TECHNICAL REPORT NO. 73-04

SILENT PATROL BOAT

FINAL REPORT

By

Charles R. Wilson
Mobility Branch

November 1972

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U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

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ABSTRACT

This report covers the design and test of a small special purpose patrol boat. The boat was designed to carry 4 men at speeds up to 15 knots, with special emphasis on a very shallow draft capability (six inches). Propulsion was obtained by using an open propeller in a tunnel, so that there was no protrusion below the keel.

FOREWORD

The use of the word "Silent" in the report title is somewhat misleading. "Silent Patrol Boat" was the title of the task under which the work was accomplished, and is, therefore, carried over as the report title. As the specific requirement for which the boat was designed became more definite, emphasis was shifted from "silent" to shallow draft, such that a more descriptive title might have been, "A Quiet Shallow Draft Patrol Boat".

The scope of the original task covered the four broad areas of conceptual design, hydrodynamic model tests, full-scale hydrodynamic, functional and noise tests, and field evaluation. During the course of the task, a shift in military force allocations reduced the significance of the role for which the boat was designed. In light of this, it was considered unjustified to expend the effort required to resolve the remaining technical problems required to make the boat a field acceptable item. As a consequence the task did not progress beyond the full-scale hydrodynamic, functional testing stage. This report covers the work up to that point.

I wish to acknowledge the assistance of Professor Richard B. Couch of the Department of Naval Architecture and Marine Engineering, The University of Michigan, who served as a consultant through much of the program; and also, Andras I. Toro, a graduate student working under Professor Couch who conducted the 1/4-scale hydrodynamic model test, and assisted with the consultations under Contract No. DAAD05-71-C-0262.

INTRODUCTION

The Army has had, from time to time, the responsibility of maintaining surveillance along specific borders or demilitarized zones, with specific emphasis on controlling unauthorized passage of personnel and equipment. Many of these zones or borders are natural boundaries such as streams or rivers which may or may not be suitable for navigation by normal boat traffic. The silent boat was designed for a specific border area which was defined by a river containing numerous shifting shoals, and a sometimes navigable flood plain.

The area of use dictated that the boat operate in water as shallow as six inches, with mud, silt, and limited vegetation. The user indicated that the boat should have the following additional characteristics:

a. Carry a useful load of 1,000 lbs. with room for four men

b. Have a quiet speed up to 10 knots

c. Have a maximum speed of at least 15 knots

d. Have an endurance of 8 hours at maximum speed

e. Have a low profile

f. Be unsinkable

g. Be easily maintained

h. Be readily repaired

i. Use conventional fuel

j. Be land transportable with a conventional boat trailer.

With the exception of the shallow draft requirement, there are a number of commercially available boats that could be readily adapted to the same basic role. The Navy experimented successfully with quieting outboard motors for patrol boat use. In their QFB (Quiet Fast Boat) project, they were able to quiet the outboard to an extent that hydrodynamic noise was the significant contributor at boat speeds in the 10 to 15 knot range, draft, however, was on the order of 1 1/2 feet.

The design emphasis in this task, therefore, has been in the direction of shallow draft, with compromises being made as required to meet the other characteristics.

DISCUSSION

Designing a powered boat to operate quietly and in extreme shallow draft conditions requires consideration of a number of factors not normally of concern with regular use boats. Shallow water trim and suck down, propulsion system protection, ingestion of mud and weeds, hydrodynamic noise, minimum power and weight, and extreme muffling, are all of concern. Each of these will be discussed in this section.

As stated earlier the hull form was designed primarily from shallow draft considerations with some compromises. At low speeds, below planing speeds, the hull should be a typical displacement-type with a narrow, flat run aft to avoid excessive trim, and suck down. As speeds increase, it becomes more efficient to plane, which suggests a hull with a wide flat run aft. Since this particular boat is intended for a speed range from very low up to the lower planing speeds, the hull form is compromised in the direction of a displacement hull. The hull configuration is shown in Figures 1 and 2. It has the following particulars:

Length, Overall	22.416 ft.
Waterline Length.	22.00 ft.
Beam (at waterline)	4.733 ft.
Draft (at 2,000 lbs)	5.40 in.
Wetted Surface.	169.568 ft^2.
*Block Coefficient (C_B).	0.665

$$*C_B = \frac{\text{Displacement (ft}^3)}{\text{Length (ft.)} \times \text{Beam (ft.)} \times \text{Draft (ft.)}}$$

It can be noted from the lines that the forward sections are canoe-like, gradually fairing into a shallow vee after-body with soft chines. A more efficient planing hull could have been generated by the use of hard chines in the afterbody, but experience has shown that the result would be a noisier hull at design speeds.

It is considered that the size and weight are both near the minimum for the intended use which is in the right direction for minimum power, and noise. It should be noted, however, that there is some margin in draft. The freeboard is quite low, in keeping with the desire for a low profile. Although sufficiently seaworthy for the intended use, an increase would be desirable from a usable volume standpoint in a field item.

Since the boat was intended to operate in silt laden water, with the possibility of some vegetation, it was considered impractical to pick up water through an intake for either propulsion or cooling. This in turn led to the choice of an open propeller in a tunnel for propulsion, and an air-cooled engine for power. Liquid-cooled engines with a closed cooling system were also considered, but due to a higher installed weight, were not chosen for the initial boat.

In order to provide for adequate propeller protection, the tunnel must extend below the propeller diameter. Since the propeller should be as large as practical in order to achieve a reasonable efficiency at the low operating speeds, the result was a tunnel that is partially above the static water line. This concept is not new, having been in use on larger craft for many years. The arrangement works well if the general guidelines of a gentle tunnel entrance angle (12^{o} or less), tip clearance nominally no more than 10% of propeller diameter, and the propeller hub submerged at rest are followed. Drag is increased slightly due to an increase in wetted area, and the necessity to lift water above its static condition. Since the tunnel exit is also above the static water line, propulsive efficiency in reverse is low.

The tunnel has another characteristic, not associated with propulsive efficiency. It acts as a skeg, which provides additional directional stability. In the case of the boat, the skeg characteristic combined with the natural stability of a high length-to-beam ratio provided too much stability and maneuverability was reduced throughout the speed range. While the maneuverability was considered marginally adequate in the tests conducted, it may be less than desired in actual field conditions.

As stated earlier, an air-cooled engine was selected. The military standard engine 4A084 (20-35 hp) seemed most suitable in that (1) it is in the right horsepower range; (2) it is currently in the Army inventory, primarily as a generator engine; and, (3) it comes standard with effective radio noise suppression. Engine characteristics and description are shown in Figure 3. Although the installed engine was adequate from a response and horsepower standpoint, testing indicated that it was operating above its continuous horsepower curve at higher boat speeds. While the engine is capable of continuous operation up to the maximum horsepower curve, operating temperatures are higher than recommended, and consequently the reliable operating life of the engine is reduced.

Machinery noise was a consideration in the initial installation, however, the work conducted to determine whether the over-temperature condition was due to installation or use consumed the time programmed for noise suppression work. The initial installation work consisted of: (1) Shock isolation of the engine from the hull and remainder of the drive train; (2) lining the engine compartment and hood with lead sheet backed with spun fiberglass; (3) baffling the air intake; (4) utilization of four cross coupled mufflers; and (5) under water exhaust. Qualitative tests indicated that the boat was relatively quiet at low speeds. No quantitative data was obtained, however, so that whether or not it was sufficiently quiet is strictly judgmental.

Quarter-scale, and full-scale hydrodynamic and functional testing was conducted. Test procedures, and the resulting data are presented in the following section.

TESTING

QUARTER-SCALE MODEL

Quarter-scale model tests were conducted to examine the shallow and deep water characteristics of the hull form generated. The model was constructed and all testing conducted by the Department of Naval Architecture and Marine Engineering Ship Hydrodynamics Laboratory, the University of Michigan under contract to LWL.

Testing was done with two configurations identical in hull form with Figure 1, the only difference between then being a single or twin screw tunnel. Both models were ballasted to a 2,000 lb. displacement and kept on an even keel at static conditions. No appendages were fitted to the hull, so that drag results are for a bare hull only. Turbulent flow was stimulated by means of small studs placed at about the leading edge of the water-plane area with the hull in a planing condition.

Resistance tests were performed in still water from a speed of 4.5 knots to 16.5 knots. The shallow water condition was simulated by a movable false bottom in the towing tank set to an average depth of 2.5 inches corresponding to a 10-inch full-scale depth. (Equipment limitations made it impractical to simulate any shallower water.) Figures 4 and 5 show the models in both shallow and deep water at ten knots. It should be noted that spray effects are more severe in model-scale than full-scale. A spray rail was incorporated at the sheer line in the full-scale boat which satisfactorily solved the problem of spray. Table 1 shows the resistance data for both the single and twin screw hulls. It is noted that for most conditions the resistance is lower for the single screw version. Figure 6 is a compilation of model data for the single screw version, with trim, heave, and effective horsepower plotted against full-scale speed. The effective horsepower has been extrapolated using the "λ^3" extrapolation without friction correction. This is considered valid in this case since the boat is basically a round bottomed hull and behaves somewhat like a displacement hull even at planing speeds.

$$EHP = \frac{V \times R \lambda^3}{550}$$

Where EHP = Equivalent horsepower

R = Model resistance (lbs.)

V = Full-scale speed (ft/sec)

$$V_{FS} = V_{MS} \lambda^{1/2}$$

λ = Model to full-scale ratio (4)

Figure 7 shows the same data for the twin-screw version.

The data indicates that even though the hull is primarily a displacement form, there is some benefit from planing at speeds on the order of 8 knots and above. This is indicated by the fact that the shallow water resistance is less than for deep water.

FULL-SCALE TESTS

A full-scale test hull was built to the lines of Figure 1 from wood, using typical light-weight boat construction. Figure 8 shows the construction details. The hull was covered with "Vectra" (polypropylene) cloth and flexible polyester resin, as a protective finish. Behavioral tests were conducted over the entire speed range in both shallow (six inches) and deep water. Figure 9 shows the hull in deep water, and Figure 10 shows it in shallow water, at approximately ten knots. Full-scale behavior was as predicted from the model tests in all conditions.

Speed trials were conducted in deep water only, due to the non-existence of a sufficient stretch of consistant shallow water. Figure 11 is a plot of speed versus engine RPM. Figure 12 is a composite plot showing the maximum, and continuous horsepower rating lines of the engine plotted as a function of boat speed, and horsepower required as predicted from model tests. The horsepower-required curve assumes an appendage drag of five (5) percent, and a propeller efficiency of sixty (60) percent. It is seen that the required horsepower line crosses the continuous horsepower line at 12.5 knots, which closely corresponds to the engine RPM range where over temperature became a problem, and intersects the maximum horsepower line at 16.8 knots which closely matches both the maximum engine RPM, and the maximum measured boat speed. This indicates that propeller efficiency is near the assumed value of sixty (60) percent, which is a reasonable value for the operating range and conditions.

CONCLUSIONS

1. The hull form and size as defined in Figure 1 are adequate for the specific job, from a hydrodynamic standpoint.

2. Additional layout work would have to be performed in order to provide for more useful volume and space in a working boat.

3. The Military Standard 4A084 engine, although capable of providing sufficient power for short periods, was not suitable for an operational version of the boat due to an over-temperature condition.

4. Additional work would be required in order to bring the engine noise down to an acceptable level.

5. Maneuverability may be marginal in operation.

6. Consideration of alternate twin screw versions would be required if much additional maneuverability is required. Twin engines would also increase reliability.

TABLE

Model Resistance for Different Conditions

	Single Screw		Twin Screw	
	Deep	Shallow	Deep	Shallow
V_m (ft/sec)	R_T (lb)	R_T (lb)	R_T (lb)	R_T (lb)
4.0	0.85	1.17	0.77	1.29
5.0	1.24	1.58	1.16	1.65
6.0	1.82	1.94	1.82	2.03
7.0	2.37	2.28	2.45	2.46
8.0	2.92	2.65	3.01	2.82
9.0	3.41	3.07	3.50	3.32
10.0	3.82	3.50	3.98	3.77
11.0	4.37	3.92	4.46	4.25
12.0	4.87	4.35	5.02	4.75
13.0	5.42	4.80	5.66	5.30
14.0	6.00	5.31	6.55	5.82

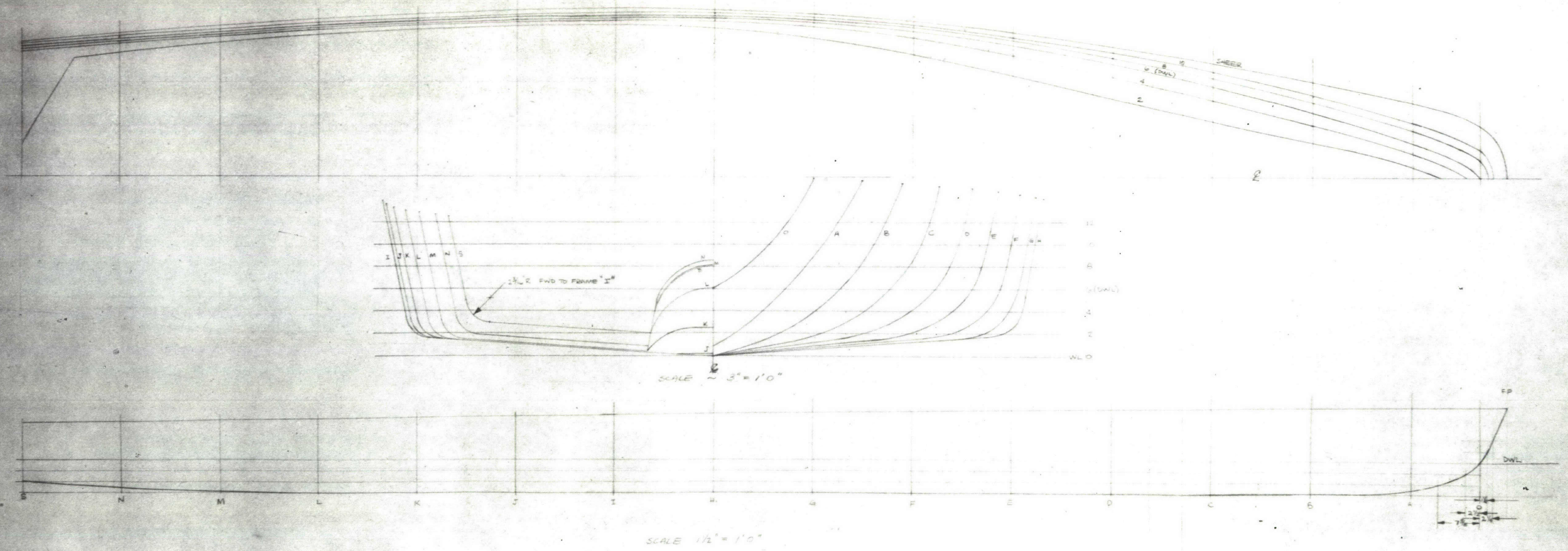


TABLE OF OFFSETS

FRAME STATIONS - HALF BREADTHS

WATERLINES	FP	O	A	B	C	D	E	F	G	H	I	J	K	L	M	N	S
2	—	—	0-2-0	0-6-1	0-9-7	1-1-5	1-5-6	1-9-4	2-0-3+	2-2-1	2-3-0+	2-2-5+	2-2-0+	2-1-2	2-0-0	1-10-0+	—
4	—	—	0-4-4	0-9-2	1-1-6	1-5-6+	1-9-5	2-0-5+	2-2-5+	2-3-7+	2-4-0	2-3-5	2-3-0+	2-2-0+	2-0-7+	1-11-4	1-10-1+
6	—	0-0-0	0-6-4	0-11-3+	1-3-7+	1-8-0+	1-11-3	2-1-7	2-3-4	2-4-2	2-4-3+	2-4-0+	2-3-4	2-2-4	2-1-2+	2-11-7	1-10-6
8	—	0-2-7+	0-8-2+	1-1-1+	1-5-5	1-9-2+	2-0-1+	2-2-3+	2-3-7+	2-4-5	2-4-7	2-4-4	2-3-7+	2-2-7+	2-1-6	2-0-3	1-11-1+
10	—	0-5-0	0-9-7	1-2-4	1-6-6	1-10-1	2-0-6	2-2-7	2-4-2+	2-5-0	2-5-2	2-4-7+	2-4-3	2-3-3	2-2-1+	2-0-6	1-11-4+
12	—	0-6-5+	0-11-2+	1-3-4+	1-7-4	1-10-5+	2-1-1	2-3-1+	2-4-5+	2-5-3	2-5-5+	2-5-3	2-4-6+	2-3-6	2-2-5	2-1-1+	2-0-0
SHEER	—	0-9-0	1-1-3+	1-5-0	1-8-3	1-11-3	2-1-6	2-3-5	2-5-1	2-5-6	2-6-0+	2-5-6	2-5-0+	2-4-0	2-2-6	2-1-2+	2-0-1

HEIGHT ABOVE BASELINE

	FP	O	A	B	C	D	E	F	G	H	I	J	K	L	M	N	S
FAIRBODY	1-3-7	0-6-0	0-0-6	0-0-0	—	—	—	—	—	—	—	—	—	—	0-0-2	0-0-7+	0-2-0
SHEER	1-3-7	NOTE ~ SHEER IS A STRAIGHT LINE															1-0-5
DECK ℄	1-3-7	1-4-3	1-4-6+	1-5-1+	1-5-4	1-5-6+	1-5-5+	1-5-5+	1-5-5+	1-5-4	1-5-3	1-5-1	1-4-5+	1-4-1+	1-3-4	1-2-6	1-1-7+

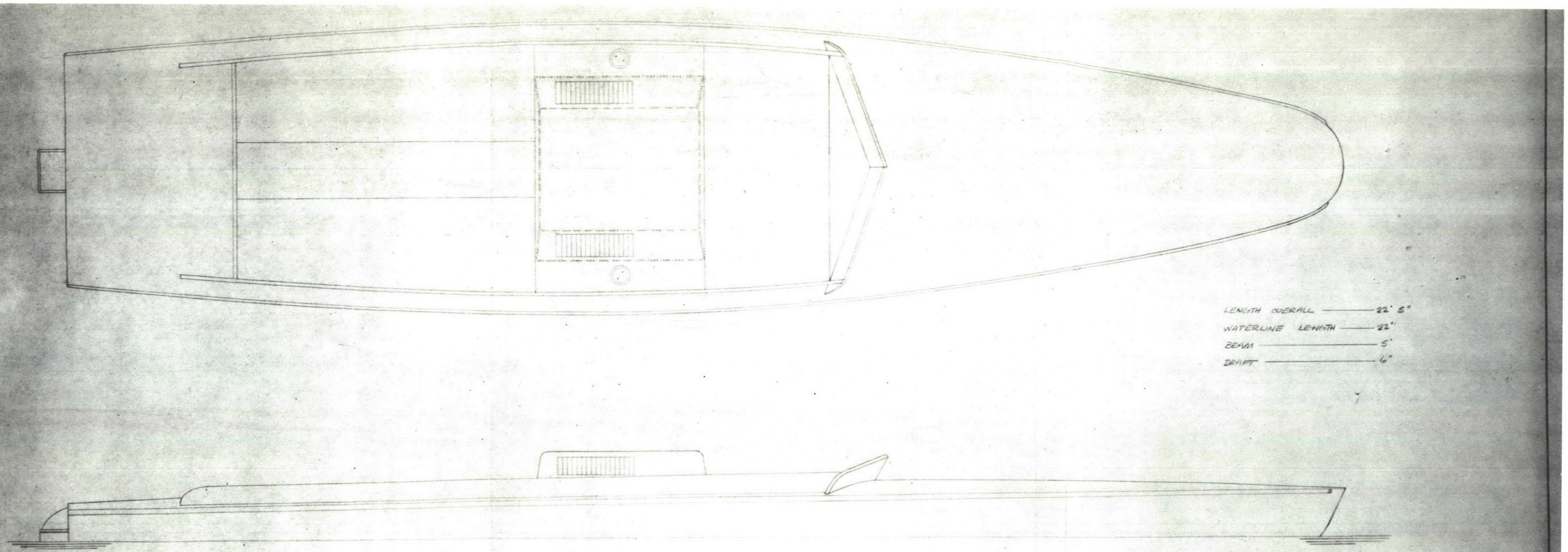
DIMENSIONS IN FT-INCHES-EIGHTHS + 1/16

FIGURE 1

UNLESS OTHERWISE SPECIFIED	ORIGINAL DATE OF DRAWING: 20 APR 71
PROJECT ENG.	CRW 4/20/71
PROJECT NO.	06-M-71

SILENT PATROL BOAT
U.S. ARMY LAND WARFARE LABORATORY
ABERDEEN PROVING GROUND, MARYLAND 21005
LINES

E 050081019



NOTES:
1- ENGINE BOX SHOWN FOR 35 HP MIL. STD. ENGINE
2- CREW & ARMAMENT ARRANGEMENTS OPTIONAL - PROTOTYPE WILL CONTROL FROM EITHER SIDE REAR COMPARTMENT
3- WATERLINE SHOWN FOR LOADED WEIGHT OF 2000#

SCALE 1½" = 1'0"

FIGURE 2

UNLESS OTHERWISE SPECIFIED — DIMENSIONS ARE IN INCHES

ORIGINAL DATE OF DRAWING: 21 APR 71

PROJECT ENG.: CRW

PROJECT NO.: 06-M-71

SILENT PATROL BOAT

U.S. ARMY LAND WARFARE LABORATORY

ABERDEEN PROVING GROUND, MARYLAND 21005

(OUTBOARD PROFILES)

SIZE: E

050081020

MILITARY STANDARD ENGINES

Application

4 BASIC STEPS to successful application of a military standard engine to any given equipment.

P 1. Determine the power required by the equipment for anticipated operating conditions.

P 2. Select the engine size by matching the power requirements of the equipment to the power available from the engine.

STEP 3. Select or design coupling and mounting arrangements to give desired physical and functional characteristics.

STEP 4. Provide installation design features to allow ease of servicing and maximum protection for the engine as well as clearance for inlet and discharge of engine cooling air.

E: The designer or engineer planning the application of any of these military standard engines should first consult the appropriate Military Standard lation procedures. These installation procedures provide the minimum requirements and guidance to insure a satisfactory engine installation.

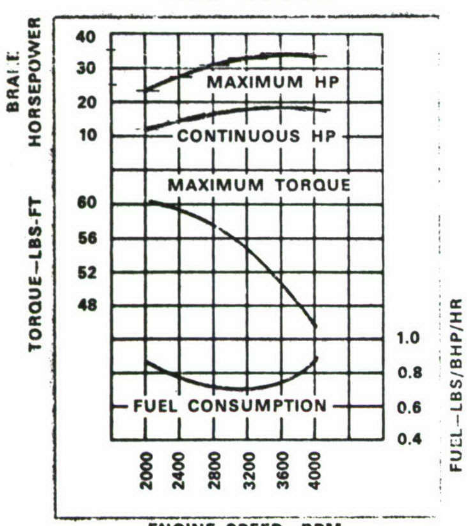
: following ılications available:

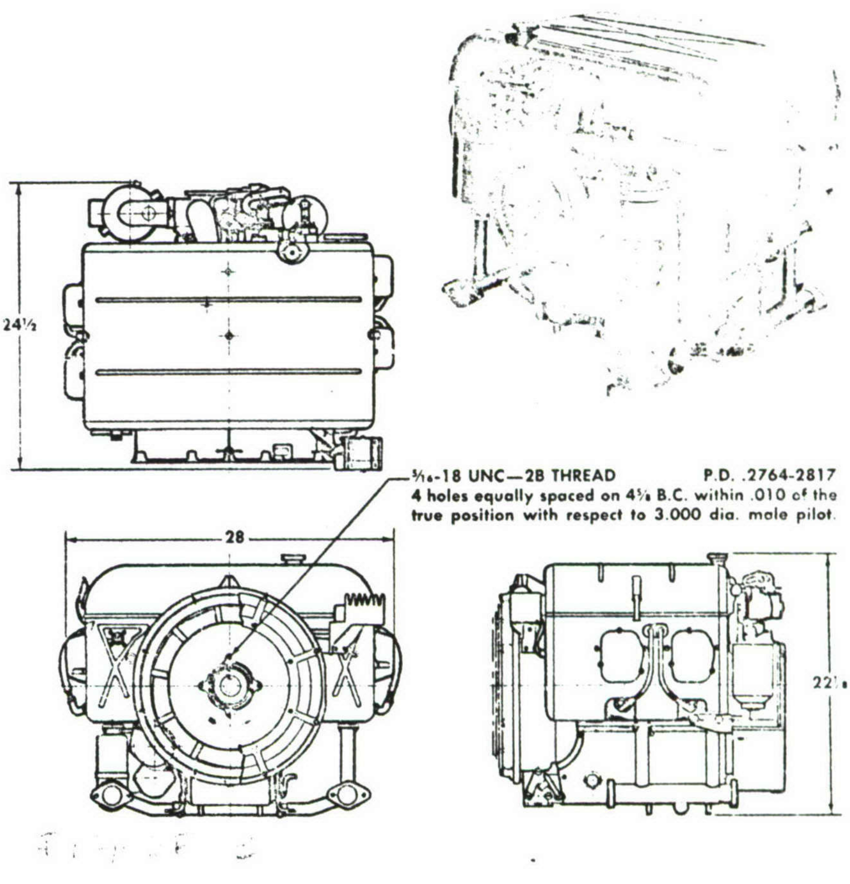
ENGINE MODEL

PUBLICATIONS	1A03	1A08	2A016	A042	4A032	2A042-4A084
Technical Manual	TM 5-5285	TM 5-2805-208-14 and 24P	TM 5-2805-208-14 and 24P	TM 5-2805-213-14 and 24P	TM 5-2805-203-14 and 24P	TM 5-2805-204-14 and 24P
Lubrication Order	L05-5285	L05-2805-208-14	L05-2805-208-14	L05-2805-213-14	L05-2805-203-14	L05-2805-204-14
Military Standard Installation Procedures	MIL-HDBK 207	MIL-STD-1226	MIL-STD-1227	Installation Procedure not available	MIL-STD-1300	MIL-STD-1402 MIL-STD-1401
Military Specifications		MIL-E-46717	MIL-E-46717		MIL-E-46717	MIL-E-62014

MODEL 4A084

MS 39302





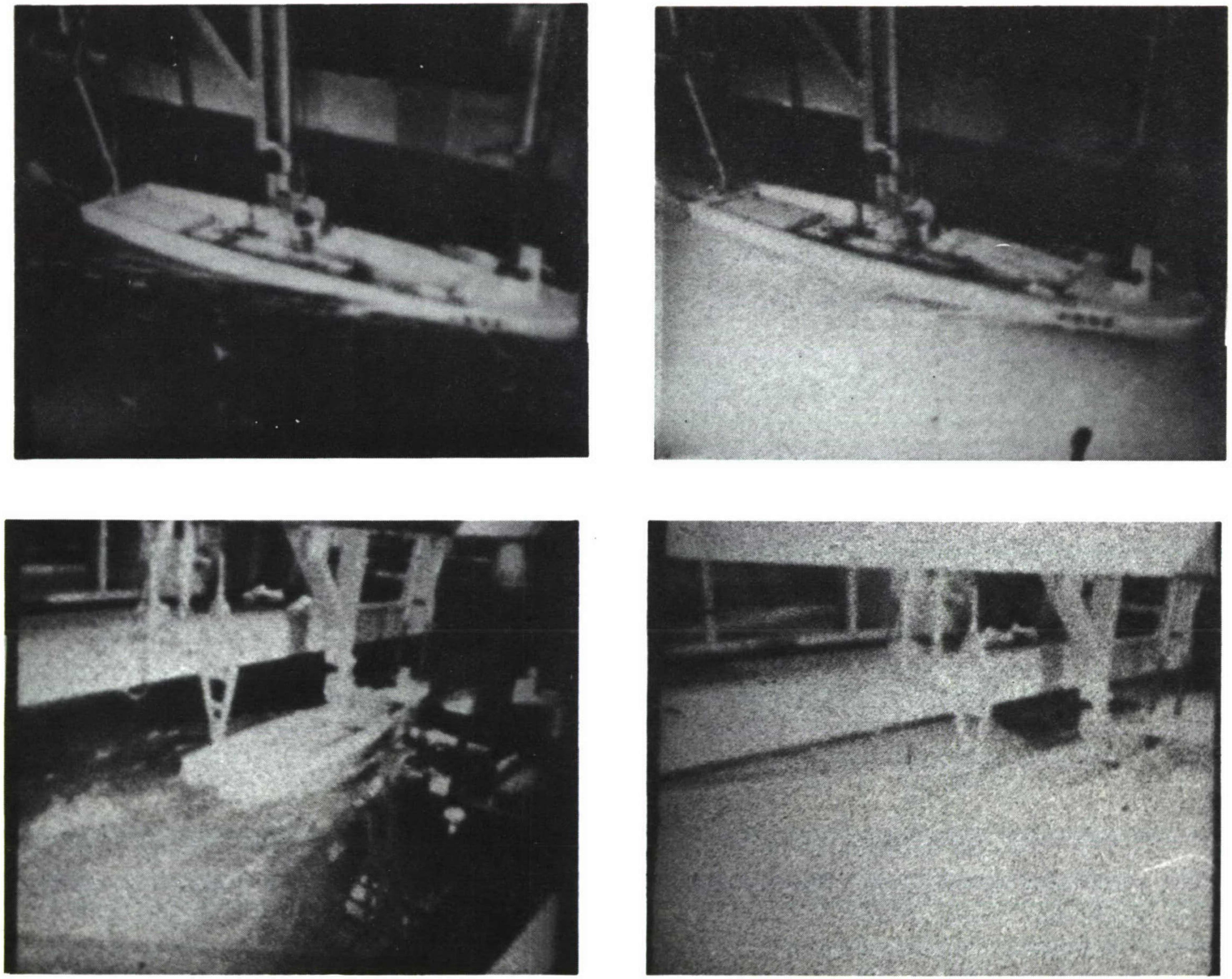


FIGURE NO. 4

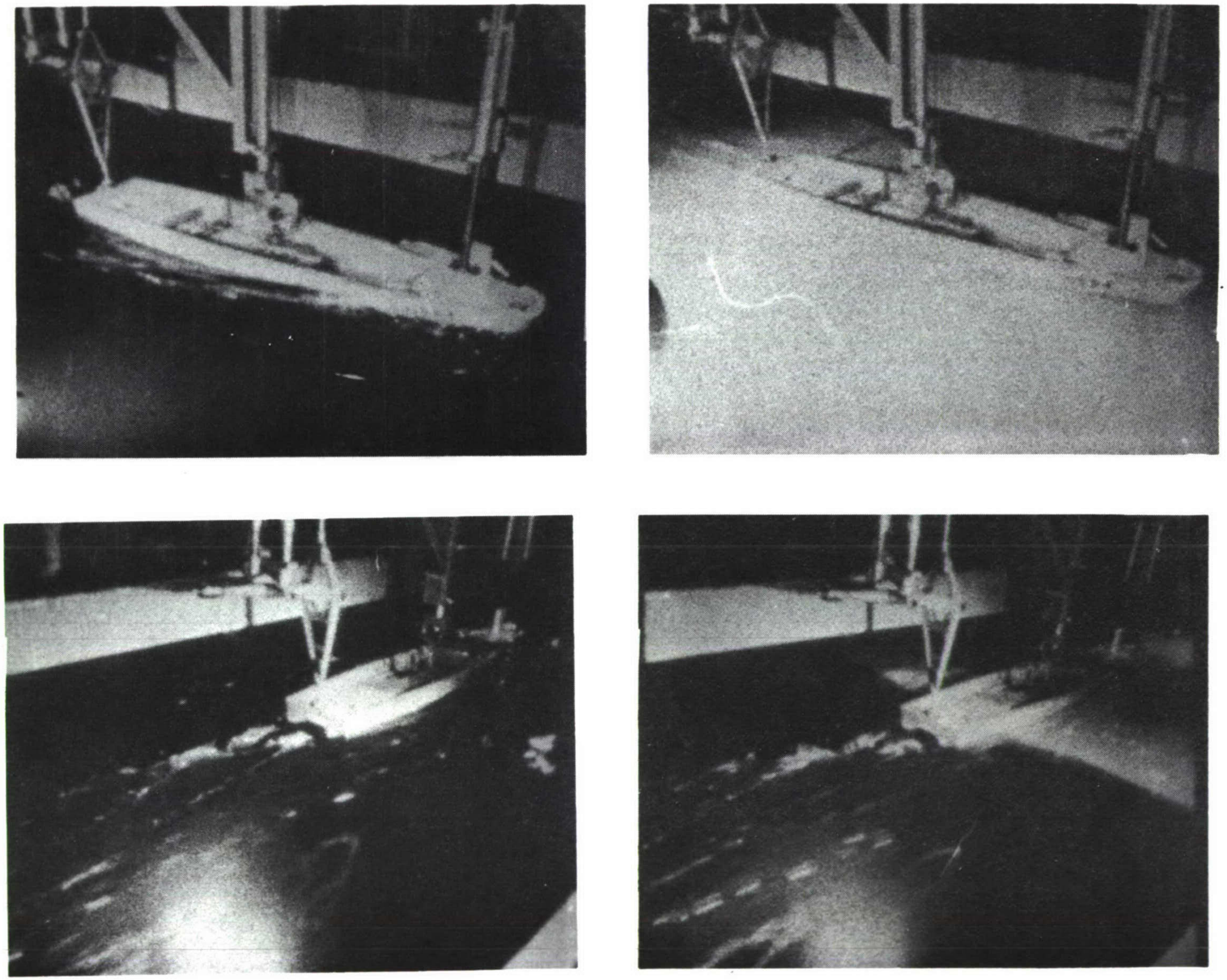


FIGURE NO. 5

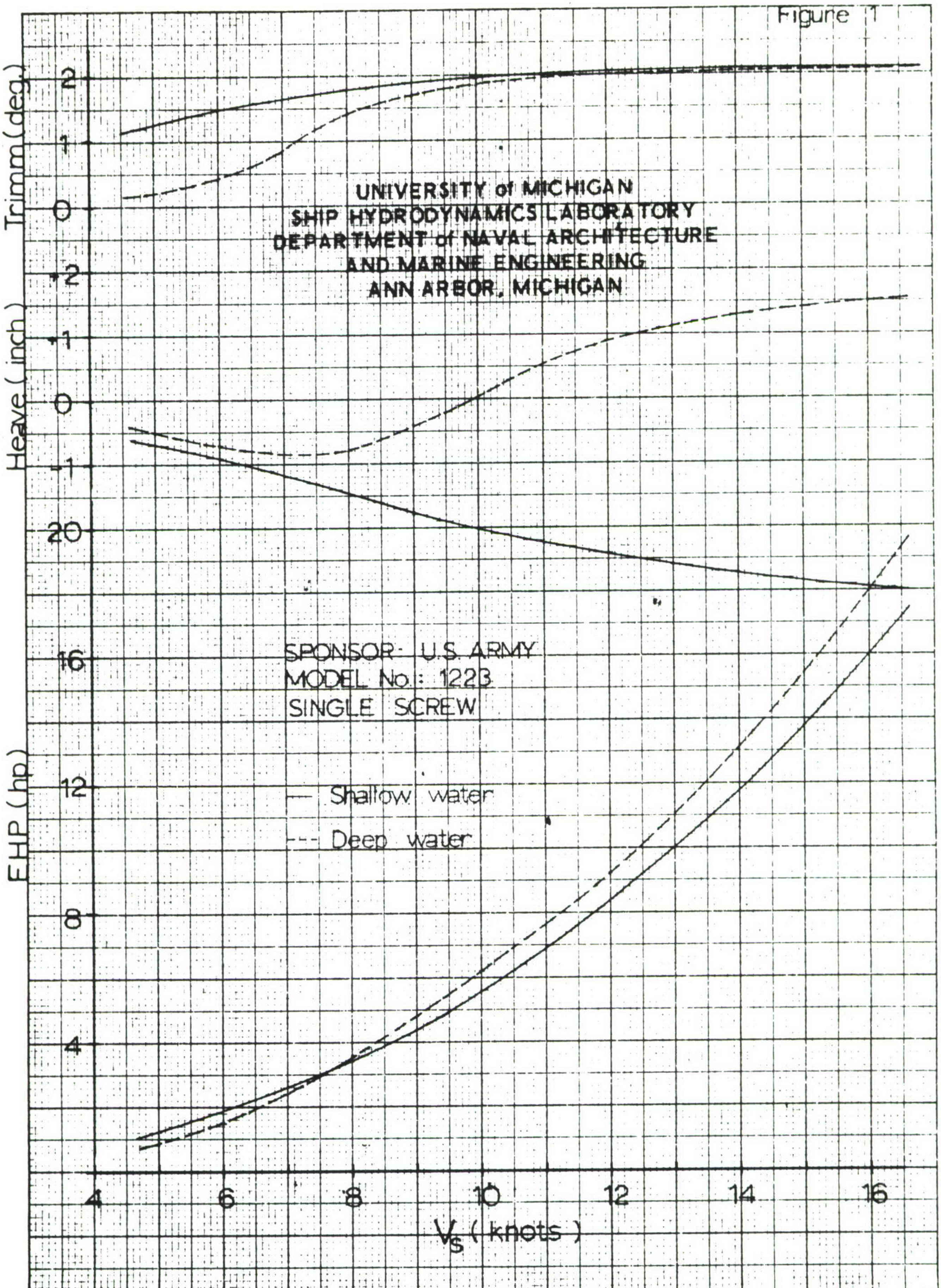


Figure 1
Trimm (deg.)
2
1
0
Heave (inch)
+2
+1
0
-1
EHP (hp)
20
16
12
8
4
UNIVERSITY of MICHIGAN
SHIP HYDRODYNAMICS LABORATORY
DEPARTMENT of NAVAL ARCHITECTURE
AND MARINE ENGINEERING
ANN ARBOR, MICHIGAN
SPONSOR: U.S. ARMY
MODEL No.: 1223
SINGLE SCREW
— Shallow water
--- Deep water
4
6
8
10
12
14
16
Vs (knots)

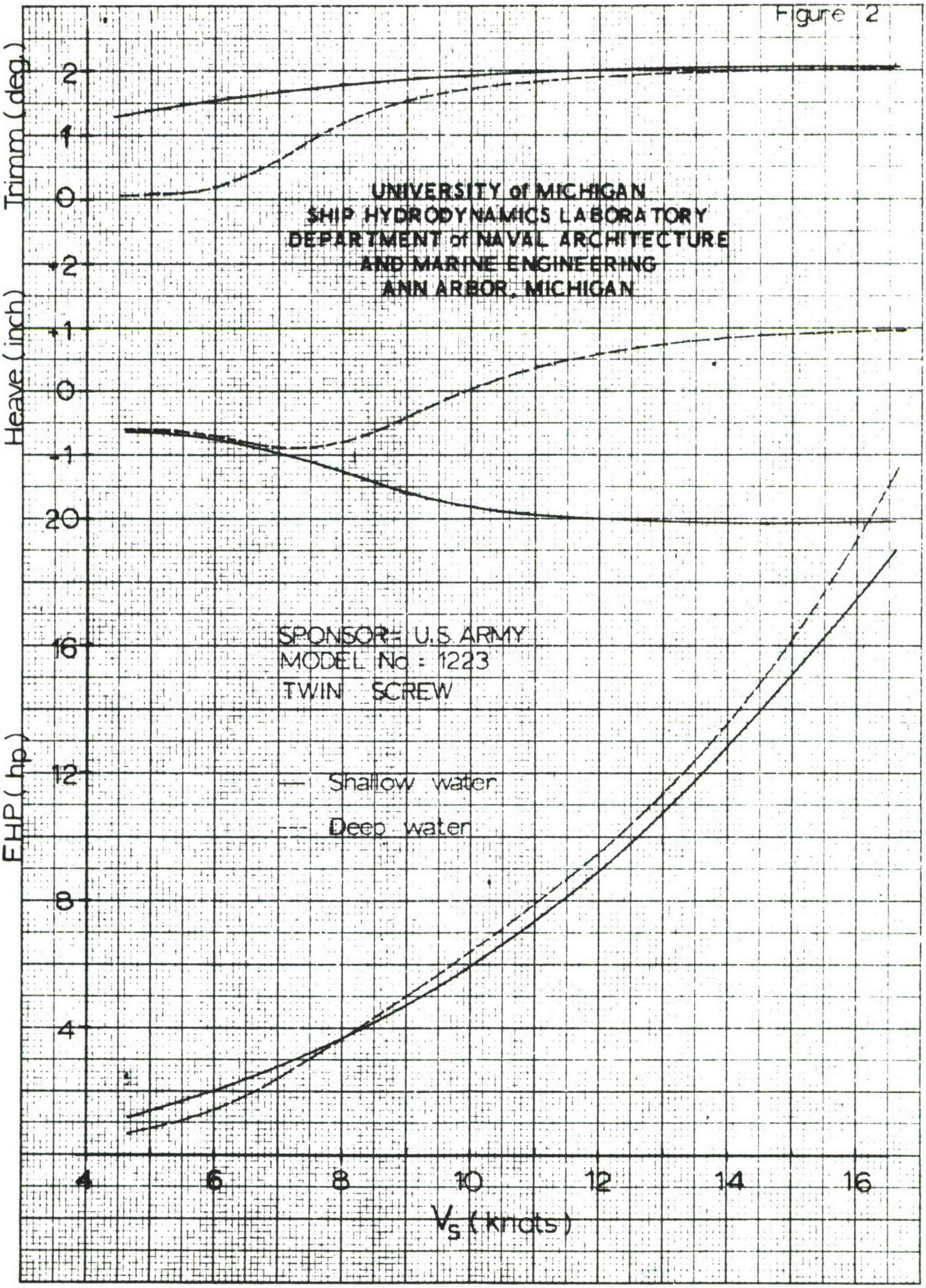


Figure 2
Trimm (deg.)
2
1
0
UNIVERSITY of MICHIGAN
SHIP HYDRODYNAMICS LABORATORY
DEPARTMENT of NAVAL ARCHITECTURE
AND MARINE ENGINEERING
ANN ARBOR, MICHIGAN
Heave (inch)
+2
+1
0
-1
20
16
12
8
4
SPONSOR: U.S ARMY
MODEL No: 1223
TWIN SCREW
EHP (hp)
— Shallow water
--- Deep water
4
6
8
10
12
14
16
V_s (knots)

FIGURE 1

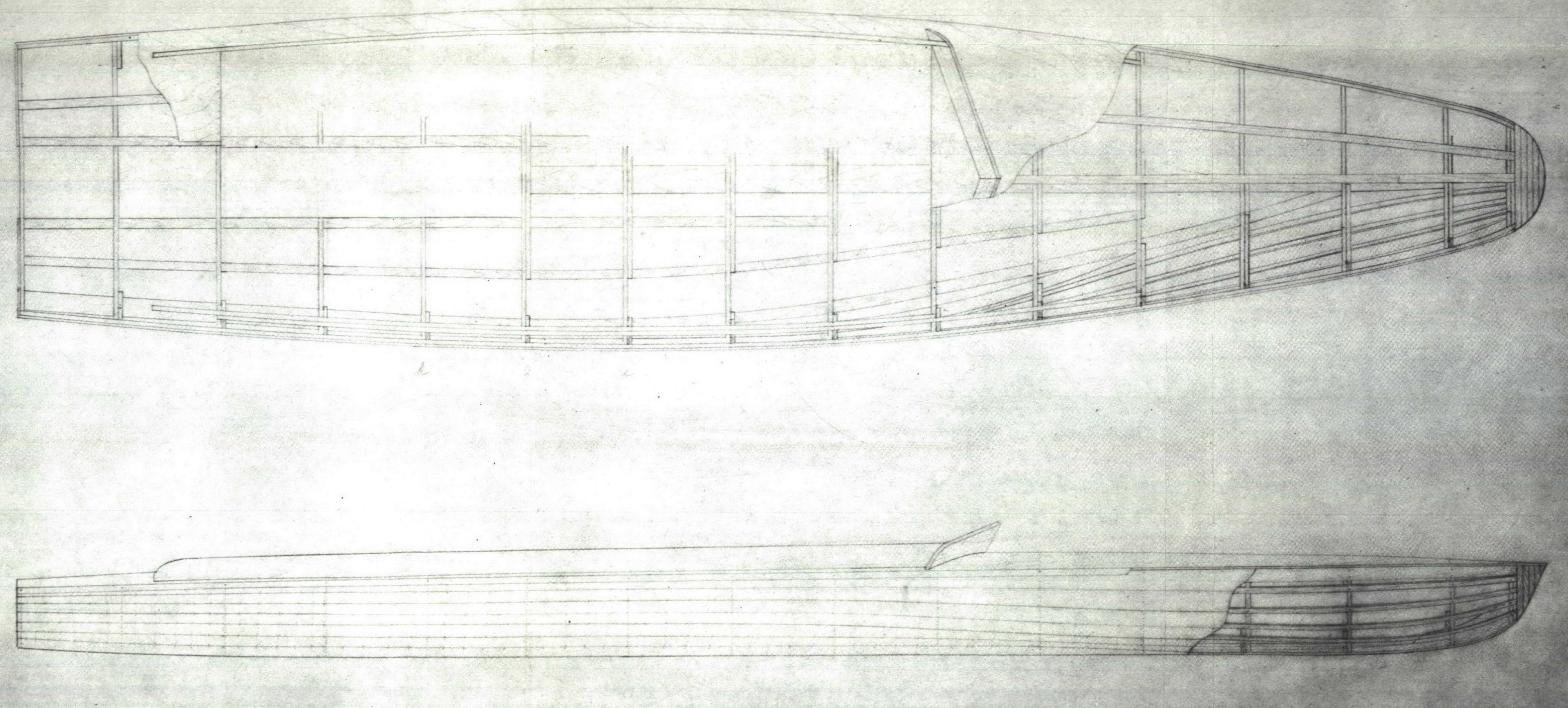


FIGURE 8

PART NAME

UNLESS OTHERWISE SPECIFIED

ORIGINAL DATE OF DRAWING: 9 APR 71

PROJECT ENG.

PROJECT NO. 06-M-71

FRAMEWORK ASSEMBLY

U.S. ARMY LAND

TYP. CONSTRUCTION

SIZE: E

APPLICATION

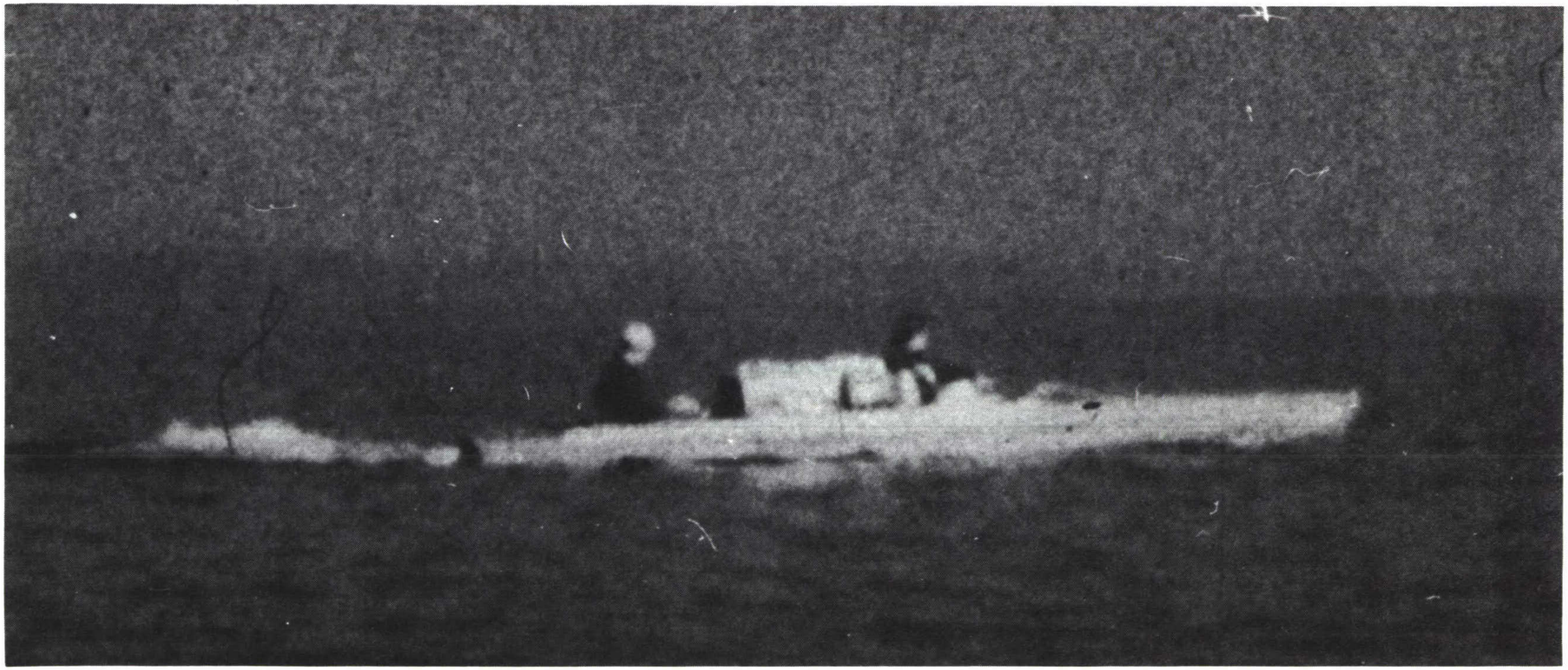


FIGURE NO. 9

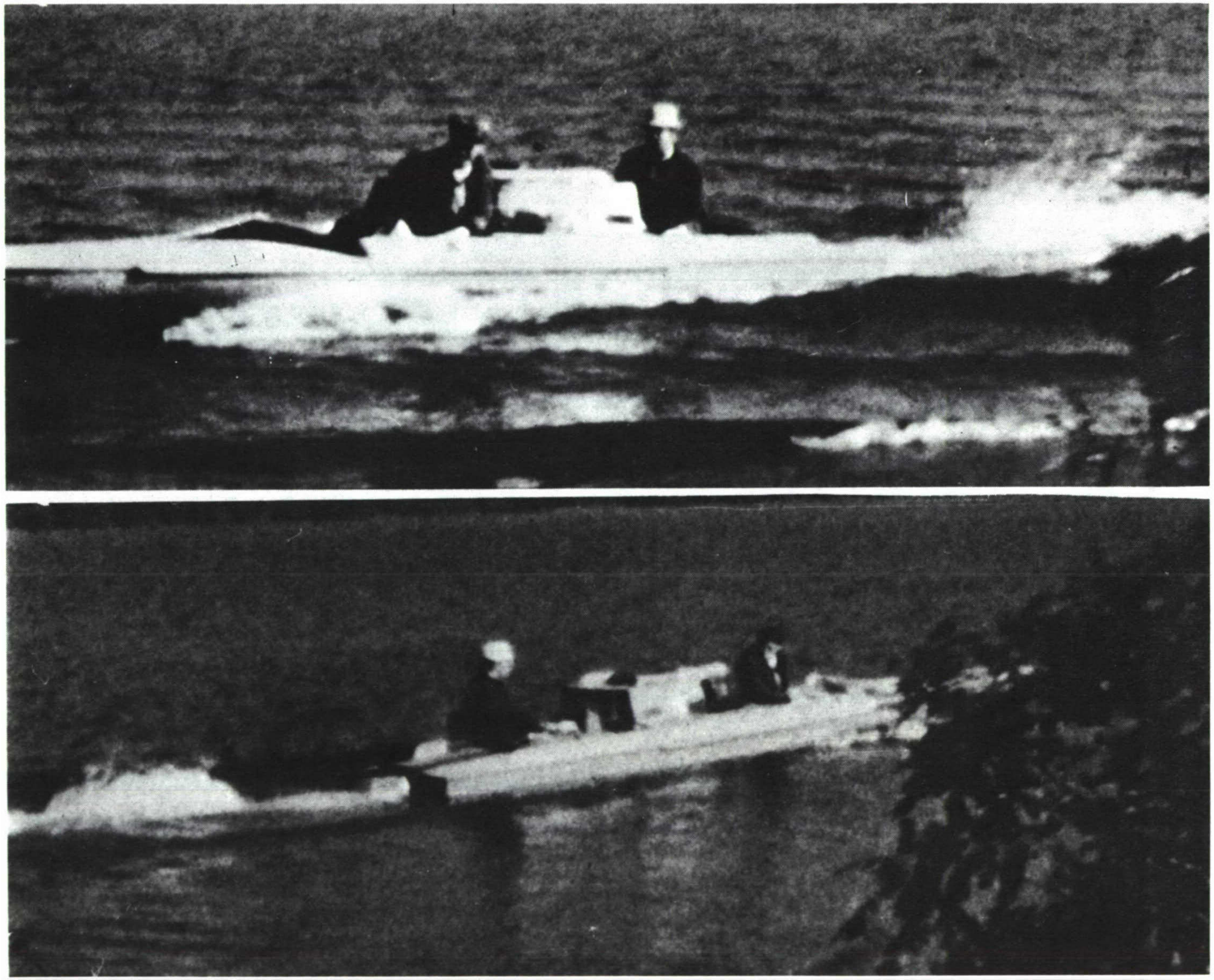


FIGURE NO. 10

SILENT PATROL BOAT TEST

3 DEC 1971

WEIGHT ~ 2200 LB.

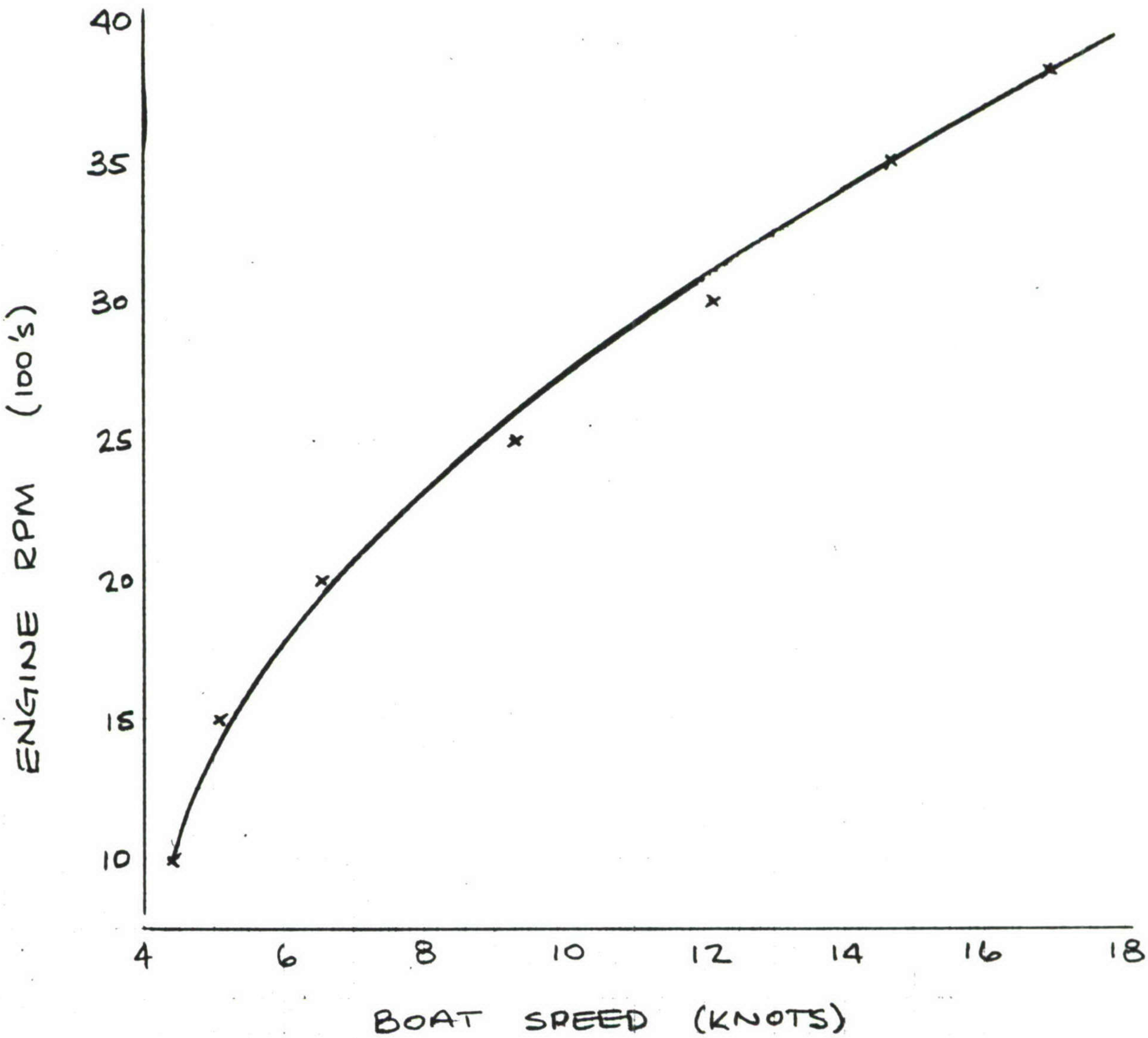


FIGURE 11

SILENT PATROL BOAT

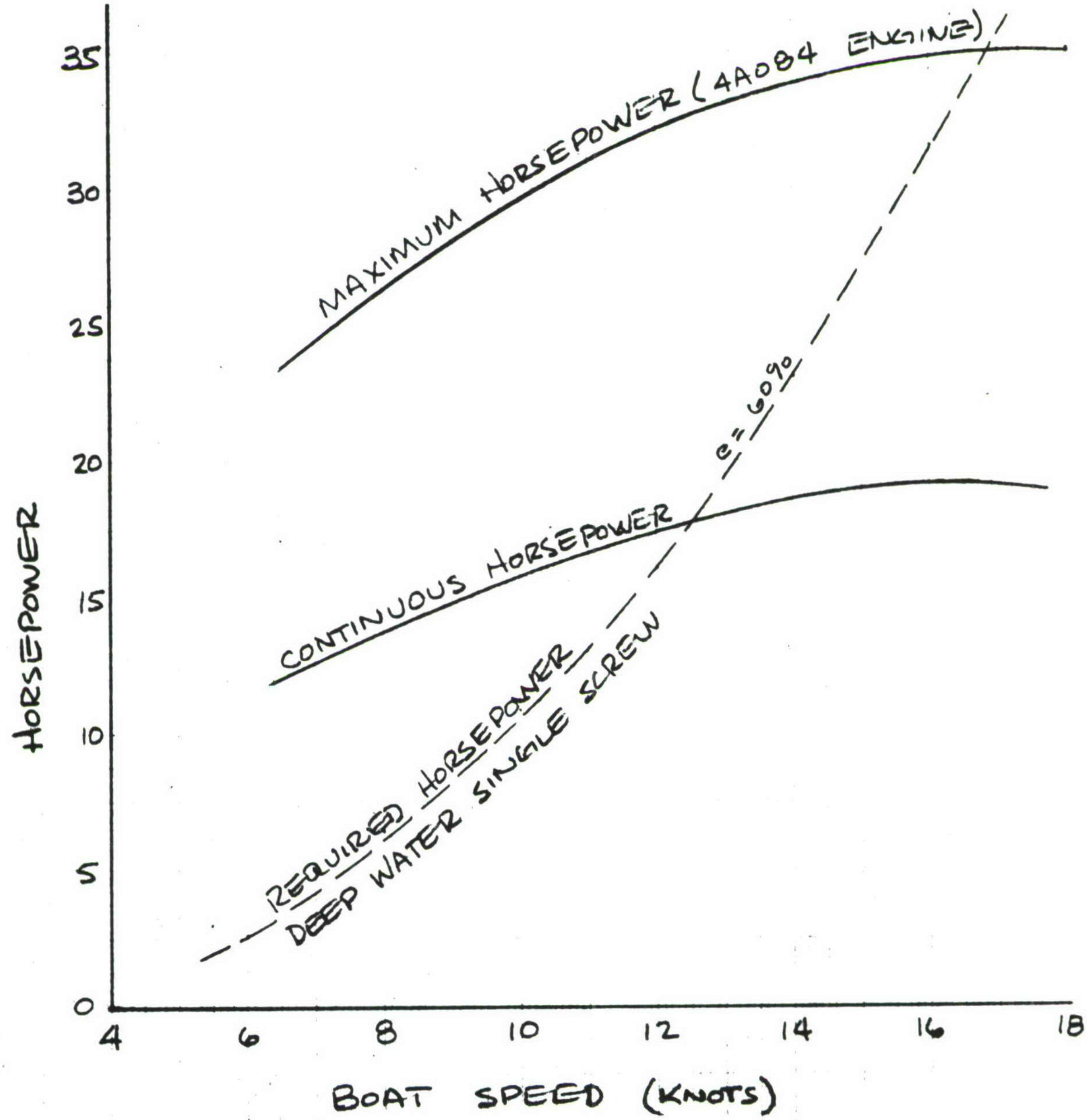


FIGURE 12

DISTRIBUTION LIST

Director of Defense, Research & Engineering Department of Defense WASH DC 20301	1
Director Defense Advanced Research Projects Agency WASH DC 20301	3
HQDA (DARD-DDC) WASH DC 20310	4
HQDA (DARD-ARZ-C) WASH DC 20310	1
HQDA (DAFD-ZB) WASH DC 20310	1
HQDA (DAMO-PLW) WASH DC 20310	1
HQDA (DAMO-IAM) WASH DC 20310	1
Commander US Army Materiel Command ATTN: AMCDL WASH DC 22304	1
Commander US Army Materiel Command ATTN: AMCRD WASH DC 22304	3
Commander US Army Materiel Command ATTN: AMCRD-P WASH DC 22304	1
Commander US Army Combat Developments Command ATTN: CDCMS-P Fort Belvoir, VA 22060	1
Commander US Army DDC Combat Systems Group Fort Leavenworth, KS 66027	1

Commander
US Army CDC Personnel & Logistics Systems Group
Fort Lee, VA 23801 1

Commander
US Army CDC Intelligence & Control Systems Group
Fort Belvoir, VA 22060 1

USACDC Liaison Officer
Aberdeen Proving Ground, MD 21005 1

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US Army Test and Evaluation Command
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US Army John F. Kennedy Center for Military Assistance
Fort Bragg, NC 28307 1

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US Army Pacific
ATTN: GPOP-FD
APO San Francisco 96558 1

Commander
Eighth US Army
ATTN: EAGO-P
APO San Francisco 96301 1

Commander
US Army Europe
ATTN: AEAGC-ND
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Commander
US Army Alaska
ATTN: ARACD
APO Seattle 98749 1

Commander
MASSTER
ATTN: Materiel Test Directorate
Fort Hood, TX 76544 1

Commander
US MAC-T & JUSMAG-T
ATTN: MACTRD
APO San Francisco 96346 2

Senior Standardization Representative 1
US Army Standardization Group, Australia
c/o American Embassy
APO San Francisco 96404

Senior Standardization Representative 1
US Army Standardization Group, UK
Box 65
FPO New York 09510

Senior Standardization Representative 1
US Army Standardization Group, Canada
Canadian Forces Headquarters
Ottawa, Canada KIAOK2

Director 1
Air University Library
ATTN: AUL3T-64-572
Maxwell Air Force Base, AL 36112

Battelle Memorial Institute 1
Tactical Technical Center
Columbus Laboratories
505 King Avenue
Columbus, OH 43201

Defense Documentation Center (ASTIA) 12
Cameron Station
Alexandria, VA 22314

Commander 2
Aberdeen Proving Ground
ATTN: STEAP-TL
Aberdeen Proving Ground, MD 21005

Commander 1
US Army Edgewood Arsenal
ATTN: SMUEA-TS-L
Edgewood Arsenal, MD 21010

US Marine Corps Liaison Officer 1
Aberdeen Proving Ground, MD 21005