THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

Department of Naval Architecture and Marine Engineering
Ship Hydrodynamics Laboratory

Model Tests of the 5.5 Meter Yacht ANTIOPE

June 1975

by
James L. Jenkins
Research Assistant
Ship Hydrodynamics Laboratory

Submitted to
Peter A. Fisher
Research Associate
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OFFICE OF RESEARCH ADMINISTRATION • ANN ARBOR

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Tests run for the Society of Naval Architects and Marine Engineers.

Abstract

The comparison of model yacht test results is an important part of improving yacht testing methods. The tests of the 1/6th scale ANTIOPE model done at the U. of M. are available in this report for comparison and correlation with actual full scale results. Documentation of the equipment and procedures used in yacht model tests is also provided. The appendices supply detailed descriptions of the equipment, procedures, and results of the tests run in 1975 at the U. of M.

MODEL TESTS OF THE 5.5 METER YACHT ANTIOPE

TABLE OF CONTENTS

1. FOREWORD

In an effort to improve methods of yacht model testing Panel H-13 of the Society of Naval Architects and Marine Engineers initiated a program of testing on the 5.5 meter yacht ANTIOPE. In 1965 the full size yacht was tested at David Taylor Model Basin. Scale replicas of ANTIOPE were distributed to towing tanks agreeing to participate in the program. The goal of the Panel H-13 program was to enhance model testing methods through intertank comparisons and correlation with accurate full scale test results.

In cooperation with the program the University of Michigan Ship Model Basin tested a 1/6th scale version of ANTIOPE in 1972. The test results, however, were never forwarded to the Society.

Consequently, I was assigned the task of reviewing the 1972 tests, determining their validity, and writing the report. After research on the 1972 tests, the task was extended to include retesting the ANTIOPE model.

The purpose of this report is to present the results of the 1975 tests on the 1/6th scale model of ANTIOPE so that they may be used in the Panel H-13 program.

The report also provides documentation on the yacht testing equipment and procedures used at the U. of M. Ship Model Basin for future reference.

2. SUMMARY

This report presents the methods and results of the 1975 tests done on the 1/6th scale replica of the yacht ANTIOPE.

The model was run at the Univesity of Michigan Ship Model Basin using a standard method of yacht model testing. The heel and yaw were fixed and the model lift and drag forces were recorded over a speed range of 1.34 to 4.14 ft/sec. The data was reduced using a simple computer program designed to extrapolate model scale forces to full scale forces. The extrapolated data compared poorly with the actual full scale data. This is probably due to errors in equipment, procedures, and scale effects.

Because of the poor correlation I recommend that the ANTIOPE program be continued and further tests be done at U. of M. The new tests should be conducted in a more scientific and professional manner.

The appendices of this report provide a collection of the test results and equipment particulars.

3. DISCUSSION

3.1 Background

In the fall of 1965, Panel H-13 (Sailing Yachts) of the Society of Naval Architects and Marine Engineers Technical and Research Program conducted tests for measurement of hydrodynamic drag and side force on the full size 5.5 meter yacht ANTIOPE. These tests and accompanying results are summarized in Technical and Research Bulletin 1-28 "Full Scale Tank Tests of the 5.5 Meter Yacht ANTIOPE."

Identical 1/6th scale models of reinforced fiberglass plastic were made available by the Society in order to enhance model testing methods through intertank comparisons and by correlation with accurate full scale tests run in a towing tank. All tanks participating in this program were expected to cooperate with the project by conducting experiments which would supplement the tests performed on the full size yacht and then forwarding a report of the results to Panel H-13.

The Ship Model Basin at the Univesity of Michigan performed initial tests on one of the 1/6th scale ANTIOPE yacht models in December of 1972. A full series of tests were run, but due to reasons unknown the results were never written up into report form.

In January 1975 the author was assigned the task of reviewing the 1972 tests, determining their validity, and making the appropriate write up. Inaccuracies in the 1972 tests made it necessary to also retest the model. It is the purpose of this report to present the results of the 1975 tests on the 1/6th scale ANTIOPE model so that they may be used in the Panel H-13 program.

The first section of the discussion will describe the problems in the 1972 test results. The second and third sections will describe the test equipment and test procedures of the 1975 tests. The fourth section will describe the reduction of the 1975 test data, and the final section will present recommendations based on the 1975 tests.

3.2 The 1972 Tests

A careful review of the 1972 test results revealed several problems which invalidated the data's reliability. The method of data reduction was faulty. The raw data was extrapolated to full scale by a computer program written by R.S. Fry, J.D. Adams, and B.J. Young in June 1972. A listing of the program was not available for inspection so a spot-check using manual calculations was performed. It was found that the program failed to convert the units feet/second to knots in the appropriate places. Also, the Reynould's Number was based on the full load water line length (LWL) instead of 0.8 LWL as is common practice in the reduction of model yacht data.

Poor documentation of the data made accurate interpretation difficult. The graphs produced by the 1972 research team were inadequately labelled and the variables used in the computer program were not clearly defined. Although these problems were not insurmountable it was decided that retesting the ANTIOPE model would be easier than correcting the errors in the 1972 results.

3.3 The Test Equipment For The 1975 Tests

The test equipment for the 1975 tests consisted of the towing tank and carriage, the sailing yacht dynamometer and associated electronic equipment, and the model. Table 1 is a summary of the principle dimensions of the towing tank and the yacht model.

3.3.1 The Towing Tank was equipped with a test carriage capable of very accurate speed control in the zero to ten feet/second range. On board the carriage was the sailing yacht dynamometer, electronic amplifiers and recording equipment used in the tests.

3.3.2 The Sailing Yacht Dynamometer has two basic components, the balance beam and the instrument block. The balance beam consists of a fixed and a pivoted beam system coupled to the model and instrument block by a floating vertical shaft. Fore and aft movements are transmitted through the shaft to the pivot beam and recorded by a transducer.

3.3.3 The Instrument Block contains the apparatus to measure the model heel, yaw, heel moment, yaw moment, and side force. The measurements were made with strain gages and tranducers. Appendix A contains diagrams and photographs which illustate the parts of the dynamometer quite clearly.

MODEL PARTICULARS

Length overall	5.21 ft
Load Waterline	3.77 ft
Max. Beam	1.05 ft
Draft	0.73 ft
Displ.	20.18 lbs

TANK PARTICULARS

Length	360.0 ft
Width	20.0 ft
Depth	11.0 ft
Water Temp.	67.0 F

Table 1 Model and Tank Particulars

YAW	HEEL		
0	0	10	20
2	0	10	20
6	0	10	20

Table 2. Heel and Yaw Test Matrix

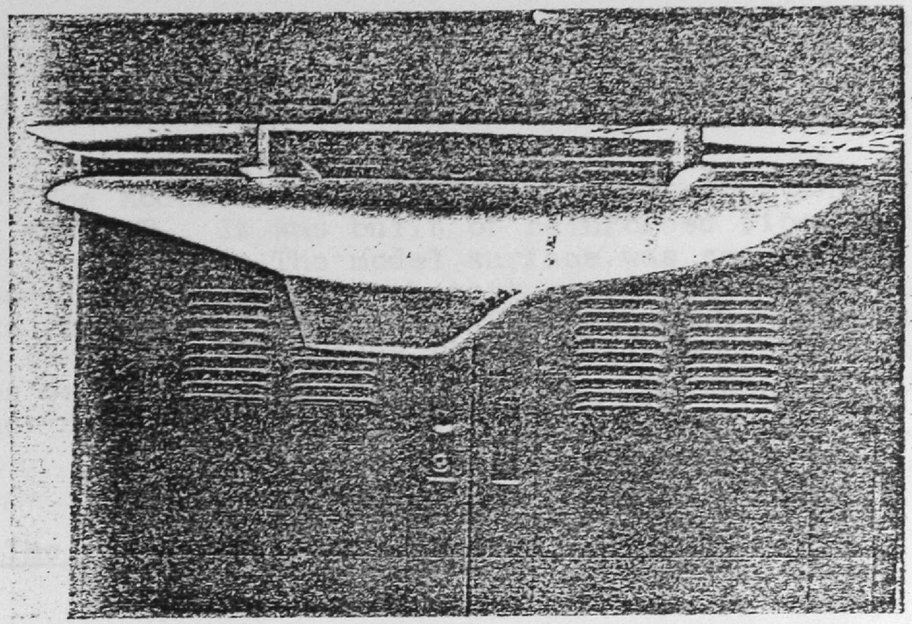


Figure 1a. Profile View of the Yacht Antiope

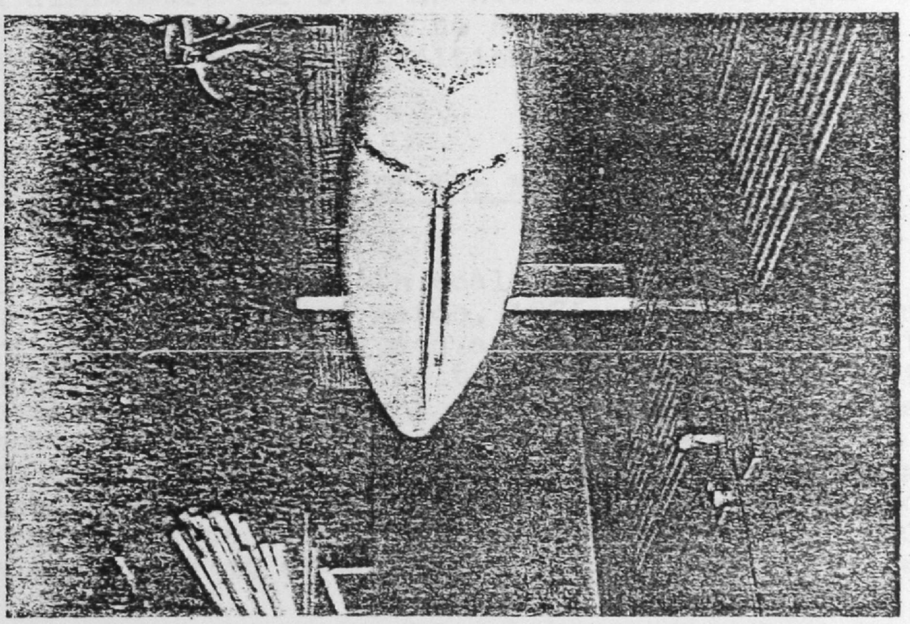


Figure 1b. View of Yacht Antiope from Bow Showig Sand Strips

The dynamometer measured forces by converting mechanical deflections into voltages. The voltages were filtered, amplified, and then scaled into model lift and drag.

3.3.4 The Model was a 1/6th scale replica of the 5.5 meter yacht ANTIOPE. It was built of reinforced fiberglass plastic by SNAME. The model surface was smooth and clean. The model was equipped with turbulence stimulator strips (size 20 grain sand, 8 grains/cm^2 density, 40 mm wide) along the forward sections of the keel and hull. These strips can be seen in Fig 1a and 1b. Appendix B shows further details of the model lines and towpoint set up.

3.4 The Test Procedure For The 1975 Tests

The test procedure used is commonly accepted as standard in the industry. Heel and yaw angles are set and the model lift and drag are recorded. The model was run over a speed range of from 1.34 ft/sec to 4.14 ft/sec. This corresponds to full scale speed of from 2.0 to 6.0 knots. Table 2 shows the test matrix of heel and yaw combinations used in the test. Each combination was run through the entire speed range. Orientation of heel and yaw rotations are illustrated in Appendix B. A waiting period of three minutes was implemented between runs so that turbulence in the tank would dissapate. If over an hour elapsed between runs a 'practice run' was taken to stir up the water and assure uniformity in the test conditions.

3.5 The Actual Testing Of The Model

The tests of the 1/6th scale ANTIOPE model were made on the 22nd and 23rd of March, 1975. The test procedure described above was followed and no major difficulties were encountered. The model was tested in a sequence which progressed from the upright condition (0 yaw, 0 heel) to the most extreme condition of heel and yaw (6 yaw, 20 heel). Two to three speeds were run during the carriage's run down the length of the tank. Black and white 35 mm photographs were taken of one run in each condition. Appendix C contains a listing of the raw data obtained from the testing.

3.6 Data Reduction

Reduction of the data consisted of extrapolating the model scale forces to full scale forces. This was accomplished with the computer program listed in Appendix D. The computer program uses the 1957 ITTC friction line for the calculation of the model and ship coefficients of friction.

The Reynould's Number used in the program calculations is based on 0.8 LWL to account for the shorter flow path over the keel. A correction factor for the stimulator drag of 0.0025 was input. This factor was based on the tests done in 1972. The full scale coefficient of lift was found by multiplying 1.25 times the model coefficient of lift.

The data produced by this program is listed in Appendix D. Graphs of drag versus speed for the four heel angles, drag versus yaw, and lift versus yaw are included in Appendix E. There is also a plot of drag versus speed comparing extrapolated full scale data and actual full scale data in Appendix E. This plot shows that there is a poor correlation between extrapolated and actual data. Scale effects are the probable cause of the discrepency. Appendix F is a discussion of the scale effects which relate to these tests.

3.7 Recommendations Based On The 1975 Tests

Research on the 1/6th scale model of ANTIOPE should be continued at the U. of M. Ship Model Basin. This recommendation is based on three facts.

3.7.1 The Scale Effects discussed in Appendix F must be taken into appropriate consideration. The 1972 and 1975 tests lack an accurate evaluation of the turbulence stimulator drag and correction factor. An inaccurate factor can significantly alter the results of the model test extrapolation.

3.7.2 The Sailing Yacht Dynamometer was not as precice and accurate as necessary for the testing of small models. Speciffically, the pivot pin in the balance beam system allowed considerable transverse 'play'. This caused a shift in the strip chart zeros and a subsequent error in the raw data.

3.7.3 The Students running the tests did not have a total grasp of the scale effect problems and the testing procedure. Errors in their test procedure could have altered the values of important variables, e.g. stimulator drag correction factor.

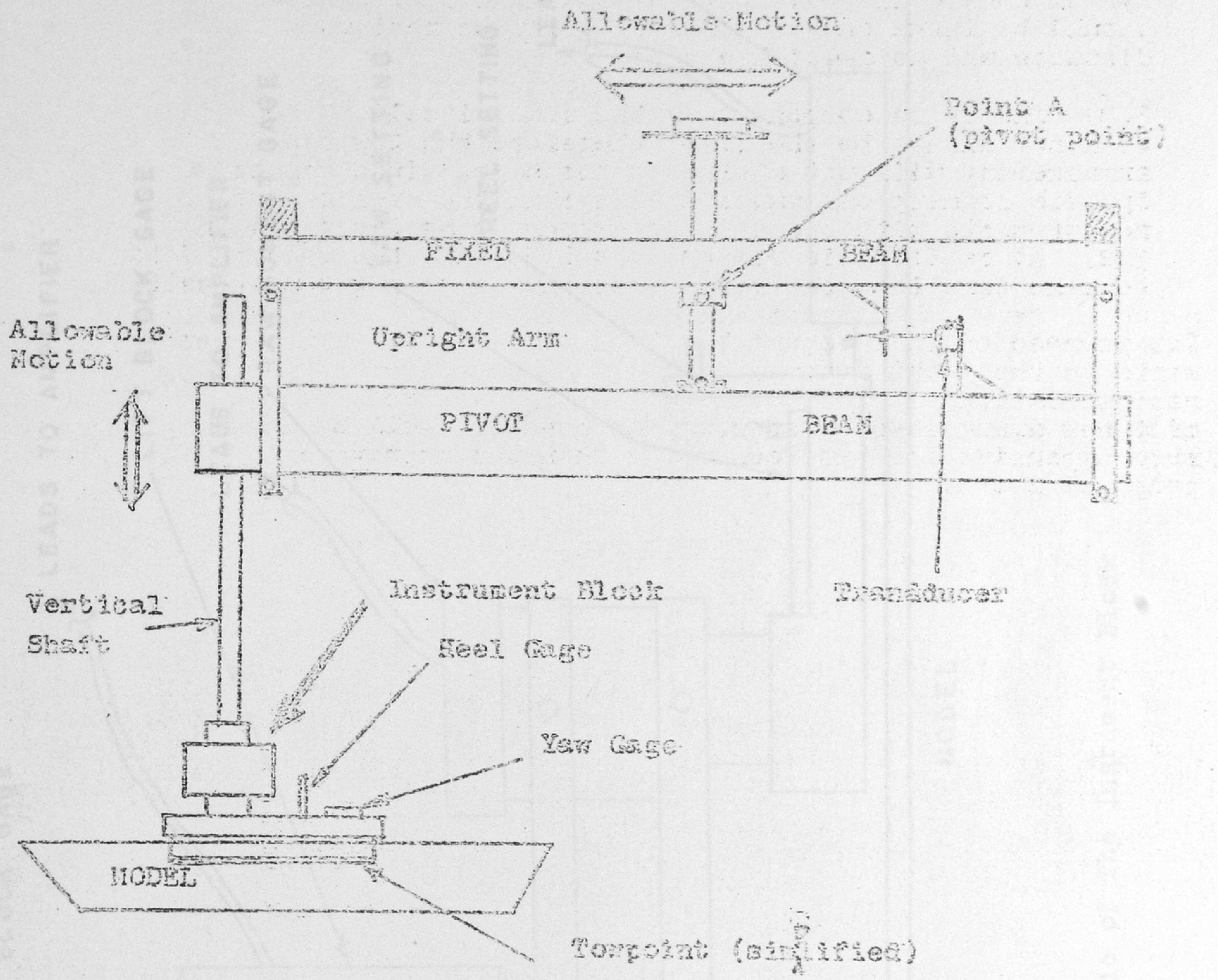
The continuation of the ANTIOPE testing program should include reanalysis of the 1972 and 1975 test data using the computer program in Appendix D. The model should also be retested to accurately determine the stimulator drag correction factor. In the retesting, an attempt should be made to refine the test equipment and test procedures at the U. of M. towing tank.

3.8 Closing

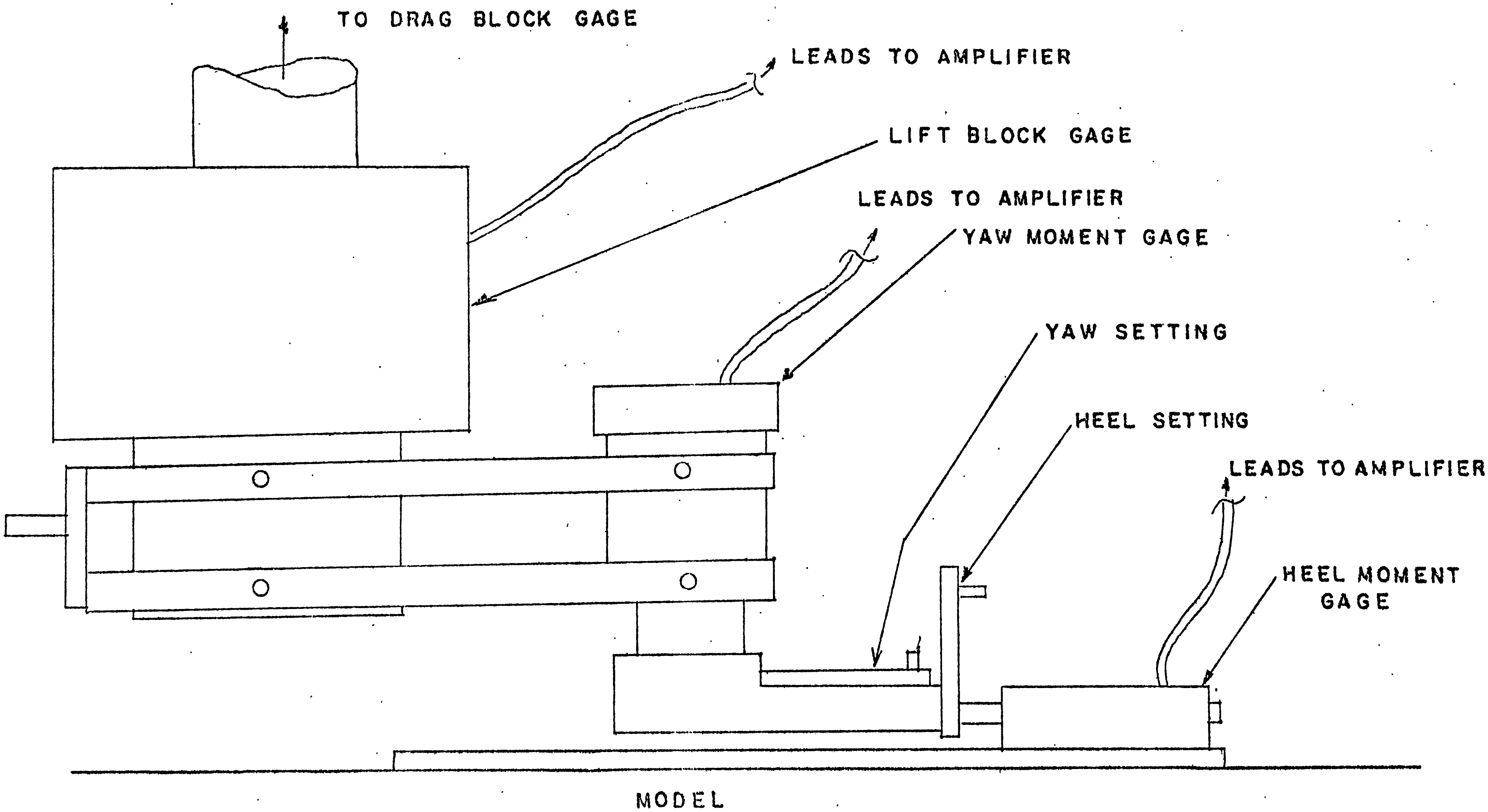
The purpose of this report has been to present the results of the tests done in 1975 on the 1/6th scale ANTIOPE model so that they may be used in the Panel H-13 program. No conclusions were drawn from the 1975 test data as this is the job of Panel H-13. The recommendations made pertain only to the ANTIOPE program at the Ship Model Basin at the University of Michigan, and are based on the results of the 1972 and 1975 tests. The Appendices of this report contain the data necessary to make conclusions and should be consulted carefully.

Appendix A

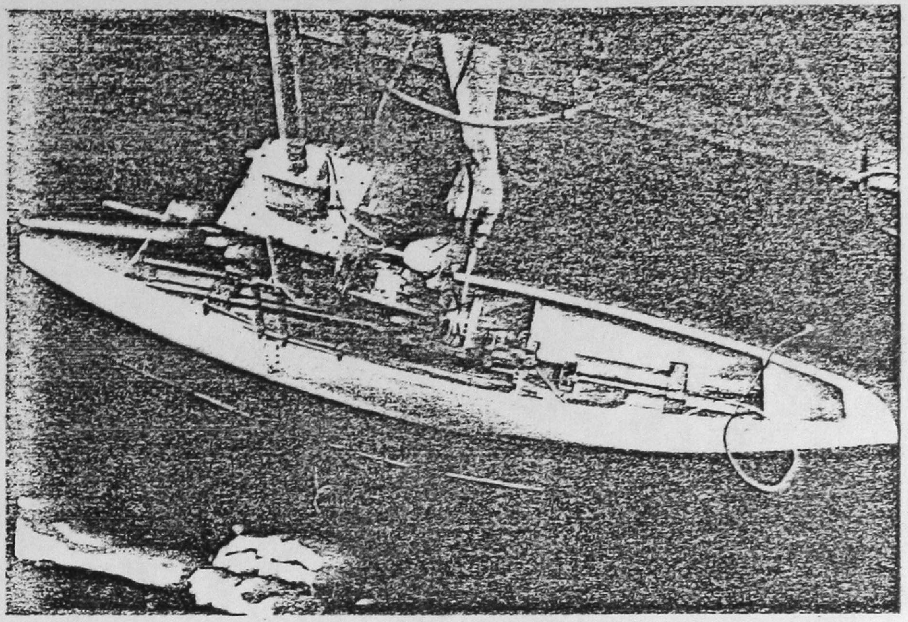
Appendix A



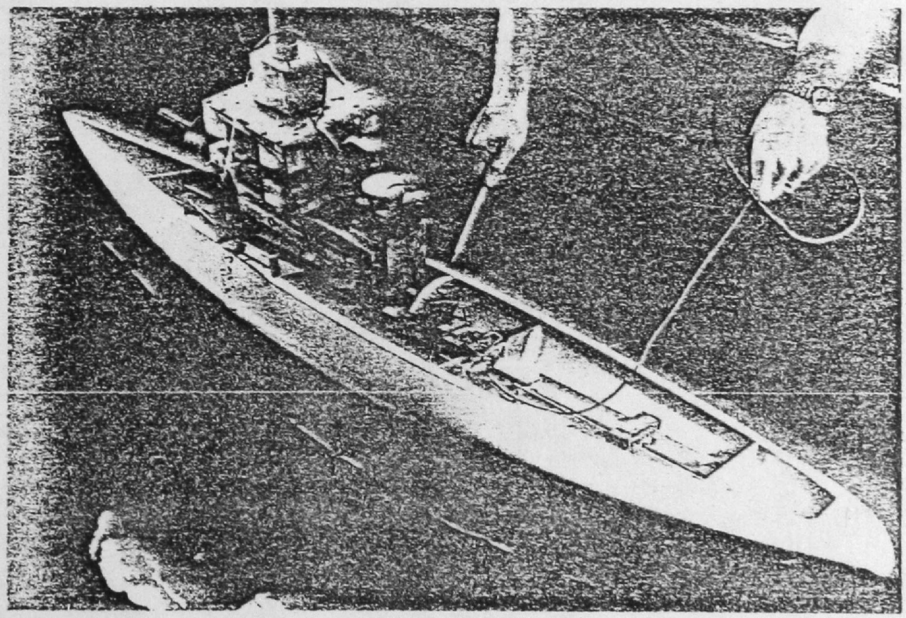
Simplified Sketch of Dynamometer.



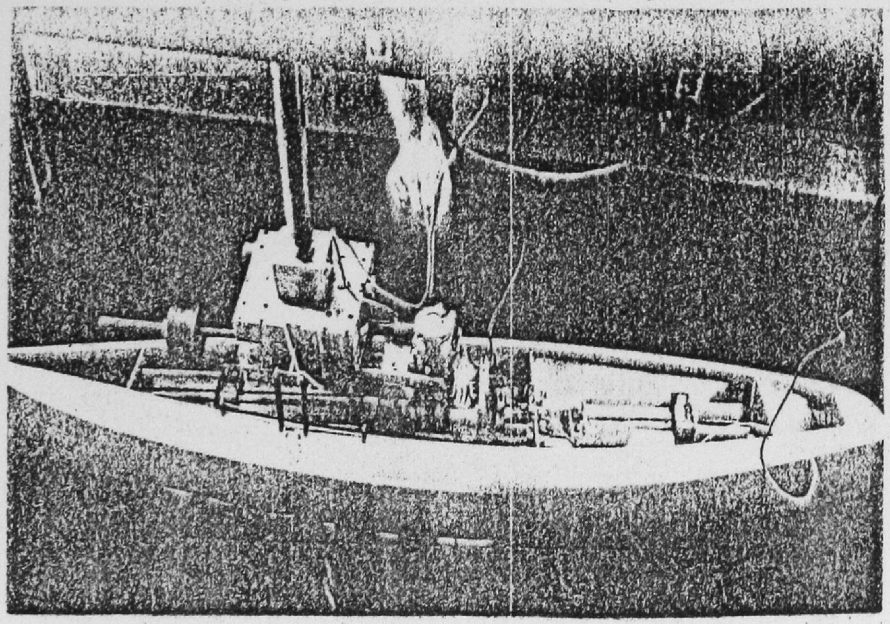
Schematic of The Instrument Block



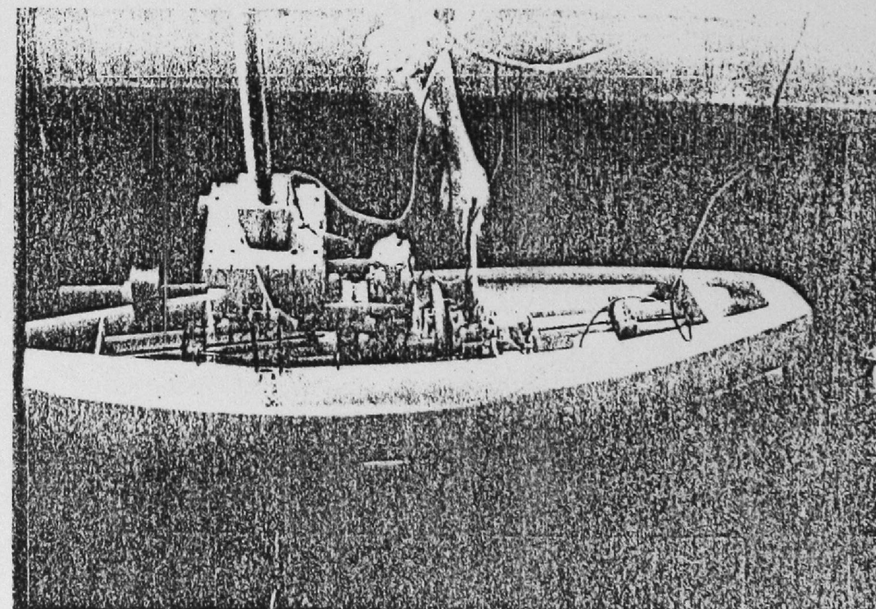
Yaw Setting of Yacht Dynamometer



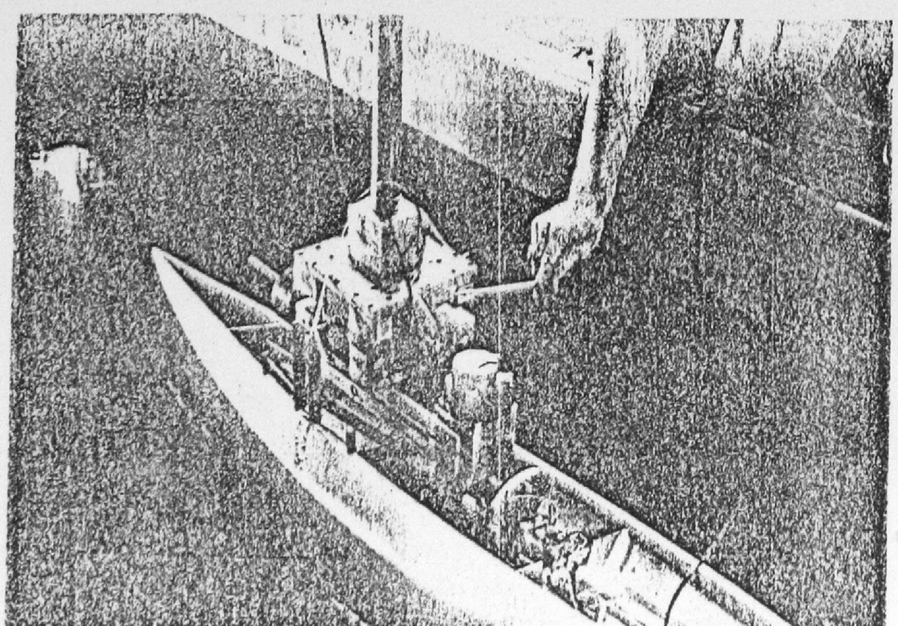
Heel Setting of Yacht Dynamometer



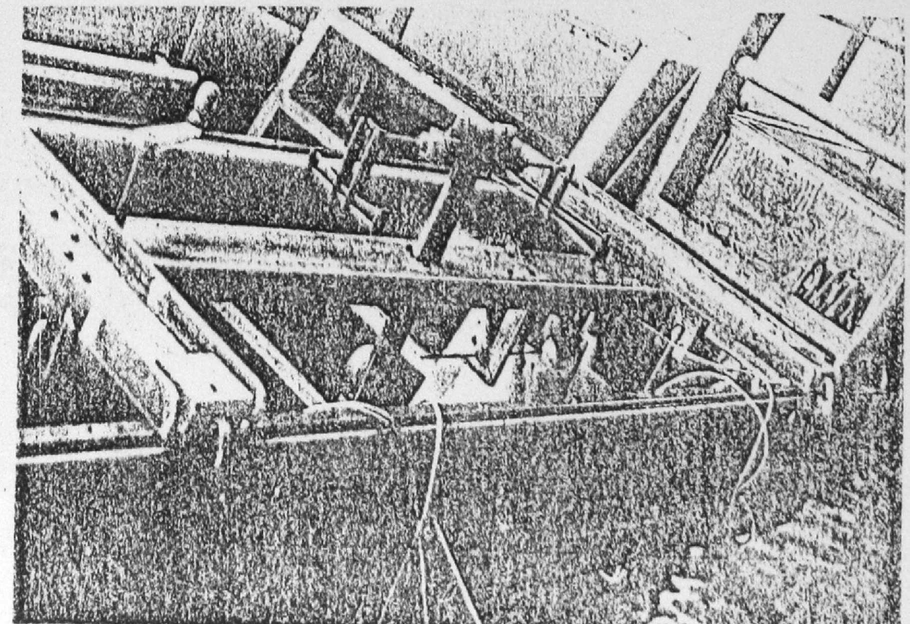
Heel Moment Gages



Yaw Moment Gages



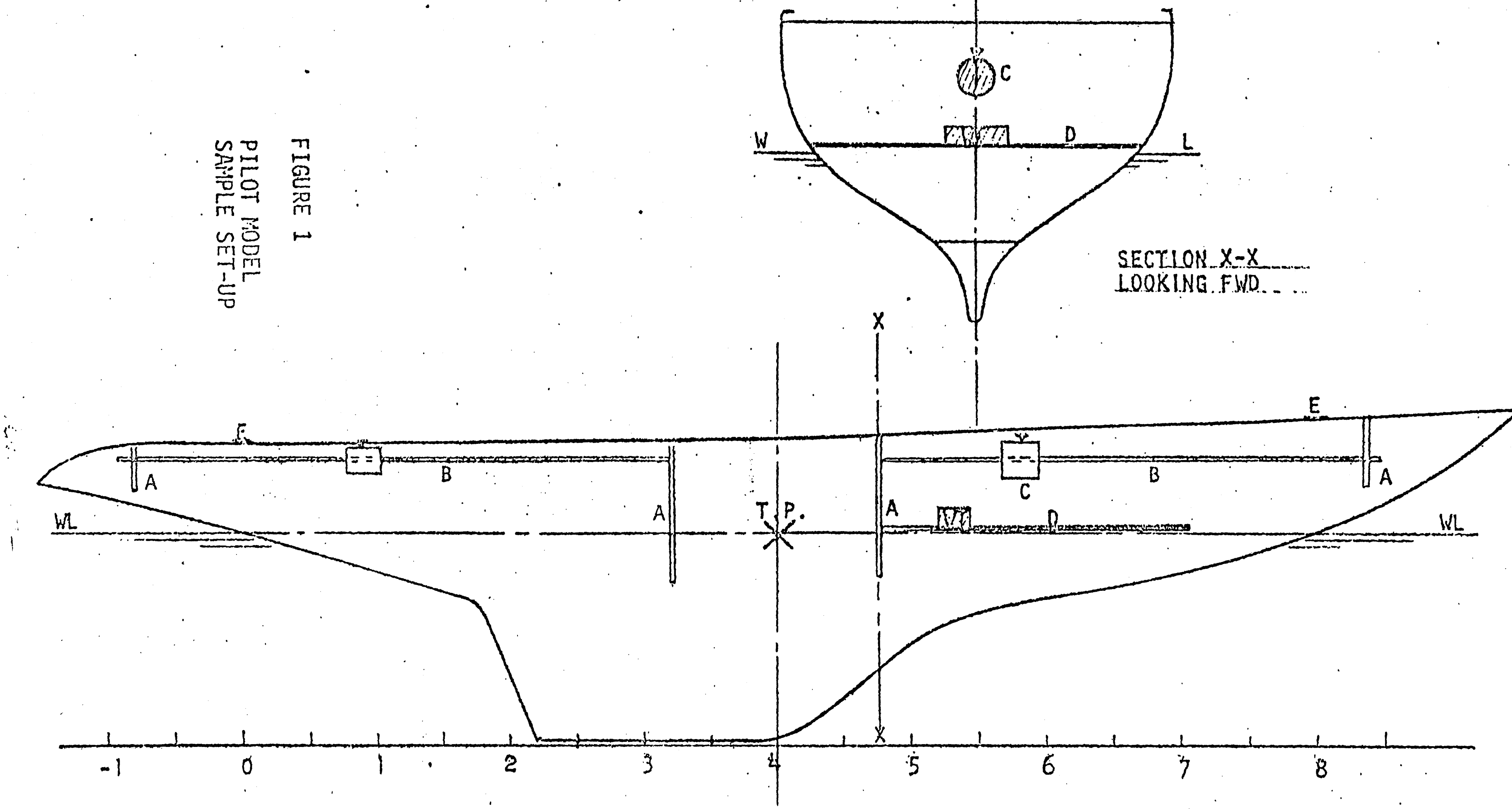
Side Force Block Gage



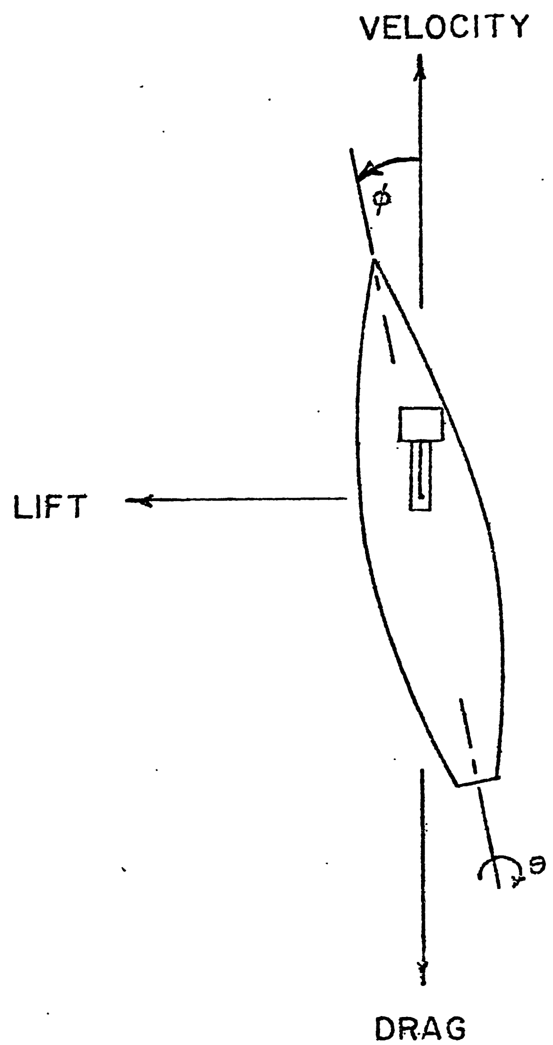
Balance Beam and Drag Block Gage

Appendix B

FIGURE 1
PILOT MODEL
SAMPLE SET-UP



A ALUMINUM PLATE SECTIONS EPOXIED TO INSIDE OF HULL TO MOUNT APPARATUS AND B
B ALUMINUM ROD POSITIONED ALONG YACHT ℄
C MOVEABLE WEIGHTS WITH LOCK NUTS TO ENABLE EASY LCG CHANGES
D ALUMINUM PLATE EPOXIED TO INSIDE OF HULL FOR SCREWING STATIONARY BALLAST TO
E LEVEL HORIZONTAL ALUMINUM PLATE AT STNS. 0 and 8 FOR FREEBOARD MEASUREMENTS
T.P. TOW POINT COINCIDING WITH W.L.



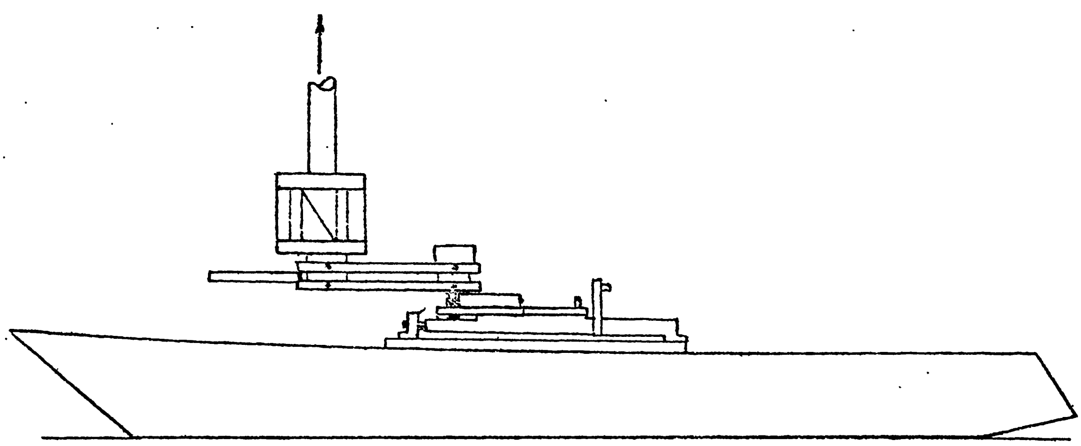


Figure 2. Heel and Yaw Orientation on Model.

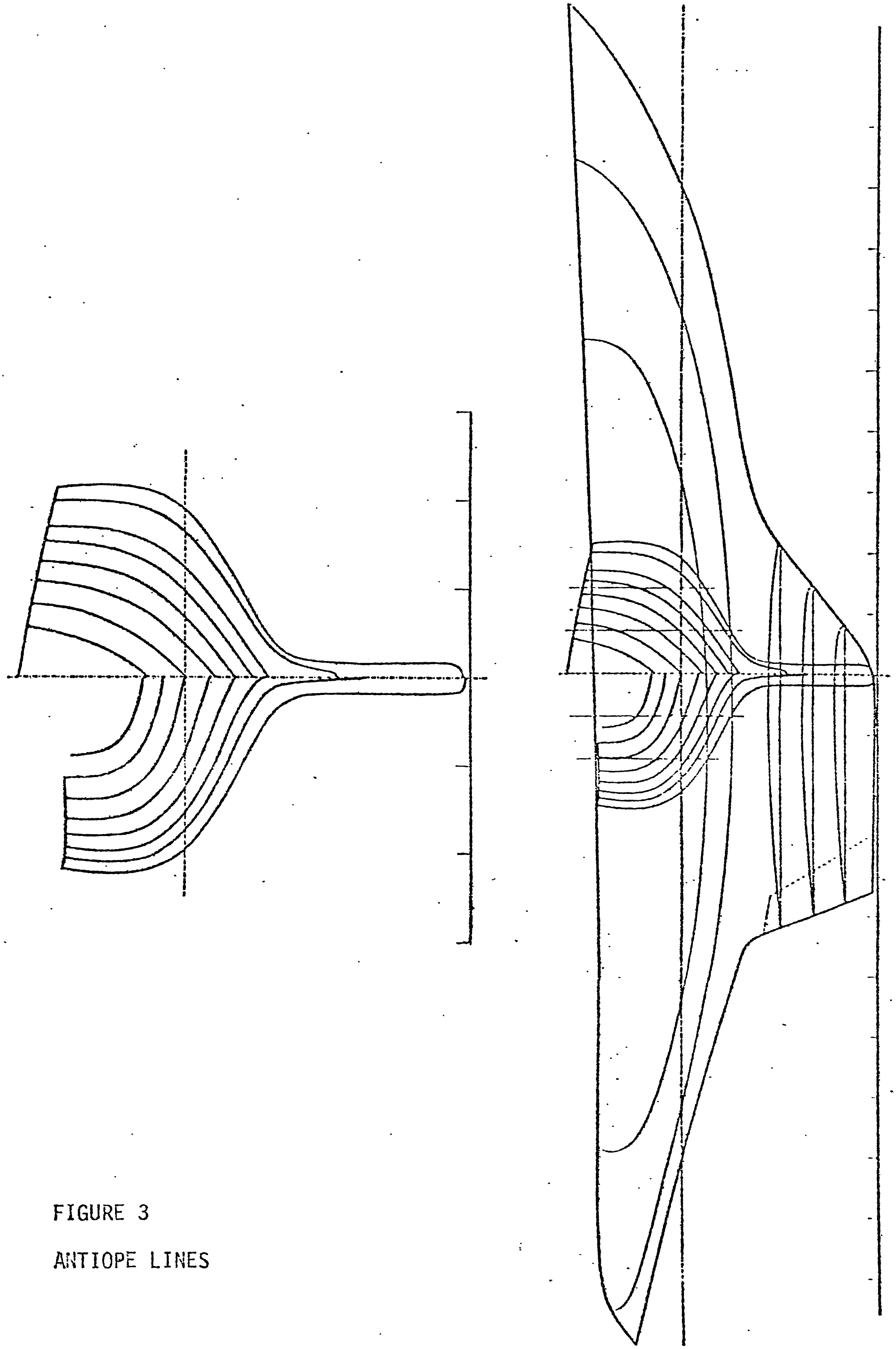


FIGURE 3

ANTIOPE LINES

Appendix C

SHIP HYDRODYNAMICS LABORATORY

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SHEET 1 of 3

3 min wait bet/run

MODEL Nº Antiope ORA Nº ______ TEST Nº 1 Δ_m = 23.18

CONDITION: No Heel No Yaw model weight = 22.18 lbs

SPEED RANGE: ______ to ______ ft/sec $\lambda = 6.0$ ballast = 3.00 lbs

DATE: 22 MAR 75 TEMP = 68 °F PERSONNEL: JJ - TW

RUN	Vm	R_T	R_{TARE}	R_T *	L_T	L TARE	L_T *	L/R_T	REMARKS
0	1.35	.084	0	.084	.01				0-HEEL 0-YAW
1	2.08	.152	0	.152	.01				
2	2.81	.29	0	.29	.03				
3	3.48	.451	0	.451	.025				
4	4.22	.512	0	.512	.038				
5	[illegible].47	.365	0	.365	.001				
6	1.34	.065	0	.065	.062				2Y - 0H
7	2.07	.138	0	.138	.160				
8	2.76	.244	0	.244	.320				↓
9	3.45	.388	0	.388	.490				
10	4.16	.690	0		.780				
11	1.33	.018	0		.250				6-Y-0-H
12	2.07	.187	0		.628				↓
13	2.79	.257	0		.765				
14	[illegible]5	.342	0		1.11				
[illegible]	[illegible]	.5[illegible]	0		1.79				
16	4.18	.930	0		1.71	1.0			
17	1.34	.072	0		-.01				0Y 10-H
18	2.59	.151	0		-.015				
19	2.78	.255	0		-.045				↓
20	3.48	.405	0		-.06				
21	4.14	[illegible].66	0		-.085				
22	1.34	.100	0		.062	NO	GOOD		2-Y 10 HEEL
23	2.09	.175	0		.132		↓		2° YAW & 10° HEEL

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SHEET 2 of 3

MODEL Nº Antelope ORA Nº ______ TEST Nº ______ Δ_m = 23.18

CONDITION: ______ model weight = 20.18

SPEED RANGE: 1.39 to 4.14 ft/sec ballast = 3.00

DATE: 22MAR75 TEMP. = 69 °F PERSONNEL: TW-JS

RUN	V_m	R_T	R_{tare}	R_T^*	L_T	L_{tare}	L_T^*	L/R_T	REMARKS
24	2.76	.281	0		.255				
25	3.45	.437	0		.419				
26	4.17	.731	0		.625				
27									
28									
29									
30									

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MODEL Nº Antelope ORA Nº ______ TEST Nº ______ Δ_m = 23.18

CONDITION: ______ model weight = 20.18

SPEED RANGE: 1.34 to 4.14 ft/sec ballast = 3.00

DATE: 23 MAR 75 TEMP. = 67 ºF PERSONNEL: TW - JT

RUN	Vm	RT	TAPE	RT*	LT	LTAPE	LT*	L/DRAG	REMARKS
27	1.34	.06	0	.06	.125	0	.125		2-Y 10 Heel
28	2.05	.123	0	.123	.226	0	.226		
29	2.78	.241	0	.241	.228	0	.228		
30	3.44	.390	0	.390	.705	0	.705		
31	4.15	.692	0	.692	1.138	0	1.138		[illegible]
32	1.34	.089	0	.089	.307	0	.307		6Y - 10H
33	2.06	.180	0	.180	.713	0	.713		
34	2.78	.341	0	.341	1.301	0	1.301		
35	3.49	.568	0	.568	1.162	1.00	2.162		
36	4.19	.940	0	.940	2.171	1.00	3.171		
37	1.33	.080	0	.080	.025	0	.025		0Y 20H
38	2.05	.138	0	.138	.038	0	.038		
39	2.79	.248	0	.248	.058	0	.058		
40	3.48	.400	0	.400	.120	0	.120		
41	4.20	.721	0	.721	.250	0	.250		
42	1.34	.078	0	.078	.110	0	.110		2Y - 20H
43	2.07	.144	0	.144	.210	0	.210		
44	[illegible]9	.250	0	.250	.358	0	.358		
45	3.54	.450	0	.450	.735	0	.735		
46	4.18	.745	0	.745	1.140	0	1.40		
47	1.36	.100	0	.100	.257	0	.257		6Y - 20H
48	2.07	.200	0	.200	.665	0	.665		
49	2.77	.356	0	.356	1.223	0	1.223		
50	3.55	[illegible]	0	.600	.582	1.5	2.082		
51	4.15	.940	0	.940	1.419	1.5	2.919		

Appendix D

Computer Program Used to Reduce the Raw Data

```
      REAL LWL,LAMDA,LIFT,LIFTM,LD
      WRITE (6,104)
  104 FORMAT (5X,'SPEED',7X,'RNY',7X,'YAW',6X,'HEEL',6X,'LIFT',6X'DRAG'
     18X,'LD',7X,'CDY',7X,'CLY')
      READ(5,102) KASES,YACHT
  102 FORMAT (I5,F3.1)
      READ (5,100) RHO,LWL,LAMDA,WETSUR,CSTUD,CA,VISC
  100 FORMAT (4F8.4,3E10.4)
      DO 20 I=1,150
      READ (5,101) VM,YAW,HEEL,DRAGM,LIFTM
  101 FORMAT (5F8.5)
C     CALCULATION OF COEFFICIENTS FOR THE MODEL
      RNM=.8*(VM*LWL)/(VISC)
      CDM=(DRAGM)/(.5*RHO*WETSUR*VM*VM)
      DUM=(ALOG(RNM)/2.30259)
      CFM=(.075)/((DUM-2.0)**2)
      CWM= CDM-CFM
C     CALCULATION OF FULL SIZE COEFFICIENTS
      VY=SQRT(LAMDA)*VM
      VK= VY/1.6889
      RNY=(.8*(VY*LAMDA*LWL))/VISC
      DMM=(ALOG(RNY)/2.30259)
      CFY= (.075)/((DMM-2.0)**2)
      CDY=CFY+CWM+CA-CSTUD
      WETSY=WETSUR*LAMDA*LAMDA
      DRAG=CDY*.5*RHO*WETSY*VY*VY
      CLM=(LIFTM)/(.5*RHO*WETSUR*VM*VM)
      CLY=CLM*1.25
      LIFT=CLY*.5*RHO*WETSY*VY*VY
      LD= LIFT/DRAG
      WRITE (4,11) VK,RNY,YAW,HEEL,LIFT,DRAG,LD,CDY,CLY
   11 FORMAT (5X,F5.2,E10.2,7X,F3.1,6X,F4.1,3F10.2,2E10.2)
   20 CONTINUE
      END
```

[redacted]

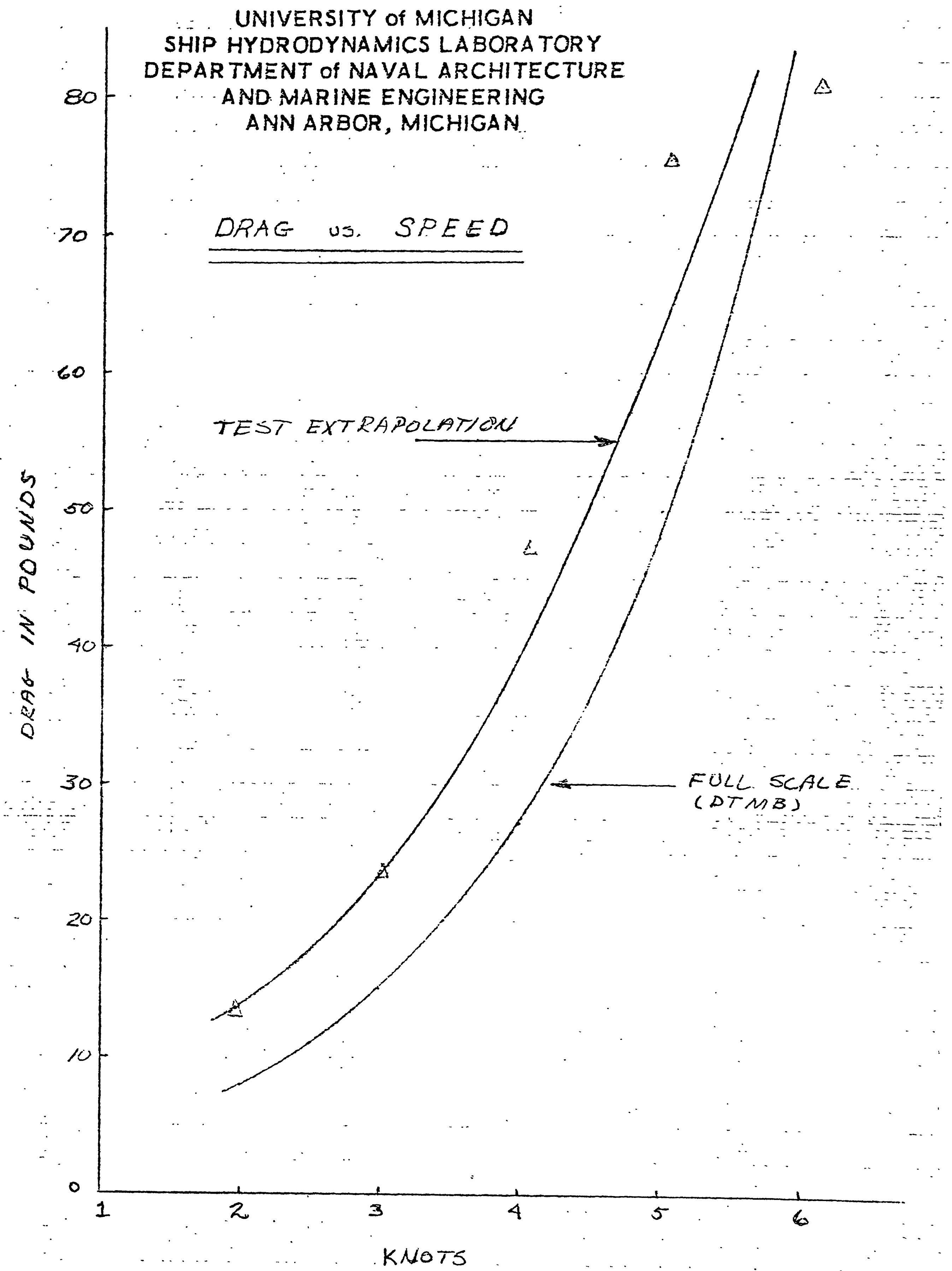
Speed	R.N.	yaw	heel	lift	drag	l/d	C_d	C_l
1.96	0.55E 07	0.0	0.0	2.70	13.73	0.20	0.79E-02	0.15E-02
3.02	0.85E 07	0.0	0.0	2.70	23.69	0.11	0.57E-02	0.65E-03
4.08	0.11E 08	0.0	0.0	5.40	47.41	0.11	0.63E-02	0.72E-03
5.05	0.14E 08	0.0	0.0	6.75	75.48	0.09	0.65E-02	0.58E-03
6.12	0.17E 08	0.0	0.0	10.26	80.08	0.13	0.47E-02	0.60E-03
5.03	0.14E 08	0.0	0.0	0.27	57.01	0.00	0.50E-02	0.24E-04
1.94	0.55E 07	2.0	0.0	16.74	9.68	1.73	0.57E-02	0.98E-02
3.00	0.84E 07	2.0	0.0	43.20	20.74	2.08	0.51E-02	0.11E-01
4.00	0.11E 08	2.0	0.0	86.40	37.93	2.28	0.52E-02	0.12E-01
5.00	0.14E 08	2.0	0.0	132.30	62.19	2.13	0.55E-02	0.12E-01
6.03	0.17E 08	2.0	0.0	210.60	119.27	1.77	0.72E-02	0.13E-01
1.93	0.54E 07	6.0	0.0	67.50	16.87	4.00	0.10E-01	0.40E-01
3.02	0.85E 07	6.0	0.0	169.56	31.25	5.43	0.76E-02	0.41E-01
3.54	0.99E 07	6.0	0.0	206.55	43.53	4.75	0.77E-02	0.36E-01
3.99	0.11E 08	6.0	0.0	299.70	59.19	5.06	0.82E-02	0.42E-01
4.99	0.14E 08	6.0	0.0	483.57	95.78	5.05	0.85E-02	0.43E-01
6.06	0.17E 08	6.0	0.0	731.70	170.86	4.28	0.10E-01	0.44E-01
1.94	0.55E 07	0.0	10.0	-2.70	11.19	-0.24	0.65E-02	-0.16E-02
3.03	0.85E 07	0.0	10.0	-4.05	23.40	-0.17	0.56E-02	-0.97E-03
4.03	0.11E 08	0.0	10.0	-12.15	40.12	-0.30	0.54E-02	-0.16E-02
5.05	0.14E 08	0.0	10.0	-16.20	65.54	-0.25	0.57E-02	-0.14E-02
6.00	0.17E 08	0.0	10.0	-22.95	113.03	-0.20	0.69E-02	-0.14E-02
1.94	0.55E 07	2.0	10.0	33.75	8.60	3.92	0.50E-02	0.20E-01
2.97	0.83E 07	2.0	10.0	61.02	17.65	3.46	0.44E-02	0.15E-01
4.03	0.11E 08	2.0	10.0	61.56	37.10	1.66	0.50E-02	0.84E-02
4.99	0.14E 08	2.0	10.0	190.35	62.73	3.03	0.56E-02	0.17E-01
6.02	0.17E 08	2.0	10.0	307.26	119.82	2.56	0.73E-02	0.19E-01
1.94	0.55E 07	6.0	10.0	82.89	14.87	5.58	0.87E-02	0.48E-01
2.99	0.84E 07	6.0	10.0	192.51	30.53	6.30	0.75E-02	0.48E-01
4.03	0.11E 08	6.0	10.0	351.27	58.70	5.98	0.80E-02	0.48E-01
5.06	0.14E 08	6.0	10.0	583.74	104.53	5.58	0.90E-02	0.50E-01
6.08	0.17E 08	6.0	10.0	856.17	172.90	4.95	0.10E-01	0.51E-01
1.93	0.54E 07	0.0	20.0	6.75	12.98	0.52	0.77E-02	0.40E-02
2.97	0.83E 07	0.0	20.0	10.26	20.89	0.49	0.52E-02	0.26E-02
4.05	0.11E 08	0.0	20.0	15.66	38.52	0.41	0.52E-02	0.21E-02
5.06	0.14E 08	0.0	20.0	32.40	64.36	0.50	0.55E-02	0.28E-02
6.11	0.17E 08	0.0	20.0	67.50	125.35	0.54	0.74E-02	0.40E-02
1.94	0.55E 07	2.0	20.0	29.70	12.49	2.38	0.73E-02	0.17E-01
3.00	0.84E 07	2.0	20.0	56.70	22.04	2.57	0.54E-02	0.14E-01
3.90	0.11E 08	2.0	20.0	96.66	39.86	2.43	0.58E-02	0.14E-01
5.00	0.14E 08	2.0	20.0	198.45	75.59	2.63	0.67E-02	0.17E-01
6.06	0.17E 08	2.0	20.0	307.80	130.90	2.35	0.79E-02	0.18E-01
1.96	0.55E 07	6.0	20.0	69.39	17.19	4.04	0.99E-02	0.40E-01
3.00	0.84E 07	6.0	20.0	179.55	34.13	5.26	0.84E-02	0.44E-01
4.02	0.11E 08	6.0	20.0	330.21	62.03	5.32	0.85E-02	0.45E-01
5.16	0.14E 08	6.0	20.0	562.14	106.79	5.26	0.88E-02	0.46E-01
6.02	0.17E 08	6.0	20.0	788.13	173.39	4.55	0.11E-01	0.48E-01

EXECUTION TERMINATED

Reduced Data

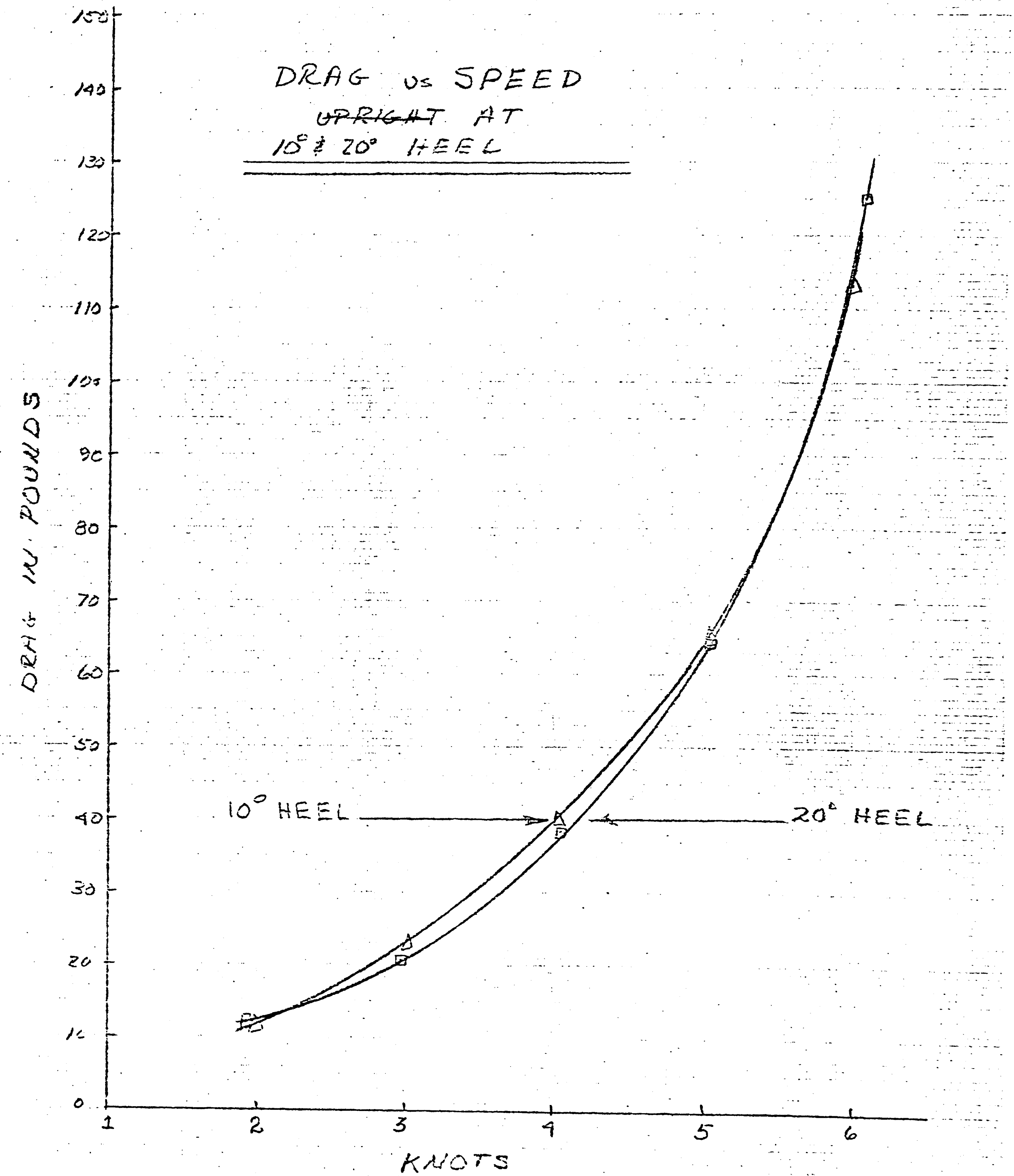
Appendix E

JLJ 1/11



DRAG VS. SPEED FOR UPRIGHT CONDITION

UNIVERSITY of MICHIGAN
SHIP HYDRODYNAMICS LABORATORY
DEPARTMENT of NAVAL ARCHITECTURE
AND MARINE ENGINEERING
ANN ARBOR, MICHIGAN



DRAG vs SPEED AT 10° & 20° HEEL
FIGURE 4a)

Figure 6. Drag Coefficient C_d Versus Yaw Angle² for 0, 10 and 20 Degrees Heel at 2, 3, 4, 5 and 6 Knots for the Full Scale Antiope.

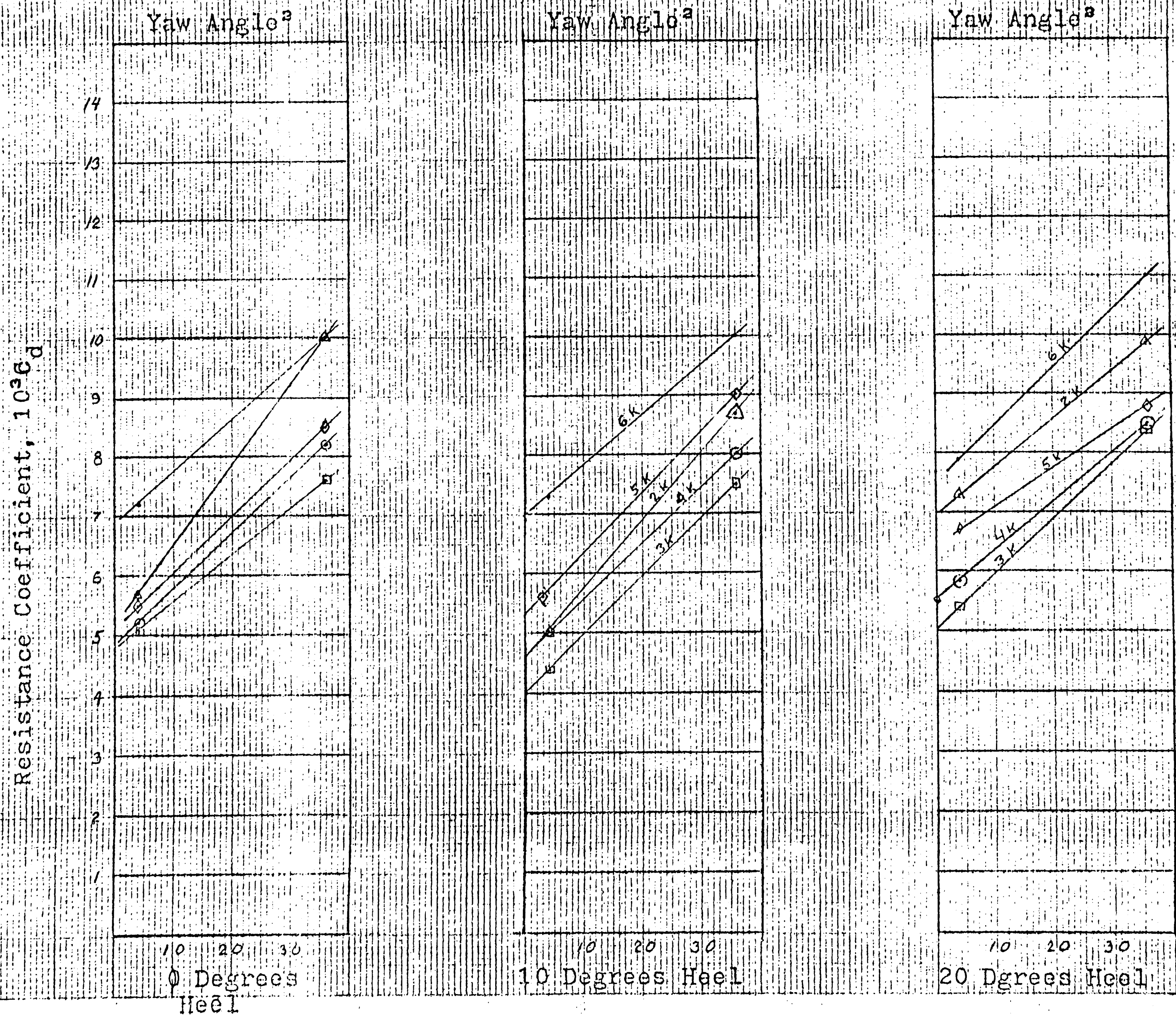
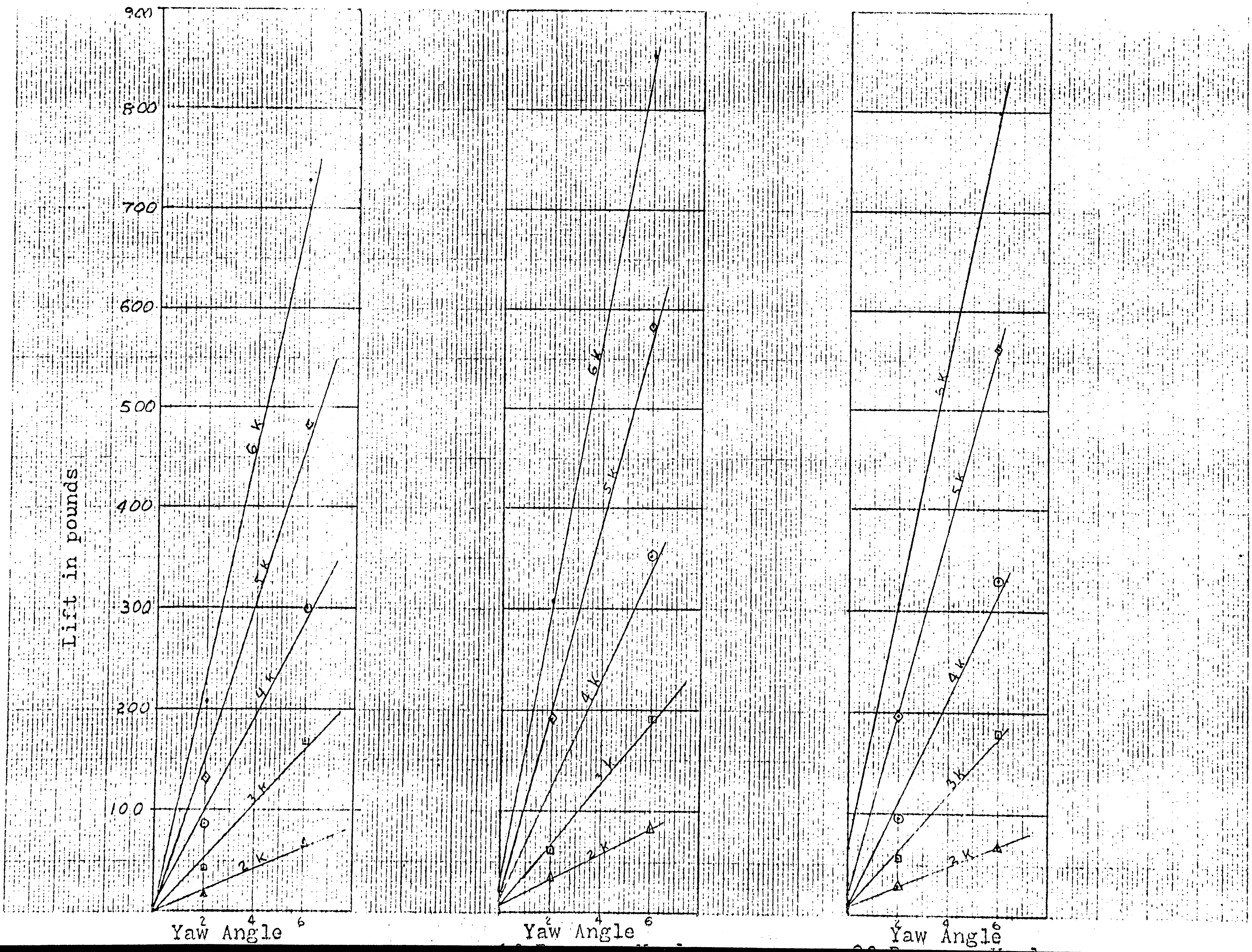


Figure 7. Lift Versus Yaw Angle for 0, 10 and 20 Degrees Heel at 2, 3, 4, 5 and 6 Knots for the Full Scale Antiope



Appendix F

Appendix F

This appendix summarizes several sections of the paper, "Scale Effects in Sailing Yacht Hydrodynamic Testing" by Karl L. Kirkman and David R. Pedrick. The paper was presented at the Annual Meeting of the Society of Naval Architects and Marine Engineers in 1974. The paper presents the results of a background study of potential scale effect problems and a broad experimental investigation.

Two factors which are relevent to the ANTIOPE model discussed below.

The accuracy of full scale yacht performance predictions from model tests is dependant on the model load water line length. The reason for this is that even with turbulence stimulators on the models fully turbulent flow is not always achieved. The full size yacht is assumed to work in the turbulent flow regime of fliud flow. To duplicate flow conditions in accordance with the laws of similitude, the model must also operate in the turbulent regime. In small models, less than 8 feet, the Reynould's Number is generally below that associated with fully turbulent flow. Therefore, in models less than 8 feet it is important proper turbulence stimulation be used and turbulent flow guaranteed.

Accurate predictions of full scale performance are dependent upon the correct determination of the turbulence stimulator drag.The correction for the drag of the stimulators is found by testing the model under similiar conditions with and without the stimulators attached. The difference in the model drag is then computed and applied as a correction factor. As the model LWL decreases the stimulator drag becomes a more significant percentage of the total model drag, and also becomes more difficult to determine accurately.

Since the 1/6th scale ANTIOPE model is small it is subject to both of the phenomenon described above. A more detailed discussion of scale effects is available in the reference paper.