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LACV-30 PRE-DELIVERY WATER TEST PROGRAM

REPORT NO. 7467-928006

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February 1978

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U.S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT COMMAND
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This report describes the initial over water checkout and shakedown tests conducted by Bell Aerospace Textron on the LACV-30-1 craft prior to its delivery to the U. S. Army.

The tests were conducted in Lake Huron from the Bell Aerospace Textron Facility in Grand Bend, Ontario, Canada, during the period from October 16 to October 28, 1975.

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SUMMARY

A limited over water test program was conducted on the LACV-30-1 craft prior to its planned delivery to the U. S. Army for Acceptance Tests. The objectives of these tests were to provide for the initial shakedown of the craft and subsystems and to establish the basic performance characteristics and compatibility of the craft with its water environment. To accomplish these objectives, check-out tests and over water handling quality, performance and miscellaneous tests were planned. These tests were conducted on Lake Huron at the Bell Aerospace Textron Facility at Grand Bend, Ontario, Canada, during the period from October 16 to October 28, 1975. Tests were made in all of the planned categories although the number made in some cases was less than planned due to normal craft shakedown problems. The results of these tests showed that the craft handled well but that the performance was not as good as predicted. This was due primarily to larger than expected leakage at the stern trunk intersections with the side trunk and longitudinal keel that existed on the craft at the time of the tests. The stern seal has since been modified to alleviate this problem.

PREFACE

This report describes the initial checkout and shakedown tests conducted by Bell Aerospace Textron on the LACV-30-1 craft prior to its delivery to the U. S. Army.

The tests were conducted under Contract No. DAAK-02-75-C-0149 with the U. S. Army Mobility Equipment Research and Development Command. Mr. John Sargent was the Contracting Officer's Technical Representative, and Mr. C. E. Burr was the BAT Program Manager.

The over water tests were conducted in Lake Huron from the Bell Aerospace Textron Facility in Grand Bend, Ontario, Canada, during the period from October 16 to October 28, 1975.

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I. INTRODUCTION

The purpose of this program was to perform limited water testing as required for the initial shakedown of the LACV-30-1 vehicle and its subsystems and to collect qualitative and quantitative data on the craft's performance characteristics and compatibility with the water environment. This was to be done using existing craft instruments and test equipment. The LACV-30-1 configuration at the time is shown in Figure 1.

Bell Aerospace Textron planned and performed two types of tests on the craft: (1) checkout tests, and (2) water tests. The checkout tests included craft preparation checks and operational checks prior to, during and after the water tests. These checks were made to insure safe operation of the craft and to minimize the down time during water testing. The water tests were made to: (1) provide operator familiarity, (2) accomplish the remainder of the necessary shakedown, and (3) obtain the desired qualitative and quantitative data on performance.

The test plan and investigation for this program is discussed in Section 2 of this report. Section 3 discusses the test results, while Section 4 contains conclusions and recommendations.

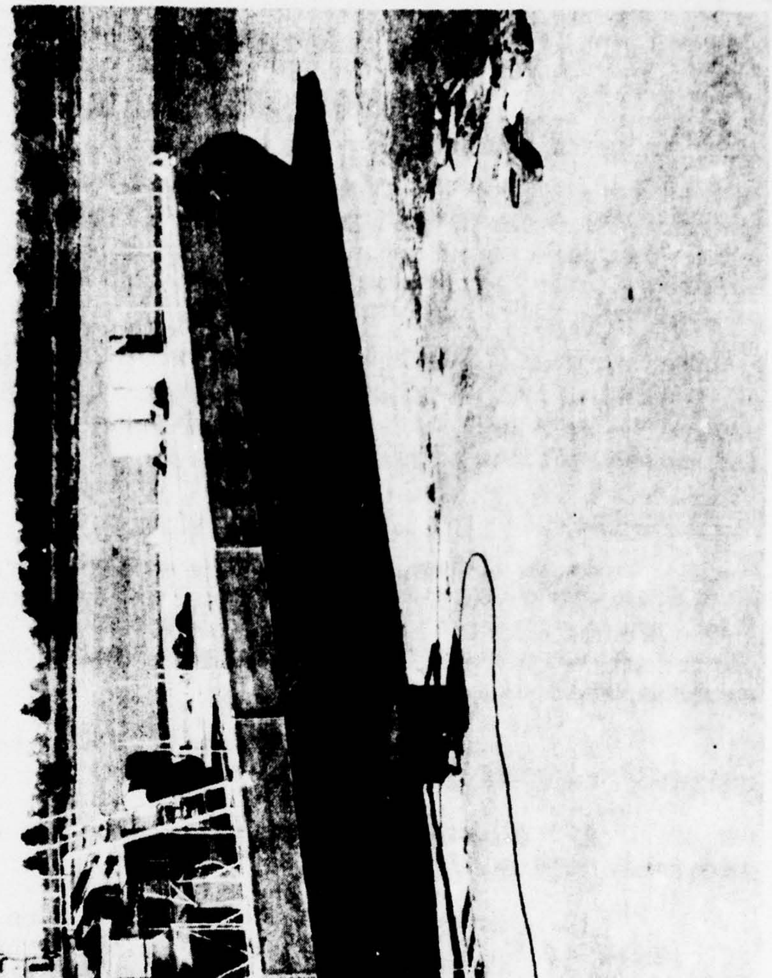


FIGURE 1

II. INVESTIGATION

CRAFT CHECKOUT PLAN

The craft checkout plan used during the test program is presented in Table 1. As shown in this table, this plan includes craft preparation checks and tests and craft and system checks before, during and after the tests. A detailed discussion of the procedure used in conducting each of these checks is contained in the Voyageur Product Test Plan (Reference 1) and the LACV-30 Addendum to it (Reference 2). Data collected from these runs included: (1) craft weight, (2) c.g. locations as a function of ballast position, (3) lift system pressures over land, and (4) speed calibration readings.

TEST PLAN

It was concluded that the following types of tests would be necessary to provide for an initial shakedown of the vehicle and systems and to provide qualitative and quantition data on the performance characteristics and compatibility of the craft in over water operation.

(1) Qualitative handling quality tests for shakedown and operator familiarization.

(2) Quantitative handling quality tests to investigate maneuverability.

(3) Quantitative performance tests to investigate influence of operating conditions on performance at hover, hump, and steady state cruise and acceleration/deceleration capabilities.

(4) Miscellaneous tests to evaluate reliability of the vehicle and systems and spray patterns.

The specific test runs and parameter variations planned to obtain handling quality and performance data are presented in the test plan in Table 2. All of the tests were conducted on Lake Huron from the BAT Grand Bend, Ontario Facility during the period from October 22 to October 28, 1975. Data collected from the ship's instruments and available test equipment included: (1) percent of maximum engine speed, N_2, (2) percent of maximum prop blade angle control, (3) engine torque and temperature on some runs, (4) indicated air speed, (5) run time, (6) visual observations of pitch trim and hump attainment from a chase boat, (7) visual observations of spray on selected runs, (8) atmospheric temperature, (9) indicated wind speed at hover, and (10) visual observation of wave height. Attainment of hump speed, (6) above, was assumed to occur when the bow wave that builds up prior to hump was visually observed to dissipate from the chase boat.

TABLE I. CHECKOUT PLAN

CRAFT PREPARATION

WEIGHT AND C.G. LOCATION
INITIAL FUEL-FILLING AND FLUSHING CHECK
POSITIONING AND LOADING
AIR MANAGEMENT SYSTEM CHECKS
ENGINE DEPRESERVATION AND TRIMMING RUN
ENGINE START CHECKS
GENERATOR SET-UP PROCEDURE

PRE-OPERATIONAL CHECK

HULL STRUCTURE AND ASSOCIATED EQUIPMENT
ENGINE BAY AND ROTATING MACHINERY
*CONTROL CABIN CHECKOUT

OPERATIONAL CHECK

*PRE-START CHECKOUT
*ENGINE START AND SHUT-DOWN PROCEDURE
INSTRUMENT CHECK
ENGINE THRUST MEASUREMENTS
RUDDER FORCE MEASUREMENTS
FUEL/TRIM SYSTEM CHECKOUT
SKIRT INSPECTION AND TRIMMING
MANEUVER AND SPEED CALIBRATIONS

POST OPERATIONAL CHECK

HULL STRUCTURE AND ASSOCIATED EQUIPMENT
CONTROL CABIN
ENGINE BAY AND ROTATING MACHINERY

*REVISED DATA SUPPLIED FOR LACV-30

TABLE 2 - TEST PLAN

TYPE OF TEST	GW LB.	FAN SPEED N_2-PERCENT	PROP BLADE BETA PERCENT	PITCH TRIM	SPEED	COMMENTS	PURPOSE
HQ-QUALITATIVE	OPERATOR DISCRETION	—	—	—	→		OPERATOR FAMILIARIZATION & CRAFT SHAKEDOWN
HQ-MANEUVERING 90 DEG TURNS	"	BEST	BEST	BEST	35 MPH AT START	90 DEG RIGHT & LEFT TURNS	DETERMINE TIME TO TURN, SPEED LOSS
HQ-MANEUVERING FIGURE 8 TURNS	"	BEST	BEST	BEST	"	CONTINUOUS 270 DEG RIGHT & THEN 270 DEG LEFT TURN	MANEUVERABILITY & CONTROL
P-HUMP ATTAINMENT OPERATION	80,000	80 TO 90%	VARY	BEST	HOVER TO HUMP	ACCELERATING RUNS	DETERMINE MINIMUM THRUST TO ATTAIN HUMP AND EFFECT OF OPERATING CONDITIONS ON TIME TO ATTAIN
"	100,000	85 TO 95%	VARY	BEST	HOVER TO HUMP	" "	
P-STEADY STATE CRUISE OPERATION	80,000	80 TO 90%	VARY	BEST	VARY IN 5 MPH INCREMENTS	ABOVE HUMP ONLY	DETERMINE INFLUENCE OF OPERATING CONDITIONS ON CRUISE SPEED
"	100,000	85 TO 95%	VARY	BEST	"	" " "	
P-HOVER	80,000 & 100,000	AS REQUIRED	AS REQUIRED	APP. ZERO	TRY TO MAINTAIN ZERO	INTO WIND	DETERMINE HOVER HEIGHT
P-ACCELERATION FROM HOVER	80,000	ADVANCE TO 90%	BEST FOR MAX. ACC.	BEST	HOVER TO APP. 50 MPH IND.	INTO WIND	DETERMINE MINIMUM TIME TO SPEED
	100,000	ADVANCE TO 95%	"	BEST	"	" "	DETERMINE MINIMUM TIME TO SPEED
P-DECELERATION FROM SPEED	80,000 & 100,000	REDUCE FROM REQ. TO APP. 70%, THEN TO 0% AT APPROX 22 MPH	REVERSE TO APP. -25	START AT BEST	START AT APP. 50 MPH	START TIMING AT START OF PROP BLADE MOVEMENT	DETERMINE MINIMUM TIME TO STOP
M-ONE HR. OPERATION	OPERATOR DISCRETION	—	—	—	→		RELIABILITY-RECORD CYCLES OF SYSTEMS
M-SPRAY	"	—	—	→	HOVER & APP. 22 MPH	VISUAL OBSERVATION	TO DETERMINE SPRAY PATTERNS

TESTS

After checkout, the first tests made were the qualitative handling quality tests for operator familiarization and system shakedown. On these tests, the craft was first trimmed to an attitude that appeared best from visual observation of the skirt contact and gap height situation. In doing this, it was found that it was difficult to obtain predicted gap height performance due to excessive leakage by the stern skirt bags which had not been refined at this point (see Reference 3). Because of this, it was found on subsequent tests that the speed margin available above hump was below predicted. Tests starting at this lower margin, particularly turns, were quite sensitive to the wind direction. Because there was frequently a significant wind on the lake during the testing period, it was necessary to perform most of the tests in both a headwind and tailwind condition. The extra runs required for this plus normal shakedown problems, particularly with the APU, made it impossible to complete all of the planned tests in the allocated test period. To reduce the test plan while still insuring that some data would be obtained in each area, the test plan was reduced by running all tests at one weight only instead of the two initially planned and by reducing the number of other planned variations in each area as required. The resulting changes to the test plan in each area are discussed along with the test results in the next section.

III. DISCUSSION OF TEST RESULTS

CHECKOUT TESTS

The checkout tests were conducted in compliance with the plan. Pertinent results from these tests are discussed below.

Weight and C.G. Location

The craft was operated on October 22 at 71,000 lb. GW for checkout tests and no trim problems were encountered. However, on tests on October 23 at 91,000 lb. GW, it was found that the fuel trim system lacked authority for level pitch trim attainment with the ballast loading shown in Figure 2. The nominal c.g. with this ballast loading was at Station 448 or 2% aft of the cp. On deck ballast was then relocated and the remaining tests on October 24 and 28 were conducted with the ballast loading shown in Figure 3. This provided for a nominal c.g. at Station 440 or 1% aft of the cp.

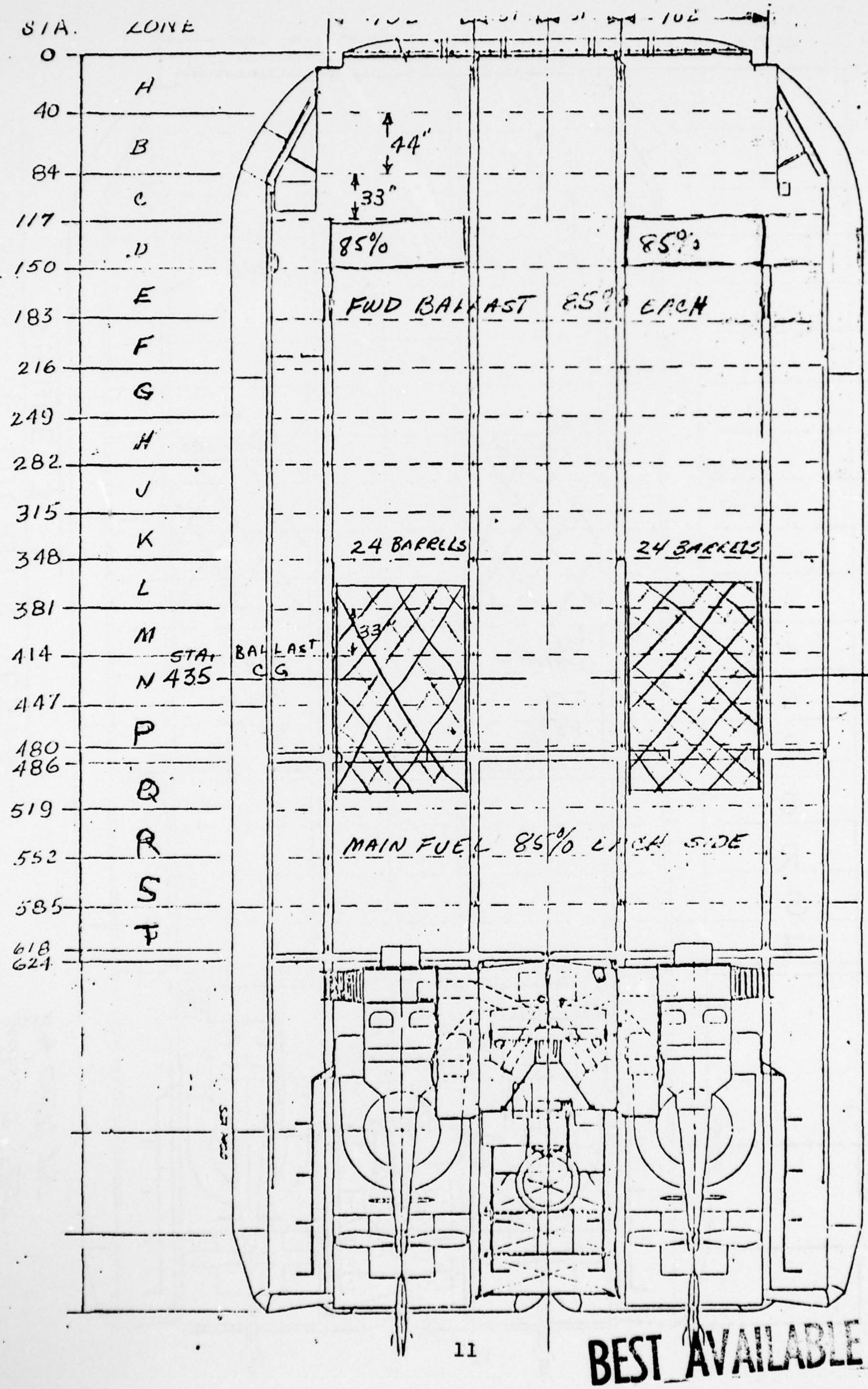
Skirt Inspection

The following observations were made during skirt inspection. The craft was to be configured at 91,000 pounds; however, due to an oversight in the refueling which was not revealed until after the inspection had been taken, the A.U.W. of the craft was 93,175 pounds. Exterior examination showed that fingers were tucking under and the triangular gaps at the aft end intersection of Rear Trunk/Keel and Rear Trunks/Outer Trunks were larger than expected. The high pressures in the Rear Trunks tended to roll them in an aft direction giving a gap between the ground and the tip of the cones of four to six inches.

The pit check revealed a keel blade clearance of approximately four inches and a measured height of 44 inches between ground and the craft bottom (WL 0). The new breakdown joints made in the keel and outer trunk proved satisfactory. Stability trunk cones were contacting the ground and were "trouserlegged", with the exception of the inboard and outboard cones which were fully inflated and provided a good seal to the keep and outer trunk.

Speed Calibrations

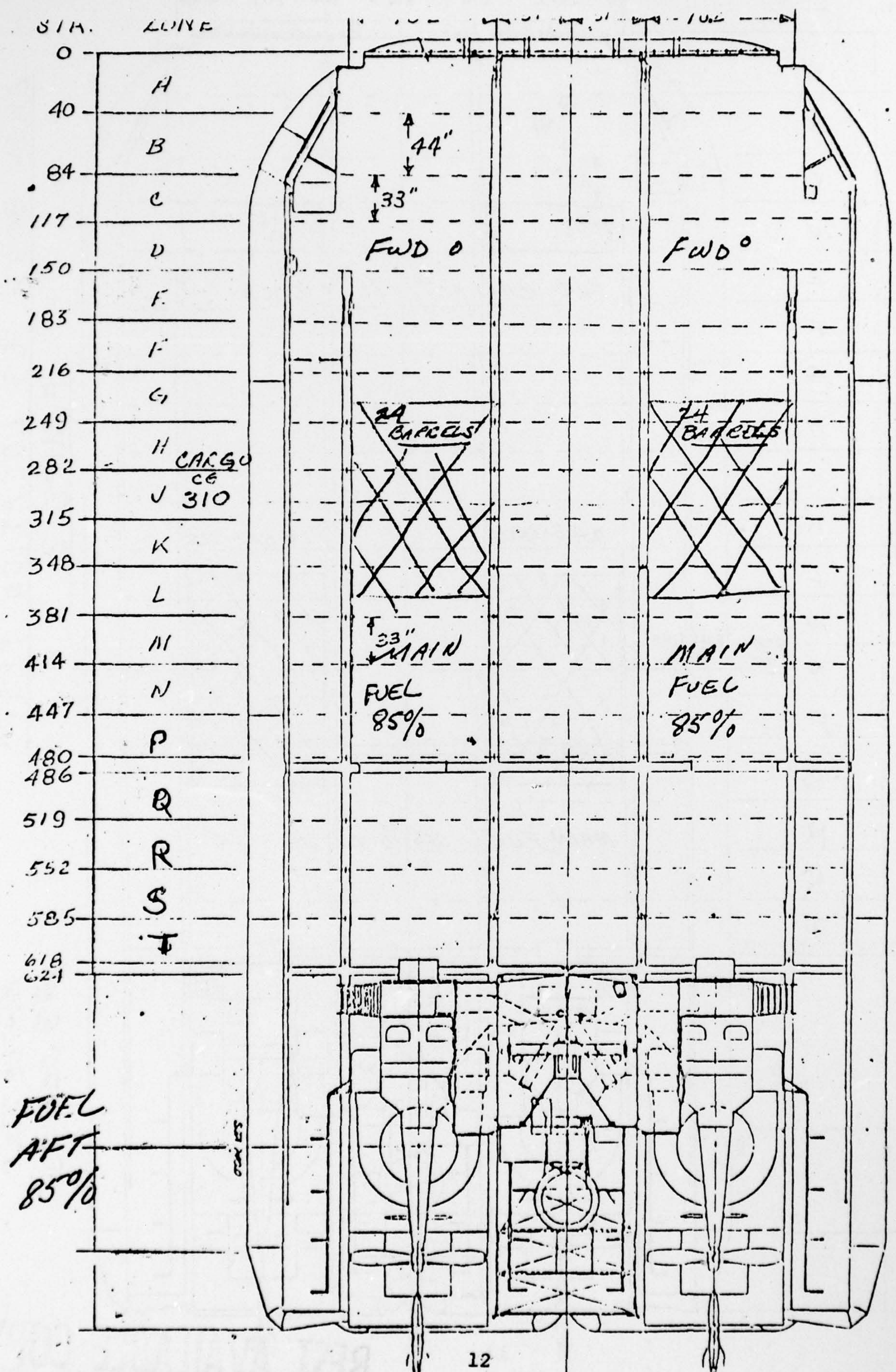
The craft speed was measured by using an anemometer to measure the indicated wind speed with the craft at hover and the indicated craft airspeed at speed. This instrument was calibrated using: (1) an Ontario Provincial Police (O.P.P.) radar on the beach, (2) timed runs over a marked measured mile, and (3) readings from a chase boat with a water pitot tube. The results of these tests are as follows:



LACV-30 IX CG LOCATION TESTS

FIGURE 2

WATER TEST 23 OCT 75



LACV-30 IX CG LOCATION TESTS

FIGURE 3

WATER TEST 24 OCT. 75

Radar	Actual Speed = 0.54 indicated speed
M.Mile	Actual Speed = 0.63 indicated speed
Chase Boat	Actual Speed = 0.62 indicated speed
Average	Actual Speed = 0.60 indicated speed

It can be seen that the agreement among the various calibration methods is quite good. However, as shown in Figure 4 for the radar calibrations, there was considerable scatter in the indicated airspeed readings. Because of this, the speeds stated should be considered approximate.

Pressure Calibration

A calibration curve for the tube used to measure the lift system pressures in the pressure survey is shown in Figure 5.

HANDLING QUALITY TESTS

Qualitative

The craft was operated on 22 October at 71,000 lb. GW for a qualitative handling evaluation. In general, it was found that the craft handled very well and made a smooth transition through hump. Tests loading (L.C.G. at Sta. 448 - 2% aft of CP), the fuel trim system lacked authority for level pitch trim attitude. On deck ballast was relocated and the remaining operations on 24 and 28 October conducted at a loading of 91,000 lb. (average), computed L.C.G. at Sta. 440, 1% aft of CP.

Quantitative Turns

On October 23 and 24, turn runnings were made both into and with the wind at water entry speeds of about 27 mph (maximum about 35 mph). This was done using rudder only and both rudder and prop pitch to make the turns. The wind/water condition on October 23 was about 6 mph with 15 inch waves while on October 24 it was about 11 mph with an 8 inch chop. The results of these runs are summarized in Table 3 in terms of the time required to make a 90 degree turn or to fall below hump speed; whichever came first. As shown, turns could be made with the wind but the entry speed and thrust margins above hump were not generally sufficient to permit turns into the wind to be made. For turns with the wind, the beneficial effects of using both rudder and prop pitch is evident.

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1323

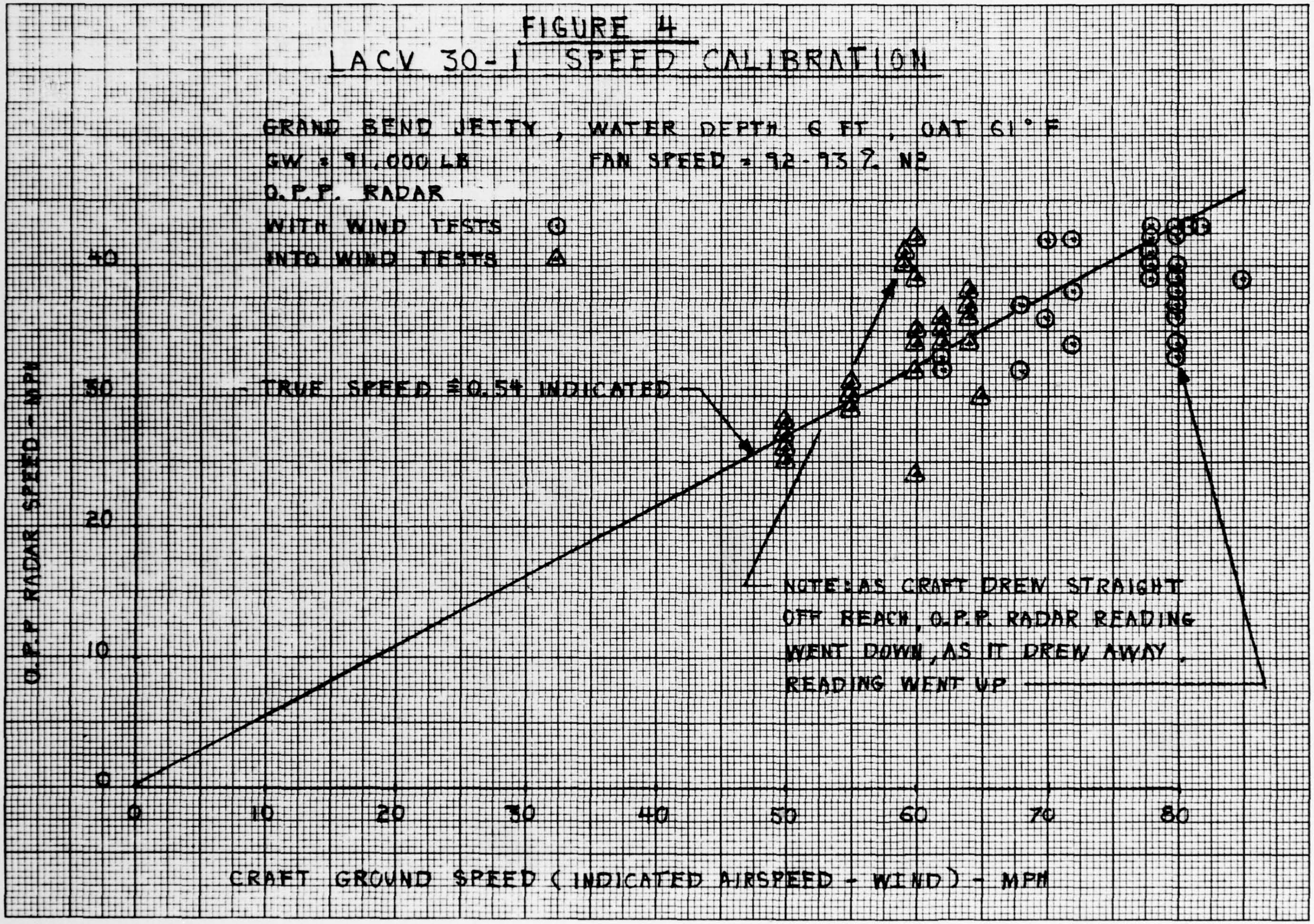


FIGURE 4
LACV 30-1 SPEED CALIBRATION

FIGURE 5
LACV-30-1 PRESSURE CALIBRATION

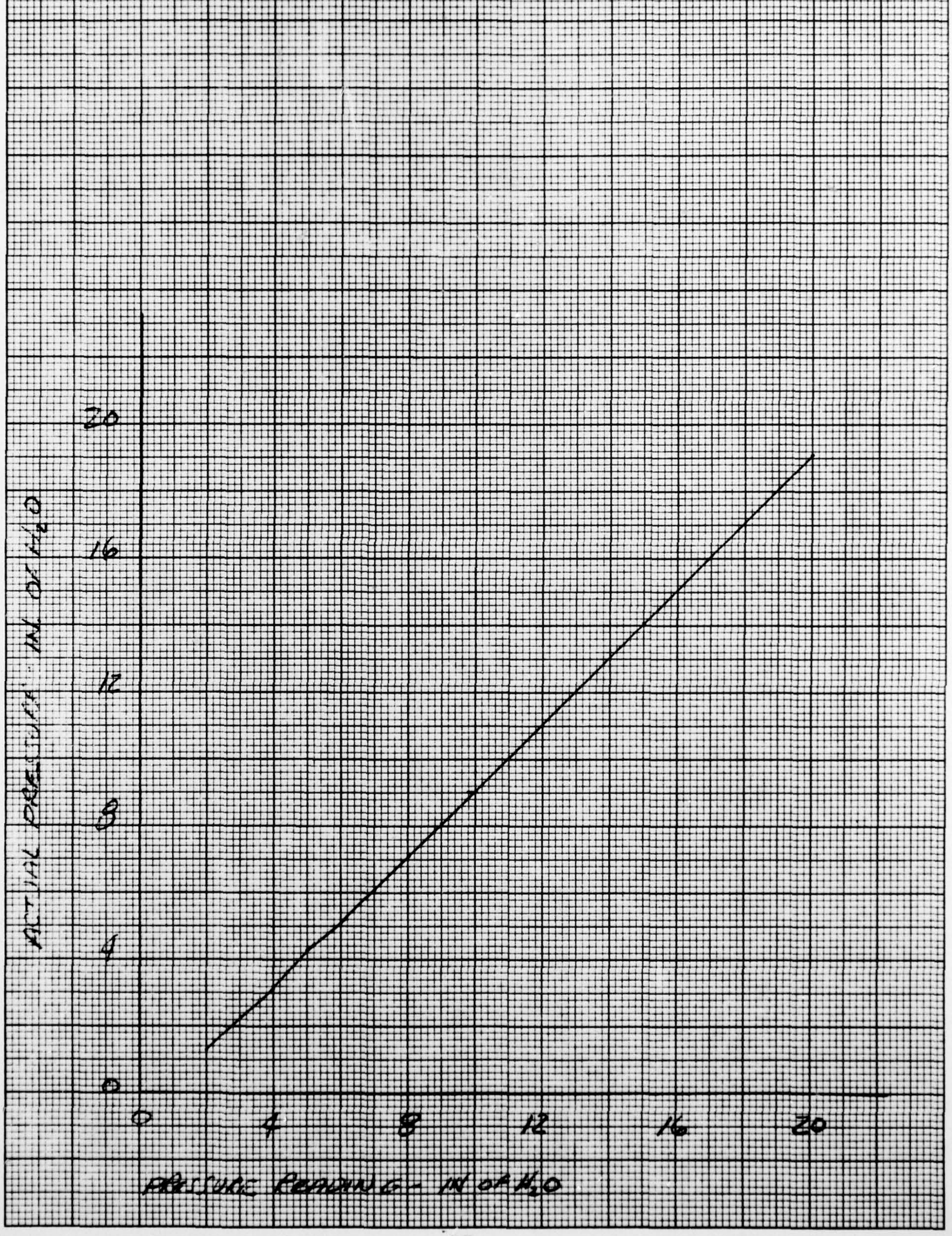


TABLE 3

LACV-30-1 TURN CHARACTERISTICS

TEST	GW	FAN N_2	OAT	IND. WIND	WAVES
Oct. 23	91,000 lb.	86%	72°F	18 mph	8 in.
Oct. 24	91,000 lb.	91%	61°F	10 mph	15 in.

TESTS	TYPE OF TURN	CONTROL	TIME SEC	CRAFT SPEED
24 Oct.	Left with wind	Rudder Only	53	Stayed Above Hump
23 Oct.	Right with wind	Rudder Only	75	Stayed Above Hump
23 Oct.	Right with wind	Prop Pitch & Rudder	45	Stayed Above Hump
24 Oct.	Left into wind	Rudder Only	24	Stayed Above Hump
24 Oct.	Right into wind	Rudder Only	15 to 20*	Fell Below Hump
23 Oct.	Left into wind	Prop Pitch & Rudder	50*	Fell Below Hump
23 Oct.	Right into wind	Rudder Only	40*	Fell Below Hump

*Turn not completed

On October 23, attampts were also made to perform figure 8 turns but it was found that these could not be made without the craft falling below hump speed when turning into the wind with an engine speed N_2 of 91%. A try was also made later in the day with an engine speed N_2 of 93%, but the craft still fell below hump speed while going into the wind although it did make it through slightly more than a 90 degree turn.

PERFORMANCE TESTS

Hump Speed Tests

On October 24 and 28, tests were conducted to determine hump speed and the best operating conditions for attaining hump in minimum time. Since the time to hump is the direct inverse of the excess thrust available over drag, minimizing the time results in a maximization of the thrust margin available. Speed checks on these tests using the chase boat and calibrated indicated airspeed readings on the craft indicate that hump speed was at about 18 mph. This is in reasonable agreement with theory and drag tests on the model which have shown hump to be at about 20 mph.

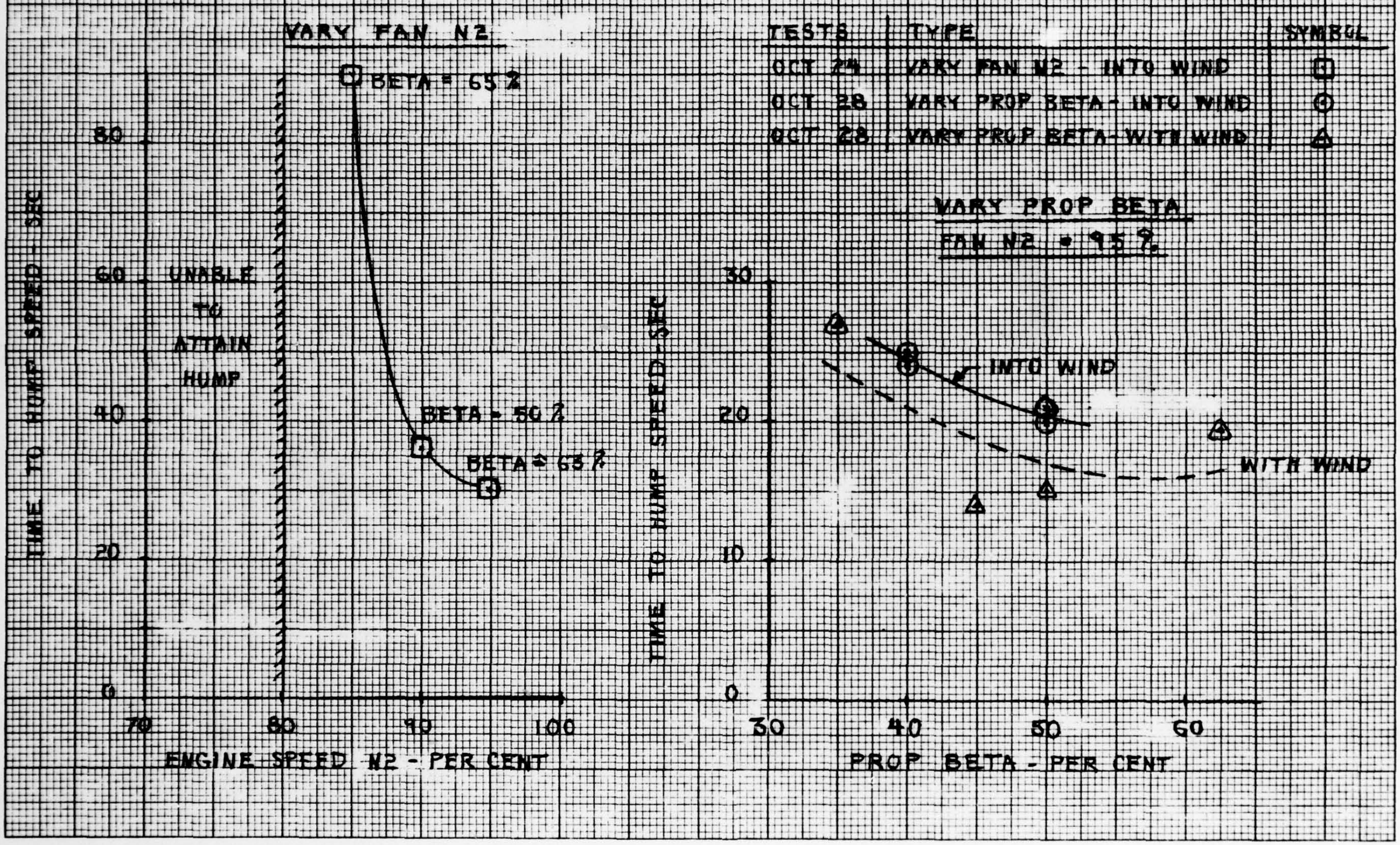
The tests on October 24 were made to determine the influence of engine speed, N_2, on the time to attain hump. They were into a wind of about 6 mph with 16 inch waves. Due to the limited test time available, this was only done for a single value of prop pitch angle at each engine speed instead of for several values as shown in the test plan. Though the prop pitch angle varied between 50 and 65% of maximum control at the different engine speeds, it is not believed that this overshadowed the influence of engine speed since subsequent tests showed that the time to hump was rather insensitive to prop pitch in this range. The tests on October 28 were made to determine the separate influence of prop pitch on the time to attain hump while operating at a constant engine speed of 95% of maximum. These tests were also made in a 6 mph wind condition with 16 inch waves.

The results of both sets of tests are summarized in Figure 6. As shown in this figure, an engine speed of about 80 to 85% of maximum appears to be about the minimum that can be used to attain hump speed. For engine speeds above this, the time to attain hump first falls off very rapidly and then appears to reach a minimum at about a speed of 95% of maximum. At this engine speed, the time to attain hump speed appears to be at a minimum between 50 and 60% of maximum control and to increase somewhat directly with decreases in prop pitch below about 50% of maximum. As shown, the time at attaining hump is influenced but not dominated by the wind condition as would be expected for low speed below hump operation. The differences between the times to attain hump speed on the October 24 and 28 tests at a 95% engine speed, 50% prop pitch condition is due to a poor pitch trim on the October 24 tests when the bow was too high by about a degree of pitch.

K•E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1323

FIGURE 6

ACV-30-1 INFLUENCE OF ENGINE SPEED AND PROP BLADE ANGLE ON TIME TO ATTAIN HUMP SPEED



Steady State Cruise Tests

Due to the limited test program and limited speed range margin available above hump, steady state cruise tests above hump were only made at the speeds that were attained at two reasonable prop pitch conditions at the maximum engine test speed of 95% of maximum instead of at engine speed and prop pitch variations that would have resulted in a range of cruise conditions at about 5 mph speed increments as originally planned. These tests were made in a 6 mph wind condition with waves of 16 inches. The results of these runs are summarized as follows:

Engine Speed (% Max.)	Prop Pitch (% Max.)	Torque (TQ psi)	Temperature (T_7 °C)	Airspeed mph
95	40	44	540	30
95	50	48	560	38

Hover Tests

Hover tests were made over land on October 16 and over water on October 23. The weight on both of these tests was to be 91,000 lb. but was actually 93,175 lb. on the over land tests due to an error in refueling. The hover tests over water were made into a headwind of about 6 mph and with waves of about 15 inches.

In addition to visual observations of the hover test over land, quantitative measurements were made of: (1) all of the significant trunk and cushion pressures, and (2) the craft trim heights at the four corners. The results in these quantitative measurements are shown in the pressure and trim survey in Figure 7. It is estimated from these measurements that the average cushion pressure on these runs was about 45.9 psf. This is in excellent agreement with the theoretical estimate of cushion pressure at this weight of 45.2 psf based on an effective cushion size of 66.5 x 30.9 ft. or 2061 sq. ft.

The hover test over water on October 23 was made for 15 minutes. The engine speed, N_2, on this test was 85% of maximum. The fuel loadings for trim on this test were: (1) forward - 85% each, (2) main - 60% starboard, 60% port, and (3) aft -12%. Both visual observations and motion pictures of this test were made.

FIGURE 7 PRESSURE SURVEY

DATE: October 16, 1975

CRAFT TYPE: LACV-30-1X NUMBER: 005

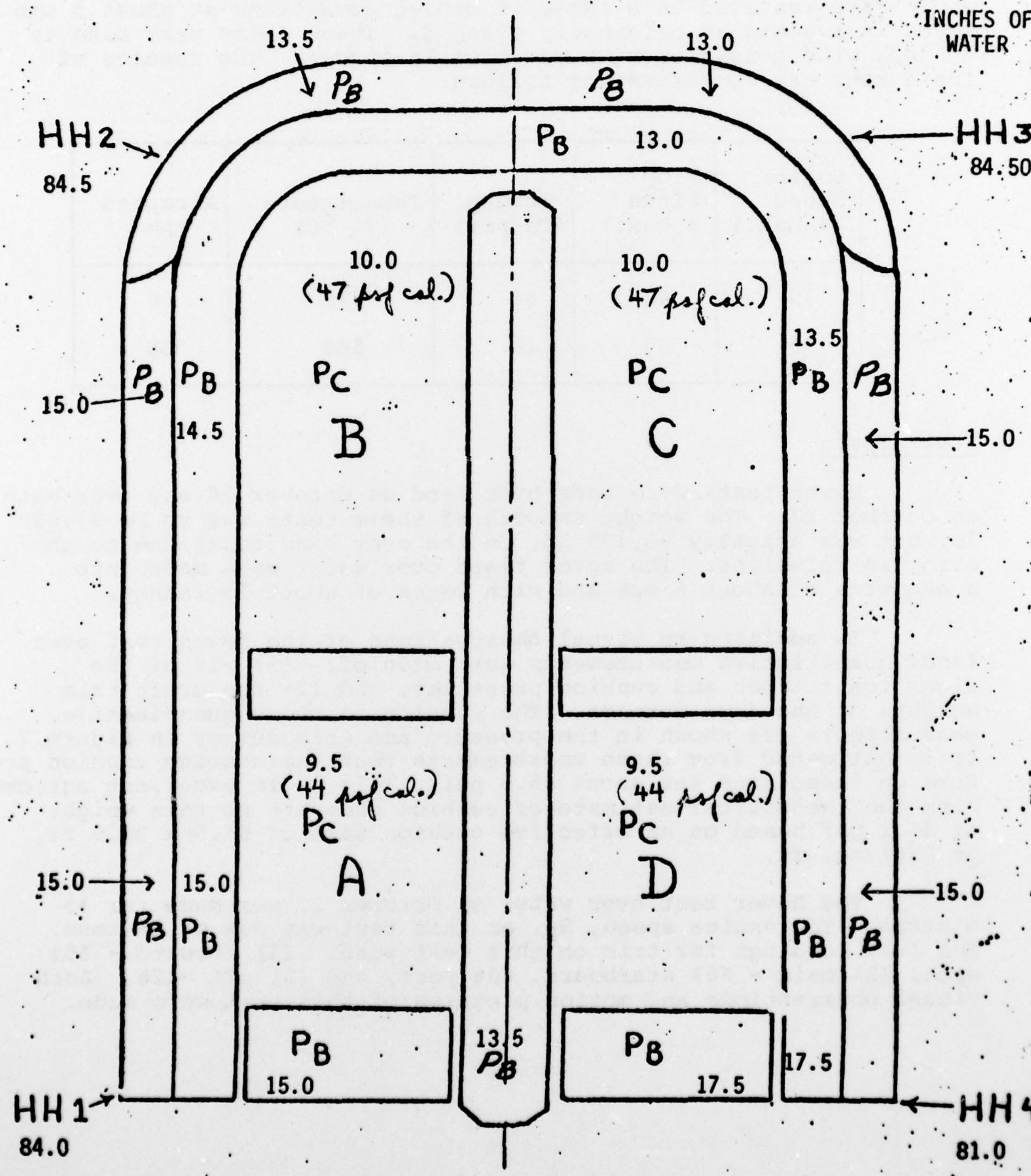
TEST LOCATION: Grand Bend

SKIRT STATE: Before modification - standard Voy skirt

A.U.W. 93,175 pounds CUSHION TEMP.: ______

O.A.T. 56°F WIND [redacted] 6 mph cal.

N_2: 91% FAN RPM: ______



Acceleration/Deceleration Tests

Acceleration tests were made on October 28, both into and with the wind. The wind was about 8 mph in the headwind case and 6 mph in the tailwind case. The lake in both cases had about 16 inch waves. Since the speed margin available above hump was limited, these tests were made to the maximum speed attainable for a given engine speed and prop pitch setting instead of to a fixed speed of about 50 mph as originally planned. The results of these tests are summarized in Table 4.

The deceleration tests were conducted on October 23 in both headwinds and tailwinds of about 12 mph and in 15 inch waves. Again, these tests were started from the speed attainable at fixed engine speed and prop pitch settings instead of from a fixed speed as originally planned. These tests were made using both full reverse on the prop pitch and then full back on engine speed. The results are also shown in Table 4.

MISCELLANEOUS TESTS

One Hour Operation

An overwater test was run to document continuous operation of the craft and subsystems for one hour. The subsystem cycles recorded during this test are shown in Table 5.

Spray Evaluation

The spray kicked up by the craft was evaluated on a 22 mph test run in waves of about 12 inch (sea state 1+) on October 28. The observed spray is recorded in the spray evaluation sheet in Figure 8.

Noise Evaluation

Noise level data was obtained in and on the craft during some static and over water tests of the LACV-30-1 (line No. 005) at/near Grand Bend, Ontario. Measurements were made using a General Radio Model GR1551C sound level meter. The data gathered cannot be considered conclusive since there were no configuration shortages in the cabin and the meter was not calibrated. However, the information was useful in determining the relative effects of location and in evaluating relative effects of cabin refinements.

TABLE 4 - ACCELERATION/DECELERATION TESTS

TYPE TEST	ENGINE SPEED (% MAX)	PROP PITCH (% MAX)	ENGINE TORQUE (PSI)	ENGINE TEMP. (T_7 °C)	SPEED-MPH START AIR/WATER	SPEED-MPH STOP AIR/WATER	TIME (SEC)
ACCEL. HEADWIND	95	50	48	560	8/0	38/30	160
ACCEL. TAILWIND	95	40	48	540	-6/0	30/36	177
DECEL. HEADWIND	FULL BACK	FULL REVERSE			36/24	12/0	10.5
DECEL. TAILWIND	FULL BACK	FULL REVERSE			21/33	-12/0	15

TABLE 5 - ONE HOUR OPERATION TEST

OVERWATER TESTS DATE: 24 Oct. '76

CRAFT TYPE: LACV-30IX S/N 005

OPERATION ITEMS
POSSIBLE CYCLES DURING OPERATION

PUFF PORTS (PORT & STBD)		-
N_1 LEVERS	(4)	- 8
N_2 SWITCHES	(2)	- 8
PROP PITCH	(2)	- CONTINUOUS
RUDDERS	(1)	- CONTINUOUS
WINDSHIELD WIPERS	(2)	- CONTINUOUS
WINDSHIELD WASHER	(2)	- 2
WINDSHIELD HEATERS	(2)	- NA
CABIN HEATERS	(2)	- NA
OIL COOLER VANES	(2)	- 2
SEAT MOVEMENT (FORE & AFT)	(2)	- 1

FIGURE 8 SPRAY EVALUATION DATE: 28 OCT 75

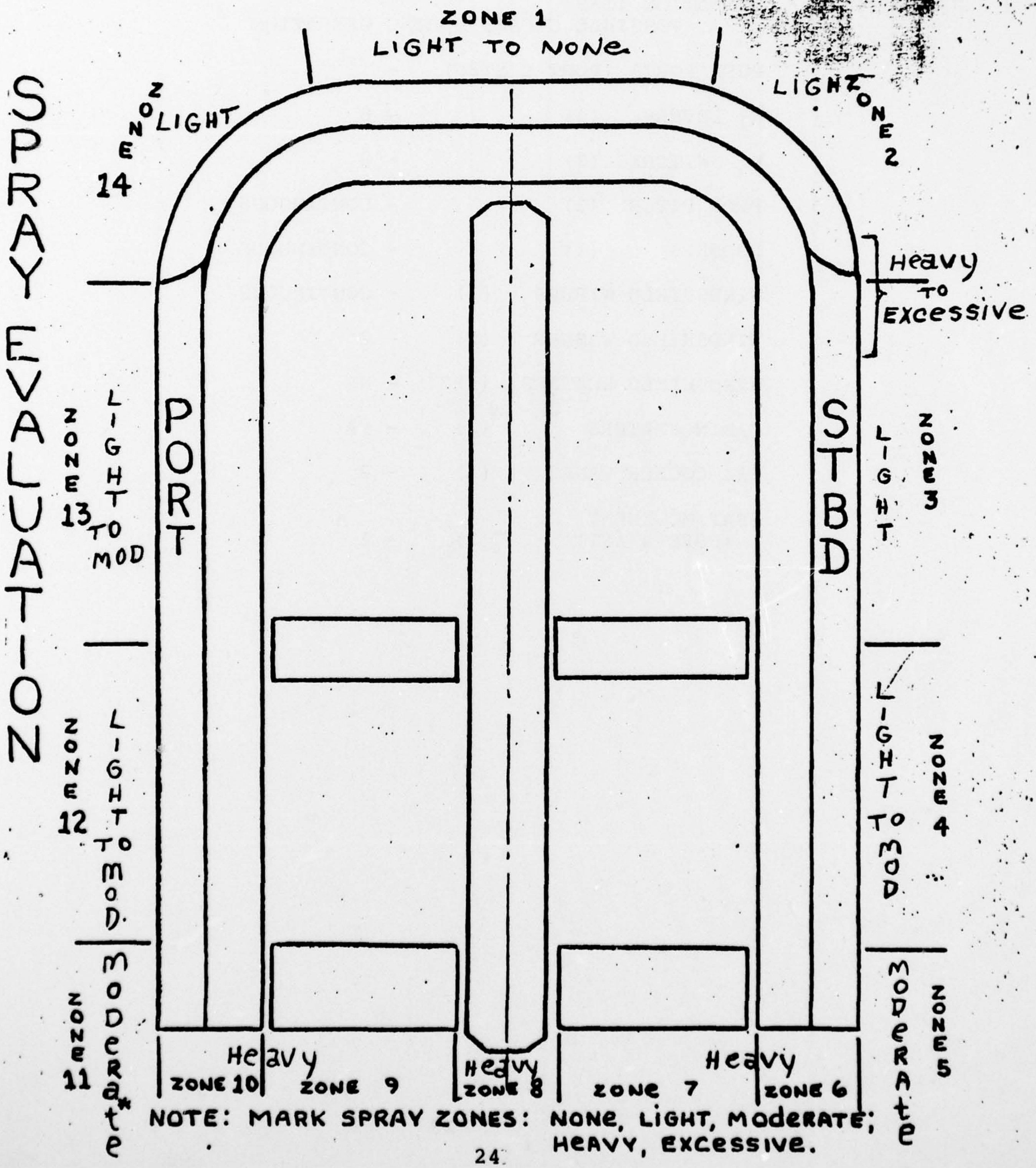
CRAFT TYPE: LACV-30-1X NUMBER: 005

TEST LOCATION: LAKE HURON (GRAND BEND)

O.A.T.: 58°F WIND DIRECTION 210° VELOCITY 20 KT

A.U.W.: 90,000 SEA STATE: 1+ DEPTH 40 FT

N_1: 92 % N_2: 94 % BETA 30 % KIAS 20



NOTE: MARK SPRAY ZONES: NONE, LIGHT, MODERATE; HEAVY, EXCESSIVE.

IV. CONCLUSIONS AND RECOMENDATIONS

It can be concluded that the test program was successful in:

(1) shaking down many of the normal operational problems in a new craft,

(2) establishing that the craft handled well,

(3) establishing that the performance was not as good as predicted and verifying that trunk refinements being considered were probably necessary to improve it.

It is recommended that this type of test be considered for any new future configurations to insure that refinements necessary to achieve full potential are made prior to final Acceptance Test.

REFERENCES

1. Bell Aerospace Textron, "Production Test Plan for Voyageur Air Cushion Vehicle," Report No. 928001, August 1975.

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3. M. Laszewski, "Stretched Voyageur Model Testing," Bell Aerospace Textron, 1975 IR&D Final Report No. 7467-927011, December 1975.