THE UNIVERSITY OF MICHIGAN

College of Engineering
Department of Naval Architecture and Marine Engineering
Ship Hydrodynamics Laboratory

RESULTS OF MODEL STILL WATER RESISTANCE TESTS ON A 782 ft. LBP TANKER WITH SEVERAL BULBOUS BOWS

by
J. L. Moss

for
Chevron Shipping Company
555 Market Street
Room 1546
San Francisco, California 94120

Administered through:

June 1968

OFFICE OF RESEARCH ADMINISTRATION · ANN ARBOR

08253

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Summary

This report is a summary of three testing programs carried out by The Ship Hydrodynamics Laboratory for the Chevron Shipping Company on a 1/50 scale model of 782 ft. LBP Oil Tanker for the purpose of designing of a large protruding bulbous bow which would decrease the resistance in the full load condition as well as in a realistic ballast condition.

In the fall of 1966, resistance tests were run on the model equipped with a conventional bow and with two alternate bulbous bow designs. In the winter of 1967, two additional bulbous designs were evaluated and in the winter of 1968, some previous tests were repeated and a fifth bulb was designed and tested. Each configuration was tested in the fully laden condition and in a ballasted condition. Details of all test conditions are given in Table I and lines of all bulbs will be forwarded separately.

While the results of the third phase of the program, carried out as a student project, did not produce satisfactory resistance reductions with the fifth bulb, B5, the following observations were made:

1. Ballast Condition

   The merits of a bulb in ballast condition are highly dependent on trim as well as on the percent of full load displacement. At the different trims tested, the same bulb, B4, in nearly the same percent ballast condition, required a difference in effective horsepower of 16 percent at 17 knots. The test conditions were:

% Full Load Displacement	% LBP Stern Trim
57.2	2.5
60.0	1.2

(In another case in the laboratory files the difference was 18 percent.)

Even without a bulb the power required is dependent on trim, although not as much as with a bulb. With a conventional bow, in the 57% displacement condition, 8.0% more power was required at 17 knots than in the 60% displacement condition.

In the first two phases of the model testing program the 60% ballast condition was used since that condition was one in which one of the ships built to the design in question had gone on trials, based on information supplied to the Laboratory at the outset of the project. A subsequent letter received was critical of the use of the 60% condition and a list of eight other conditions was suggested. From among the eight alternative conditions the 57% condition was selected as being representative.

At 18 knots where the effective horsepower in the 60% ballast condition is about the same as at 17 knots in full load with the conventional bow, bulb B4 reduced effective horsepower over that required with a conventional bow by about 13% in the 60% condition but only by about 7.0% in the 57% condition.

In summary, the third phase of the project included tests in the 57% ballast condition with bulb B4 and the conventional bow, which clearly demonstrated the powering penalties associated with large amounts of stern trim when compared to the test results of the second phase in the 60% condition with the same bow configurations. It is interesting to note that other information in the Laboratory files indicates that oil tankers in 55-60% ballast conditions normally operate with about 1.5% LBP stern trim. There are few, if any, cases of the stern trim exceeding 2.0%.

2. Full Load

Large bulbous bows are usually most effective in reducing resistance of oil tankers in the ballast conditions, but also reduce resistance in full load conditions by several percent. However, results on the first four bulbous designs indicated no powering improvements in the full load condition. In the opinion of the writer, this should have been viewed as very unusual and cause for skepticism regarding the conventional bow results since the results with bulbs were consistent with changes in bulb size.

In the third phase of the program, full load condition tests were repeated with the conventional bow and bulb B4. There were negligible differences when the results with bulb B4 were compared, but the model resistance with the conventional bow was not repeatable. The new results were significantly higher, about 9% effective horsepower at 17 knots. Therefore, bulb B4 reduced the effective horsepower over that of the conventional bow by 7.5% at 17 knots, a finding consistent with others in the Laboratory files.

Conclusions and Recommendations

On the basis of the results of sixteen model tests which were run it may be broadly concluded that:

a. Of the five bulbous bows tested, bulb B4 yielded the best results considering both ballast and full load conditions.

b. Worthwhile reductions in effective horsepower, on the order of several percent, have been obtained in the full load condition.

c. Substantial reductions in effective horsepower, up to 15%, have been obtained in ballast condition, but stern trim should not be excessive if these reductions are to be realized.

d. It may be advisable to test additional ballast conditions which would encompass a range of percent displacements and trims in order to indicate more clearly bulb benefits within the range of normal operating conditions.

e. The design and model testing of yet another bulb design, taking into account the results to date and desired operating conditions, including percent time in full load and ballast, ballast drafts fore and aft and propulsion operating changes due to increased ship speed with a bulb, might further reduce powering requirements. It is recommended that a brief study be undertaken, the purpose of which would be to determine possible benefits of another bulb configuration.

The remainder of this report includes the detailed information of test conditions and results for the complete program.

Model and Tests

The model was built of sugar pine to a linear scale of 1:50 from drawings supplied by the Chevron Shipping Company. The design has been referred to as the "Uddevalla" class of tanker hulls, a number of which are in existence. Therefore, the project involved bulb designs which could merely be appended without requiring modifications of the existing hulls. Furthermore, all added volume was kept forward of station 1.5. For the model, replaceable bow inserts were constructed for the conventional bow and the several bulbs.

Turbulent flow was stimulated by a girth wire located 5% LBP aft of the FP and by small studs on the bulbs. An additional girth wire, placed near the stern shoulder, had the effect of reducing transient fluctuations in the measured total resistance.

Complete test conditions are listed in Table I as well as the details of the extrapolation procedure used.

Results

Effective horsepower predictions versus speed in knots are given in Figs. 1-3 for the full load, ballast and 57% ballast conditions, respectively. Figs. 4 and 5 show the percentage change in power with the conventional bow due to the addition of the various bulbs.

In the full load condition all the bulbs reduced the effective horsepower required at speeds near the design speed of 17 knots. In fact, at 17 knots all bulbs except bulb B5 reduced the effective horsepower by nearly the same amount, about 6 percent. At that and higher speeds bulb B4 gave the best results, although somewhat better results were obtained with bulb B2 through the speed range of from 15 to 17 knots. Assuming the constant effective horsepower of 15,800 required by the ship equipped with a conventional bow, the ship may be expected to attain a speed of 17.3 knots fully loaded and with bulb B4. The actual speed gain may be somewhat different because the propulsive coefficient will vary somewhat with speed.

Bulb B4 also gave the best results in the ballasted conditions. Again assuming constant effective horsepower, the speed would be 18.7 knots with bulb B4 in the 60% ballast condition. With the conventional bow the speed would be 17.9 knots. In terms of power reduction, bulb B4 reduced the effective horsepower by 16 percent at 18.7 knots in the 60% ballast condition.

In the 57% ballast condition only bulbs B4 and B5 and the conventional bow were tested.

Poor results were obtained with bulb B5 owing to its large size but a speed of 17.9 knots would be obtained with bulb B4 at 15,800 effective horsepower. The advisability of operating the ship in the 60% condition in preference to the 57% condition is made evident by the 0.8 knot higher speed possible in the 60% condition.

The method of predicting increased speeds due to the bulbs suffers from the assumptions of unchanging propulsive coefficient with bow configuration, speed and load conditions. Also, the ship's machinery may not permit the higher shaft revolutions which may be required by the higher speeds. It has been demonstrated that bulbous modifications to a hull form tend to increase propulsive efficiency.* In any case, average speed gains in ballast and full load conditions on the order of 0.5 knots or more should be possible with the installation of bulb B4.

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* Couch, R. B. & J. L. Moss , "Application of Large Protruding Bulbs to Ships of High Block Coefficient," TSNAME, 1966.

TABLE I

Test Conditions, Full Scale Values

Scale Ratio 1:50

Test No	Bow Condi-tion	% Full Load Dis-placement	Test Date	LBP, Ft.	B Ft.	T_E Ft.	T_A Ft.	S Sq. Ft.	Δ LTSW	$\frac{A_{FP}}{A_X}$
1	CV	100	9/26/66	782.0	116.0	42.88	42.88	131,200	88390	0
2	CV	60	10/4/66					103,400	53030	----
3	B1	100	10/11/66			42.88	42.88	133,500	88820	10.1
4	B1	60	10/11/66					105,600	53290	----
5	B2	60	11/9/66					105,500	53250	----
6	B2	100	11/11/66			42.88	42.88	133,300	88750	8.6
7	B3	60	1/23/67					105,500	53260	----
8	B3	100	1/23/67			42.88	42.88	133,300	88770	8.1
9	B4	100	2/10/67			42.88	42.88	133,100	88570	~7.6
10	B4	60	2/10/67					105,300	53140	----
11	B4	100	1/17/68			42.88	42.88	133,100	88570	~7.6
12	B4	57	1/18/68			16.00	35.50	105,800	50710	----
13	CV	100	2/13/68			42.88	42.88	131,200	88390	0
14	CV	57	2/17/68			16.00	35.50	103,800	50590	----
15	B5	100	3/8/68			42.88	42.88	133,800	89140	15.3
16	B5	57	3/8/68			16.00	35.50	107,000	51020	----

Extrapolation based on a.) 1947 ATTC friction coefficients, b.) C_A = 0.0001, c.) 59°F S.W., d.) No appendages, e.) standard blockage correction, f.) length = LBP = 782.0 ft.

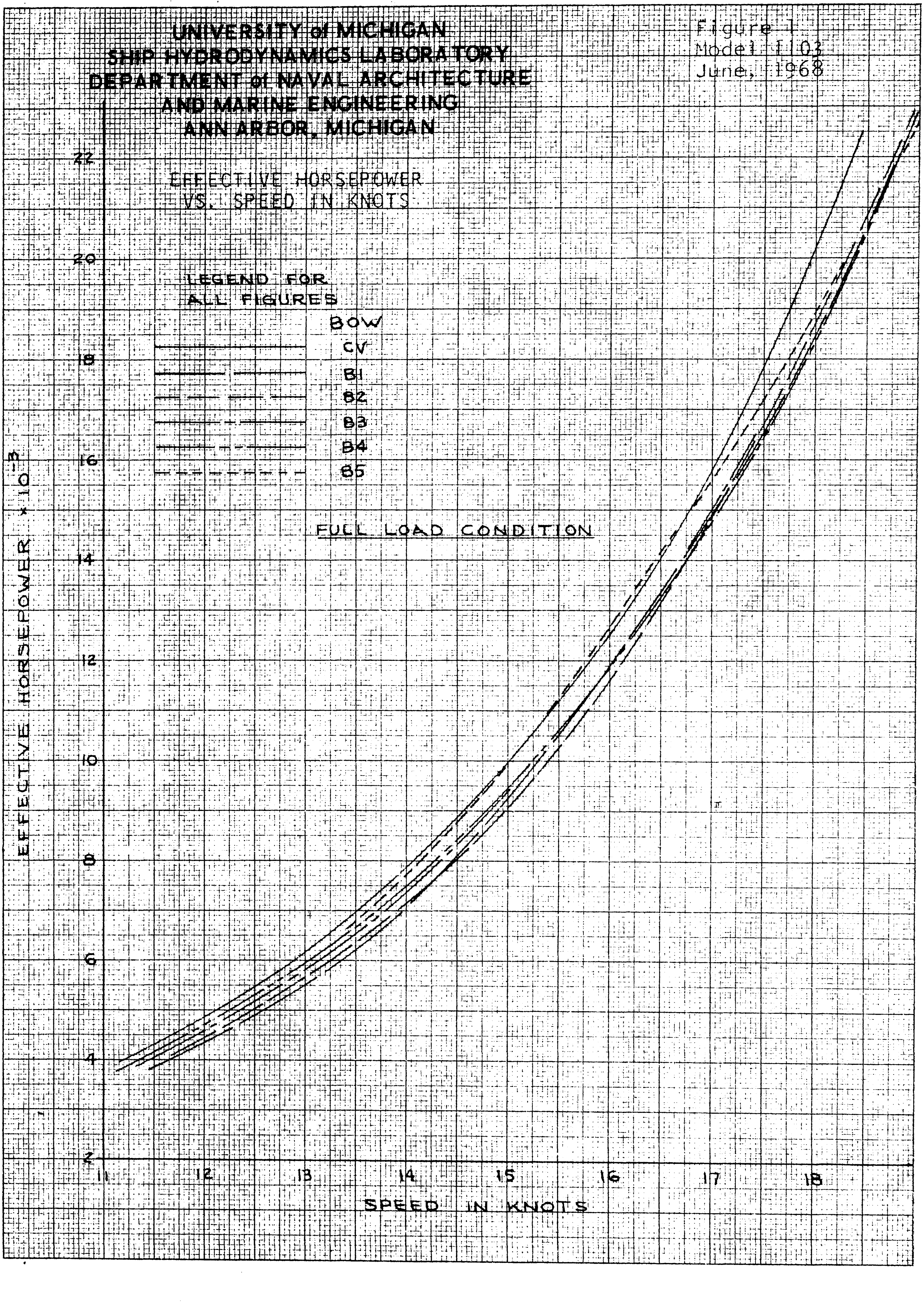
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Figure 1
Model 1103
June, 1968
EFFECTIVE HORSEPOWER
VS. SPEED IN KNOTS
LEGEND FOR
ALL FIGURES
BOW
CV
B1
B2
B3
B4
B5
FULL LOAD CONDITION
EFFECTIVE HORSEPOWER × 10^-3
22
20
18
16
14
12
10
8
6
4
2
11
12
13
14
15
16
17
18
SPEED IN KNOTS

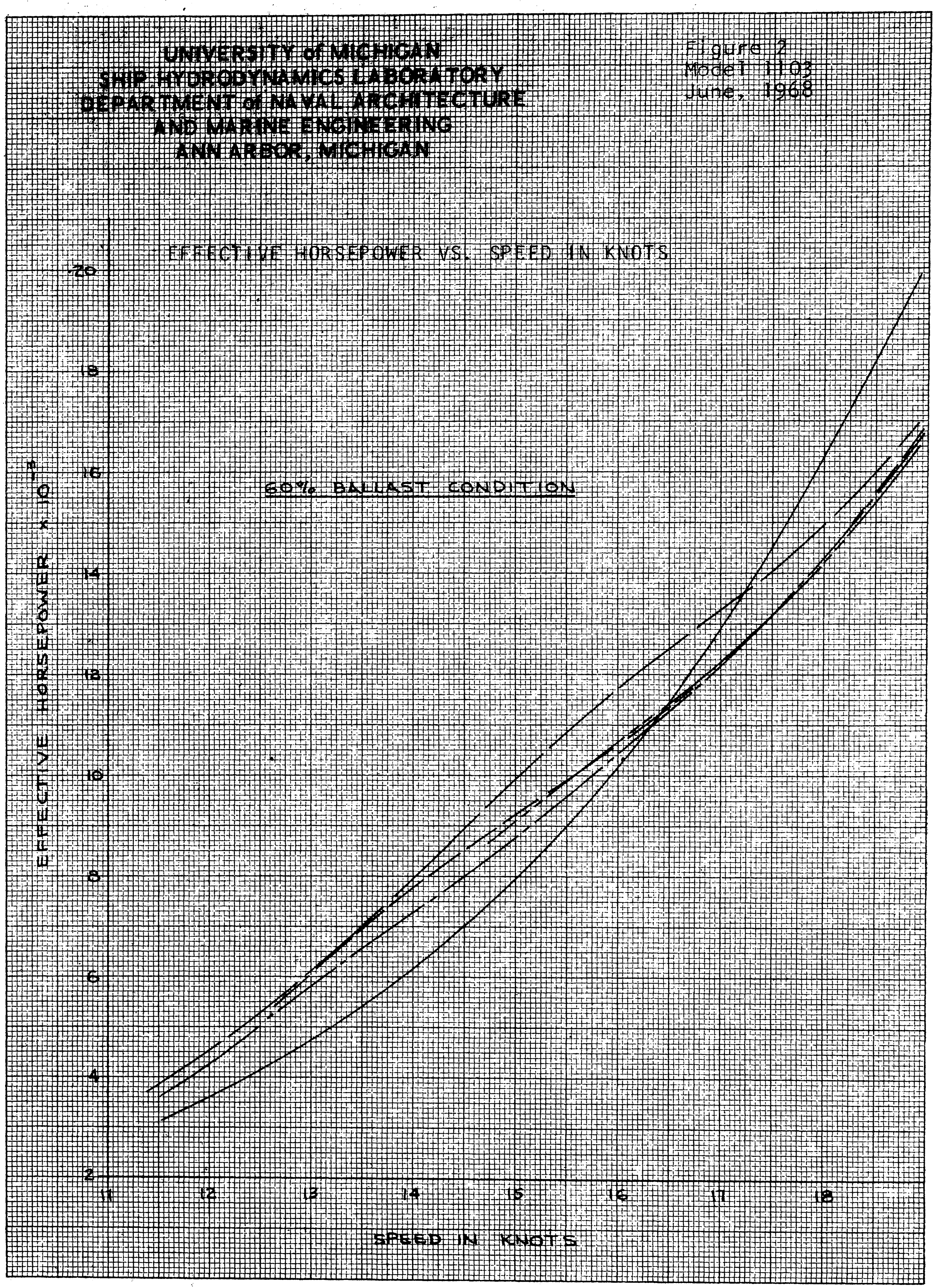

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Figure 2
Model 1103
June, 1968
EFFECTIVE HORSEPOWER VS. SPEED IN KNOTS
60% BALLAST CONDITION
EFFECTIVE HORSEPOWER x 10⁻³
SPEED IN KNOTS
20
18
16
14
12
10
8
6
4
2
11
12
13
14
15
16
17
18

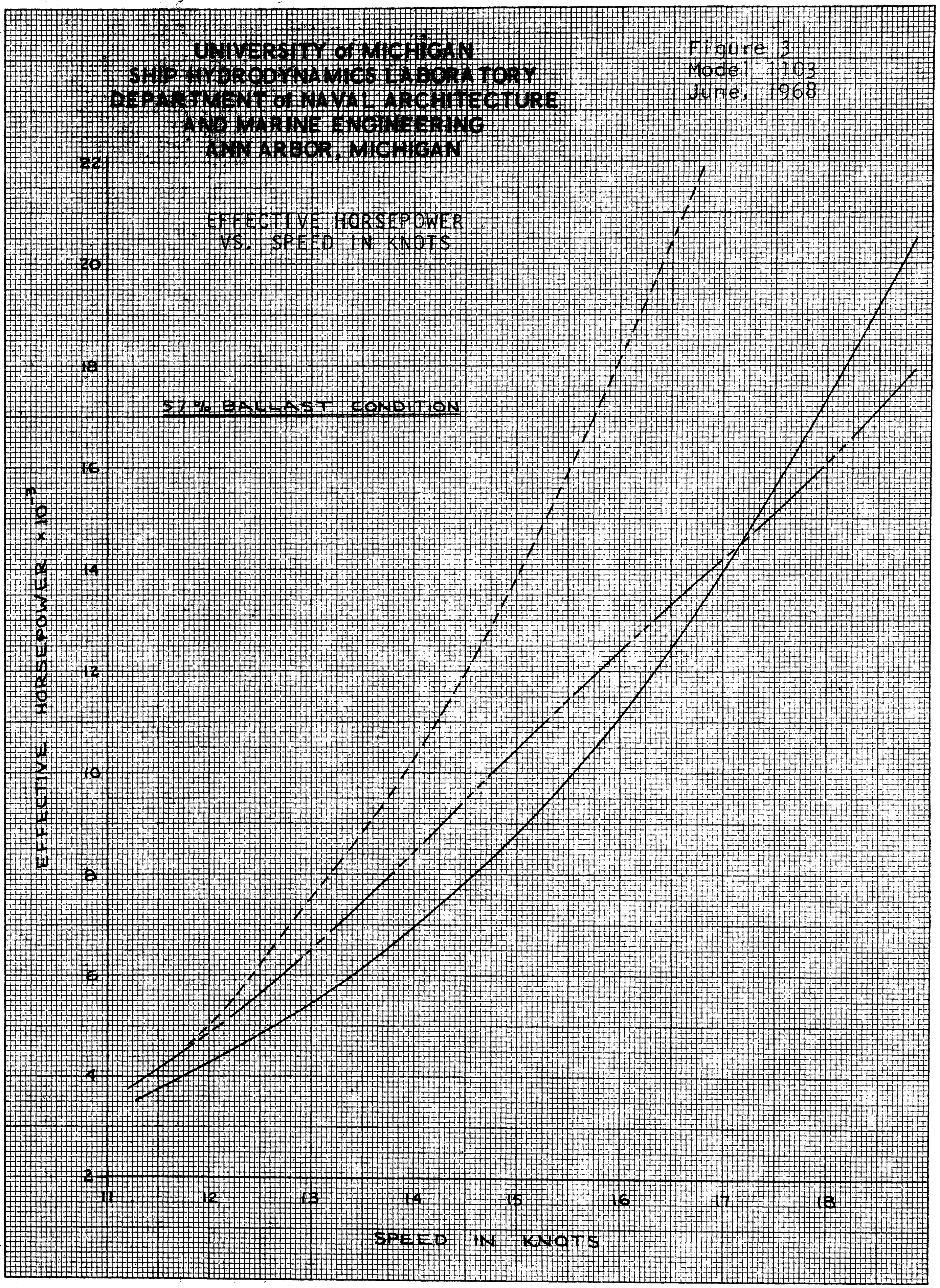
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Figure 3
Model 1103
June, 1968
EFFECTIVE HORSEPOWER
VS. SPEED IN KNOTS
57% BALLAST CONDITION
EFFECTIVE HORSEPOWER x 10^-3
SPEED IN KNOTS
2
4
6
8
10
12
14
16
18
20
22
11
12
13
14
15
16
17
18

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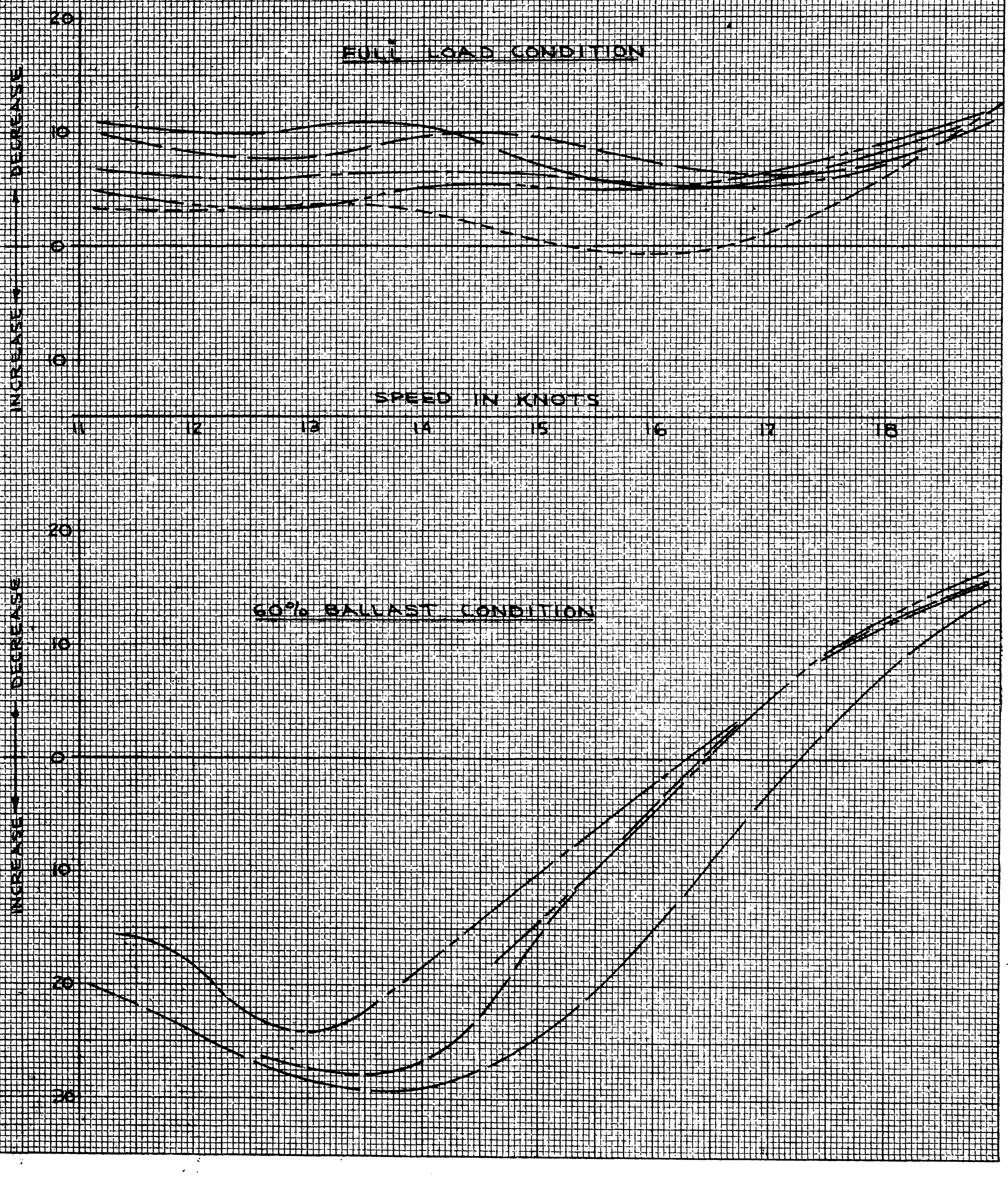
Figure 4
Model 1103
June, 1968

PERCENT CHANGE IN CONVENTIONAL BOW EFFECTIVE
HORSEPOWER DUE TO BULB vs. SPEED IN KNOTS



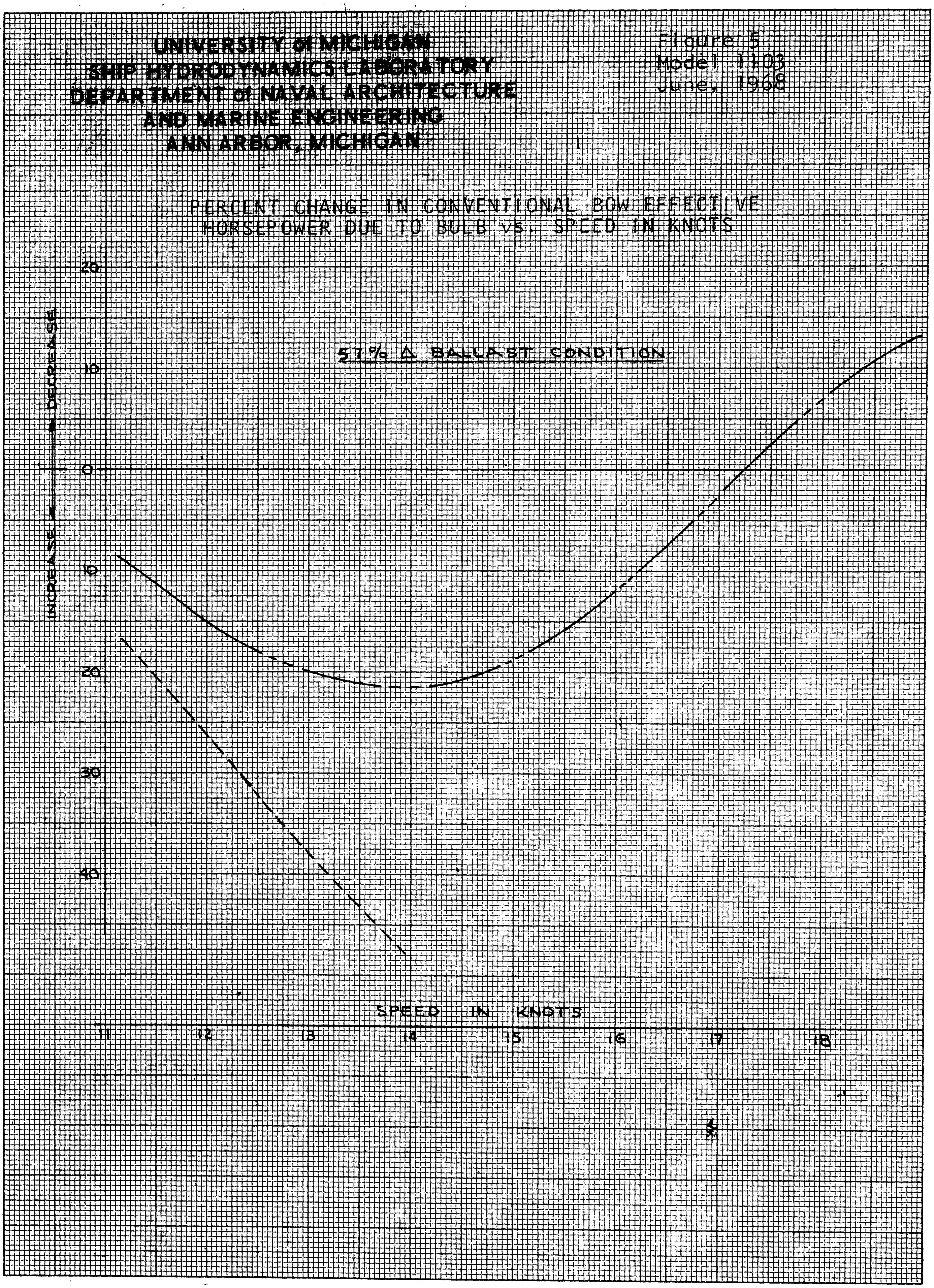

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Figure 5
Model 1103
June, 1968
PERCENT CHANGE IN CONVENTIONAL BOW EFFECTIVE
HORSEPOWER DUE TO BULB vs. SPEED IN KNOTS
57% Δ BALLAST CONDITION
INCREASE ← → DECREASE
20
10
0
10
20
30
40
SPEED IN KNOTS
11
12
13
14
15
16
17
18