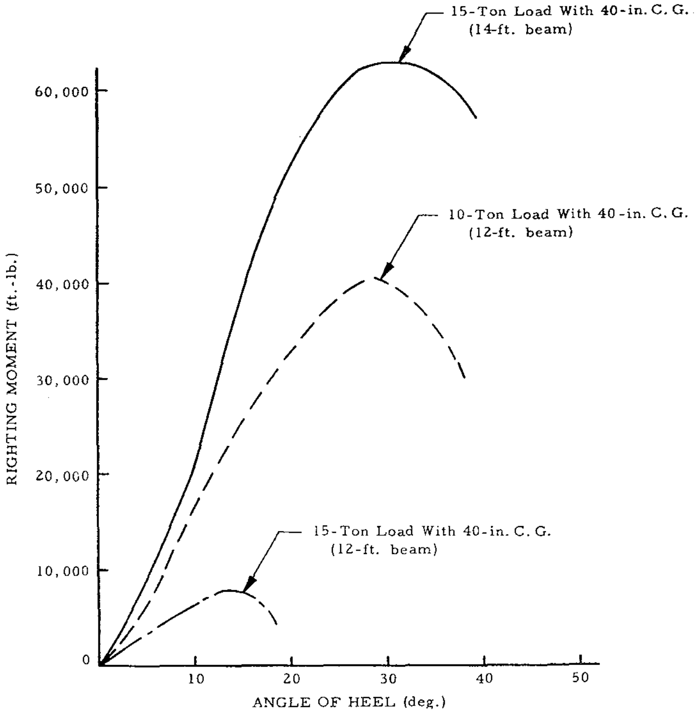


Figure 151. Righting Moment Curves for the LARC-XV-1X--Original and Modified Beams.

---

* 15-ton, 40-inch-center-of-gravity load, 14-foot widened beam.

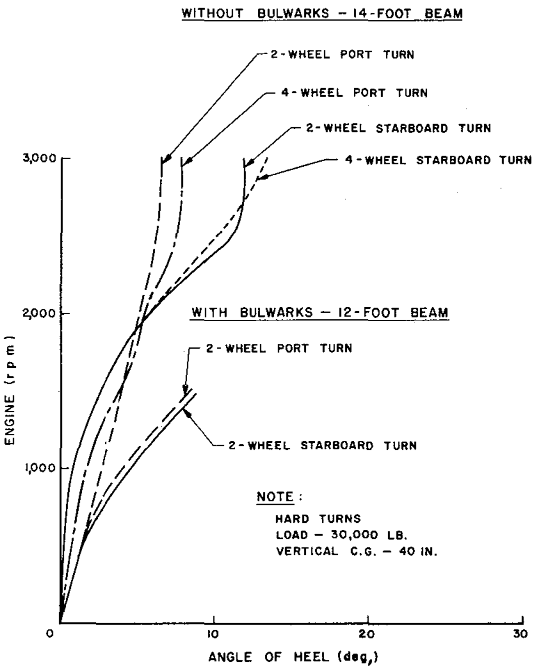


Figure 152. Comparison of Dynamic Stability of LARC-XV-1X--Before and After Widening Beam.

TABLE 54
DYNAMIC STABILITY TESTS--WITH BULWARK CURTAINS

Engine Speed (rpm)	Load (ton)	Center of Gravity (in.)	Steering	Direction of Turn	Angle of Heel (deg.)
1,000	-	-	2 Wheel w/Rudder	Port	1.0
1,500	-	-	"	"	2.0
2,000	-	-	"	"	3.0
2,500	-	-	"	"	5.3
2,950	-	-	"	"	6.0
1,000	-	-	"	Starboard	1.0
1,500	-	-	"	"	2.5
2,000	-	-	"	"	4.5
2,500	-	-	"	"	7.0
3,000	-	-	"	"	9.0
1,500	7.5	40	2 Wheel w/o Rudder	Starboard	4.0
2,000	"	"	"	"	5.5
2,500	"	"	"	"	6.0
3,000	"	"	"	"	6.5

TABLE 54 - contd.

Engine Speed (rpm)		Center of Gravity (in.)	Steering	Direction of Turn	Angle of Heel (deg.)
1,000	9	43	2 Wheel w/Rudder	Starboard	2.0
1,500	"	"	"	"	3.5
2,000	"	"	"	"	5.0
2,500	"	"	"	"	16.0
3,000	"	"	"	"	19.5
3,000	"	"	"	Port	9.5
2,000	10	40	2 Wheel w/Rudder	Port	4.5
2,500	"	"	"	"	6.5
3,000	"	"	"	"	9.5
1,500	"	"	"	Starboard	6.0
2,000	"	"	"	"	9.0
2,500	"	"	"	"	15.0
2,700	"	"	"	"	18.0
3,000	"	"	"	"	19.0
1,000	12	40	2 Wheel w/Rudder	Port	2.5
1,500	"	"	"	"	4.0
2,000	"	"	"	"	6.5
2,500	"	"	"	"	14.0
600	"	"	"	Starboard	1.0
1,000	"	"	"	"	2.0
1,500	"	"	"	"	5.5
2,000	"	"	"	"	17.0
1,000	13.5	40	2 Wheel w/o Rudder	Starboard	0.5
1,500	"	"	"	"	2.8
2,000	"	"	"	"	7.3
2,500	"	"	"	"	13.8
3,000	"	"	"	"	14.5
600	15	40	2 Wheel w/Rudder	Port	2.5
900	"	"	"	"	3.0
1,100	"	"	"	"	4.0
1,300	"	"	"	"	7.0
1,500	"	"	"	"	8.5
600	"	"	"	Starboard	2.0
900	"	"	"	"	2.5
1,100	"	"	"	"	4.0
1,300	"	"	"	"	6.5
1,300	"	"	"	"	7.5

TABLE 55
DYNAMIC STABILITY TESTS--WITHOUT BULWARK CURTAINS

Engine Speed (rpm)	Load (ton)	Center of Gravity (in.)	Steering	Direction of Turn	Angle of Heel (deg.)
1,000	15	30	2 Wheel w/Rudder	Port	1.5
1,500	"	"	"	"	4.0
2,000	"	"	"	"	15.0
2,300	"	"	"	"	17.5
1,000	"	"	"	Starboard	3.5
1,500	"	"	"	"	6.0
2,000	"	"	"	"	19.0

DETERMINATION TWO. LARC-XV-1X Modified Hydraulic System

Procedure

Because of difficulty experienced with the original hydraulic system in the LARC-XV-1X, the open-center system was converted to a closed center system. The open-center system is powered by a gear pump that maintains continuous flow against minimal losses through an open-ended circuit until a demand is placed on the system whereby flow is diverted to that circuit. The closed-center system is powered by a variable-stroke piston-type pump which discharges into a dead-end circuit and pressurizes that circuit by being stroked back to zero flow until a demand is placed on the closed circuit whereby flow is diverted to satisfy that demand. The closed-center system was installed; a brief operational test was conducted at Cape Canaveral, Florida, prior to the endurance tests.

Results

Operationally, the closed-center system functioned satisfactorily. However, excessive heat and noise created problems, which are currently being investigated.

DETERMINATION THREE. Engine Horsepower

Procedure

Tests were conducted at Cape Canaveral, Florida, during August 1962 to confirm results obtained during similar tests performed on the western coast of the United States. In addition, the effective horsepower at the propeller was to be recorded. (See Appendix III for procedures used and data recorded.)

Results

Results of tests conducted in Florida paralleled those of tests performed on the West Coast (see Appendix III). The maximum horsepower recorded was 310 horsepower at 3,000 rpm. Efforts to obtain power and thrust at the propeller were nullified by failure of the instrumentation insulation, which peeled off during initial operations; as a result, bilge water shorted the wiring. Time did not permit reinstrumenting.

Observation

Although the delivered horsepower was not obtained, extrapolations can be made from prior contractor tests of the gasoline-powered LARC-XV with reasonable accuracy. Analysis by similitude follows:

> Predicated on an effective horsepower of 397 horsepower recorded on the gasoline-powered LARC-XV and on a 484 installed horsepower, losses through the power train are approximated as 18 percent. Therefore, it is reasonable to assume that the effective horsepower for this diesel-powered installation is reduced by 104 (0.18 × 575) to 471 horsepower. Accordingly, for the difference of 91 horsepower (575 - 484), an increase in water speed of only 1/2 mile per hour (10 - 9.43) was realized. Although this speed may vary slightly (considering differences in weight and beam design for the production design of the LARC-XV), there is sufficient justification herein to warrant consideration of an engine having less horsepower if engine life considerations are ignored.

DETERMINATION FOUR. Nominal Ground Pressure

Procedure

Since the lighter weight was symmetrical about the longitudinal center line and since the load was equally distributed between the wheels, only the forward and aft starboard wheels were measured. Tire pressures were measured with a master gage, and all tires were evenly pressurized.

The lighter was raised, and the tires were inked; next, the lighter was lowered vertically onto nonblotting paper on a concrete surface; then, the lighter was vertically raised and the paper showing the tire imprint was removed. After a run was indexed, the paper was allowed to dry. The area of the inked surface was then measured and recorded.

Results

The maximum width of the tire imprints was 23 inches; the maximum length was 52-3/8 inches. The footprint area varied from approximately 400 to 1,140 square inches, resulting in ground pressures ranging from 15 psi to 34 psi. Detailed results of the tests are shown in Table 56 and Figure 153.

TABLE 56
NOMINAL GROUND PRESSURE

Tire			LARC	Wheel	Tire Footprint	Ground Pressure	
Location		Pressure (psi)	Load (tons)	Load (lb.)	Area (sq. in.)	Individual (psi)	Average (psi)
Stbd.	Fwd.	5	0	8,550	577.75	14.80	16.69
"	Aft	"	0	14,850	998.49	14.87	
"	Fwd.	"	15	16,050	917.77	17.49	
"	Aft	"	15	22,350	1139.95	19.61	
Stbd.	Fwd.	15	0	8,550	403.42	21.19	23.53
"	Aft	"	0	14,850	674.51	22.02	
"	Fwd.	"	15	16,050	639.72	25.09	
"	Aft	"	15	22,350	865.22	25.83	
Stbd.	Fwd.	25	0	8,550	281.44	30.38	31.28
"	Aft	"	0	14,850	508.00	27.26	
"	Fwd.	"	15	16,050	473.70	33.88	
"	Aft	"	15	22,350	665.66	33.58	

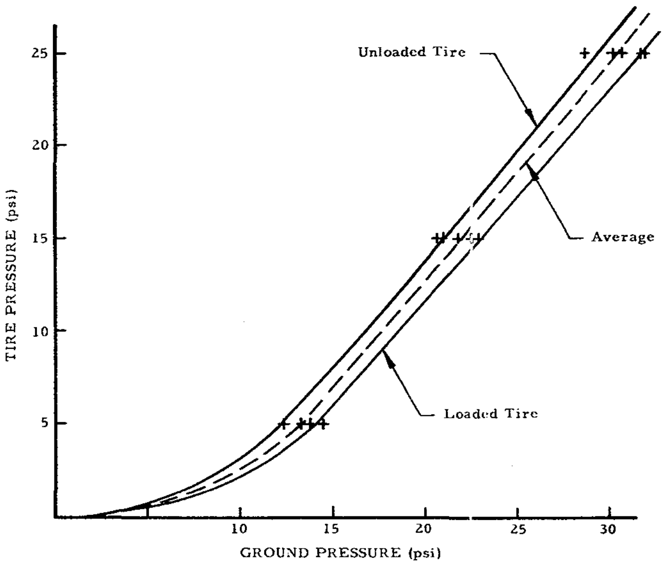


Figure 153. Nominal Ground Pressure. (Tire size = 24 x 29, 16-ply.)

Observations

Measurements were made on the lighter after the beam was widened to 14 feet. The axle loads used in determining the wheel loading for this test were those on the lighter prior to widening the beam and were evenly increased to represent the additional beam width weight, which was assumed to be symmetrical. Results of this test are accurate to within a 10-percent margin of error. Errors in approximating the periphery of imprint can occur because of some smudging and running of the ink.

Under certain conditions of heavy wheel loading, a center portion of the tire imprint would not be inked on the paper; it is assumed that the tire buckled in that area.

EVALUATION

In general, tests showed that the LARC-XV-1X fulfills the requirements of the military and technical characteristics. However, certain areas require additional consideration.

Since the widened beam (14 feet) and the increased weight of the LARC-XV may present a transportability problem, especially in foreign countries, it is believed that a further evaluation of the modified prototype is necessary. The problem of transporting the lighter by various modes of transportation should be anticipated and explored immediately by cognizant agencies.

Shipside unloading tests of CONEX containers should be conducted under various conditions so that the structural-strength limits of the LARC-XV can be determined.

Further environmental tests should be conducted in order to determine whether the cooling system complies with the ambient requirements specified in the military characteristics; that is, 115° F. to -25° F. Unfavorable climatic conditions at Yuma, Arizona, prohibited testing with high ambient temperatures. Although 115° F. is not realistic for shoreline temperature, compliance with this requirement should be determined by actual test to assure continuous operation of these prototype engines under these conditions. Additional cold-weather tests at the specified -25° F. should be conducted to determine the adequacy of the starting system and of the heating system at low ambients. No cold-weather starting kits are provided in this design.

Tests should be conducted to establish the mobility index for specific tire inflation schedules in order to provide a mobility yardstick for comparison with similarly indexed equipment.

Results of the heat measurement tests indicate that the keel coolers are not required. It is believed that further marine tests of the cooling system should be conducted; both the main and auxiliary keel coolers should be bypassed in order to determine the effects of elimination.

While it has been concluded that smaller capacity engines can be used to power the LARC-XV, possibly at the expense of a shorter engine life, further tests should be conducted to determine the loss of water speed that would result if these engines were used. (Such a program was initiated by USATRECOM in January 1963.)

Although LARC communications were not adversely affected by conduction interference occurring at low frequencies in the electrical system, it is believed that the changes made by the manufacturer of the LARC-XV alternators should be subjected to testing for interference to determine the adequacy of the modifications.

It is believed that multifuel tests should be conducted, although such tests were not specified in the military characteristics. The performance of various fuels could be compared, and any adverse effects that resulted from a particular fuel could be detected.

BIBLIOGRAPHY

Engineering Test Report, LARC-XV, Prototype No. 1, Report No. 1, Contract DA 44-177-TC-479, Ingersol Kalamazoo Division, Borg-Warner Corporation, Kalamazoo, Michigan, July 1960; Addendum, October 1960.

Jennerstown Brake Tests, LARC-XV-2X, Report No. 1, Contract DA 44-177-TC-479, Ingersol Kalamazoo Division, Borg-Warner Corporation, Kalamazoo, Michigan, August 1960.

Lighter, Amphibious, Resupply, Cargo, 15-Ton (LARC-XV), Endurance Test Report, U. S. Army Transportation Research Command, Fort Eustis, Virginia, February 1963.

Powering Characteristics in Still Water and Waves for LARC 15 as Represented by Model 4721, Report No. 1337, David Taylor Model Basin, Washington, D. C., August 1959.

Report on Cargo Trials of the LARC XV, E-4 (Transportation) War Office, London, SW1, England, April 1962.

Report of Service Test, Lighter, Amphibious (LARC 15-Ton), U. S. Army Transportation Board, Fort Eustis, Virginia, February 1963.

Test Report on the LARC-XV-4X, Letter Report by Federal Republic of Germany, 1962. (Test report available in USATRECOM.)

Towing Tests of a Proposed Lighter, 15-Ton Amphibious, Report LR 702, Contract DA 44-177-TC-390, Stevens Institute of Technology, Hoboken, New Jersey, June 1958.

APPENDIX I

MILITARY AND TECHNICAL CHARACTERISTICS WITH REVISIONS

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF TRANSPORTATION
WASHINGTON 25, D.C.

READ FOR RECORD
TCTC ITEM 4047

TCAFO-T

6 July 1962

SUBJECT: LIGHTER, AMPHIBIOUS: (LARC-XV) self-propelled aluminum 15 ton, design 8004; revision to military and technical characteristics and type classification as STD-A

Reference: Coordinating Subcommittee, TCTC, Item 2028/60

APPROVALS:

For the Chief of Transportation:	For the Secretary of the Army:
/s/ F. H. PURDY for N. A. GAGE, Jr. Colonel, TC Chairman, TC Technical Committee	/s/ GILLMAN C. OLIVER for JOHN A. TODD Major, GS Office, Chief of R&D, AGS

At Meeting 140A, held 6 July 1962, the Transportation Corps Technical Committee and the representative of the Secretary of the Army, approved subject action subject to desert testing of vehicle prior to production to insure adequate cooling under high temperature operating conditions; and to vehicle meeting the high temperature limitations specified in the military and technical characteristics according to plan of test; and with the following corrections:

Cover letter:

P 1. Insert "6 July 1962" as date of this item.

P 1, par 1. Add subpar i. "i. Memorandum for Record TCREC, dated 19 June 1962, subject: 'Failures During Engineering and Endurance Test of LARC-XV-IX.'"

P 4, par 3e. Add subpar (1) and (2).

"(1) In accordance with Message (U) ATDEV-2, CGUSCONARC to RUEPJEDA/DA for CRD, with information copies to DCSOPS, DCSLOG, TO, 26 June 1962:

(a) This HQ has reviewed the deficiencies and shortcomings which were reported during engineering and endurance tests of subject vehicle and modifications made or to be made to correct same.

COPY

(b) In view of the results of these tests and modifications made during the tests or to be made in the production vehicle, this HQ concurs in the proposed type classification standard A of Lighter Amphibious (LARC-XV), Self-Propelled, Aluminum, 15-Ton with the following comment:

1. It is noted that this vehicle has not been tested under desert conditions. This HQ considers desert test of this vehicle absolutely essential prior to production to insure adequate cooling under high temperature operating conditions."

"(2) In accordance with memorandum for record of test, referenced in par 1i above, results of the tests conducted on this vehicle are shown below:

(a) The deficiencies requiring elimination in order to make the vehicle acceptable for use on a minimum basis; and the suggested corrective actions to be taken are:

1. The Operating Cab.

a. Not enough vision, too close to the cargo compartment, too hard for the men to evacuate the cab in case of trouble.

b. Remodeling the complete cab by constructing a full scale model to be positive that all deficiencies are corrected.

2. Stability.

a. The LARC as tested did not have the stability for a 15-ton load 40-inch CG.

b. Lighter's beam has been extended to 14 ft 6 in to provide adequate marine stability to lift payloads up to 30,000 lbs. with a load CG of 40 in. Original MCs specified a load CG of approximately 18-20 in., however, the reevaluation of the intended operational use of subject lighter indicated that a higher load CG was most desirable. Experience in connection with production of LARC-V indicated that a minimum cost the higher load CG could be transported by increasing the width of the LARC-XV by 2 ft. Operational tests conducted at Cape Canaveral 16 June 1962 indicated that subject item with the increased beam will provide adequate stability to lift the payload of 30,000 lbs. with a load CG of 40 in.

3. Electric Wiring and Control.

a. Items not water-and-oil proof.

b. All wiring and controls will be of a marine-type installation which will be water and oil proof, thereby eliminating the deficiency found during the test.

4. Environmental Test.

a. Prior to production it is anticipated that LARCs XV-1X and 2X will be subject to high range temperatures as stated in the military characteristics.

(b) The shortcomings which should be corrected; and the corrective action taken are; and all corrective actions taken have been proof tested with a minimum of 500 hours, and further testing is being conducted at Cape Canaveral, Florida.

1. Brakes.

a. Brakes would not release.

b. During test, return line was too small. Line was enlarged, correcting the brake deficiencies.

2. Fuel Transfer Pump.

a. Internal short.

b. Field Engineer Carter Carburetor Corporation visited test site, Ocean Side, California, and determined that they were selling the wrong fuel pump for this application. The proper pump was supplied and installed, correcting this deficiency.

3. Hi Low Clutch Pack.

a. Low-range clutch plates burned because of low oil pressure.

b. Installation of new lube oil pump, and increased oil pressure.

4. Lube Oil Pump.

a. Broken shafts caused by insufficient clearance of thrust bearings.

b. Installation of a new lube oil pump from a different manufacturer which had ball bearings instead of thrust bearings.

5. Ramp Extension Control.

a. Control linkage and operating valves not properly installed plus too much pressure exerted on the rams.

b. Mounting of control linkage was properly reinforced, and the lube pressure to activate the hydraulic rams was reduced.

6. Transfer Case.

a. The tooth of the high-range drive gear sheared off due to the improper hardness of gears from the manufacturer.

b. Installation of gears that were manufactured and hardened within proper tolerances.

7. Wheel Mounting Flange.

a. Casting broke just inboard of C-V joint.

b. Installation of a modified casting which had been preheated, and elimination of the stress riser.

8. Hydraulic Pumps.

a. Broken shafts due to insufficient clearance of thrust bearings.

b. Installation of a new lube oil pump from a different manufacturer which had ball bearings instead of thrust bearings.

9. The Fuel Inlet For Fuel Tanks.

a. Water getting into fuel tanks caused by water awash on cargo deck seeping into fuel tanks.

b. Raising fuel inlet pipes of fuel tanks to the forward cheeks of the LARC.

10. Various Controls.

a. Improper operation thereof.

b. All control deficiencies have been corrected on LARC-XV-1X, and these corrections will be corrected on blue prints prior to production of the end item."

Exhibit A:

P 2, par 3d. Delete and substitute therefor:

"d. Transportability: The lighter must be capable of inland waterway and sea transport. Air and rail transport are not required. Public highway transport, although severely restricted may be required for short distances when special permits can be obtained. However, such movement over public highways will not be considered a military necessity for the purpose of securing highway permits. Tie-down devices, lifting points, and towing hooks shall be provided."

P 3, par 6a. Delete and substitute therefor:

"a. Engine- The power plant shall be selected from engines available in the military system, or commercially available, shall be as light as possible consistent with satisfying the performance requirements as outlined in paragraph 3 above, and shall operate over a broad fuel spectrum. An air-cooled engine shall be considered with desirable characteristics of operation over a broad fuel spectrum."

P 4, par 6e. 11th line, delete "not", the third from the last word. Add the following sentence to this paragraph: "Selection of either land speed ratio may be accomplished while the lighter is not in motion."

/s/ F. H. Purdy
F. H. PURDY
Deputy Chairman
TC Technical Committee

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF TRANSPORTATION

TCTC ITEM 4047
MEETING 140A

TCREC-DPE

SUBJECT: LIGHTER, AMPHIBIOUS: (LARC-XV) self-propelled aluminum 15 ton, design 8004; revision to military and technical characteristics and type classification as STD-A

FROM: TCTC Coordinating Subcommittee

TO: Transportation Corps Technical Committee

1. References:

a. TCTC Item 1725, Meeting 102, held 22 March 1956, Development Project 9-57-03-000, Marine Craft; initiation of project and consolidation of projects, approved by the Technical Committee 22 March 1956 and by Ch/R&D, OCofS on 19 November 1956.

b. Disposition Form, Comment No. 2, Ch/R&D to Chief of Transportation, subject; "Development of Amphibious Lighters," file CRD/D 13752, dated 30 January 1958, directing initiation of the development of amphibious lighters.

c. TCTC Item 2261, Meeting 114, held 6 March 1958, Task 113M Project 9-57-03-000, Lighter 15-Ton Amphibious (U); initiation; military and technical characteristics of item.

d. TCTC Record and Information Item 3313, Meeting 126, held 17 December 1959, Renumbering of Transportation Corps Research and Development Projects and Tasks; Changes in Titles; redesignating Task 113M, Project 9-57-03-000 as Task 9R57-02-018-02.

e. Report TREC 61-55, "Engineering Test Report LARC-15 Prototype No. 1," dated July 1960.

f. TCTC Item 3695, Meeting 136, held 1 June 1961, 9R57-02-018-02, Amphibious Concepts and Designs (U); initiation.

g. TCTC Item 3841, Meeting 138, held 21 December 1961, 9R57-02-018-02, Lighter, 15-Ton, Amphibious (U); supersession.

h. TCTC Coordinating Subcommittee Item 2028, Meeting 60, held 6 March 1962, LIGHTER, AMPHIBIOUS: (LARC-XV) self-propelled aluminum 15-ton, design 8004, type classification as STD-A, approved for referral to TC Technical Committee.

COPY

2. Discussion:

a. Subject item was developed by the Transportation Corps under ref. 1c as directed by ref. 1d. Three (3) prototype units were procured for engineering and service tests. Accelerated service test of the item was conducted, see ref 3e. Report of the service test is being published and will be distributed to all interested agencies. Lighter's beam has been extended to 14 feet 6 inches to provide adequate marine stability to lift payloads up to 30,000 lbs. with load CG of 40 inches. Original MC's specified a load CG of approximately 18-20 inches; however, the re-evaluation of the intended operational use of subject lighter indicated that a higher load CG was most desirable. Experience in connection with production of LARC-V indicated that, at a minimum cost, the higher load CG could be transported by increasing the width of the LARC XV by 2 feet. Operational tests conducted at Cape Canaveral 16 June 1962 indicated that subject item with the increased beam of 2 feet will provide adequate stability to lift the payload of 30,000 lbs. with a load CG of 40 inches. Further testing of the item is being conducted to provide technical data for FY 63 procurement package and to obtain other related data on repair parts, serviceability, value analysis, maintainability and human engineering.

b. The item was developed and the engineering testing was performed under authority contained in Annex II, Task 9R57-02-018-05 Amphibious Concepts and Designs(U). (Originally Task 113M, Project 9-57-03-000, thence Task 9R57-02-018-02).

c. The military and technical characteristics were approved by ref 1c. Revisions to the MC's and TC's proposed by this action are as listed in Exhibit A.

3. Pertinent data, par 5g AR 705-6:

a. Description and purpose: The item is a self-propelled amphibious lighter of 30,000 pounds cargo capacity, constructed of aluminum, equipped with four rubber-tired wheels. It is propelled in water by a single four-bladed propeller and has a maximum speed in still water of approximately 9.5 statute mph. Drive originators with two diesel engines which gather through torque converters and thence through a series of transmissions which can be so engaged as to provide either land or marine drive. Wheels have low-pressure tires, and are without articulated suspension. Steering is 4 wheel for land, through hydraulic cylinders and for marine through linkage. It is capable of operation cross-country with maximum speed on smooth, hard, level surface of 25 mph. The LARC-XV is 45 feet in length with a beam of 14 ft. 6 in. and is constructed under Transportation Corps design 8004. The purpose of the item is to provide transportation of cargo from shipside through the surf zone to the beach and to inland objectives. It is designed for expedient unloading by use of fork lift trucks and by the ramp for vehicles. The lighter is capable of fording streams, rivers, lakes and inland waterways as well as operation on land and through surf zones. The item is powered by two high speed lightweight industrial type diesel engines. The engines are not covered by military specification or Logistics Directive No. 115-715. No currently standard type engine meets the requirements for application to subject item.

In accordance with AR 705-6, Change No. 3, 21 March 1961, the following list of Components for LARC-XV is included in the type classification:

FSN	Description	U/I	Qty
6140-057-2554	BATTERY, STORAGE: (96906) no. MS 3500-3 type 6TN(ORD)	EA	4
4210-270-4512	EXTINGUISHER, FIRE: (81349) no. MIL-E-468, type 1, class 1, 5 lb. (ENG)	EA	3
6230-117-0928	FLASHLIGHT: (81349)no. MIL-F-3747, MX991 (ENG)	EA	1
4930-837-5516	GREASE GUN, HAND: (81349) no. MIL-G-22588, 14 oz capacity, 6000 psi min pressure (QM)	EA	1
2540-312-1984	HEATER, CAB, MODIFIED: (75418) no. K 630MOD (TC)	EA	1
4930-173-5353	OILER, HAND: (81348) no. Fed GGG-O-591, type II, class B, Style A, 5 oz (QM)	EA	1
*5820-892-0871	RADIO SET: (80058) no. AN/VRC46(SIG)	EA	1
**2610-064-533	TIRE, PNEUMATIC: (73842) no. 742074, 24.00-29x16 P.R. (TC)	EA	4

* Signal Corps requested to consider replacing this item with one less costly.

** In accordance with current Army regulations, TC will manage this item until transferred to the designated Defense Supply Agency Activity.

b. The item name is in accordance with current Federal Catalog System.

c. The using agency of the item is the Department of the Army, and other agencies of the Department of Defense if desired.

d. Item has been assigned to Federal Supply Class 1930 and is the logistics responsibility of the Transportation Corps under AR 701-1930.

e. Extensive service tests have been conducted on subject item at Yuma Test Station, Arizona, Coronado Beach, California, Oceanside, California, and Cape Canaveral, Florida. Results of these tests indicate that the item is suitable for type classification. Any modifications that may be required at the completion of these tests will be made prior to production.

f. Stock status; Three (3) prototype units procured for Engineering-Service Testing.

g. The estimated current cost in quantity procurement is $155,000. each.

h. No units were procured in the current fiscal year (1962). None in the two preceding fiscal years, and none are on outstanding contracts.

i. The item is intended for future procurement.

j. It is estimated that training, operational, and maintenance literature will be available at the time of delivery of the first production models.

k. It is considered that under mobilization conditions, sufficient quantities of critical and strategic materials to meet requirements will be available for the manufacture of the item.

l. The proposed action will not cause a new or substantially increased use of a material likely to be short under current or wartime conditions.

m. Initial basis of issue for Class II items:

Table	Title	Allowance
TOE 55-139	Transportation Amphibious Company Medium LARC-15	25
TA 80-10P	1 unit	25 each per unit
TA 80-12P	1 unit	12 each per unit
TA 74-5P	1 unit	2 each per unit

n. Initial monthly replacement factors are estimated as follows:

(1) Peacetime	-	.0104
(2) Wartime:		
(a) CONUS	-	.0104
(b) Active Theater	-	.0208

o. The security classification of the item, its components, nomenclature, and of this action is Unclassified.

4. The provisions of paragraph 5h of AR 705-6 have been complied with except for the following sub-paragraphs:

a. Repair parts have been selected to support the scope of maintenance set forth in the preliminary maintenance allocation chart and will be available at the time of delivery of the first production models.

b. A maintenance evaluation is in preparation and will be available to using agencies prior to production. A preliminary maintenance allocation chart was prepared as part of the maintenance package. Final maintenance allocation chart is in preparation.

c. Transportability: The item meets the transportability requirements of the military characteristics. Air transportability and movement by rail is not required. Movement over public highways is severely restricted and movement over public highways for long distances is not required. Tie-down devices, lifting points and towing hooks have been provided.

d. Environmental tests have not been completed. It is anticipated that the high temperature range of the military characteristics will be met during Cape Canaveral testing.

e. Bridge classifications for subject item are class 24 empty and class 54 loaded. Bridge classifications for the item with the additional width and weight, ref. 2c, is undetermined.

5. Recommendations:

a. It is recommended that subject item be type classified as STD-A with the following nomenclature and reference numbers:

(1) Nomenclatures:

(a) Complete: LIGHTER, Amphibious: (LARC-XV) self-propelled, aluminum, 15 ton, design 8004.

(b) Generic: LIGHTER AMPHIBIOUS(LARC-XV) SELF-PROPELLED ALUMINUM 15 TON

(2) FSN: 1930-710-5729

(3) EAM line item number: 745030.

b. It is recommended that the military and technical characteristics, as revised, be approved (See Exhibit A).

/s/ M. D. Davis
M. D. DAVIS
Chairman
TCTC Coordinating Subcommittee

1 Incl
EXHIBIT A

EXHIBIT A

TCTC ITEM 4047
MEETING 140A

LIGHTER, AMPHIBIOUS: (LARC-XV) (U)

Military and Technical Characteristics

Revised 20 June 1962

1. Type: Marine craft, deck cargo, amphibious, 4 x 4

2. Payload: 30,000 lbs.

3. Performance:

a. Water: With payload having load CG of 40 inches the lighter shall be capable of safe operation in temperature, tropic and arctic zones, through varied sea and surf conditions, without covering, night and day.

(1) Speed - 9.5 statute miles per hour in smooth water with reverse commensurate with optimum propeller.

(2) Surf capability - 12 foot plunging breaker.

(3) Turning radius - minimum practicable, 52 ft. maximum.

(4) Stability - With payload having load CG of 40 inches, the lighter shall be laterally stable and capable of remaining afloat and righting itself from the maximum practicable induced roll, not less than 30 degrees.

(5) Trim:

(a) With centrally located rated load, the lighter shall not trim by the head, nor trim more than 3 inches by the stern.

(b) Transverse trim shall not exceed ± 1 inch.

(6) Range - 12 hours at 75% power.

b. Land: With payload having load CG of 40 inches, the lighter shall be capable of safe operation in temperate, tropic and arctic zones, over beaches, coral reefs, and open unimproved terrain.

(1) Gradeability: Lighter must be capable of operating on a 40% slope.

COPY

(2) Forward speed - 25 MPH max. on level hard surface.

(3) Reverse speed - 25 MPH max. on level hard surface.

(4) Stability - safe operation on 25% hard surface side slope.

(5) Turning radius - 52 ft. max. to outside track

c. Climatic limitations:

(1) The lighter shall be capable of satisfactory performance at any air temperature from + 115°F to -25°F. Winterization kits may be utilized for extension of the lower limit. The lighter shall be capable of safe storage at temperatures of + 160°F. (for periods of approximately four hours daily) to -65°F. (for periods of approximately 3 days duration).

(2) The lighter shall perform satisfactorily at 100% relative humidity at all temperatures below 90°F., above 90°F., at the maximum obtainable relative humidity, but not exceeding the vapor pressure of 36mm of mercury.

d. Transportability: The lighter must be capable of sea transport. Air, rail and highway transport is not required.

4. Physical requirements:

a. General:

(1) The design of the lighter shall be such that a minimum of resistance to propulsion will be effected while water-borne and operating as a displacement vessel.

(2) Standard military and commercial components shall be used where practicable.

(3) Location of cab and arrangement of controls shall be such that they permit the direction of land travel to be opposite that of water travel.

(4) Gross weight of the lighter with rated load shall be the minimum practicable, not to exceed 80,000 lbs.

b. Hull: The design and construction of the hull shall be such that the maximum strength for the least weight will be realized. Interior compartments shall be watertight and equipped with quick opening access hatches with provision for engine aspiration and cooling when waterborne. The interior structure shall allow the maximum ease of maintenance and repair.

(1) Cargo well:

(a) The cargo well deck shall be located above the loaded waterline and be made watertight. Provision shall be made for discharge of sea water at the maximum practicable rate.

(b) The minimum usable cubic capacity shall be 810 cu. ft. to the top of the coaming with a minimum inside width of 11 ft. and minimum depth of 3 ft. 3 in.

(c) Unloading ramp shall be provided at the end of the cargo compartment.

(d) The cargo deck shall be capable of safely supporting any item of materiel of the infantry division which can be loaded aboard the lighter through the ramp.

(e) Fittings shall be provided for securing of cargo.

(2) Control stations:

(a) Space shall be provided for seating of the driver and assistant behind a fixed windshield. Transparent portion of the windshield shall be suitable plastic material.

(b) A permanent top shall be provided for protection of the crew and controls, fitted with fabric side curtains.

5. Dimensions:

a. Length - minimum practicable, not to exceed 45 ft. over-all.

b. Width - minimum practicable, not to exceed 175 inches.

c. Ground clearance - maximum practicable, not less than 24 inches with normal load and tire pressures.

d. Angle of approach - maximum practicable, not less than 22°, with normal load and tire pressures.

e. Angle of departure - maximum practicable, not less than 25°, with normal load and tire pressures.

f. Freeboard - maximum practicable, not less than 3 inches to main deck line, amidships, with payload load.

6. Power train:

a. Engine - The power plant shall be selected from engines available in the military system, or commercially available, and shall be as light as possible consistent with satisfying the preceding performance requirements. An air-cooled engine shall be considered with desirable characteristics of operation under a broad fuel spectrum.

b. Transmission - The transmission shall provide the sole function of transmitting and reversing engine rotation at approximately a 1:1 speed ratio, in addition to providing a neutral gear. Engine power shall be supplied to the transmission through a suitable torque converter which shall have the added capability of providing mechanical transmission at 1:1 speed ration by manual control.

c. Suspension - The lighter shall be designed without articulated wheel suspension.

d. Transfer case - The transfer case shall supply land drive or marine drive, independently or simultaneously. For land drive, each wheel shall be powered through a fixed gear ratio except for a selective high or low range speed ratio at the transfer case; a simple and sole differential effect shall be incorporated in the transfer case between the port and starboard wheels. All intermediate requirements of speed ratio shall be provided by the torque converter. The selective high and low range speed ratio shall be realized on land drive only, independently of marine drive.

e. General - It is intended that the above described power train will deliver power from the engine through a torque converter capable of being locked out for marine drive, thence through a transmission primarily for selective reversing, thence through a transfer case containing fixed gear drive for marine propulsion and a selective two-speed range for land propulsion, the latter being independent of the former, and thence to each wheel through fixed gearing. With this arrangement, selective speed range of land drive is permitted without affecting the simultaneous use of marine drive, thereby simplifying driver controls. Transfer of drive from land to marine and marine to land shall be capable of being accomplished while the lighter is not in motion.

f. Transmission shafting - Shafting between the various gear units shall be such that a maximum of flexibility will be allowed.

g. Brakes - Service brakes of Gerling type shall be provided for each of the four wheels. These brakes shall provide equal braking in either direction of travel.

h. Steering - Steering shall be provided for all wheels with power boost, and shall be linked to the rubber controls in such a manner that movement of the steering control will produce the same turn on land and water. Control shall be selective front and rear to allow crabbing.

i. Tires - Tires shall be standard desert type tubeless tires of sufficient size to provide 110% Ejlund Mobility factor at ML-1 inflation schedule.

j. Controls - All operational controls, control levers, throttles, valves, switches, etc., shall be within easy reach of the driver unless otherwise specified herein. One set of controls shall be provided for water and land operation, where possible.

7. Special characteristics:

a. Towing and lashing fittings - Suitable fittings shall be provided forward and aft for towing and lashing for transport.

b. Windshield wipers - Power operated windshield wipers shall be provided for areas of forward visibility.

c. Lifting and mooring fittings - Combination lifting eyes and mooring bitts located forward and aft shall be provided for hoisting the lighter with normal load aboard in APA or AKA using conventional ships gear. Mooring eyes shall be provided port and starboard for mooring alongside.

d. Marine propulsion - The marine propeller shall operate in a tunnel, protected to the maximum practicable extent by the surrounding hull plating. Consideration shall be given to use of propeller shrouding for maximum efficiency and protection from grounding.

e. Bilge pump - Two independently driven bilge pumps of at least 100 gallons per minute capacity each shall be provided for bilge stripping with intake from the lowest point in the hull bottom.

f. Hull drain valves - Drain valves, with clearly marked and easily accessible controls, shall be strategically located for hull drainage while the lighter is on land. Provision shall be made to insure water-tightness, safety and reliability while afloat.

g. Hull fender - A continuous molded or extruded rubber fender, semielliptical in section, shall be provided around the hull at the main deck line.

h. Lights - In addition to lights required for normal land operations, navigation lights shall be provided.

i. Cargo compartment cover - No means of covering the cargo compartment shall be provided.

j. Winch - Provision for installation of a suitable winch of 20,000 lbs. capacity shall be included in the design.

k. Instruments - Warning lights which are standard in the military system will be used in lieu of appropriate instruments.

l. Radio - Provision for installation of vehicular mounted radio shall be included in the design.

m. Navigation aids - A suitable compass shall be installed in the driver's compartment of the lighter.

n. Electrical system - The entire system shall be 24 volt.

8. Stowage: Provision shall be made for stowage of the following:

a. Vehicular tools.

b. First aid kit. (AMS standard)

c. Seventy-five pound high-tensile Danforth anchor and 250 ft. of synthetic anchor line.

d. Signal lamp.

e. Portable fire extinguishers with provision for activation by remote control.

f. Boat hook.

9. Ease of maintenance: The lighter shall be so designed to permit maximum ease of servicing, adjustment and replacement of parts and subassemblies under field condition, in a minimum of time.

APPENDIX II

RDT & E PROJECT CARD

1. TYPE OF REPORT ☒ NEW ☐ FINAL
☒ REPLACES (No. & Date) 9R57-02-018-05 31 May 61

REPORT CONTROL SYMBOL CSCRD-1(R2)

2. TASK TITLE. Amphibian Concepts and Designs (U)

3. SECURITY OF Task U

4. TASK NO. 9R57-02-018-05

5. 3695/136

6. REPORT DATE 20 Mar 62

7. BASIC FIELD OR SUBJECT Marine Craft

8. SUB FIELD OR SUBJECT SUB GROUP Barges, Boats, Lighters & Vessels

9. CATEGORY SO

10a. COGNIZANT AGENCY Transportation Corps

b. DIRECTING AGENCY USATRECOM

c. REQUESTING AGENCY Transportation Corps

11a. CONTRACTOR AND/OR GOVERNMENT LABORATORY

b. CONTRACT NUMBER

12. PARTICIPATION BY OTHER MILITARY DEPTS. AND OTHER GOVT. AGENCIES

14. SUPPORTING PROJECTS

18. EST. COMPLETION DATES
DEV.
ENGR TEST.
USER TEST
OPERATIONAL

13. COORDINATION ACTIONS W/OTHER MILITARY DEPTS. & OTHER GOVT. AGENCIES
Ord Corp IEL 5-4-101-5
Corps of Engineer

15. DATE APPROVED 1 June 1961

16. PRIORITY 1-B

17. BUDGET CODE 5400

19. EST. SUPPORT LEVEL
☐ UNDER $50,000
☐ $50,000 - $100,000
☐ $100,000 - $250,000
☐ $250,000 - $500,000
☐ $500,000 - $1,000,000
☐ OVER $1,000,000

20. CDOG: Ref Par 1012d, 1636b(3) 1610b(9)

21. SPECIAL CODES

22. REQUIREMENT AND/OR JUSTIFICATION

The Transportation Corps has a requirement for Amphibious Lighters of various concepts and designs which will materially increase the effectiveness of its over-the-shore operations.

23. Brief of project and objective:

a. Brief:

(1) Briefs of amphibious lighters are attached as supplements.

(2) Objective: To investigate amphibious concepts and designs, including various means of powering. See supplements.

b. Approach: Supplements indicate specific approaches.

c. Tasks: Work will be accomplished under the following supplements:

I High-Speed Amphibian (Light)
II Plenum Air Tread (PAT) Amphibian
III High-Speed Amphibian (Medium)

DD FORM 1 FEB 60 613 PREVIOUS EDITIONS ARE OBSOLETE. PAGE 1 OF 4

LI 32A

RDT & E PROJECT CARD CONTINUATION	REPORT DATE 20 Mar 62	Task No. 9R57-02-018-05

d. Other information:

(1) Participation/Coordination/interest: UK (I); Marine Corps (I)

(2) Funding program:

FY 62	300M
FY 63	50M
FY 64	435M
FY 65	1600M
FY 66	1025M
FY 67	1175M
FY 68	950M
To complete	300M p/a

e. Background history and progress:

(1) Lighter, 5-Ton, Amphibious; Task initiated in January 1958 as Task 114M, Project 9-57-03-000, for preliminary design studies. Upon completion of studies a contract was awarded Ingersoll-Kalamazoo Division, Borg-Warner Corp., for construction of one LARC 5. This was later increased to seven. Type classified in FY 61.

(2) Lighter, 15-Ton Amphibious: Task initiated in March 1958 as Task 113M, Project 9-57-03-000, (subsequently redesignated as Task 9R57-02-018-02). Preliminary design studies were conducted. Contract awarded Ingersoll-Kalamazoo Division, Borg-Warner Corporation, for design and construction. Preliminary tank tests conducted by Stevens Institute. Use of 270HP Ford industrial liquid-cooled V-8 gasoline engine approved. Design completed. The first LARC 15 prototype (IX) was delivered in December 1959. The LARC 15-2X was completed in March 1960 and after testing has participated in Triphibious Exercises at Fort Story, Virginia, during October 1960. LARC 15-3X was completed in June 1960 and has since been utilized in support of Project Mercury at Cape Canaveral, Florida. After completion of initial testing Larc 15-1X was returned to contractor's plant to correct deficiencies found during test. During FY 62 LARC 15-1X and 2X have been modified and fitted with diesel engines; extensive component shifting being necessary in order to accomodate the increased weight of the diesel engines. Engineering and service test of the new power train is in process and due for completion by the end of FY 62. In-house studies are being conducted at USATRECOM for consideration of powering by multifuel engines and use of hydrostatic and electric drives. In addition, deficiencies detected from field operation of the three prototypes are under study in order to provide optimum design prior toengineering and endurance tests which will be conducted during FY 62. Type classification is expected during 3rd quarter FY 62.

(3) Studies have been completed establishing as fact, that Amphibious craft capable of water speeds in excess of 25MPH are technically feasible. Hydro-[illegible], Hydrofoil and GEM concepts have been considered and designs have been

developed for the hydroplane types. Experimenting and testing has been conducted on a Hydrofoil Amphibian using a WWII DUKW as a test bed.

f. Future plans:

(1) FY 63: Complete modifications and testing of LARC 5 and LARC 15.

(2) FY 64 and beyond:

(a) To investigate and evaluate new and promising concepts of amphibious lighters which appear to offer greater performance over existing equipment.

(b) For information on additional work planned on specific items refer to attached supplements.

g. References:

(1) TCTC Item 1725, Meeting 102, held 22 March 1956, Development Project 9-57-03-000, Marine Craft; initiation of project and consolidation of projects approved by Tech Committee 22 March 1956 and by CH/R&D, OCofS on 19 Nov 1956.

(2) DF, Cmt #2, C/R&D to CofT, file CRD/D 13752, dated 30 May 58, subject: "Development of Amphibious Lighters (U)", directing initiation of the development of amphibious lighters.

(3) TCTC Item 2261, Meeting 114, held 6 March 1958, Task 113M, Project 9-57-03-000, Lighter, 15-Ton, Amphibious (U); initiation of military and technical characteristics of item; subsequently redesignated as Task 9R57-02-018-02.

(4) TCTC Item 2267, Meeting 114, held 6 March 1958, Task 114M, Project 9-57-03-000, Lighter, 5 Ton, Amphibious (U), initiation of military and technical characteristics of item; subsequently redesignated as Task 9R57-02-018-03.

(5) TCTC Record and Information Item 3313, Meeting 126, held 17 December 1959. Renumbering of TCR&D Projects and Tasks: Changes in Titles.

(6) TCTC Item 3395, Meeting 128, held 16 June 1960, LIGHTER AMPHIBIOUS: (LARC-5) self-propelled, gasoline, aluminum, 5 ton, design 8005; revised military and technical characteristics and type classification as STD-A; Task 9R57-02-018-03 Lighter, 5 Ton, Amphibious (U); completion.

(7) TCTC Item 3556, Meeting 131, held 17 November 1960, LIGHTER, Amphibious; (LARC-5) self-propelled, gasoline, aluminum, 5 ton, design 8005; amendment of military and technical characteristics.

(8) TCTC Coordinating Subcommittee Item 1011, Meeting 54, held 23 May Task 9R57-02-018-05, Amphibious Concepts and Designs (U); initiation; approved for referral to TC Technical Committee.

RDT & E PROJECT CARD CONTINUATION	REPORT DATE 20 March 1962	TASK NO. 9R57-02-018-05

(9) TCTC Item 3695, Meeting 136, Held 1 June 1961, Task 9R57-02-018-05, Amphibious Concepts and Designs (U); initiation.

(10) TCTC Item 3841, Meeting 138, held 21 December 1961, Task 9R57-02-018-02, Lighter, 15 Ton, Amphibious (U); supersession.

RDT & E PROJECT CARD CONTINUATION	REPORT DATE 20 Mar 62	TASK NO. 9R57-02-018-05

Task 9R57-02-018-05, Amphibian Concepts and Designs (U)

SUPPLEMENT I: High-Speed Amphibian (Light) (U)

1. Contractor:

2. Objective:

a. CDOG 1012d. QMDO Priority II.

b. To develop a high-speed amphibian (light) of greater speed, versatility, stability, and considerably more sea-worthy than the current LARC amphibians.

3. Approach:

a. FY 64: Conduct feasibility study to determine technical and military characteristics of an amphibian to meet objectives.

b. FY 65: Design and procure long lead-time components.

c. FY 66: Construct amphibian (light).

d. FY 67: Conduct engineering and service tests. Modify as required.

e. FY 68: Prepare final report and type classify.

4. Other information:

a. Participation/coordination/interest:

b. British/Candaian comments:

c. Program funding:

FY 64	100M
FY 65	750M
FY 66	750M
FY 67	100M
FY 68	50M

DD FORM 1 FEB 60 613c REPLACES DD FORM 613-1, WHICH IS OBSOLETE. PAGE 1 OF 1

RDT & E PROJECT CARD CONTINUATION	REPORT DATE 20 Mar 62	TASK No. 9R57-02-018-05

Task 9R57-02-018-05, Amphibian Concepts and Designs (U)

SUPPLEMENT II: Plenum Air Tread (PAT) Amphibian (U)

1. Contractor:

2. Objectives:

a. CDOG paragraph 1612b, QMDO Priority II.

b. The objective of this task is to initiate an extensive evaluation of this concept when applied to amphibians for logistical over-the-short operations. The evaluations, which will include experimental testbed operations, will seek to determine the relative value of the vehicle when compared to other amphibians, especially in adverse, marginal shore lines.

3. Approach:

a. FY 64: Conduct a technical feasibility study to determine solutions to existing and anticipated problems.

b. Conduct component research and development to produce acceptable components needed in the over-all vehicle development.

c. Prepare suitable military and technical characteristics which are capable of being met by the current state-of-the-art. Coordinate military characteristics with Combat Development Group.

d. FY 65: Prepare preliminary designs for prototypes.

e. Design and construct prototypes.

f. FY 66: Conduct engineering and service tests.

g. Make modifications and retest as necessary.

h. FY 67: Prepare suitable reports and type classify, if appropriate.

4. Other Information:

a. Participation/coordination/interest:

b. British/Canadian comments:

c. Program funding:

FY 64	FY 65	FY 66	FY 67
300M	800M	150M	50M

RDT & E PROJECT CARD CONTINUATION	REPORT DATE 20 March 1962	TASK NO. 9R57-02-018-05

Task 9R57-02-018-05, Amphibian Concepts and Designs (U)

SUPPLEMENT III: High-Speed Amphibian (Medium) (U)

1. Contractor:

2. Objective:

a. CDOG 1012d. QMDO Priority II.

b. The logistical support system must have sufficient mobility to be immediately responsive to support requirements of the combat elements. One of the modes to be used is amphibious vehicle. This research will cover development of a high-speed amphibian (medium) of greater speed, versatility, stability, and more seaworthy than the current LARC amphibians.

3. Approach:

a. FY 64 & 65: Conduct mimimum feasibility studies based on development of th light amphibian (SUPPLEMENT II).

b. FY 66: Complete feasibility studies and develop military and technical characteristics. Conduct component development to solve any problems.

c. FY 67: Design and initiate prototype construction.

d. FY 68: Complete prototype construction and initiate engineering and servic tests.

e. FY 69: Modify if necessary, prepare procurement package and type classify.

4. Other information:

a. Participation/Coordination/Interest:

b. British/Canadian comments:

c. Program funding:

FY 64	10M
FY 65	15M
FY 66	100M
FY 67	1000M
FY 68	800M
FY 69	200M

DD FORM 1 FEB 60 613c REPLACES DD FORM 613-1, WHICH IS OBSOLETE. PAGE 1 OF 1 PAGES

APPENDIX III

HORSEPOWER DETERMINATION OF LARC-XV-1X AND LARC-V-5X

Thomas G. Broskie, Test Engineer

BRIEF

The accurate measurement of horsepower is an engineering determination often desired for transportation prototype items. However, many combined physical factors (for example, limited mounting space, vibration, shaft eccentricity, runout, and contaminents such as dust, dirt, oil, and water) make this determination very difficult with any degree of accuracy. This report describes the advantages and disadvantages of a torque measuring system which was used to determine horsepower on the LARC-XV-1X and the LARC-V-5X. Curves of horsepower, torque, and rpm on these two vehicles are presented. Operational problems encountered in running the above series of tests are also discussed.

CONCLUSIONS

It is concluded that:

1. Horsepower on the LARC-XV-1X and the LARC-V-5X was measured with an estimated accuracy of ± 5 percent.
2. The combination of strain gages and the FM-FM telemetry system provides the best system yet found for rapid field measurement of torque when determining horsepower. (However, certain complexities will require additional training of laboratory technicians.)
3. In spite of the very active cooperation of the entire LARC detachment, optimum test conditions were seriously limited because operational commitments of the group delayed completion of tests.

RECOMMENDATIONS

It is recommended that:

1. The FM-FM telemetry system with strain gages be used for determinations of torque and horsepower until future developments in instrumentation provide a more accurate and a more conveniently installed system.

2. The two receiving stations be returned to the USATRECOM Laboratory as soon as is practical in order to train the laboratory technicians properly in the use of the FM-FM telemetry system.

3. Assurance be given that operational commitments will not make the test item unavailable for anticipated engineering tests at Cape Canaveral when the presence of technicians is required.

TEST INSTRUMENTATION AND PROCEDURES

General

The determination of horsepower on any shaft requires the measurement of rpm and torque. Instrumentation used to measure these two variables on this series of tests is described below:

RPM

Recording of revolutions per minute technically is no problem. A high output magnetic pickup with a pulse-rate converter was used on this series of tests because of the greater ease of installation.

Torque

Of the many schemes for measuring the very small angular twist on a shaft under a torsional load, strain gages give the best resolution, require virtually no space, and do not load the shaft itself. However, the output of a strain-gage bridge is so low (approximately 20 millivolts or less) that when the output is taken off the shaft by slip rings, the noise level produced by vibration, shaft eccentricity, and runout often greatly reduces the static resolution and, under extreme conditions, may completely mask the output signal. In addition, slip rings and their associated brushes are very difficult to install, particularily with the precision necessary for operation with the low-level signals obtained from strain gages. Therefore, the FM-FM telemetry system was evaluated as a means of obtaining the advantages of a strain-gage torsion meter without the disadvantage of the usual slip rings. The telemetry system used was manufactured by Electronetics Corporation, Melbourne, Florida, and consists of a battery-powered solid-state transmitter and a 110-volt a-c receiving station. The following two sizes of transmitters were used in the test series:

Large transmitters:	3 inches in diameter by 4 inches in length; weight with battery, 2 pounds
Small transmitters:	1 inch in diameter by 1-1/2 inches in length; weight with battery, approximately 6 ounces

While sizes were different, electrically the transmitters were almost identical. Both had an adjustable FM carrier frequency of from 88 to 108 megacycles. This carrier frequency was frequency modulated by a subcarrier oscillator with an adjustable center frequency of 4,000 cycles per second. Excitation voltage for the strain-gage bridge was provided by the subcarrier oscillator.

The receiving station consisted of a standard FM tuner plus a discriminator to detect changes in subcarrier frequency and to provide a d-c output proportioned to those changes. A standard CEC 5-114 oscillograph was used to record signals from the receiving station. Since a torque signal is highly transitory and since only the average volume of this signal was desired, a 7-349 galvanometer was used in the oscillograph. This galvanometer has a cutoff frequency of 6 cycles per second and averages out all dynamic data with a higher frequency.

Rail Pressure

Rail pressure was also measured on the LARC-XV-1X. Standard CEC pressure cells with a d-c balance box and a CEC oscillograph were used to record this variable. Because of the dynamic nature of the signal, 7-349 galvanometers were also used for this parameter.

LARC-XV-1X

Since primary interest in horsepower determination was on the LARC-XV-1X, it was decided to instrument this vehicle first. Accordingly, strain gages were bonded to the two drive shafts, and the large transmitters with batteries were installed in a cylindrical bracket (see Figures 154 and 155). By August 1962, all wiring and a calibration using a torque arm and precision 50-pound weights were completed. In addition, all cabling, brackets, and instruments necessary for installation of the magnetic pickups and pressure cells were checked and calibrated by this date. Unfortunately, with the LARC-XV-2X deadlined, it was necessary to install a Hiab crane on the LARC-XV-1X in order for the LARC detachment to meet operational commitments with Project Mercury. Therefore, installation of the instrumented drive shafts was delayed until 15 August 1962. On 16 August, the vehicle was in operational use. Most of 17 August was spent in correcting steering difficulties on the vehicle, and on 18 August all instruments were ready for a final checkout. At this time, it was found that both transmitters were inoperative. Therefore, the shafts were removed. Two very minor difficulties were located and repaired: one wire was resoldered where centrifugal force had thrown an oversized solder joint off the shaft, and one high-resistance connection was removed because of corrosion. Both shafts were then replaced and checked. On 20 August, the LARC-XV-1X was not tested, since tests could possibly have jeopardized an operational commitment on the 21st. After the Project Mercury training exercise on 21 August, all instruments were installed. On 22 August, horsepower determinations were made with the LARC-XV-1X unloaded. On 23 August, after a 5-hour delay because of the breakdown of a Pan-American crane, horsepower determinations were again made. This time, the LARC was loaded with from 16 to 17 tons, consisting of two CONEX containers weighing 15 tons, the housing containing all instruments, and the Hiab crane used in Project Mercury operations.

That no major technical problem was found with the large transmitters was due, in part, to the work of the LARC test team while on the western coast of the United States. Both drive shafts used had been dynamically balanced with the transmitter, battery, and brackets installed. While the large transmitter gives a much better signal level than the small transmitter, and contains other more desirable features, it cannot be used in high-speed shafts unless it is dynamically balanced—a task often impossible to accomplish in the field.

The principal problem limiting the accuracy of the torsion meter on the LARC-XV-1X was the inaccessible location of the drive shafts. Ordinarily, a strain-gage circuit is calibrated prior to each test run by shunting a calibration resistor across one arm of the bridge. Once the shafts were installed in the LARC-XV-1X, there was no way of getting to them without removing the pumps on the torque converters. Therefore, both power and calibration leads were extended to the end of the shaft. These leads could be reached by lying on top of the engine manifold. With the engine cold, power could be turned on and a calibration made; once the engine was hot, however, further calibrations were impossible. The estimate of ± 5 percent accuracy was made based on the scatter of reduced data points. Figures 156, 157 and 158 show torque, rail pressure, and horsepower versus rpm on the unloaded LARC-XV-1X; Figures 159 through 162 give the same information on the LARC-XV-1X with the 16-to 17-ton load.

LARC-V-5X

Once the LARC-XV-1X was deadlined for installation of the Hiab crane, it was decided to check horsepower on the LARC-V-5X, equipped with a Ford Model 543 industrial engine. Strain gages were bonded to the drive shaft on 11 August; the machining of necessary brackets was completed on the morning of 14 August, and the installation was complete and ready for tests by late afternoon of the same day. Unfortunately, the LARC-V-5X was also needed in support of Project Mercury; it was, therefore, held in the area for installation of radios on the 15th and was in operational use on the 16th of August. On 17 August, it was found that the torsion meter was inoperative. The shaft was removed and the trouble located. Again the trouble was minor—fatigue failure of the antenna wire at the transmitter—and was quickly repaired. On the morning of 24 August, the instrumented shaft was reinstalled and the horsepower determinations were made. At no time did the installation of the torsion meter cause unbalance. Figures 163 and 164 show the torque and horsepower, respectively, versus rpm for the LARC-V-5X.

EVALUATION

It is believed that the small transmitter provides the best means yet found for determining torque and horsepower. Once personnel are sufficiently trained in its use, a torsion meter can be installed, calibrated, and made ready for tests in approximately 3 days.

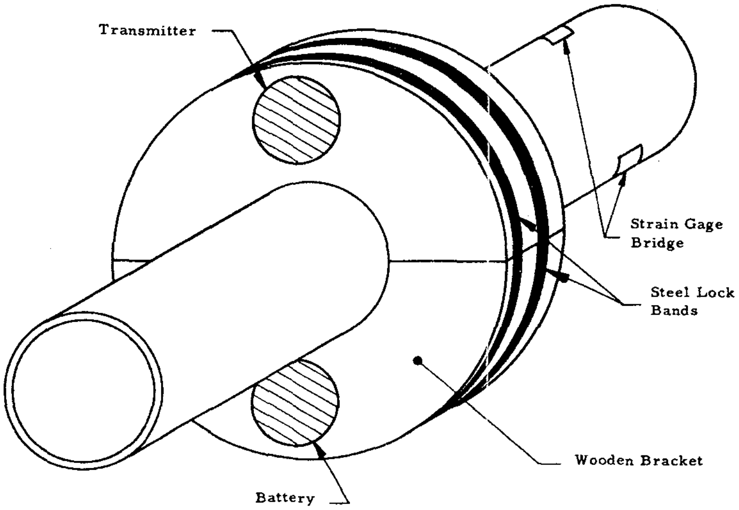


Figure 154. Torsion Meter Installation--LARC-XV-1X.

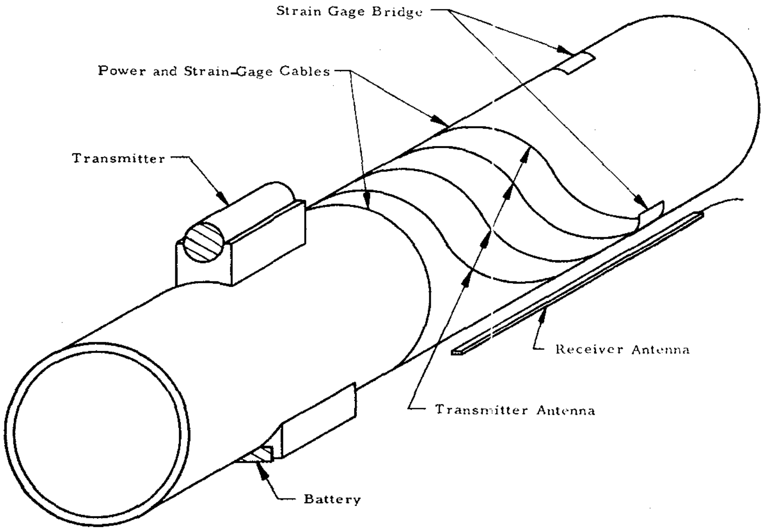


Figure 155. Torsion Meter Installation--LARC-V-5X. (Both brackets bonded to shaft with epoxy cement. Transmitter, receiver, and all wires tied to shaft with nylon lacing cord.)

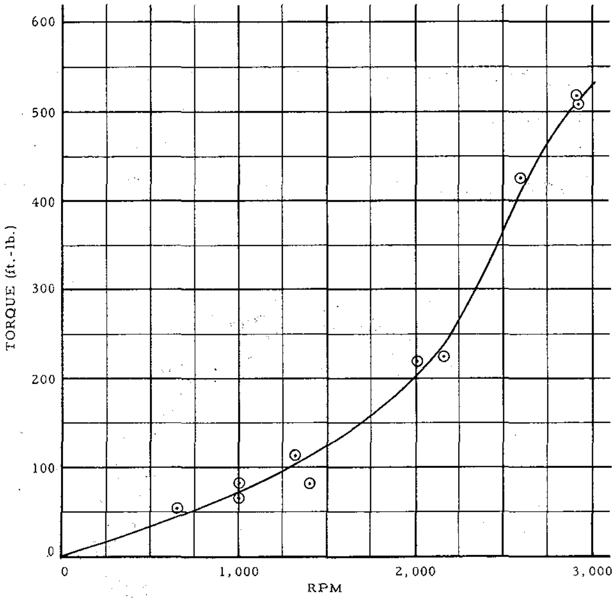


Figure 156. Torque Versus RPM With LARC-XV-1X Unloaded. (Port engine only; data questionable on starboard engine.)

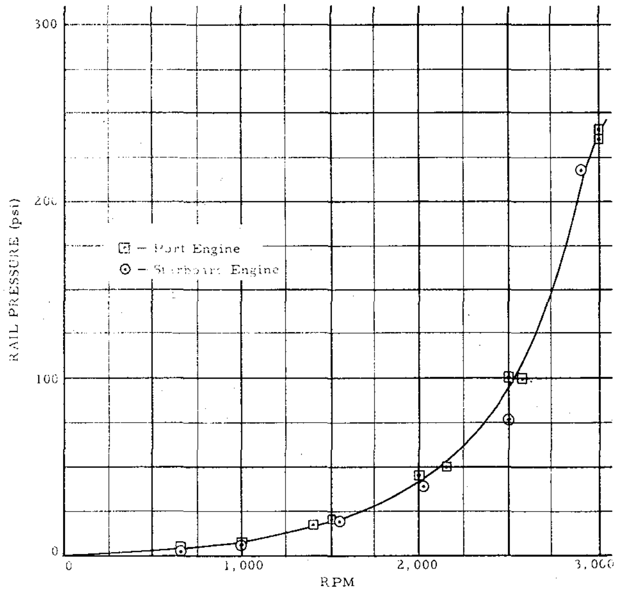


Figure 157. Rail Pressure Versus RPM With LARC-IV-1X Unloaded.

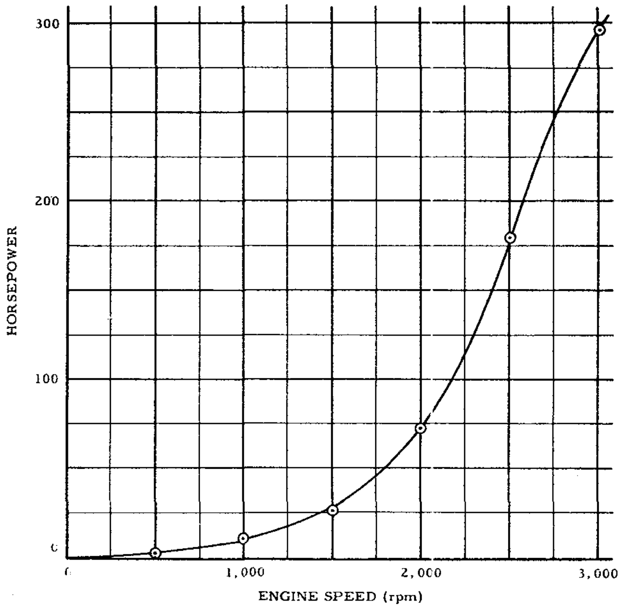


Figure 158. Horsepower Versus RPM With LARC-XV-1X Unloaded. (Port engine only; data questionable on starboard engine.)

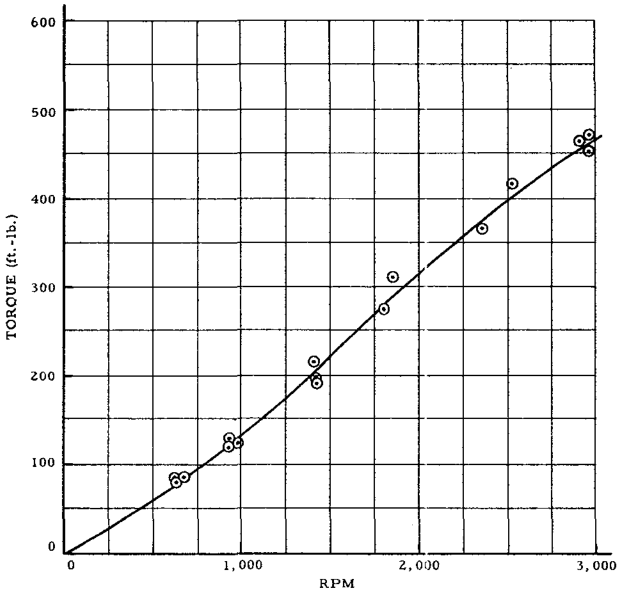


Figure 159. Torque Versus RPM for Starboard Engine With LARC-XV-1X Fully Loaded.

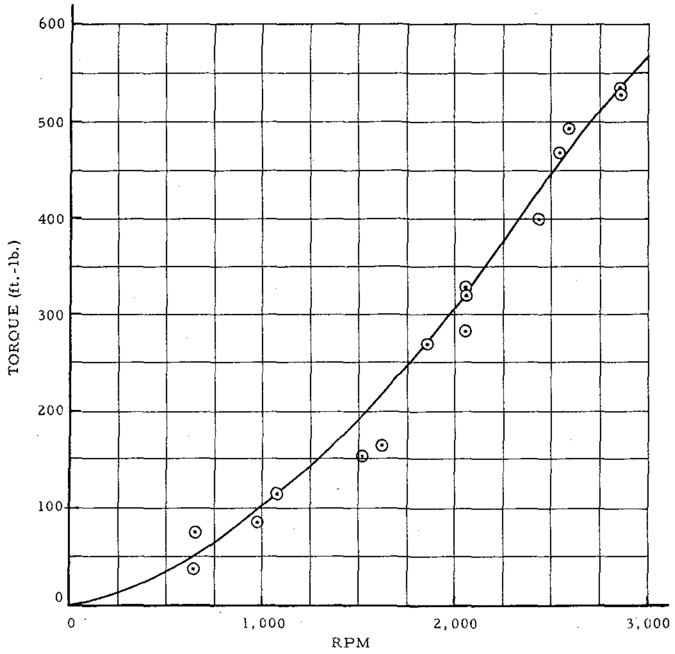


Figure 160. Torque Versus RPM for Port Engine With LARC-XV-1X Fully Loaded.

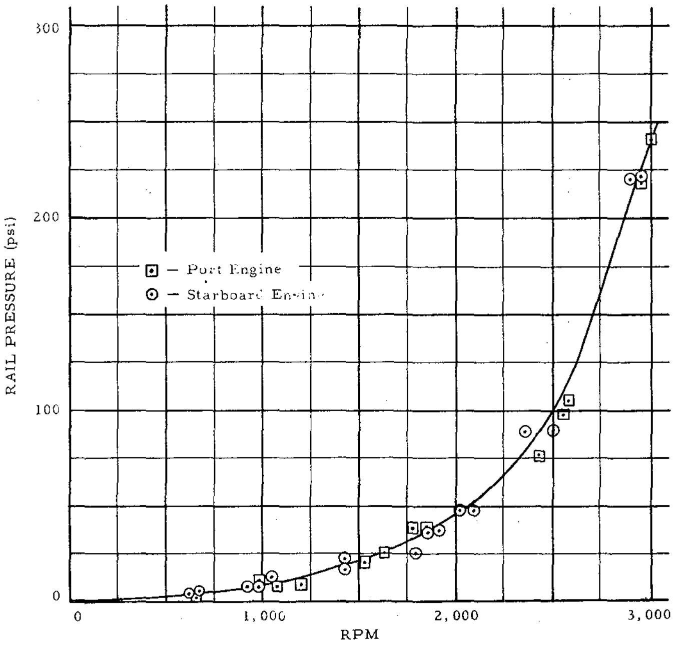


Figure 161. Rail Pressure Versus RPM With LARC-XV-1X Fully Loaded.

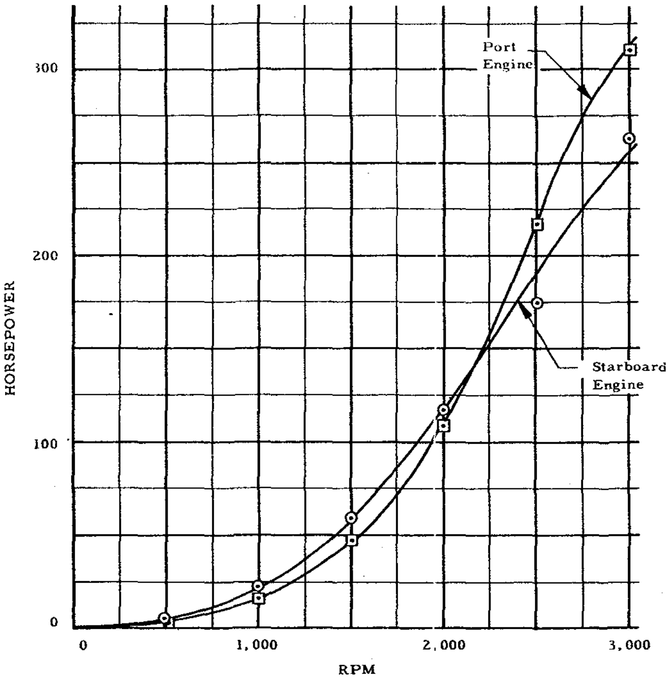


Figure 162. Horsepower Versus RPM With LARC-XV-1X Fully Loaded.

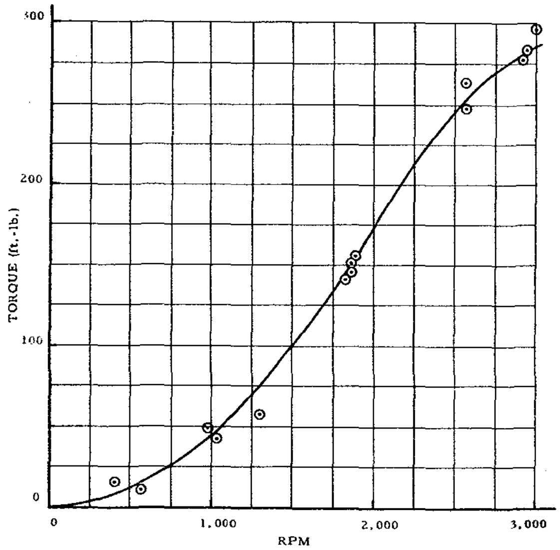


Figure 163. Torque Versus RPM--LARC-V-5X.

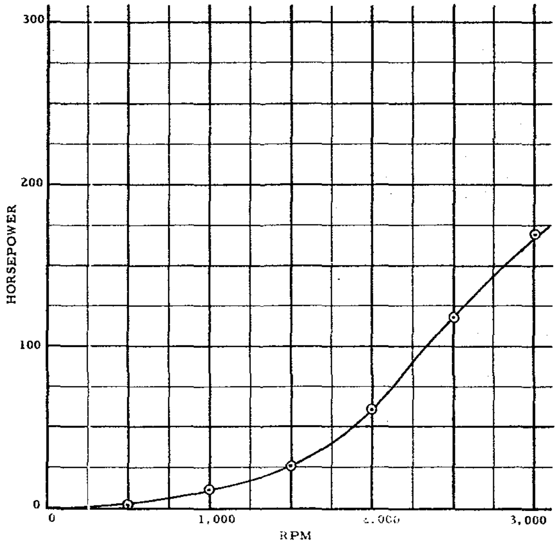


Figure 164. Horsepower Versus RPM--LARC-V-5X.

APPENDIX IV

U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY
FIELD STATION NR. 1
P. O. Box 6262
Milwaukee 9, Wisconsin

RADIO INTERFERENCE REDUCTION EVALUATION REPORT

SIGRA/SL-FS1
3X 90-90-004-06

FS1-13-62
6 April 1962

SUBJECT: LARC-15-1X Lighter, Amphibian Resupply Cargo, 15-ton, Manufactured by Ingersoll Rand Corporation, Kalamazoo, Michigan

1. SUMMARY:

The modified prototype LARC-15-1X Lighter does not meet the requirements of MIL-I-10379A because of excessive conducted interference emanating from the charging system at 1.5 and 3.0 megacycles.

2. PROJECT DATA:

a. Suppression Specification: MIL-A-10379A

b. Authorization: Letter LARC-15-1X, LARC Test Team #1, 23 Feb 62, subject: "Request for Radio Interference Suppression Re-Tests on Lighter Amphibian Resupply Cargo, 15 Ton (LARC)."

c. Date & Location of Tests: 19-21 March 1962 at Camp DelMar, Camp Pendleton, Oceanside, California.

d. Participating Personnel:

(1) Curtiss-Wright Corporation:

Mr. C. Comps, Engineer

(2) Ingersoll-Rand Corporation:

Mr. D. Arnold, Engineer

(3) USATREC, LARC Test Team #1:

Mr. John F. Sargent, Project Engineer

(4) USASRDL Field Station Nr. 1:

Mr. R. C. Hizer, Project Engineer

COPY

3. EQUIPMENT:

a. Description: The LARC-15 vehicle originally investigated in January 1960 was driven by two gasoline engines incorporating a Leece-Neville alternator type charging system. The vehicle has been modified and is now driven by two Cummins Model VINE 265, V-8 cylinder, 300 HP at 3000 RPM diesel engines each incorporating a Curtiss-Wright Model 14Y11B08, 125-ampere alternator and Bendix Model 2, Type 1588 carbon-pile regulator. The alternator is a high-speed, lightweight, 125-ampere DC output, self-contained rectification, 28-volt DC unit. The alternator does not contain a commutator, brushes, slip rings, or a rotating winding. The rectification is obtained by eight silicon diode rectifiers located in the alternator case.

b. Radio Interference Producing Devices:

(1) Alternators (2): Curtiss-Wright 14Y11B08, 7.5-ampere field, 24-volt, 15,000 RPM, 125-ampere maximum output

(2) Regulators (2): Bendix Model 2, Type 1588, carbon-pile

(3) Windshield Wipers (2): American Bosch Model WWC-24-F60

(4) Heater: Stewart Warner Model 1030-D24

(5) Tachometer & Speedometer Sending Unit: Ordnance #8685200

4. TEST PROCEDURE AND RESULTS:

a. Preliminary Examination: Initial examination revealed that the alternator and regulator were not bonded properly and the connecting cables were not shielded. The personnel heater was improperly bonded and the two windshield wipers were not bonded.

b. Test Procedure: Tests for radiated interference were conducted over the frequency range of 0.15 thru 1000.0 megacycles with the antenna of the test equipment located and oriented as prescribed in the applicable sub-paragraphs under paragraph 4.3 of the governing specification. Tests for conducted interference were performed at the radio transmitter junction box over the frequency range of 1.5 thru 40.0 megacycles.

c. Permissible Limits: The following permissible limits of interference prescribed by Military Specification MIL-S-10379A were utilized throughout the investigation:

Test Equipment	Frequency Range (Megacycles)	Permissible Limits (Microvolts per Kilocycle)
Test Set AN/URM	Radiated Interference	
Test Set AN/URM-3	0.15 to 40.0	0.75
Test Set AN/URM-7	40.0 to 95.0	0.1
	96.0 to 1000.0	0.2
	Conducted Interference	
Test Set AN/URM-3	1.5 to 10.0	10.0
	10.0 to 40.0	5.0

d. Test Results: Initial tests on the vehicle as submitted with all electrical components operating revealed no radiated interference in excess of the permissible limits cited above. Initial conduction tests, with the receiver input cable conduction block tapped in the radio transmitter junction box revealed excessive interference at 1.8 and 3.0 megacycles. Attempts to reduce the interference, such as bonding the alternator and regulator, switching the leads between the alternator, soldering the clamped leads to the diode rectifiers in each alternator, and switching the leads to the two regulators, were of no avail.

5. CONCLUSIONS

It is concluded that satisfactory attenuation of the radiated interference emanating from the charging system was due largely to the shielding afforded by the vehicle hull and bulkhead. It is further concluded that the charging system does not meet the requirements of MIL-S-10379A because of excessive conducted interference at 1.5 and 3.0 megacycles. However, inasmuch as radiated interference does not exceed permissible limits and as the excessive conducted interference is at frequencies (1.5 and 3.0 mc) that do not affect the vehicle communication equipment, the system may be considered acceptable when installed in a LARC Amphibious Lighter.

6. RECOMMENDATIONS:

In order to assure interference-free operation throughout the life of the unit, it is recommended the final design of the LARC-15 Lighter incorporate the following radio interference suppression applications:

a. The charging regulator bonded to the vehicle sponson with a plated tooth-type lockwasher under the head of each of four cap screws.

b. The alternator bonded to the vehicle engine with a tinned copper braid bond strap bonded at the engine and alternator with plated tooth-type lockwashers under the head and nut of the mounting bolts.

c. The leads between the alternator, regulator, and control box shall be enclosed in tinned copper braid shielding or woven metal hose shielding. The shielding shall be terminated with appropriate threaded fittings and/or soldered metal ground clamps bonded with plated tooth-type lockwashers.

d. The windshield wipers and their mounting brackets bonded with plated tooth-type lockwashers at the mounting bracket and the cab.

e. The personnel heater bonded through its mounting bracket to the vehicle hull with a tinned copper braid bond strap and/or plated tooth-type lockwashers.

f. All electrical sub-assemblies and accessories, except indicating meters, shall be bonded with tinned copper braid bond straps and/or plated tooth-type lockwashers.

/s/ R. C. Hizer
R. C. HIZER
Project Engineer

APPROVED:

/s/ Leland J. Chapman
LELAND J. CHAPMAN
Chief Engineer
USASRDL Field Station Nr. 1

DISTRIBUTION:
LARC Test Team #1, Coronado, Calif. (5 cys)
Curtiss-Wright Corp., Attn: Mr C. Comps (3 cys)
Ingersoll-Rand Corp., Attn: Mr D. Arnold (3 cys)
SigC Ln Engr, USA Ord Arsenal, Detroit (2 cys)
CG, Engr Maint Center, EMCJX-E (3 cys)
CO, USAEPO, Chicago, Attn: Code 10-2, Mr. P. Gilson (2 cys)
USASRDA, SIGRA/TN (1 cy)
USASRDL, SIGRA/SL-LNF (2 cys)
USASRDL, SIGRA/SL-LNE (1 cy)
USASRDL, SIGRA/SL-GR (1 cy)
USASRDL Field Sta #1 (3 cys)

COPY

APPENDIX V

TORSIOGRAPH TEST OF VINE ENGINE IN LARC-XV

Excerpt From Cummins Interoffice Memorandum Dated 18 October 1961

* * *

Results:

The engine, loaded on the propeller curve, was within acceptable torsional limits. Maximum torsional amplitude in the engine speed range was the fourth order, first mode critical of .21° double amplitude at 2090 RPM. The fourth order cyclic had an amplitude of .45° double amplitude with the propeller engaged and with the engine at low idle. The fourth order cyclic critical was at or below 250 RPM. Curves of the test data are attached.

Procedure:

The LARC-15 torsional test was run at Lake Lemon near Bloomington, Indiana. Vibration was measured on the port engine, serial No. 295923. This installation used the following parts: Vibration damper 152228, crankshaft pulley 145826, flywheel 149314 and flexible coupling 151316.

Data was taken on the propeller power curve from low idle throttle position to full throttle. A Brush recording was run to determine the speed of the fourth order cyclic critical.

Discussion:

An oversized propeller limited maximum engine speed to 2850 RPM. Rated engine speed is 3000 RPM. There was no rapidly rising flank at 2850 RPM.

The Brush recording indicated that the fourth order cyclic stopped the engine rotation at approximately 250 RPM. The cyclic critical occurred at or below this speed. The recorded trace showed a maximum cyclic amplitude of approximately 2° at 250 RPM.

* * *

COPY

Excerpt From Cummins Interoffice Memorandum Dated 28 November 1961

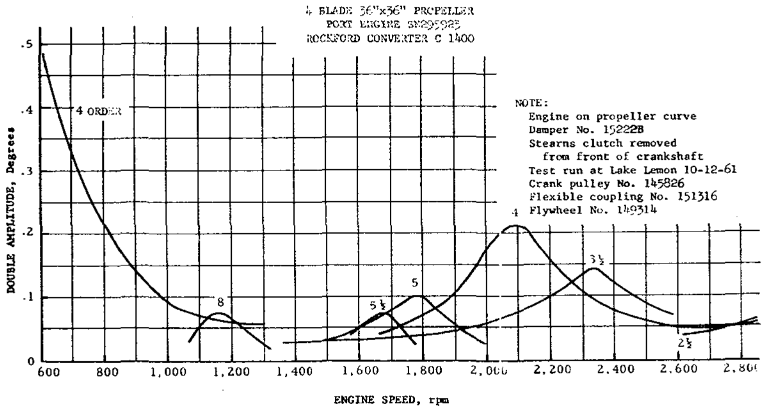
* * *

Torsiograph tests were conducted by J. C. Williams on October 12, 1961 at the front end of one of the Vine engines installed in the LARC-15 vehicle to determine the proper tuning of the rubber vibration damper and the correct stiffness rate of the soft coupling employed behind the engine to isolate the engine from the remote mounted torque converter. Additional testing was done by the writer at the retarder output shaft on October 27, 1961 to determine whether torsional vibration could have caused the torque converter pump and transmission teeth failures which were experienced on the LARC-15 vehicle.

Conclusion:

J. C. Williams' tests indicated that the damper is properly tuned for this application and that the soft coupling employed behind the engine has a stiffness rate which places the 4th order, first mode critical at 250 engine RPM, an optimum location. Thus, from 500 engines RPM on up, no engine torsionals can be transmitted to the system. This point was further proven by the tests conducted by the writer on the retarder shaft. No engine harmonics could be picked up there. Instead, a frequency of 7 to 9 cycles per second was recorded throughout the entire operating range. The amplitude of this frequency increased with driveline speed and was, therefore, considerably higher in "high range" than in "low range"; however, it was far from being critical. As a result, the torsional characteristic of the entire system can be considered as satisfactory and the failures experienced on the different components must be due to design deficiencies and improper hardening.

* * *



4 BLADE 36"x36" PROPELLER
PORT ENGINE SN295925
ROCKFORD CONVERTER C 1400

NOTE:
Engine on propeller curve
Damper No. 15222B
Stearns clutch removed
from front of crankshaft
Test run at Lake Lemon 10-12-61
Crank pulley No. 145826
Flexible coupling No. 151316
Flywheel No. 149314

Figure 165. Torsional Vibration of LARC-XV-1X.

DISTRIBUTION

Office of Ordnance, ODDR&E	2
First U. S. Army	1
Second U. S. Army	1
Third U. S. Army	1
Fourth U. S. Army	1
Sixth U. S. Army	1
USA Command & General Staff College	1
U. S. Army Arctic Test Board	1
Deputy Chief of Staff for Logistics, D/A	2
The Research Analysis Corporation	1
Army Research Office, Durham	1
Office of Chief of R&D, D/A	1
Army Research Office, OCRD	1
Deputy Chief of Staff for Military Operations, D/A	1
U. S. Army Engineer Research & Development Laboratories	1
U. S. Army Tank-Automotive Center	1
Chief of Transportation, D/A	2
U. S. Army Combat Developments Command, Transportation Agency	1
U. S. Army Transportation Board	1
U. S. Army Aviation and Surface Materiel Command	2
U. S. Army Transportation Research Command	29
U. S. Army Transportation School	5
U. S. Army Research & Development Group (Europe)	3
U. S. Army, Pacific	1
Hq, Eighth U. S. Army	1
U. S. Army, Ryukyu Islands/IX Corps	3
U. S. Army, Hawaii	3
U. S. Army, Communication Zone Europe	3
U. S. Army Caribbean	1
Marine Corps Landing Force Development Center	1
Marine Corps Liaison Officer, U. S. Army Transportation School	1
U. S. Army Standardization Group, Canada	1
U. S. Army Standardization Group, U. K.	1
U. S. Government Printing Office	1
Defense Documentation Center	10
U. S. Army Transportation Engineering Agency	1
U. S. Army Mobility Command	3

U. S. Army Materiel Command	5
USA Combat Developments Engineering Command	2
USA Combat Developments Command	2