THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING
Department of Naval Architecture and Marine Engineering
Ship Hydrodynamics Laboratory

Final Report

RESISTANCE AND PROPULSION TEST RESULTS ON TWO C_B = 0.60 MERCHANT HULL GEOSIMS

J. L. Moss

Project Director: R. B. Couch

Under contract with
U. S. Department of Commerce
Maritime Administration
Contract No. MA2564 Task 6
Washington, D. C.

Administered through: June 1967

OFFICE OF RESEARCH ADMINISTRATION · ANN ARBOR

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Introduction

Over the past several years, under contract with the Maritime Administration, The University of Michigan Ship Hydrodynamics Laboratory has undertaken resistance and propulsion tests of a number of merchant hull forms. One principal aim of this work has been to establish a source of ship model propulsion testing for use by government and industry. Therefore, the intent of the work has mainly been to determine the degree of correlation of results between Michigan and the David Taylor Model Basin.

The contents of this report review the history of the past testing programs, present the results of the latest series of experiments and discuss these results in context with those previously obtained from the standpoint of correlation.

Review of Past Work

All of the tests reported to date were run on 14 ft. L_{PP} models, a size chosen so that the model propeller diameters would be at least six inches and the model hulls not unduly large. It was intended that blockage effects should be minimized without propulsion scale effects becoming serious. The first results reported were of Series 60, C_B = 0.60, 0.75(1) and 0.80(2), parent hull forms. Correlation with DTMB predicted P_S was fairly good, and there was evidence of only minor scale effects among individual propulsive parameters.(3)

Based on the apparent validity of the first results, a Task Order was established to design and test a series of 14 ft. L_{PP} "V" sectioned hull forms which were geometrically related to Series 60. Five models were constructed, with C_B = 0.60 - 0.80 in 0.05 increments, and still water resistance and propulsion experiments were conducted on each. When finally reported the results exhibited differences in predicted power from the parent form counterparts greater than anticipated.(4) Almost simultaneously equally disturbing results were obtained on a model of one of the versions of the Maritime Administration's design PD-108.(2) Scale effects on individual propulsive parameters greater than exhibited in previous test results were noted.

Present Work

From the work reviewed above it was concluded that generally larger models might be required in order to satisfactorily correlate results with those obtained at DTMB. If the discrepancies found were created by propeller scale effects, it was reasoned that larger models might reduce the effects to a reasonable minimum and that the blockage incurred by the larger ship models might still be adequately corrected. On this basis a new task was funded and 17 ft. L_{PP} models of Series 60 parent and "V" forms, C_B = 0.60, were constructed and tested. Simultaneously, a 20 ft. L_{PP} model of the C_B = 0.60 "V" was constructed and tested at DTMB for correlation purposes. Two geosim series resulted, one of the parent and one of the "V" form, each with between perpendicular lengths of 14, 17 and 20 ft. Subsequently, new, more accurately built propeller models were obtained for use with all the Michigan models all four of which were run with the old and new propellers. This was decided upon in order to demonstrate the differences found owing to the inexact replicas of the original DTMB parent propeller.

The present report publishes the results of the 14 ft. and 17 ft. models with old and new propellers and compares these results with those of DTMB found with 20 ft. models. Also, the effect on correlation owing to two different readily acceptable methods of extrapolation of model results to full scale is demonstrated. It should be mentioned that in past reports all results were compared with those of DTMB using identical data analysis and extrapolation procedures insofar as possible. The only exception has been in the blockage corrections used on the Michigan data. This procedure was followed so that all differences in predictions would be functions of scale effects only, although no attempts were made to scientifically deal with these effects. In the present report both the A.T.T.C. and I.T.T.C. friction lines have been used on the results from one of the 17 ft. models whereas in the past only the American line has been used. The additional use of the International line here does not necessarily present a method of scale effect correction but serves merely to demonstrate the effect on correlation of the use of a somewhat different extrapolation method.

Models

The following tables identify the hull models used in the two geosim series and the various propellers used on these models.

HULL MODELS

Series 60, C_B = 0.60 parent form		Series 60, C_B = 0.60 "V" form	
L_{PP} (ft.)	Model No.	L_{PP} (ft.)	Model No.
14.000	912 & 1089	14.000	924
17.000	976	17.000	1020
20.000	4210	20.000	4969

The 20 ft. models were tested at DTMB. All others were tested at Michigan. Unfortunately, before being tested with propeller 23 model 912 was damaged and rendered useless for further testing. It was replaced with model 1089 and tests were run to determine if the previous results obtained with model 912 were repeatable. They were.

PROPELLER MODELS

Old	New	Tested with Models
1		912, 924
	23	1089, 924
14		976, 1020
	24	976, 1020
3378		4210, 4969

Figure 9 shows the open water characterizations for all propellers used. Generally, the new Michigan propellers and the DTMB propeller 3378 have characteristic curves in fairly good agreement but the older Michigan propellers do not correlate well. Discussion of propeller construction and test accuracy is given in the appendix.

Restricted Channel Effects and Data Analysis

Blockage corrections have been made to all tests. Although there is a regularly used restricted channel correction made to the test data at the Michigan model basin,[3] the correction used for the tests reported here was somewhat different. For each model, the resistance of that model was compared to the resistance of the DTMB parent reduced to either 14 ft. or 17 ft. L_{PP}. The difference in resistance was treated as a restricted channel increment thereby ignoring any other effects present such as small scale effects induced by the friction lines or the normal differences in results from one model basin to another. This procedure produced similar resistance increment corrections for the 17 ft. L_{PP} models, and somewhat smaller corrections for the 14 ft. models.

In carrying out the propulsion tests and analyzing the data blockage corrections as obtained above were included. The blockage correction was added to the "D_F" towing force applied to the model in the "Continental Method" of conducting model propulsion tests. Otherwise the data was analyzed as usual. That is, the A.T.T.C. line was used except in one case where I.T.T.C. was also used as indicated on Figure 3. Throughout the correlation allowance was C_A = 0.0004.

Figure 11 exhibits the effects of the blockage correction normally used in the case of the 17 ft. models. This is included in order to demonstrate the differences in power predictions which would have been incurred had the usual correction been used.

Results

Generally, the results will be discussed by comparison of Michigan and DTMB predictions, both using the A.T.T.C. line with $C_A = 0.0004$. The question of extrapolation procedure will be taken up separately. Also comparisons will be made only with the newer Michigan propellers (no. 23 for the 14 ft. models and no. 24 for the 17 ft. models) since the open water characterizations for these propellers agreed fairly well with those of the parent 3378.

Old and New Propeller Models

However, two remarks should be made with regard to the old and new propeller models. Differences in predicted RPM between old and new propellers on all four Michigan ship models are consistent with the inaccurate pitch of propellers 1 and 14. For example propeller 1 was about seven percent over-pitched at the 0.7R compared to its newer counterpart (propeller 23) and the DTMB propeller 3378. Consequently, Figure 1 shows that propeller 1 turned a few RPM slower, full scale, than did propellers 23 and 3378.

Another consistent finding with regard to the two sets of propeller models is that since the newer ones had higher open water efficiencies in the operating ranges of advance coefficients, the propulsive coefficients are also higher with propellers 23 and 24. For example from Figure 9 propeller 24 has higher open water efficiency than propeller 14 by seven percent at an advance coefficient of 0.77. From Figure 3 for model 976 the higher open water efficiency is exhibited as a three to four percent increase in overall propulsive efficiency near design speeds. The balance is compensated for in the relative rotative and hull efficiencies.

Shaft Horsepower and RPM Predictions

The predicted shaft horsepower from the two 17 ft. models is shown in Figures 3 and 7. In both cases, "U" and "V", the results compare with those predicted by DTMB within about two to four percent in the speed range of most interest, 20 to 21 knots. Considering the complete speed range slightly better average correlation, two to three percent, was obtained with both models. Fig. 10 shows the actual percentages plotted over the complete speed range.

As explained in a preceding section, blockage was accounted for in both resistance and propulsion test data analysis by enforcing predictions of effective horsepower equal to those predicted by DTMB. Figure 11 illustrates that had the usual Michigan blockage correction been used that the predicted shaft horsepower from the tests of model 976 would have been slightly lower, commensurate with about one percent reduction in effective horsepower prediction. That is, the amount of blockage corrected would have been slightly in excess of that necessary for agreement with DTMB in effective horsepower prediction. While the shaft horsepower correlation would have improved, the propulsive efficiency would have improved only slightly owing to minor propeller unloading. Similar remarks apply to the "V" hull blockage shown in Figure 11 except that in the 20 knot range the usual correction would have been insufficient. Therefore, correlation of the shaft horsepower prediction of model 1020 with that of model 4969 would deteriorate slightly compared to the results shown in Figure 7. However, at slower speeds the effect of the blockage correction would be the same for "U" and "V". Obviously there is need for more accurate blockage corrections.

Figures 1 and 5 show similar results for the 14 ft. "U" and "V" models, respectively. As mentioned in a previous section of this report the correlation with the 14 ft. "U", models 912 and 1089, is rather good while that of the 14 ft. "V", model 924, is poor. Even with the aid of the more efficient propeller 23 there is still an 11 percent discrepancy in shaft horsepower at 20 knots when compared to the results obtained with model 4969. Likewise, comparison of predicted shaft horsepower between the 14 and 17 ft. "U" forms at 20 knots shows much better agreement than a similar comparison of "V" forms.

Relative to the results of all other models in the two geosim series those of model 924 are unacceptable. Even with review of the past several years' effort no rational explanation can be offered except that extreme flow dissimilarities may exist at the 14 ft.

size in the "V" geosim. The individual propulsive parameters shown in Figure 6 do not help to clarify the matter. Rather oddly the relative rotative efficiency was reduced markedly by the new propeller which, in turn, compensated for that in increased open water efficiency. Irregardless of which propeller was used on model 924, the hull efficiency was poorer than with model 4969, the combination resulting in poorer propulsive efficiency. These apparent scale effects show that 14 ft. model lengths may be unreliable in specific cases and unfortunately cast doubt on the validity of all propulsion results of the "V" series tested at Michigan.

Propulsive Factor Scale Effects

The main purpose of the work which is the subject of this report has not been to study scale effects but rather to evaluate correlation. However, geosim tests have traditionally been used to examine the scaling of wake fractions and thrust deduction factors. A few observations are therefore offered. One part of Reference 3 reviewed the current knowledge of propulsive parameter scale effects taking into account results of early Series 60 tests conducted at Michigan. Although it was pointed out in that report that very little scientific knowledge on the subject is in the literature, particularly with regard to thrust deduction factor, the Michigan results conformed fairly well to the pattern of geosim comparisons and scale effects on wake and thrust deduction exhibited by the Michigan data were small. Similar conclusions can be drawn relative to the results in Figures 2, 4 and 8 of this report. Variations in average values of wake fraction and thrust deduction factor seldom vary by more than two or three points in going from the 14 ft. model size to 20 ft. What variations that do exist are similar to the results reviewed in Reference 3. That is, somewhat heavier wakes are exhibited on the smaller models and thrust deductions are greater or about the same. Although the Dutch "Victory Ship" and the "Albacore" data show increasing thrust deduction with increasing size there is an equal amount of data which shows the opposite trend. Therefore, those scale effects which are exhibited in this report are considered unimportant except in the case of model 924 which has already been discussed.

Method of Extrapolation

Since, in analyzing test data in the previous reports, the method of extrapolation has been identical to that used at DTMB in order that the differences in results would tend to indicate the degree of scale effects and normal differences from one model basin to another no attempt has been made to date to demonstrate the effect on correlation of a different extrapolation procedure. The A.T.T.C. friction coefficients with $C_A = 0.0004$ have always been used. However, in this report Figure 3 shows additional curves of P_S, RPM and η_D obtained by use of the I.T.T.C. coefficients with $C_A = 0.0004$. To obtain these curves prediction of effective horsepower equal to that of DTMB has again been enforced. This time, however, P_E from the 17 ft. model was obtained with use of the I.T.T.C. line and from the 20 ft. model with the A.T.T.C. line. This procedure is not inconsistent in that the measure of shaft horsepower correlation is still valid. The alternative method would have been to extrapolate both 17 ft. and 20 ft. results using the I.T.T.C. still enforcing equal effective horsepower predictions. However, the difference in predicted shaft horsepower would be nearly the same with either method. The procedure used still demonstrates the manner in which the I.T.T.C. line favors the smaller model.

For model 976 use of the I.T.T.C. line improves the correlation by about one to two percent so that predicted shaft horsepower from the 17 and 20 ft. models differs by about two to three percent at speeds above 19 knots and at lower speeds correlation is somewhat better. The effect of using the international line on the predictions from the 17 ft. "V", model 1020, would be about the same.

Conclusions

The following conclusions are drawn based on the results presented in this report as well as all of the work which has preceded the 17 ft. model tests. Recommendations are included with regard to the degree of correlation generally obtainable at the Michigan laboratory as it affects future work.

1. Model sizes should be about 17 ft. for conventional ship forms. Smaller models present the risk of non-correlation in some cases the reasons for which cannot be explained solely as propulsion scale effects although evidence of such effects does exist. Seventeen foot models exhibit only negligible scale effects on wake fraction and thrust deduction factor. For other ship types, hull model sizes should be adjusted to compensate for resulting propeller model sizes.

2. The extrapolation procedure should be based on the I.T.T.C. friction coefficients since correlation can be improved by about one percent compared to use of the A.T.T.C. line. The possibility of the Michigan laboratory adopting slightly smaller correlation allowances should be considered since lower shaft horsepower predictions would result. Effective horsepower predictions would also be lower but to a lesser extent since propulsive efficiencies would increase owing to propeller unloading.

3. The data used to formulate the usual Michigan blockage correction should be reanalyzed based on the I.T.T.C. line (the correction is now based on the A.T.T.C. line) and newer data should be included in the analysis. This step, incorporated with adjusted correlation allowances, should improve both effective and shaft horsepower predictions. The possibility exists that even larger than 17 ft. models could be tested with an improved blockage correction available.

4. Propellers should be used which are more accurately constructed than the original Michigan propellers. Construction accuracy can account for two to four percent in shaft horsepower prediction.

5. No doubt at least some of the lack of correlation between Michigan and DTMB is owing to normal differences found from one laboratory to another. Minor differences in test procedure, dynamometry and human factors can be expected to cause a two to three percent discrepancy in power predictions.

6. With regard to past results from tests of 14 ft. models, validity cannot be guaranteed in all cases. However, it may be that propulsion predictions are acceptable in some cases. Particularly the C_B = 0.75 and 0.80 "V" models may have given good results but this can only be conjectured. If the need of accurate predictions for the "V" series forms is sufficiently important, it can be recommended that larger models be tested.

It is believed that adoption of the above recommendations would be sufficient to allow power predictions within two to three percent of those which might be otherwise obtained at DTMB.

Table 1

Ship Model Characteristics

	"U" Hulls				"V" Hulls			
Model No.	Full Scale	912 & 1089	976	4210	Full Scale	924	1020	4969
λ	-	42.857	35.294	30.000	-	42.857	35.294	30.000
LWL, ft.	610.05	14.235	17.285	20.335	610.05	14.235	17.285	20.335
L_{PP}, ft.	600.00	14.000	17.000	20.000	600.00	14.000	17.000	20.000
B, ft.	80.00	1.867	2.267	2.667	80.00	1.867	2.267	2.667
T (even keel), ft.	32.00	0.747	0.907	1.067	32.00	0.747	0.907	1.067
S, sq. ft., bare	61,380	33.42	49.27	68.20	62,170	33.85	49.91	69.08
Rudder	570	0.31	0.46	0.63	570	0.31	0.46	0.63
Total	61,950	33.73	49.73	68.83	62,740	34.16	50.37	69.71
Δ*	26,350	729.6	1306.3	2127.1	26,330	729.0	1305.3	2125.4

*L.T.S.W. @ 59°F full scale
lbs. F.W. @ 70°F model

Table 2

Propeller Model Characteristics

Prop. No.	Full Scale (design)	1	14	23	24	3378
D	22.40	6.272	7.616	6.229	7.605	8.960
P	24.08	7.194	8.218	6.742	8.464	9.632
P/D	1.075	1.147	1.079	1.082		1.075
A_E/A_O	0.550	0.550	0.550	0.550	0.550	0.550
MWR	0.261	0.261	0.261	0.261	0.261	0.261
BTF	0.045	0.045	0.045	0.045	0.045	0.045
Rake, deg.	6	6	6	6	6	6
Z	4	4	4	4	4	4
λ	-	42.857	35.294	42.857	35.294	30.000

Dimensions are in feet for full scale and inches for models.

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3. Kim, Hun Chol, Moss, James L., "Research in Resistance and Propulsion: Part III. Blockage Correction in a Ship Model Towing Tank and Scale Effect on Propulsive Parameters," Department of Naval Architecture and Marine Engineering, The University of Michigan, Report 04542-3-F, March 1963.

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5. Weaver, Jr., A. H., "Powering Characteristics of Two V-Bow Variations for Series 60, 0.60 C_B, Compared to the Parent, TMB Models 4964, 4210, and UM Model 924", David Taylor Model Basin, Report 1812, January 1964.

6. Todd, F. H., "Series 60, Methodical Experiments with Models of Single-Screw Merchant Ships," David Taylor Model Basin, Report 1712, July 1963.

APPENDIX

Propeller Construction and Test Accuracy

The same discrepancies in propulsion test results which prompted the geosim tests discussed in the main body of this report also instigated a review of model propeller construction and testing accuracy at Michigan. Over a period of time three propellers were chosen for section measurements at DTMB. Two of these propellers, Nos. 1 and 14, were those used on the 14 ft. and 17 ft. ship models, respectively, reported in the main text. The third propeller, No. 12 was used on the 14 ft. model of PD-108. The sections of these propellers were all measured at DTMB as well as their parent counterparts. Propellers 23 and 24 were measured at Michigan.

In addition, propeller 12 was tested in open water at DTMB. Fig. A-1 shows the results of the open water tests at The University of Michigan and at DTMB for propeller 12 as well as DTMB results for propeller 3566, the latter used on the parent PD-108. In the operating range of advance coefficient there is good agreement between the two tests. At both higher and lower advance coefficients there is some lack of correlation which may be owing to instrumentation differences at the two laboratories and the section discrepancies. noted in Table A-2.

Figs. A-2 through A-6 show the section measurements for propellers 1, 14, 3378, 23 and 24, respectively. In each case the propeller in question is compared to the intended design which for all five propellers is the same. Generally, the main difference between propellers 1 and 14, manufactured at The University of Michigan, and 3378 is that the former have larger leading edge radii and the angle of the trailing edge is somewhat greater. The effect of the leading edge discrepancies is to decrease the section camber about 15%. Hence, the lift of the sections might be somewhat decreased, but due to the overall increase in thickness torque measurements should increase. The latter might be further aggravated if separation occurs at the comparatively blunt trailing edges. Efficiency then should be expected to be diminished which is the case as shown in Fig. 9 in the main body of this report. Generally the sections of propellers 23 and 24 are more accurately constructed than their respective 1 and 14 counterparts. This is particularly true at the 0.7R radii and with respect to camber and leading edge degree of bluntness. However, propeller 24 is over-pitched nearly as much as propeller 1. Consequently, the better correlation of open water characterization of propellers 23 and 24 with 3378 than that of propellers 1 and 14 is confirmed by the section measurements. The run-out values of thrust coefficient are not completely consistent with pitch differences among the various propellers. This indicates that the effects of P/D ratio and blade section shape are not independent which should be expected since propeller test results from systematic series with different section designs do not exhibit identical run-out values for the same P/D ratio.

With regard to open water Reynolds Number, all propellers were tested at a Reynolds Number at least 2.6×10^5. This corresponds, in the case of the Michigan propellers to rotary speeds of 1000 to 1200 RPM. These speeds are higher than experienced during SHP tests so as a matter of routine several runs are made in open water tests at rotary speeds comparable to those experienced behind ship models near design speeds. Normally, negligible differences in open water characteristics are found between the results of tests at different Reynolds Numbers.

Finally, in Fig. A-1, it is noted that small changes in the characteristics of propeller 3566 took place over a period of seven years. It is assumed that small retained stresses induced at the time of construction are gradually reduced over a period of years and that small thermal stresses occur during storage. In the process small pitch and/or section shape alternations may occur in time. In the operating range of advance constants the efficiency is either unchanged or varies an inconsequential amount. However, it is assumed that for the analysis of data on model 4969 the original curves for propeller 3378, published first in 1954, were used. Perhaps small changes, which would affect the results for model 4969, would have been found had the propeller been retested.

Table A-1

Propeller Model Characteristics

Prop. No.	Full Scale	12	3566
D	21.00	6.682	8.799
P	22.19	7.083	9.297
P/D	1.057	1.060	1.057
$AE/A0$	0.514	0.514	0.514
MWR	0.250	0.250	0.250
BTF	0.050	0.050	0.050
Rake, deg.	6.5	6.5	6.5
Z	4	4	4
λ	-	37.714	28.640

Dimensions are in feet for full scale and inches for models.

Table A-2

Table of Measurements for UM Propeller No. 12

measurements in 1/1000 ths of an inch;
negative sign indicates undersized

L.E. indicates leading edge.
T.E. indicates trailing edge.

		BLADE 1		2		3		4	
	r/R	L.E.	T.E.	L.E.	T.E.	L.E.	T.E.	L.E.	T.E.
FACE	0.3	ok	ok	ok	ok	ok	ok	ok	ok
	0.4	ok	ok	ok	ok	ok	ok	ok	ok
	0.5	-010	ok	ok	-020	-010		-020	ok
	0.6	ok	ok	-005		-010		-020	ok
	0.7		-004	-007		-010		-008	ok
	0.8		-005		-012	-008		-005	ok
	0.9		-004		-010	ok	ok	ok	ok
	0.95		-004		-010	ok	ok	ok	ok
BACK	0.3	ok	ok	ok	ok	ok	ok	ok	ok
	0.4	ok	ok	ok	ok	ok	ok	ok	ok
	0.5	ok	+020	ok	+020	+020		ok	ok
	0.6	ok	ok	+012		+025		ok	ok
	0.7	ok	ok	+015		+020		+005	ok
	0.8	ok	ok	+015		+012		ok	ok
	0.9	-005	ok	ok	+008	+008		-008	ok
	0.95	-020		ok	+005	ok	ok	-020	

FIGURES

1. P_E, P_S, RPM and η_D for 600 ft. L_{PP} from 14 ft. and 20 ft. "U" models.
2. Propulsive parameters from 14 ft. and 20 ft. "U" models.
3. P_E, P_S, RPM and η_D for 600 ft. L_{PP} from 17 ft. and 20 ft. "U" models.
4. Propulsive parameters from 17 ft. and 20 ft. "U" models.
5. P_E, P_S, RPM and η_D for 600 ft. L_{PP} from 14 ft. and 17 ft. "V" models.
6. Propulsive parameters from 14 ft. and 20 ft. "V" models.
7. P_E, P_S, RPM and η_D for 600 ft. L_{PP} from 17 ft. and 20 ft. "V" models.
8. Propulsive parameters from 17 ft. and 20 ft. "V" models.
9. Open water characteristics for propellers 1, 14, 23, 24 and 3378.
10. Ratios of P_S comparing 17 ft. and 20 ft. predictions for "U" and "V" hulls for 600 ft. L_{PP}.
11. Ratios of P_E comparing 17 ft. and 20 ft. predictions for "U" and "V" hulls for 600 ft. L_{PP} with and without blockage corrections.

A-1. Open water characteristics for propellers 12 and 3566.
A-2. Section measurements for propeller 1.
A-3. Section measurements for propeller 14.
A-4. Section measurements for propeller 3378.
A-5. Section measurements for propeller 23.
A-6. Section measurements for propeller 24.

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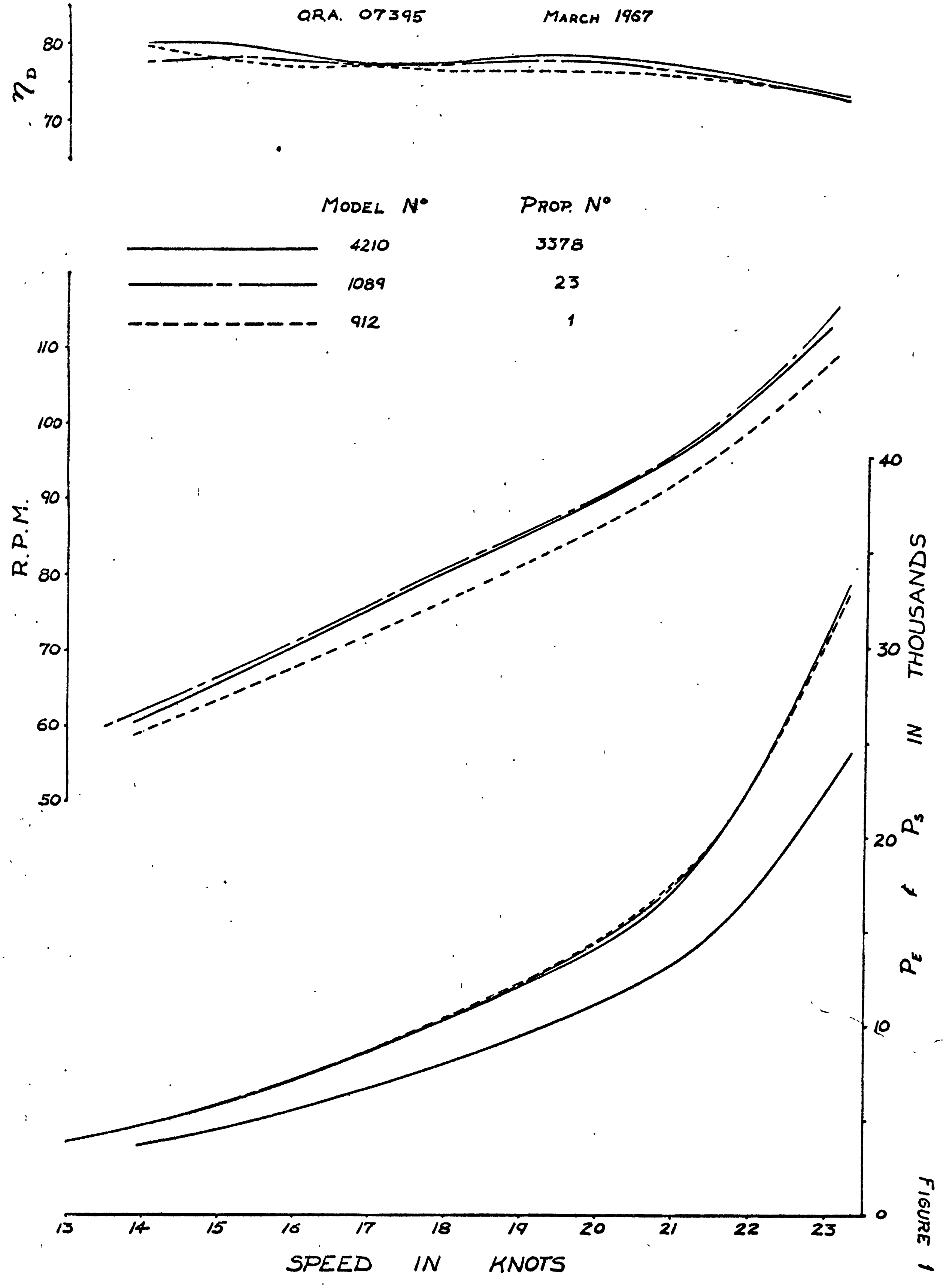

FIGURE 1

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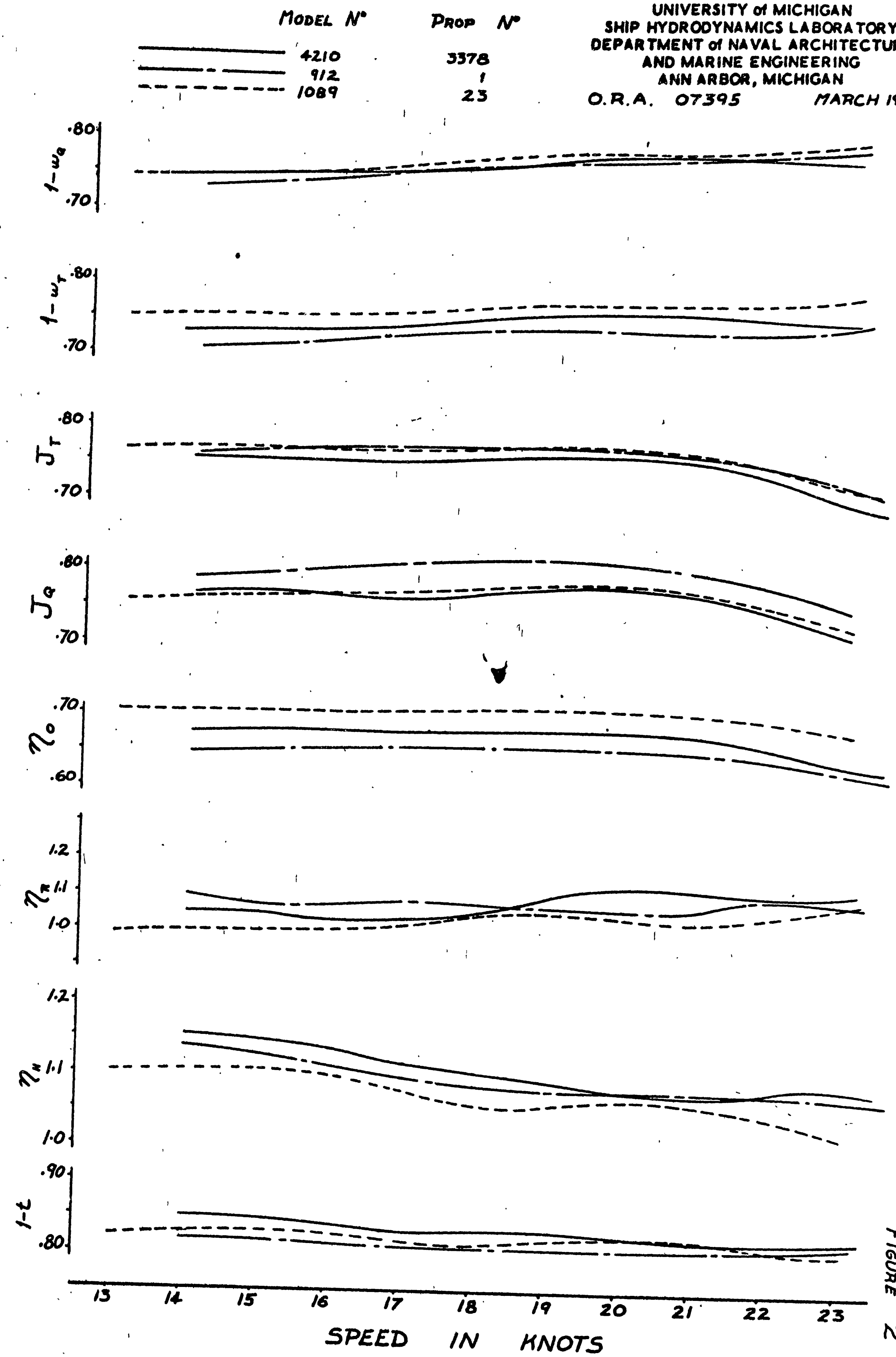

FIGURE 2

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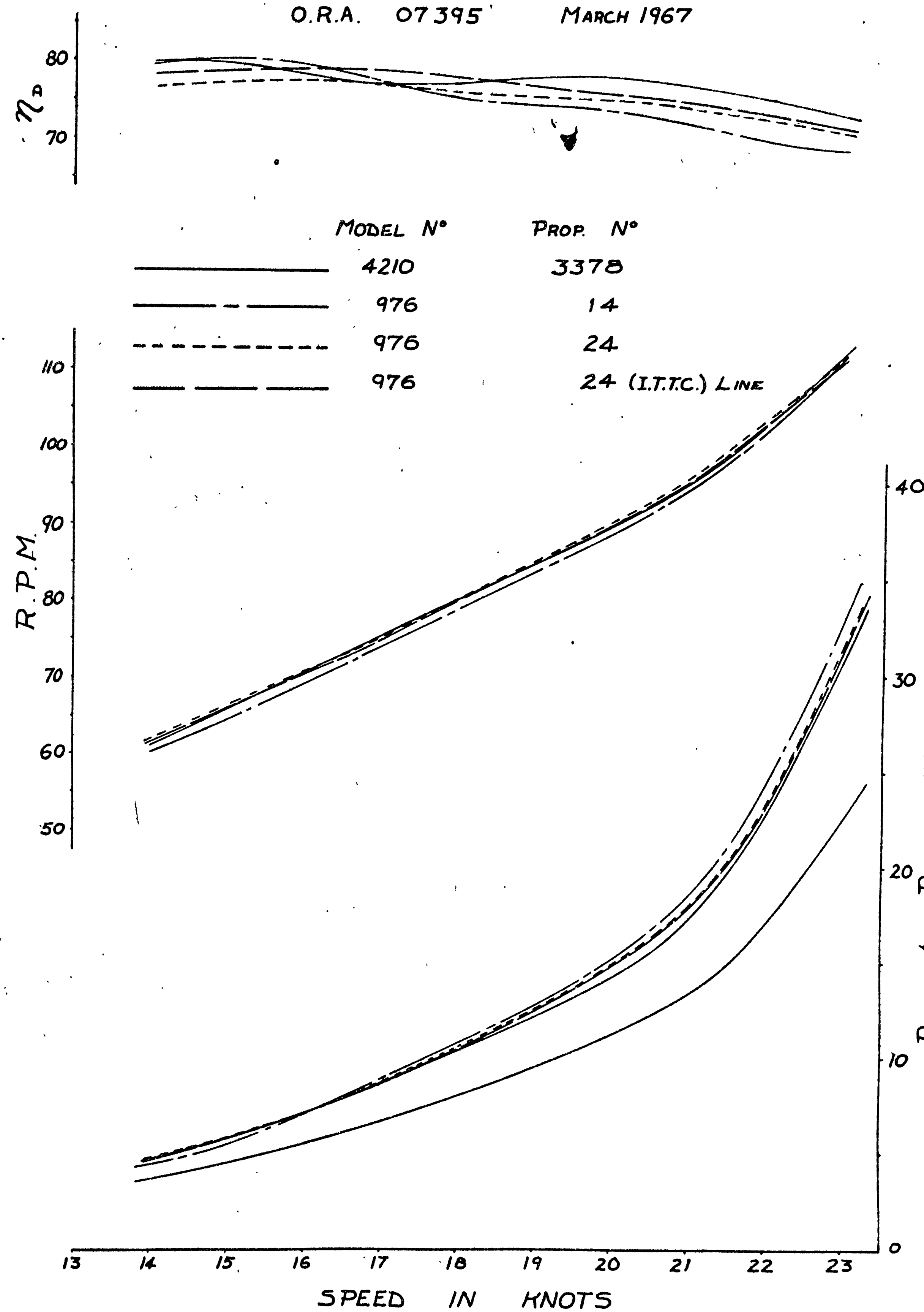

FIGURE 3

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MODEL N°	PROP N°
4210	3378
976	14
976	24

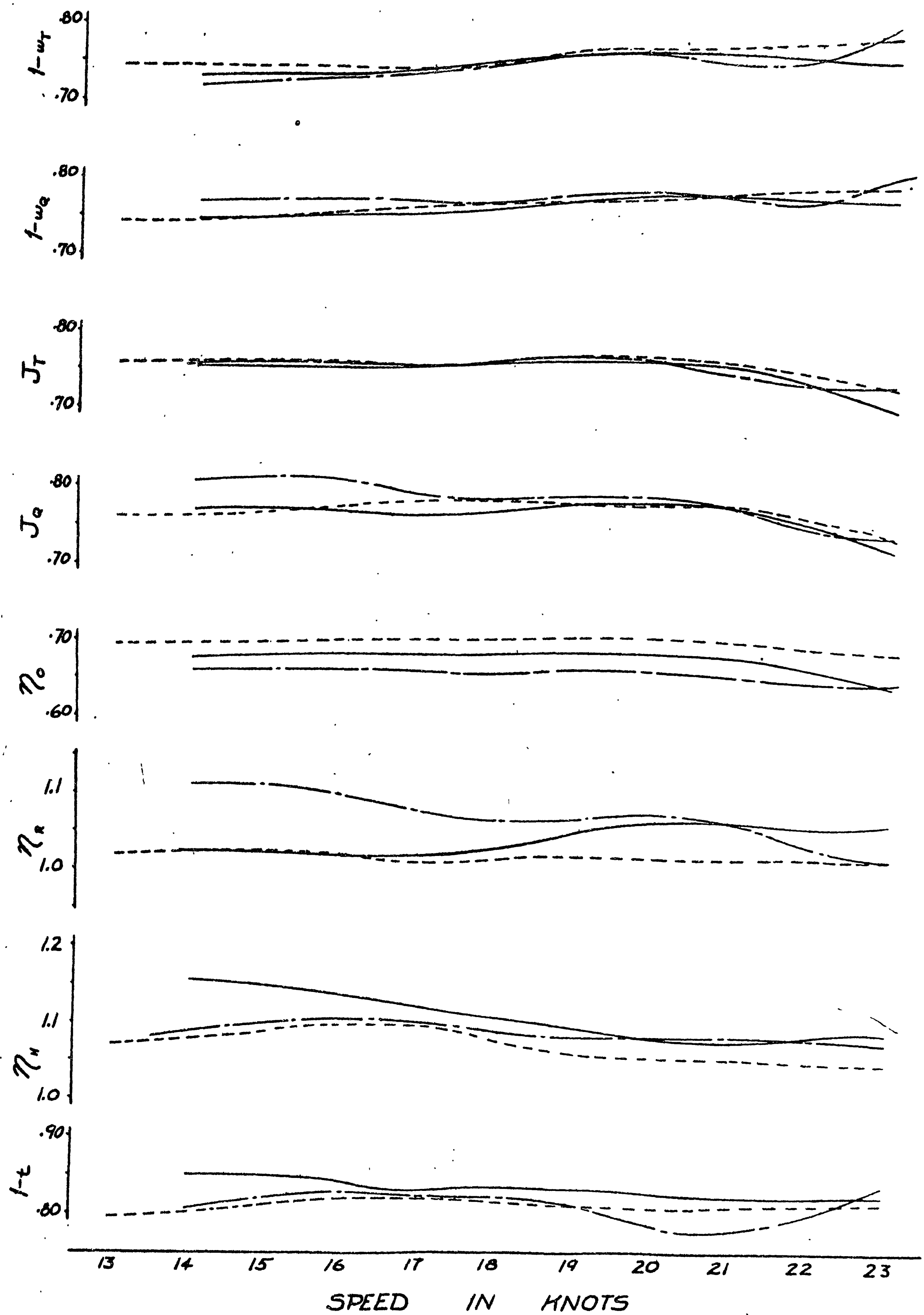

FIGURE 4

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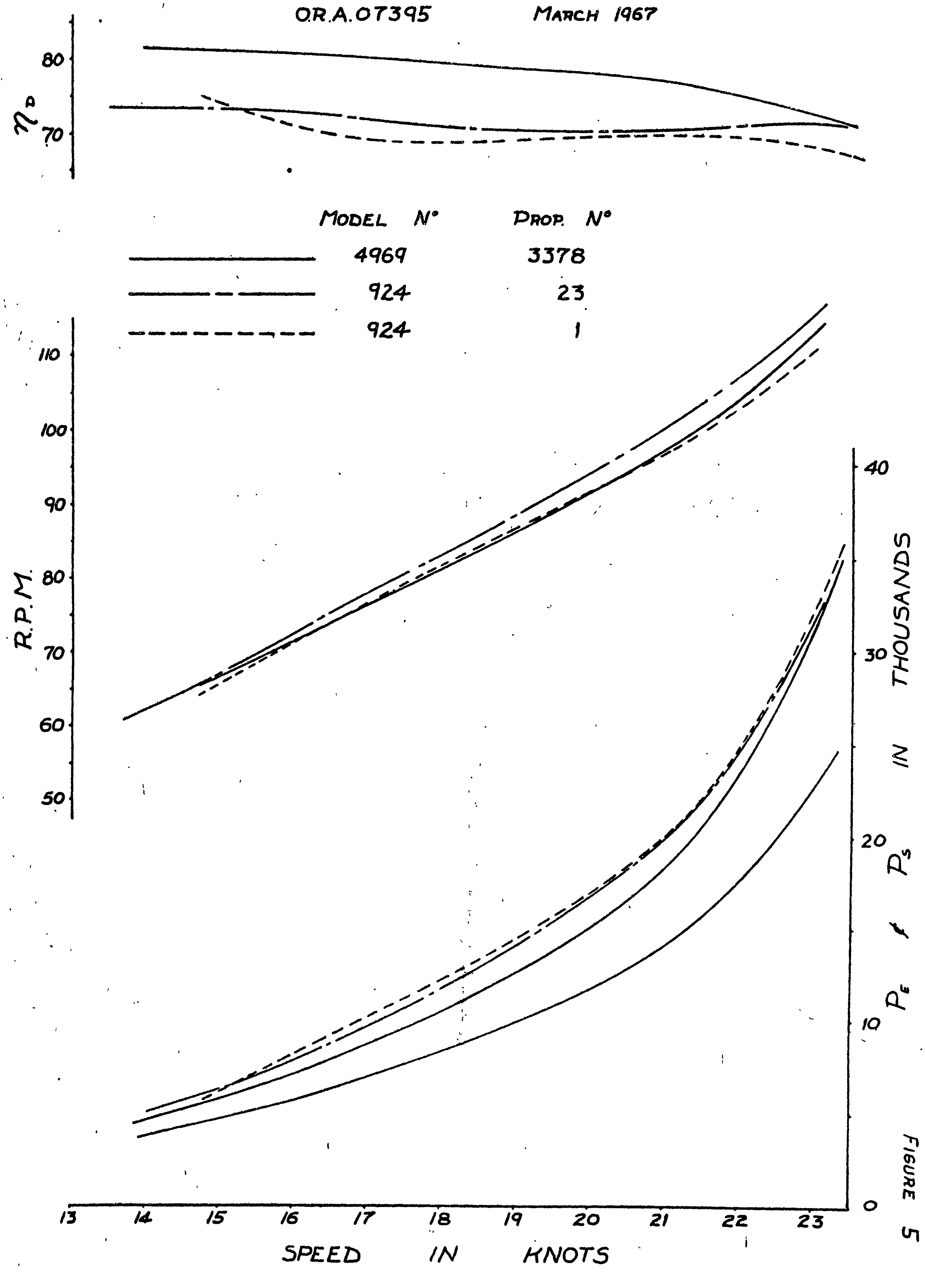
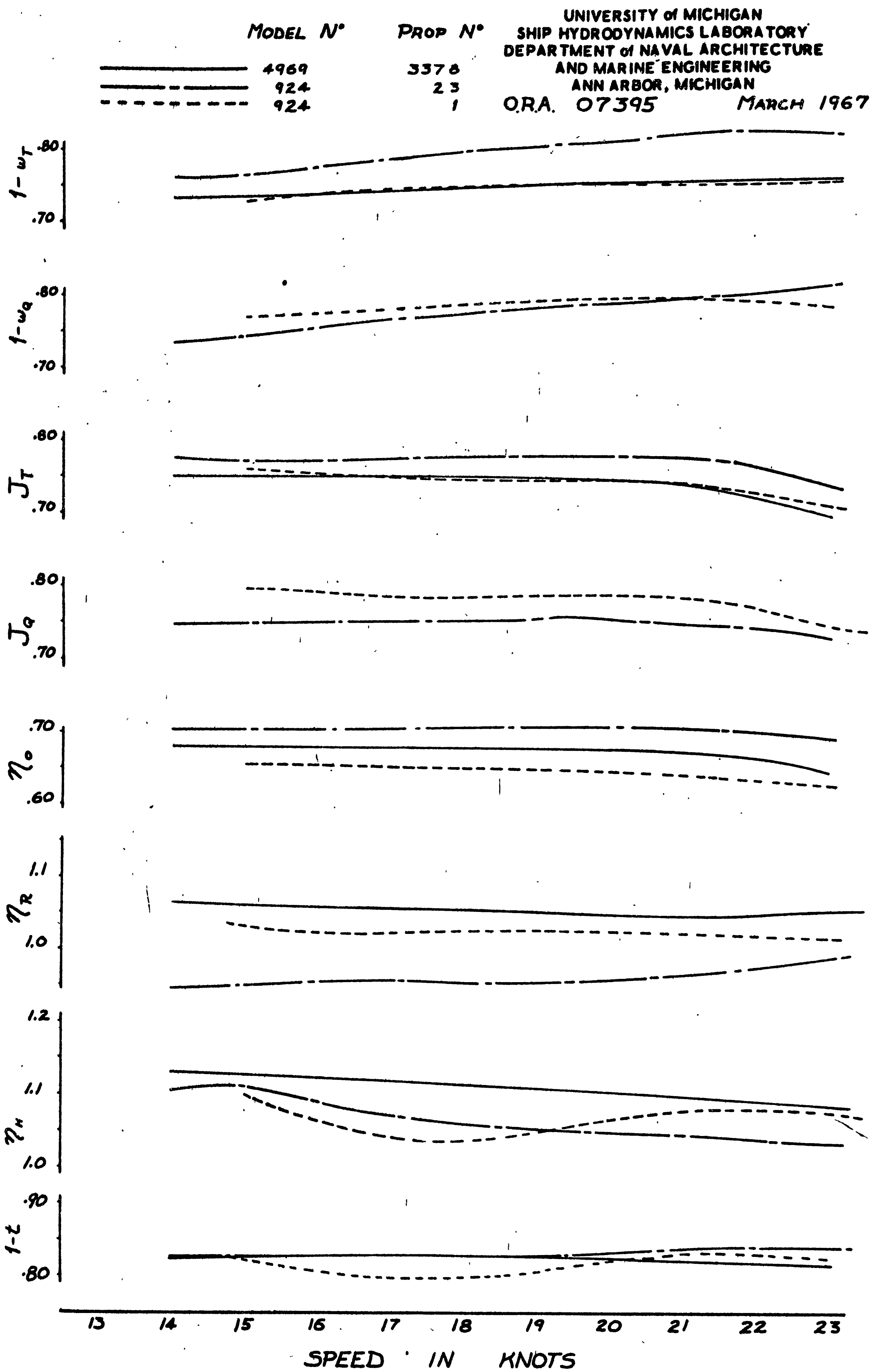


FIGURE 5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MARCH 1967
MODEL N°
PROP N°
4969
3378
924
23
924
1
1-wT
1-wQ
JT
JQ
ηO
ηR
ηH
1-t
.80
.70
.60
1.1
1.0
1.2
.90
13
14
15
16
17
18
19
20
21
22
23
SPEED IN KNOTS

FIGURE 6

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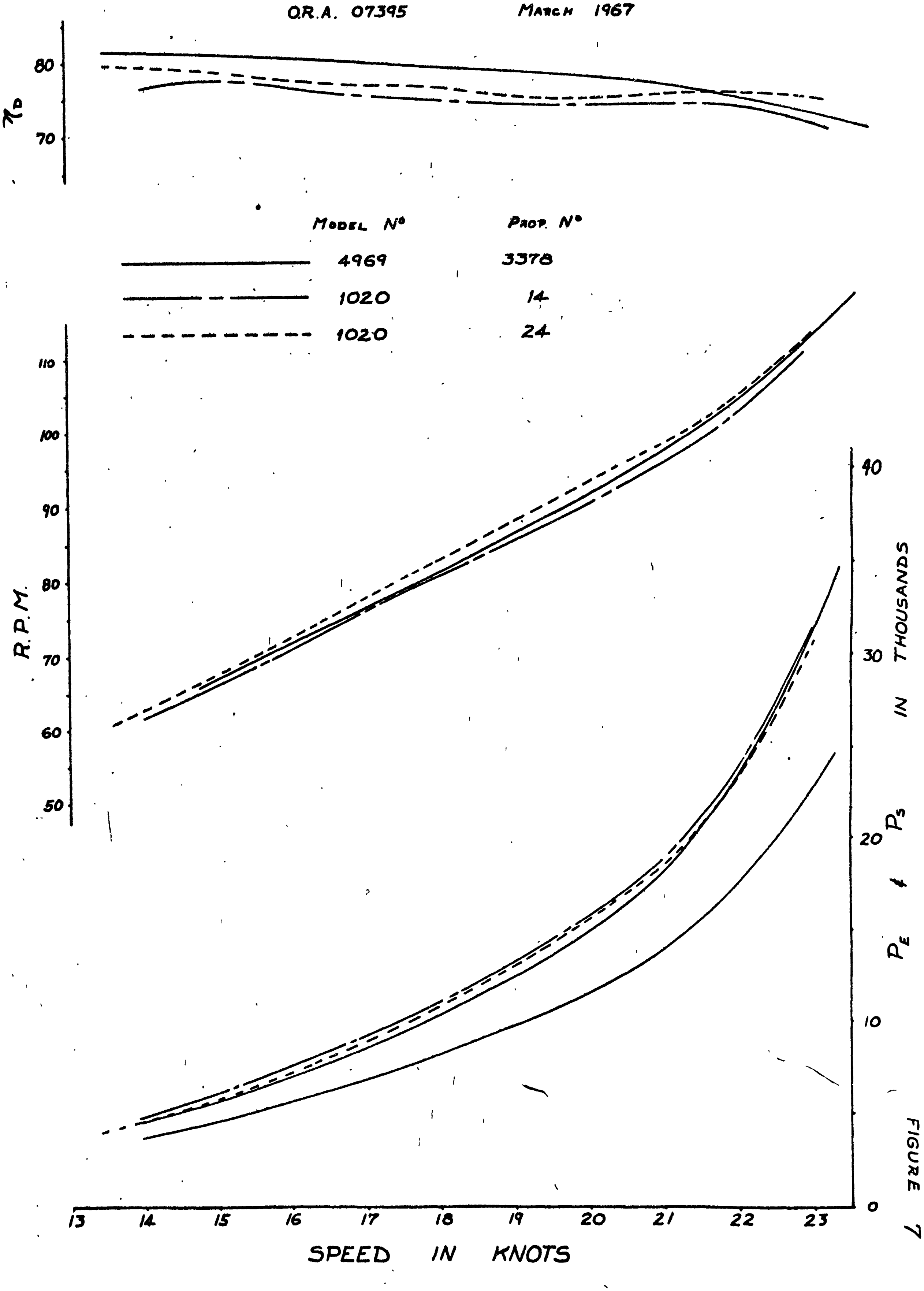

FIGURE 7

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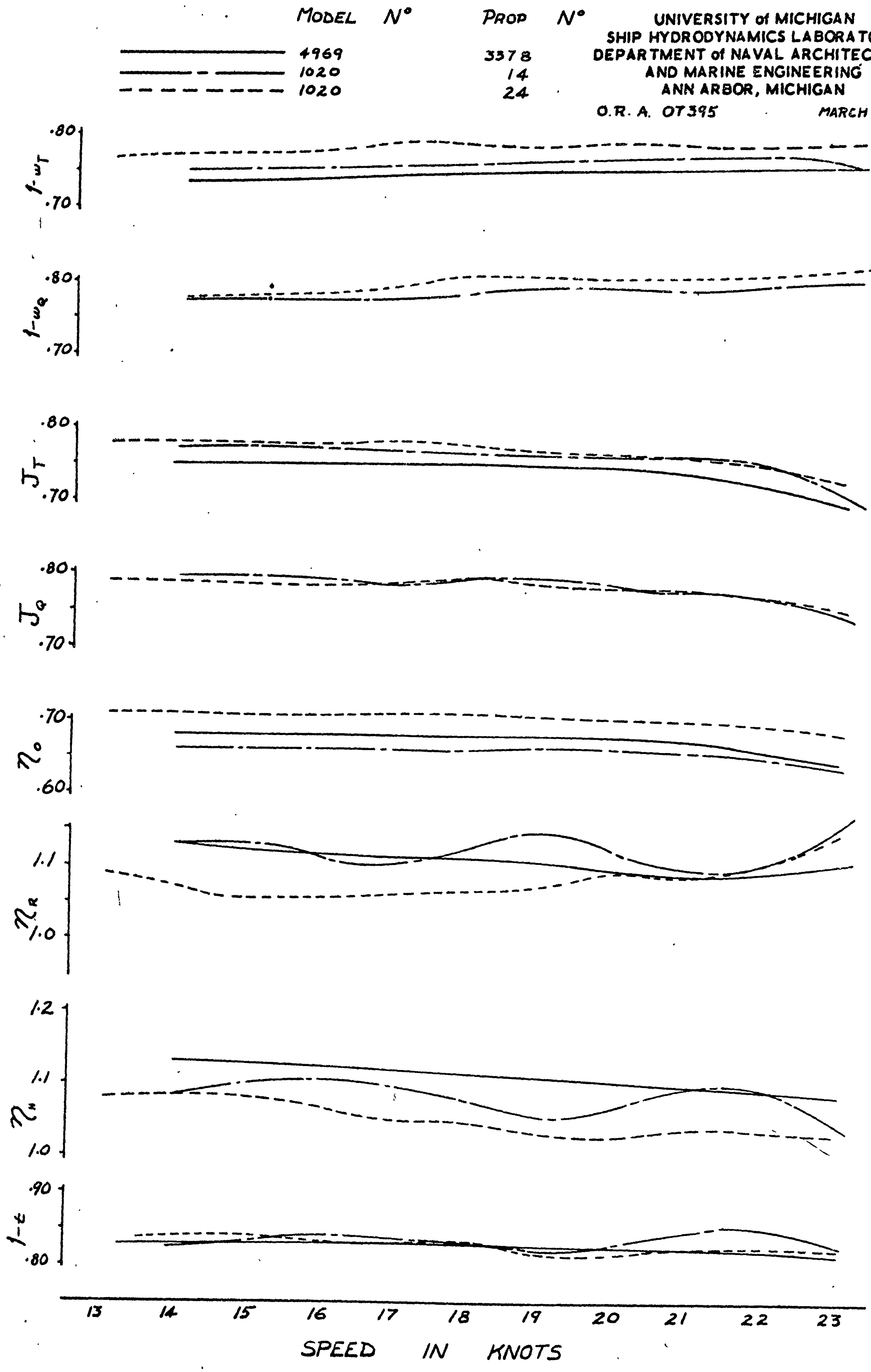
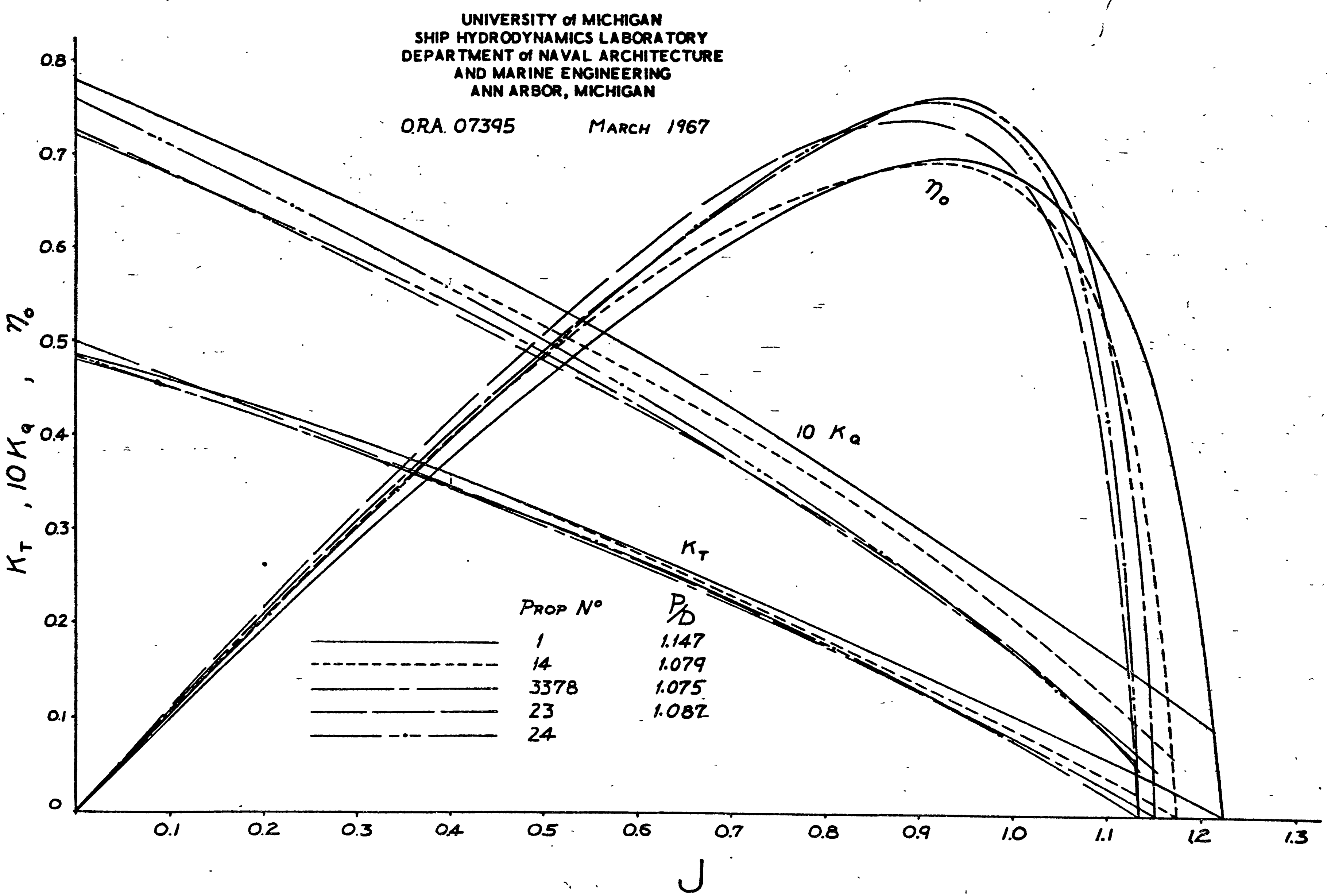


FIGURE 8

FIGURE 9



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K_T , $10K_Q$, η_o
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
η_o
$10\,K_Q$
K_T
PROP N°
P/D
1
1.147
14
1.079
3378
1.075
23
1.087
24
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
J

FIGURE 10

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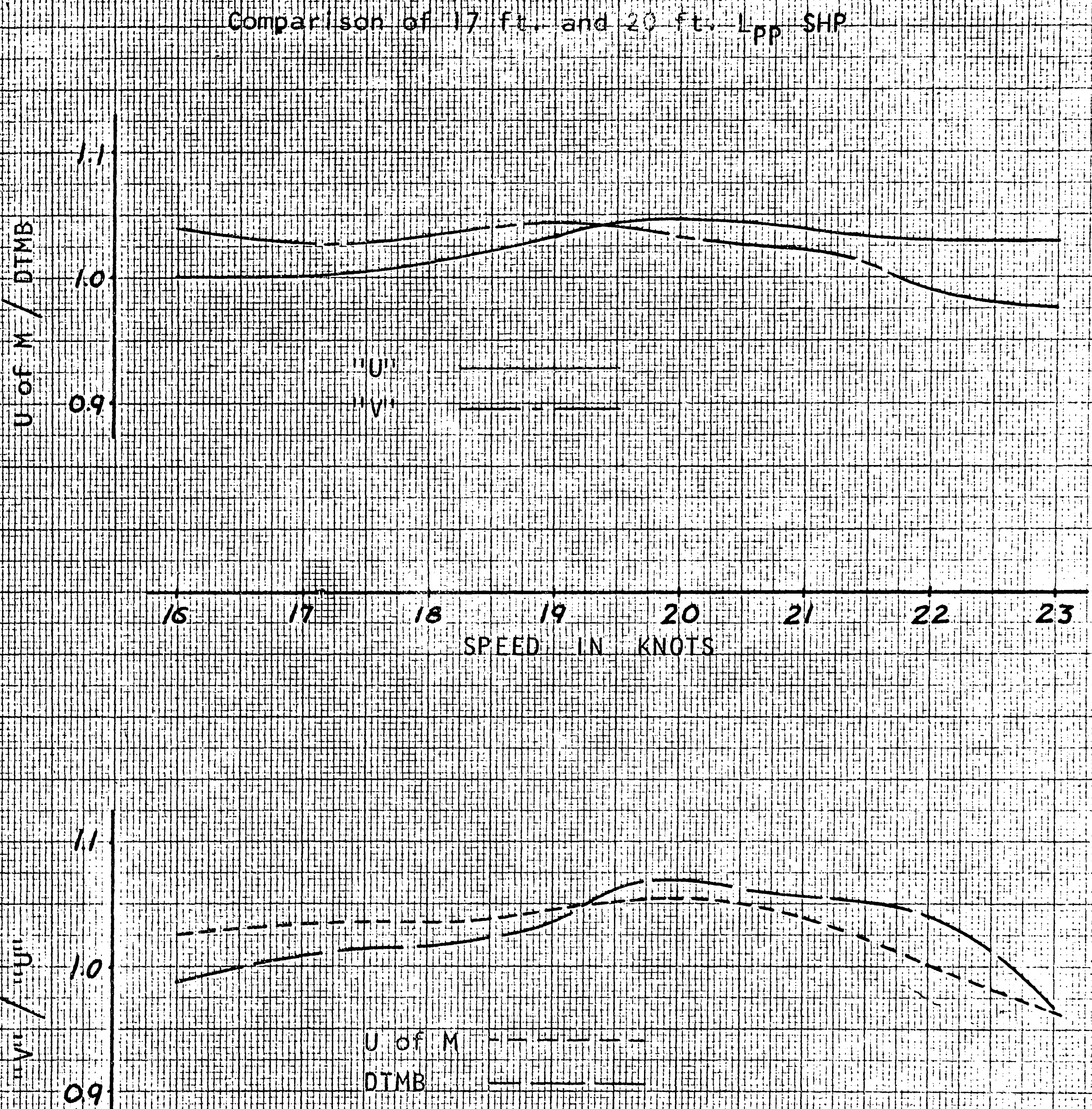

FIGURE 11

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WITH AND WITHOUT BLOCKAGE CORRECTIONS
COMPARISON OF P_E FOR U.M. & D.T.M.B. RESULTS FOR 17 FT. MODELS.

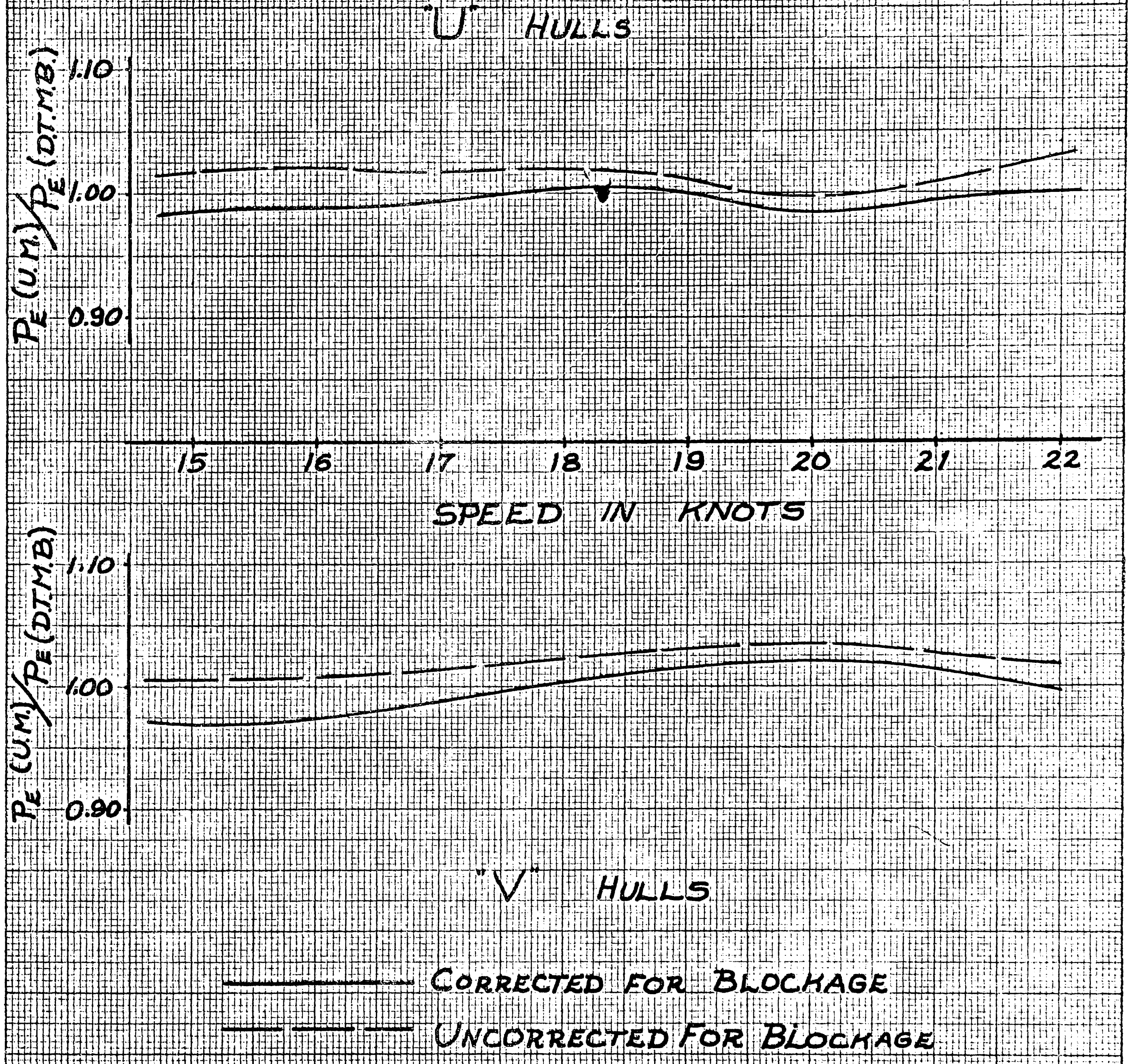

FIGURE A-1

Open Water Characteristics for U of M Prop. No. 12 & DTMB Prop. No. 3566
Tested at U of M and DTMB

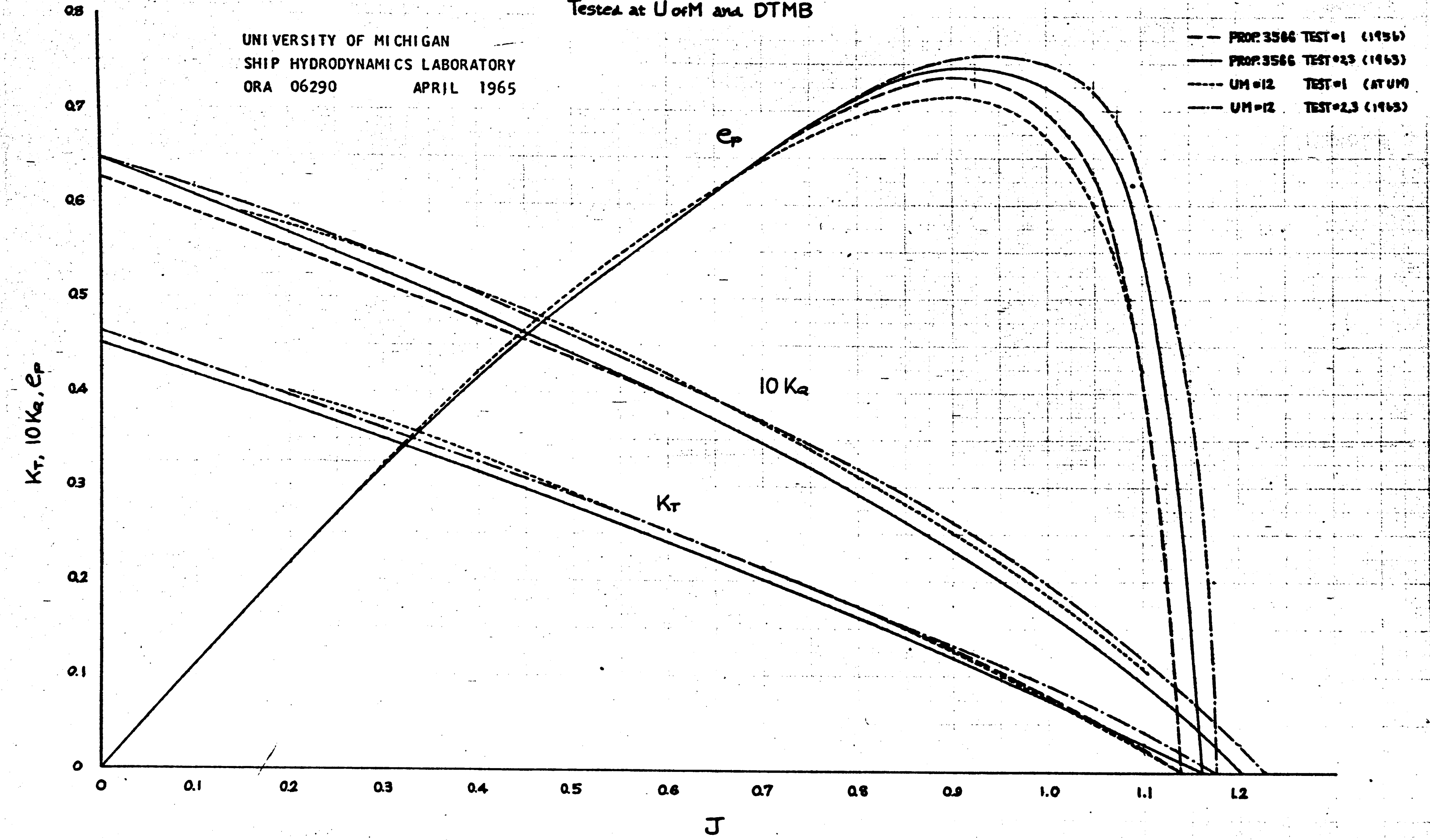

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FIGURE A-2

Section Measurements for U of M Prop. No. 1

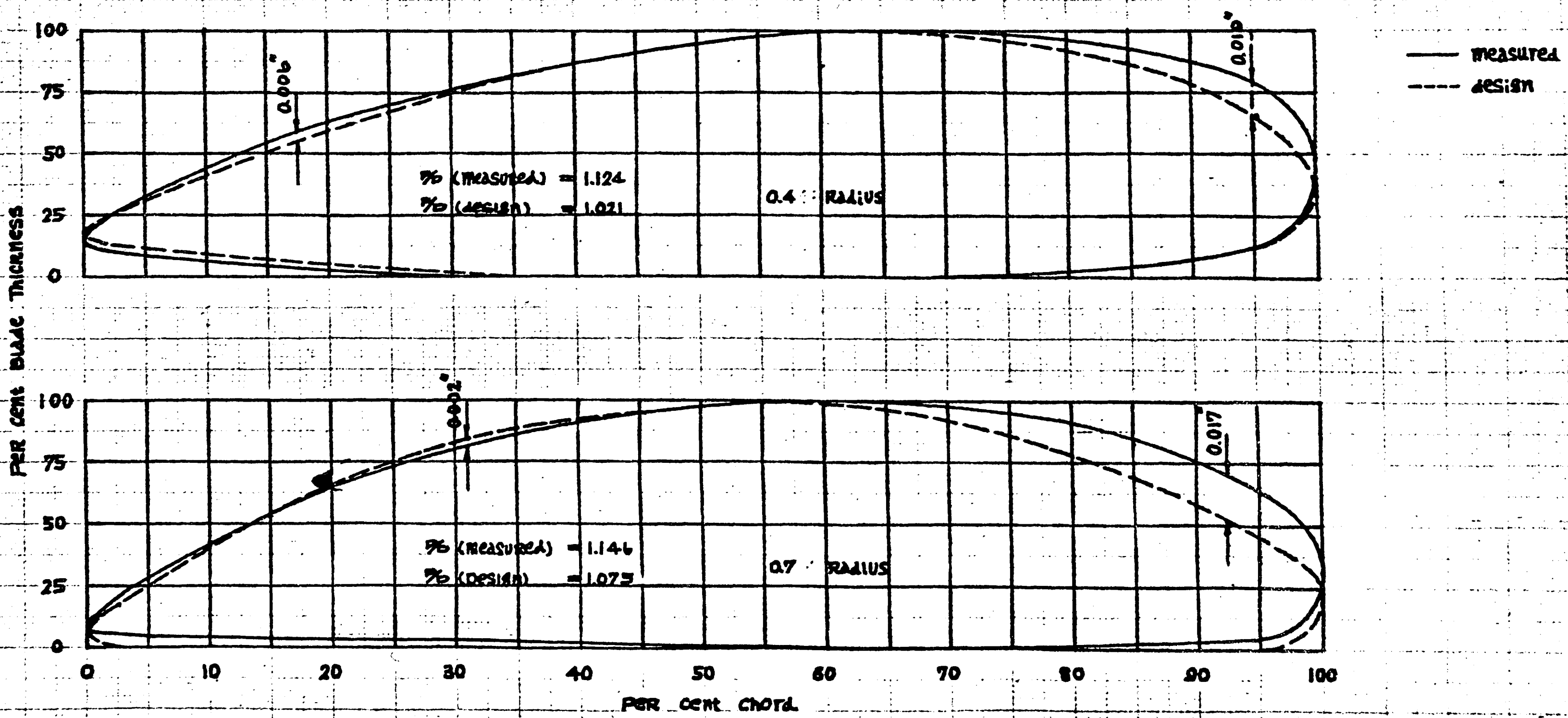

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FIGURE A-3

Section Measurements for U of M Prop. No 14

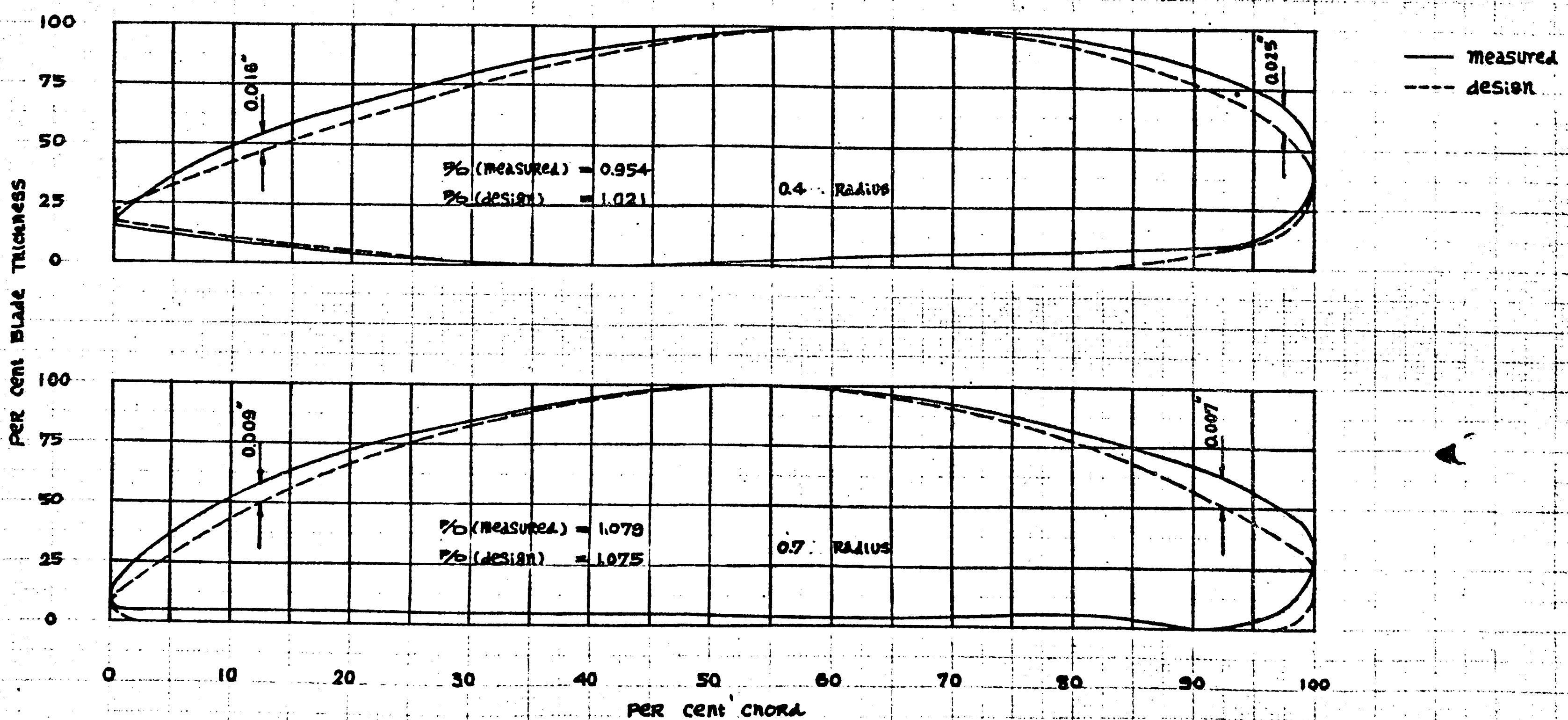

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FIGURE A-4

Section Measurements for DTMB Prop. No. 3378

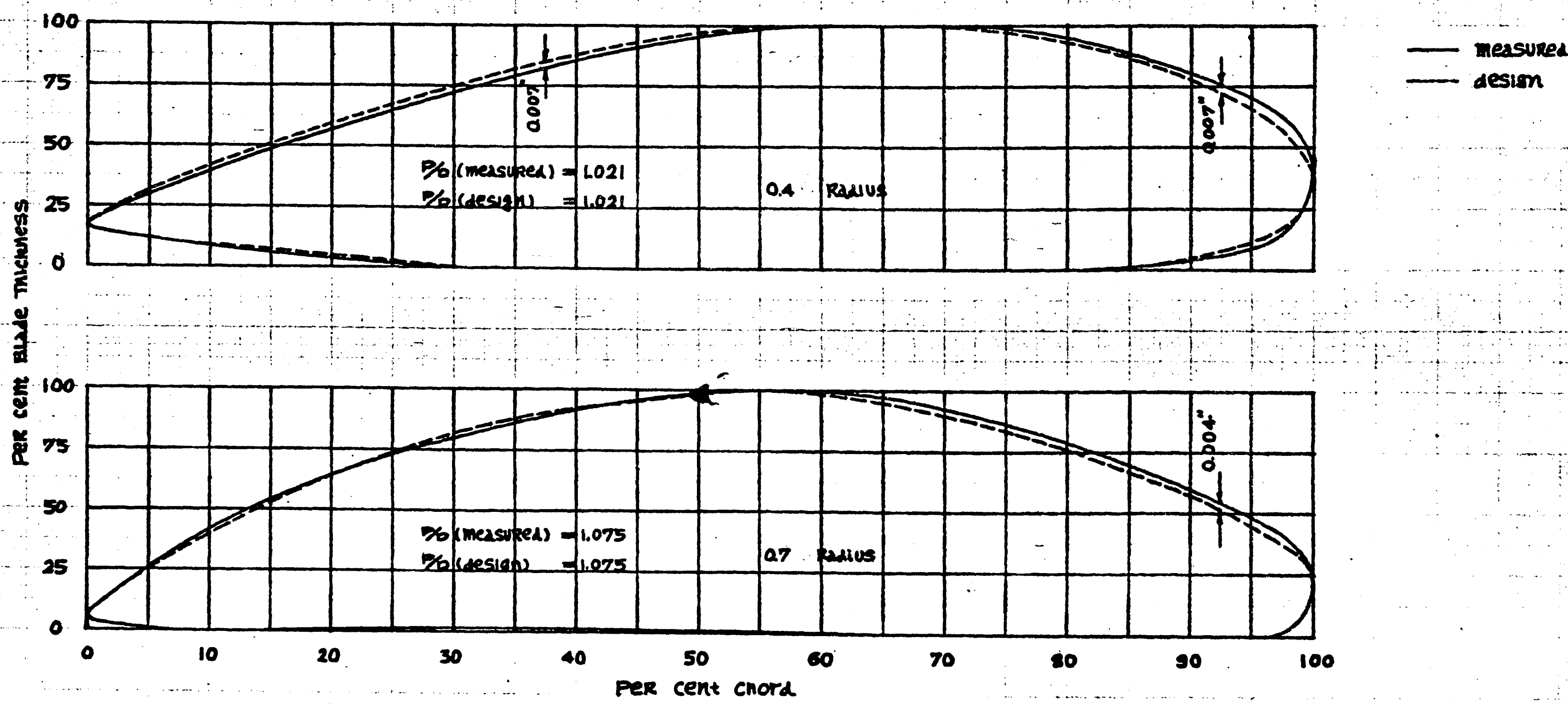

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FIGURE A-5

Section Measurements for U of M Prop No 23

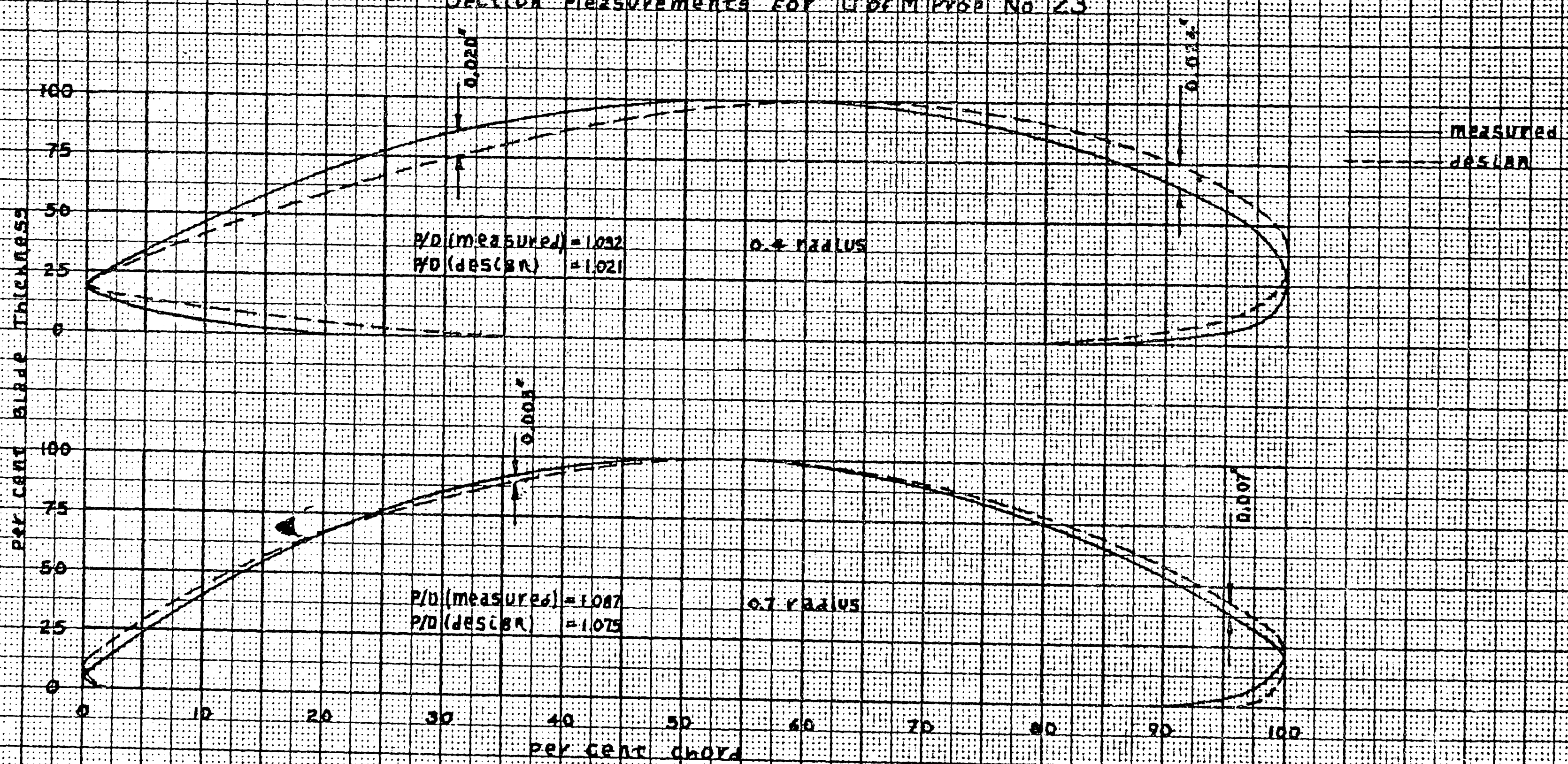

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FIGURE A-6

Section Measurements for U of M Prop No. 24