YLOR MODEL BASIN WASHINGTON 7 D.C.

DEPARTMENT OF THE NAVY

[redacted]

HYDROMECHANICS

o

AERODYNAMICS

o

STRUCTURAL MECHANICS

o

APPLIED MATHEMATICS

WAKE ANALYSIS OF SHIP MODELS TWIN-SCREW MERCHANT TYPES

by

H.M. Cheng

and

J.B. Hadler

[redacted]

Distribution of This Document is Unlimited

HYDROMECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

October 1965

Report 2074

WAKE ANALYSIS OF SHIP MODELS
TWIN-SCREW MERCHANT TYPES

by

H.M. Cheng
and
J.B. Hadler

Distribution of This Document is Unlimited

October 1965

Report 2074
S-R011 01 01
Task 0401

TABLE OF CONTENTS

LIST OF FIGURES

NOTATION

D	Propeller diameter
J_a	Apparent advance coefficient V/nD
n	Propeller revolutions
P	Pressure factor $(V_b^2)_{max}/\overline{V_b^2} = 1$
R	Radius of propeller
r	Radial coordinate
U	Blade element velocity
V	Model or ship velocity
$\underline{V}$	Resultant wake velocity vector
V_b	Resultant inflow velocity to blade
$\overline{V}_b$	Mean resultant inflow velocity to blade
V_r	Radial component of velocity vector
$\overline{V}_r$	Mean radial component of velocity vector
V_t	Tangential component of velocity vector
$\overline{V}_t$	Mean tangential component of velocity vector
$(\widetilde{V}_t)_n$	n^{th} harmonic amplitude of tangential velocity
V_{tr}	Transverse component of velocity vector
$\overline{V}_v$	Volumetric velocity
V_x	Longitudinal component of velocity vector (normal to the plane of propeller)
$\overline{V}_x$	Mean longitudinal component of velocity vector
$(\widetilde{V}_x)_n$	n th harmonic amplitude of longitudinal velocity
X, Y, Z	Cartesian coordinates
α_h	Projected angle of velocity vector on X-Y plane
α_v	Projected angle of velocity vector on X-Z plane
β	Advance angle in degrees
$\overline{\beta}$	Mean advance angle
$\Delta\beta$	Variation of advance angle from its mean
θ	Position angle (angular coordinate) in degrees

Hull coefficients are in accordance with SNAME-recommended standard.

ABSTRACT

This report, the fourth in a series on studies of the wake in the propeller plane of ship models, presents the results of the wake of twin-screw merchant-type ship models using the IBM-7090 computer. The data presented are the interpolated longitudinal and tangential velocity distributions, their computer mean values, the harmonic contents of these velocity components, the maximum variations in the resultant inflow velocity, and the advance angles and their variations. Also included are the calculated volumetric wake velocities.

ADMINISTRATIVE INFORMATION

The work reported herein was sponsored by the Bureau of Ships under the CORE Program (S-R011 01 01) of the David Taylor Model Basin.

INTRODUCTION

This is the fourth of a series of reports on studies of the wake in the propeller plane of ship models. The first three reports [1,2,3*] presented, respectively, the results of the analyses of the wake of single-screw DE-type, twin-screw military types and single-screw merchant-type ship models. This report presents the results of the wake analysis of twin-screw merchant-type ship models.

In all, 10 models were analyzed, including one naval oiler. This group is further subdivided into smaller groups according to the general stern configuration and the arrangement of supports for outboard shafting; that is, skegs, bossings, or struts.

Figure 1 shows sketches of the hull lines of representative models and Table 1 provides the model data and the major hull characteristics. Photographs of the various types of stern designs are shown in Figure 1A. The first subgroup consists of four models, 3913, 3917-1, 4013, and 4013-4, which have twin skegs for shafting support. Models 3913 and 3917-1 are very similar, having identical forebodies and slightly different sterns. Models 4013 and 4013-4 are the same except that the skegs on Model 4013-4 have been cut short.

Model 3931 is the only model with bossings. Three different bossings (B, C, D) were designed. The inclination of the reference planes with the horizontal is slightly different for these designs; that is, 30 deg, 37.5 deg, and 42 deg, respectively (Figure 2). Wake measurements were made for each bossing design.

The third subgroup consists of Models 3979, 4567-2, 4691, and 4997 with twin-arm struts for shaft support. Their hull lines are quite different.

---

*References are listed on page 40.

Models 4691 and 4833 are designed for tanker service and are the same, except the former has a conventional stern with twin-arm struts supporting the shaft whereas the latter has the special TMB stern. A direct comparison between these two sterns is presented.

The data reported are the axial and tangential wake velocity distributions in the plane of a propeller, their computed circumferential mean values and harmonic contents at various radii, the maximum variations in the resultant inflow velocity, and the advance angles and their variations. The calculated volumetric wake velocities are also presented. The reader is referred to Reference 1 for discussions of the test procedures, the method of data reduction, and the applications of wake data in propeller-ship design.

TEST PROCEDURE AND DATA REDUCTION

The wake surveys for the various models were conducted in the deep-water towing tanks at the Model Basin. The surveys span a time period of approximately 20 years.

To obtain the velocity field behind a ship model, the pressures at various points in the field are measured with a spherical pitot tube while the model is being towed at a given speed and draft condition. The dynamic pressure at test points is then derived from the measured pressure.

Only the field of the port propeller is surveyed for the ships reported here because for a twin-screw ship, the flow at the propeller plane is assumed to be symmetrical with respect to the center vertical plane of the ship. On most ships, the port propeller shaft has a larger shaft angle dictated by the machinery arrangement. When the tests were conducted, all appendages except the rudder were installed. Measurements were made at only one speed for each of the models. Note that Table 1 shows the speeds to be comparable except for tankers, which have a considerably lower speed.

The pitot tubes used for the surveys were either of the so-called 5-hole design or of the 13-hole design. The 13-hole pitot tube was used for the measurements on the models tested prior to 1955; the 5-hole tubes were used for the remainder of the models.

Reference 1 describes in detail the method of mounting and aligning the pitot tube equipment on the model to obtain the desired field points.

The test data are used as input to the computer program for analyses. The procedure of data reduction is similar to that described in Reference 1.

PRESENTATION OF DATA

Two types of information are presented: the test data and the computed results. The test data are those obtained from the model experiments at discrete test points. The computed data are the quantities calculated on the basis of the test data. For convenience, a standard length on waterline of 600 ft and a standard propeller diameter of 18 ft were chosen for the presentation of the computed results.

The test data are tabulated in Figures 20 through 30 in the Appendix. Some of these data have been published in References 4 through 8.

Figures 3 through 7 show the interpolated circumferential distribution of the longitudinal and tangential velocity components at the test radii. From these figures, it may be observed that the velocity pattern at the various radii tested has a characteristic shape. The longitudinal component shows velocity defects in the region nearest the hull in the shadow of the propeller shaft and behind the skegs or bossings. The magnitudes vary depending upon the types of appendage. In general, the models with skegs and bossings have a larger dip than those with struts. The maximum magnitude is in the order of 50 percent of the model speed. Note in Figure 3 that the velocity distribution curves also dip down at the bottom of the propeller disk where the skeg ends; this clearly shows the effect of the skegs on the velocity distributions. Comparing Model 4013 and 4013-4, we find that the shorter skeg on Model 4013-4 has very little effect except at the inner radii and gives an almost uniform flow nearing the bottom of the propeller disk (180-deg position).

The tangential component is more noticeably affected by skegs and bossings. In general, it shows roughly a symmetrical flow pattern with the plane of symmetry in the 160-deg to 340-deg position. For the models with skegs and bossings, the maximum occurs in the 60-deg region, 30 deg either side of the plane of symmetry; for the models with struts, the distribution is approximately sinusoidal. The maximum magnitude is approximately ±15 to 25 percent of the model velocity; models with bossings have a larger fluctuation and models with struts have relatively lower variations.

Model 3931 (Figure 5), which has three bossing designs at different angular positions to the hull, shows that the shapes of the flow patterns are similar but that the magnitudes vary somewhat. From Figure 5 it may be noted that the longitudinal velocity behind bossing "D" is significantly lower than the other two. In view of the limited number of circumferential measurements, it is not certain how meaningful this difference may be. It has a significant effect on the derived quantities shown in Figures 10 and 16.

Figure 7 presents direct comparison between two different stern designs: conventional stern with struts supporting the outboard shafting (Model 4691), and the special TMB-type stern (Model 4833). It is surprising to find that the special stern creates a considerably less favorable longitudinal distribution and offers only marginal improvement in the tangential component.

The interpolated circumferential distribution curves of the longitudinal and tangential components are analyzed for their harmonic contents. The data are presented according to the subgroups. The circumferential mean values obtained at various radii for the various subgroupings are shown in Figure 8. Also shown in this figure are the calculated volumetric mean velocities. Reference 1 defines this term. The amplitudes and phase angles for various orders of harmonics are obtained from the harmonic analysis of the velocity curves and are shown in Figures 9 through 14. The spots shown in these curves are the calculated values of the amplitudes and phase angles at the test radii.

To furnish useful information in analyzing the performance and the cavitation characteristics of a propeller operating in a nonuniform wake field, the wake data are further analyzed in terms of maximum variations, or maximum fluctuations in the resultant inflow velocity to the propeller blade and in the advance angles. As shown in Figure 15, the velocity at the blade elements depends on the propeller rotational speed. To establish proper geometric relationships, it is necessary to assume certain operating conditions, namely, the advance coefficients J_a. Since the designed advance coefficient for the various models varies from 0.90 to 1.05, except for the tankers which have a lower J_a, an advance coefficient of 1.0 was arbitrarily chosen for this analysis. As given in Reference 1, the computed quantities show a relatively small change over a wide range of J_a values.

Figure 16 presents the calculated mean values of the advance angle $\bar{\beta}$ at various radii, their maximum variations $\pm\Delta\beta$, and the so-called pressure factors which represent the minimum pressure at the propeller blade element. This minimum pressure results from the fluctuations in the inflow velocity expressed as percent of the mean resultant velocity.

DISCUSSION

From a comparison of the results between each subgroup and the models within each subgroup, the following is observed:

1. The radial distributions of the mean longitudinal velocities for the models are comparable in magnitude, varying only slightly with respect to radius because the circumferential distributions at the various test radii are almost the same. The magnitude of the mean longitudinal velocity is in the order of 90 percent of the model velocity.

   In general, the models with struts have slightly higher values; the models with skegs, slightly lower. Note that the radial distributions of the mean velocity for the models with struts have shapes that are similar to those shown in Reference 2 for twin-screw military-type ships but are at lower values.

2. The radial distributions of the mean tangential velocity are again fairly flat with a magnitude that is nearly zero due to the nearly symmetrical circumferential distribution. The trailer ships, represented by Models 4013 and 4013-4, which are far from being symmetrical, show a relatively larger mean tangential velocity.

3. The amplitudes and phase angles for various orders of harmonics show quite a large scatter among the models, indicating that the harmonic contents of the circumferential distributions of the wake velocity are somewhat different even though the mean values are fairly close. As a whole, the values for the ships with struts, Figure 11, are lower than

those for the ships with skegs or bossings, Figures 9 and 10. The results of the tests on the bossing, Figure 10, provide the only direct comparison. For the harmonics of primary interests, 3rd through 7th, bossing B shows significantly lower values. The results of the harmonic analysis of the tangential velocity component shown in Figures 12, 13, and 14 are consistent with the observations noted for the longitudinal component.

4. The maximum and minimum values of the advance angle shown in Figure 16 clearly illustrate the advantage of the strut support in reducing the cavitation problem, particularly the back cavitation as shown by the magnitude of the $-\Delta\beta$ angle. Within each group, the $-\Delta\beta$ value shows a large amount of scatter. This is due to the minimum longitudinal velocity in the region behind the shaft shadow, strut, or bossing. Since in these tests relatively few measurements were made in this region, the magnitude is somewhat uncertain.

5. Figures 17, 18, and 19 show a comparison of the computed results for Models 4691 and 4883. The former has a conventional stern with struts and the latter has a special stern which was developed to obtain a larger wake fraction and to create a minimum of circumferential velocity variations. The wake patterns for these two sterns, as pointed out earlier, are quite different and the derived results reflect this difference. As shown in Figure 17, a significantly higher wake was achieved. The larger variations in velocity already noted resulted in greater cavitation problems, as shown in Figure 17 by the significantly greater value of the maximum and minimum advance angle. The comparison of the harmonics does not clearly indicate that one stern is markedly better than the other if propellers of conventional numbers of blades (4, 5, or 6) are considered. The amplitudes for some of the harmonics are greater for the special twin-nacelle stern but the phase shift from the root to the tip is also greater. Thus, depending upon the details of the propeller-blade design, the vectorial sum of the total unsteady force over the blade may be little different from that of the stern provided with struts.

CONCLUSIONS

1. The ships in this report represent an extremely wide range of designs and service. Despite the wide variation in hull geometry, the variations in the mean values are surprisingly small, thus indicating that the details of hull design are not very significant. The actual variations in the pattern are almost completely dominated by the details of the appendage design.

2. Comparisons of strut with skeg- or bossing-supported propeller shafts show that struts are markedly superior so far as cavitation and the unsteady propeller forces are concerned.

3. The variations in the advance angles and the harmonics within the various groups are fairly wide but between groups they show a clear trend. How much variation is due to detailed differences of appendages and how much to lack of sufficient data is not clear. A greater deliniation of the velocity in the region of the appendages is necessary for concise comparisons.

RECOMMENDATIONS

As a result of this analysis, the following recommendations are made regarding future work on twin-screw merchant-type ships.

1. Any future wake surveys should include a more careful exploration of the region behind the struts and propeller shaft.

2. Since high powers are usually associated with multi-screw ships, strut-supported shafts should be given preference over skegs and bossings in order to reduce propeller cavitation and shaft vibration problems.

ACKNOWLEDGMENTS

The authors wish to express their thanks to Max H. Morris, Inc., for assistance in the collection of data and in the preparation of final graphs and to Mr. George Smith of the Applied Mathematics Laboratory for his help in the computer work.

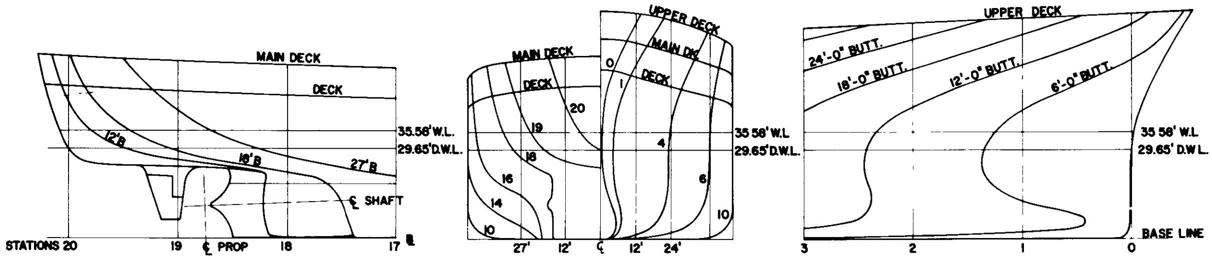
TABLE 1

Model Data — Twin-Screw Merchant Ships

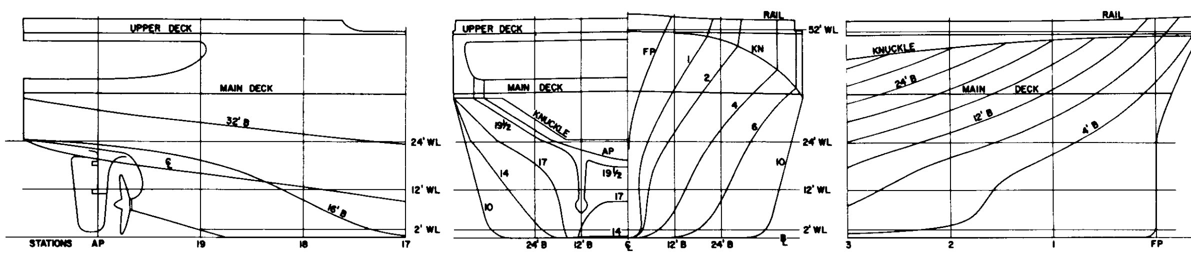
Service*	C-P	C-P	C-P	C-P	P-TR	C-P	T	T	N
Particulars:	Model 3913	Model 3917-1	Model 3931	Model 3979	Model 4013	Model 4567-2	Model 4691	Model 4833	Model 4997
Length of LWL, L_{WL} Ft	20.00	20.00	20.00	20.00	20.49	19.67	24.54	24.54	22.30
Beam, B Ft	2.415	2.415	2.74	1.97	3.13	2.80	3.50	3.50	3.35
Draft, H Ft	0.81	0.81	0.923	0.71	0.83	0.901	1.301	1.301	1.235
Displacement, FW, Δ Ton	0.64	0.64	0.845	0.44	0.744	0.81	2.47	2.47	1.66
Test Velocity, V Kt	4.10	4.10	4.03	4.53	4.85	4.01	2.93	2.93	3.74
$V/\sqrt{L_{WL}}$	0.917	0.917	0.900	1.013	1.071	0.897	0.592	0.592	0.791
Propeller Diameter, D Ft	0.536	0.565	0.585	0.48	0.566	0.583	0.583	0.583	0.732
Advance Coeff., $J_a = V/nD$	0.99	1.05	0.96	1.033	0.944	0.972	0.758	0.776	0.900
Ship-Model Scale, λ	37.25	37.25	32.50	43.75	26.50	30.00	37.715	37.715	--
LWL Coefficients:									
C_B	0.59	0.59	0.599	0.67	0.500	0.59	0.794	0.794	0.643
C_P	0.60	0.61	0.616	0.56	0.542	0.61	0.797	0.797	0.653
C_X	0.98	0.98	0.972	0.98	0.923	0.96	0.996	0.996	0.984
C_{PA}	--	--	0.632	--	0.568	--	0.76	0.76	0.66
C_{PVA}	--	--	--	--	--	--	0.87	0.89	0.75
L_R/L_{WL}	--	--	0.50	--	0.50	--	0.35	0.38	0.52
L_{WL}/B	8.28	8.28	7.30	10.14	6.54	7.02	7.01	7.01	6.67
B/H	2.98	2.99	2.97	2.78	3.77	3.10	2.69	2.69	2.74
$\Delta_{SW}/(0.01\ L_{WL})^3$	82.7	82.7	108.1	56.9	88.5	109.5	172.0	172.0	150.9
Shaft Support	Twin-Skeg	Twin-Skeg	Bossing**	2-Arm Struts & Bossing	Twin-Skeg	2-Arm Struts	2-Arm Struts		2-Arm Struts
Rudder	Twin	Twin	Single	Single	Twin	Single	Twin	Twin	Twin

* C - Cargo, P - Passenger, T - Tanker, TR - Trailer, N - Naval Auxiliary

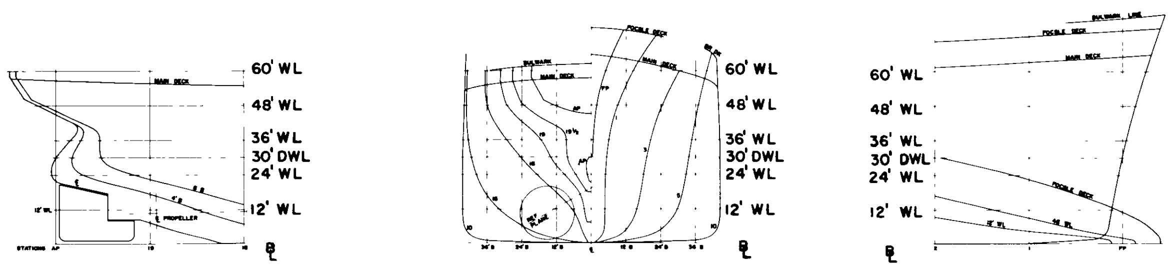
** Three Bossing Designs



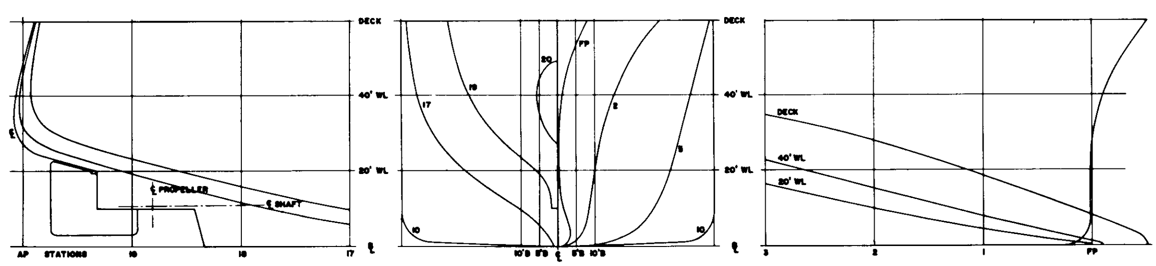
MODEL 3913



MODEL 4013

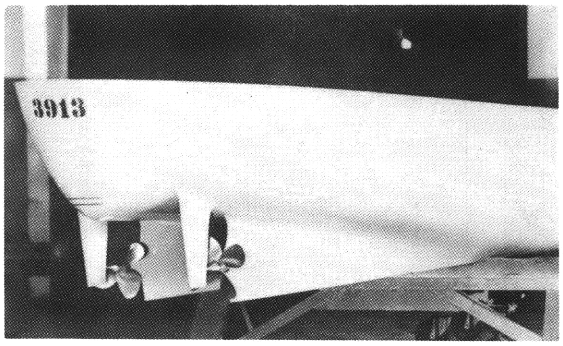


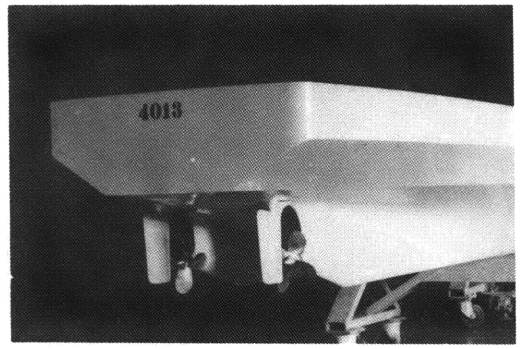
MODEL 3931



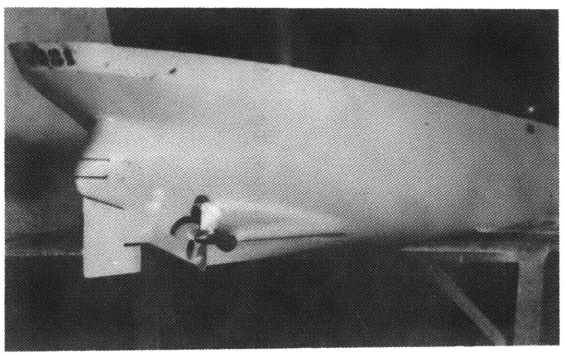
MODEL 4567-2

Figure 1 - Lines of Twin-Screw Merchant Ships

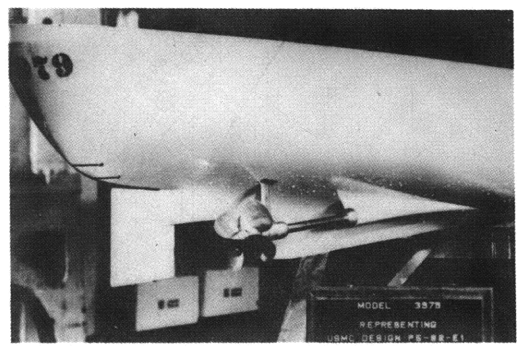




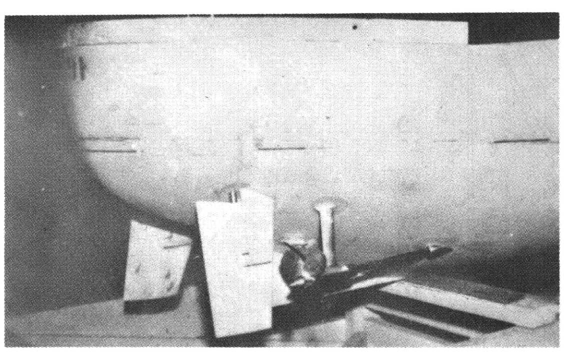
Twin-Skegs



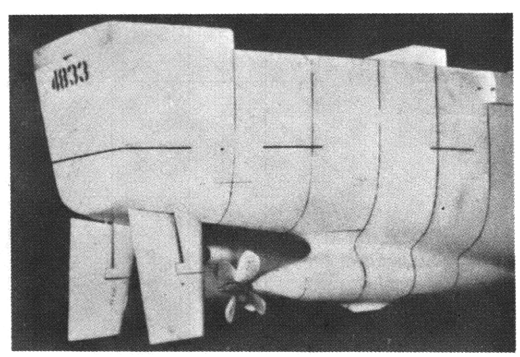
Bossing



Struts and Bossing

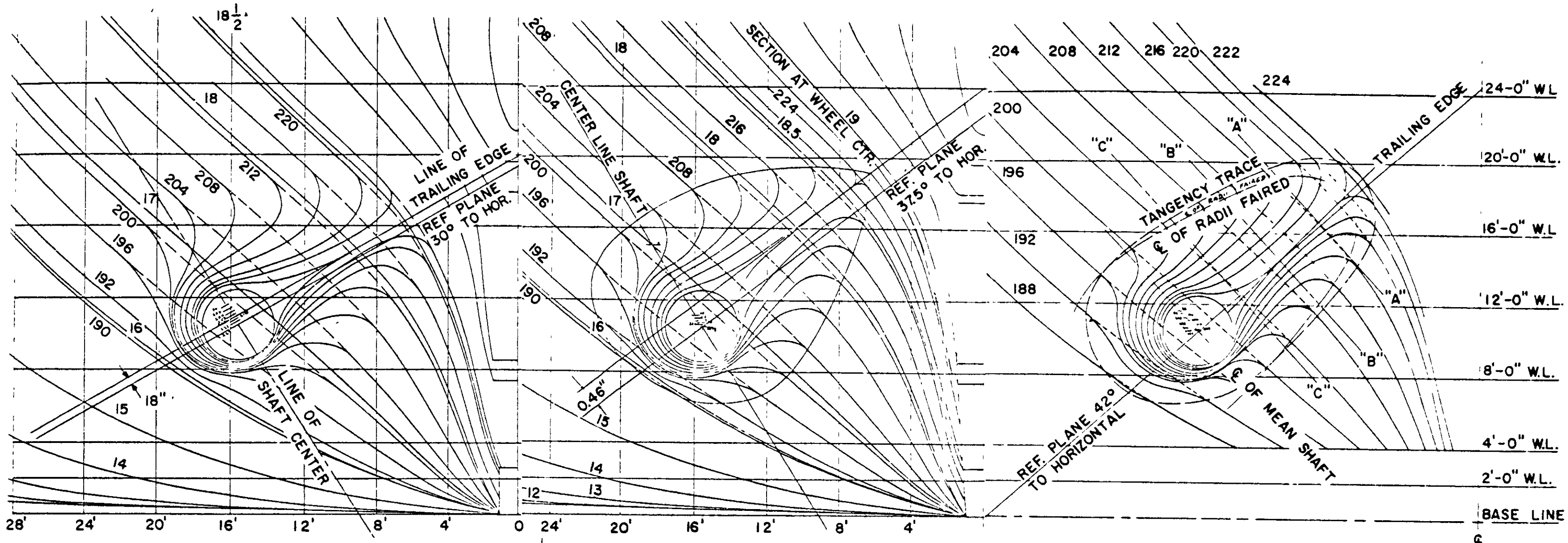


Struts



TMB Special

Figure 1A - Photographs of Sterns of Twin-Screw Merchant Ships



BOSSING "B"

BOSSING "C"

BOSSING "D"

Figure 2 - Bossing Designs for Model 3931

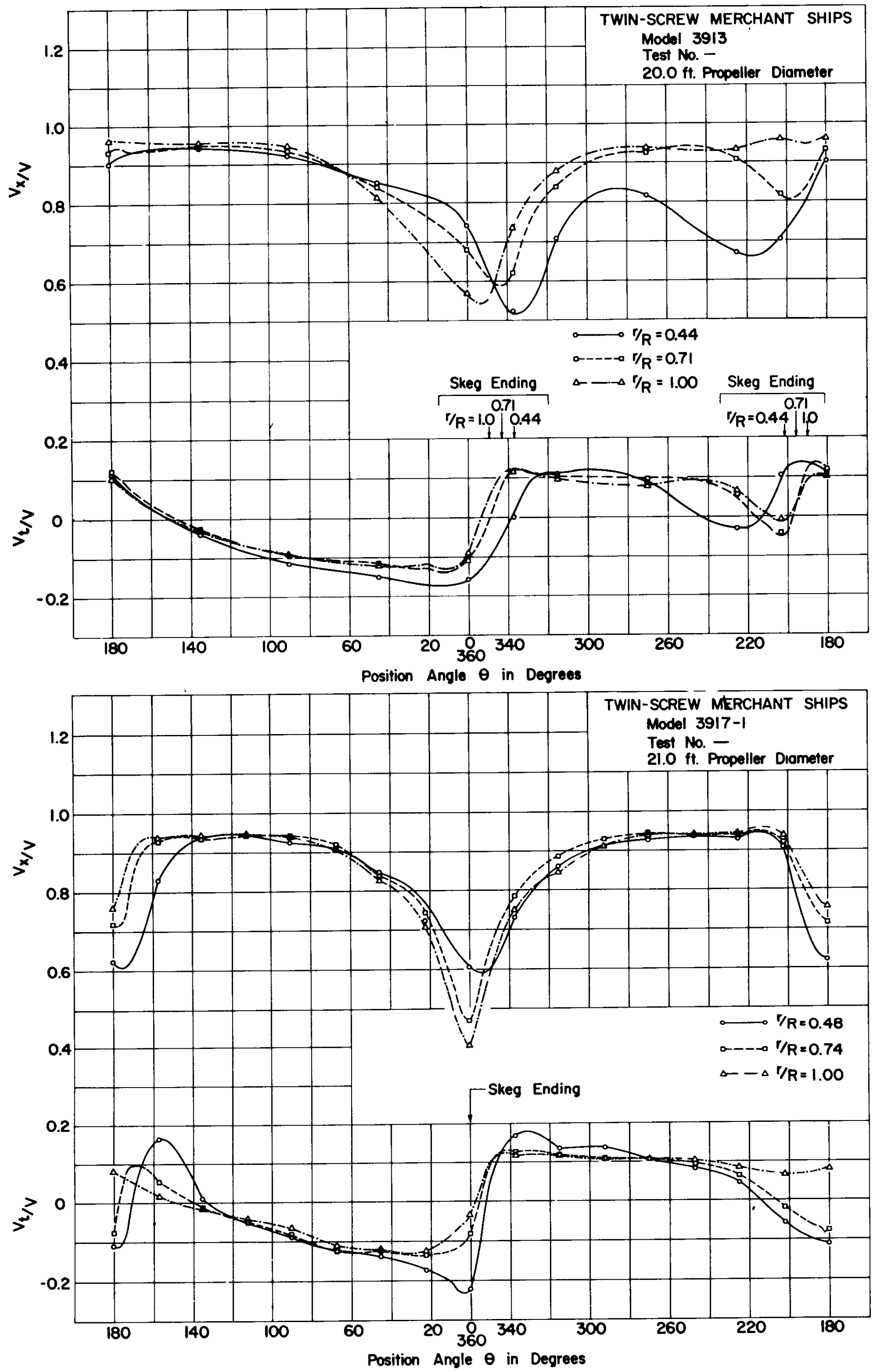
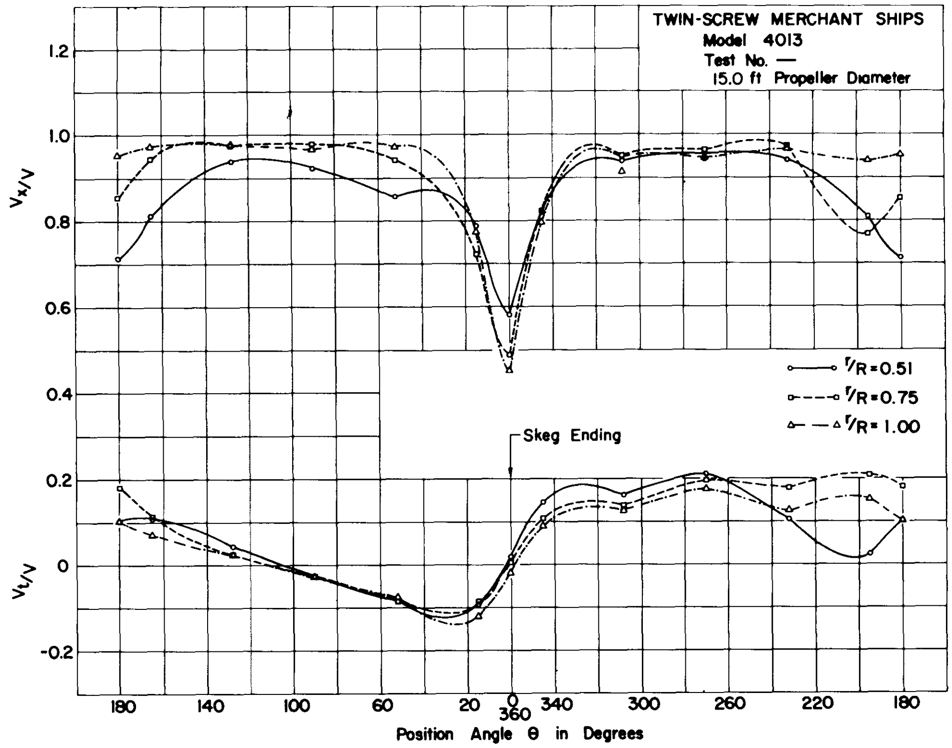


Figure 3 - Circumferential Distributions of Longitudinal (V_x/V) and Tangential (V_t/V) Velocity Components, Stern with Skegs, Models 3913 and 3917



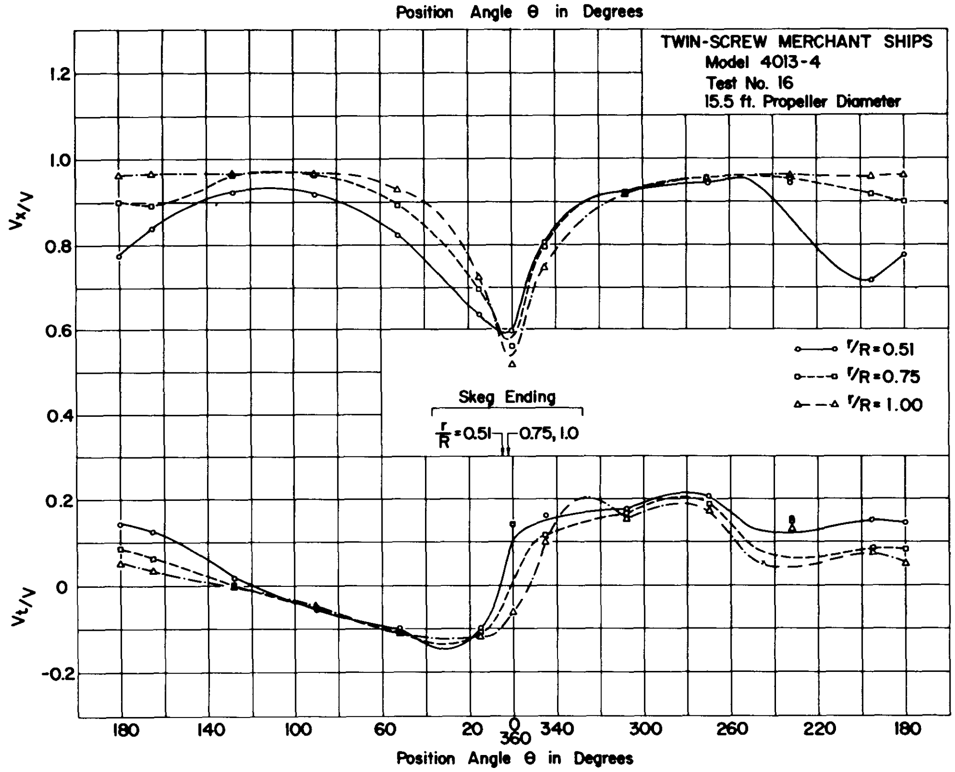


Figure 4 - Circumferential Distributions of Longitudinal (V_x/V) and Tangential (V_t/V) Velocity Components, Stern with Skegs, Models 4013 and 4013-4

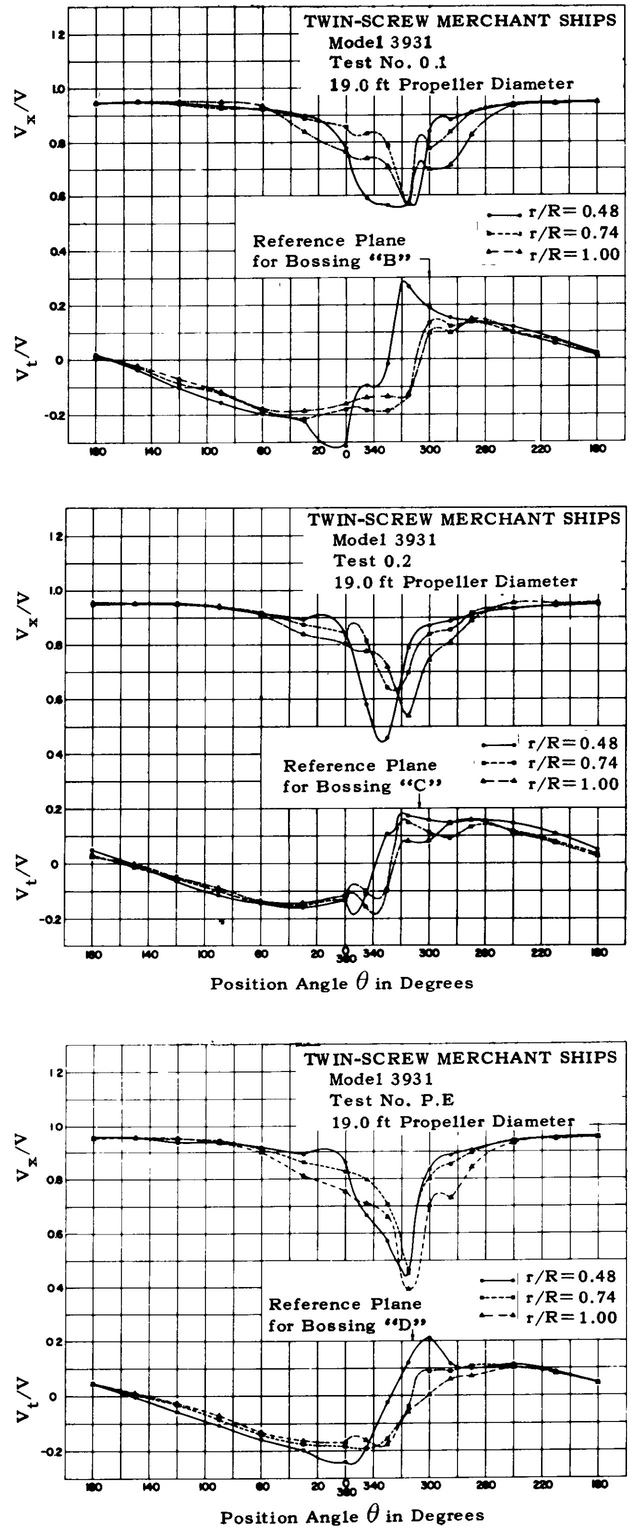


Figure 5 - Circumferential Distributions of Longitudinal (V_x/V) and Tangential (V_t/V) Velocity Components, Stern with Bossings, Model 3931

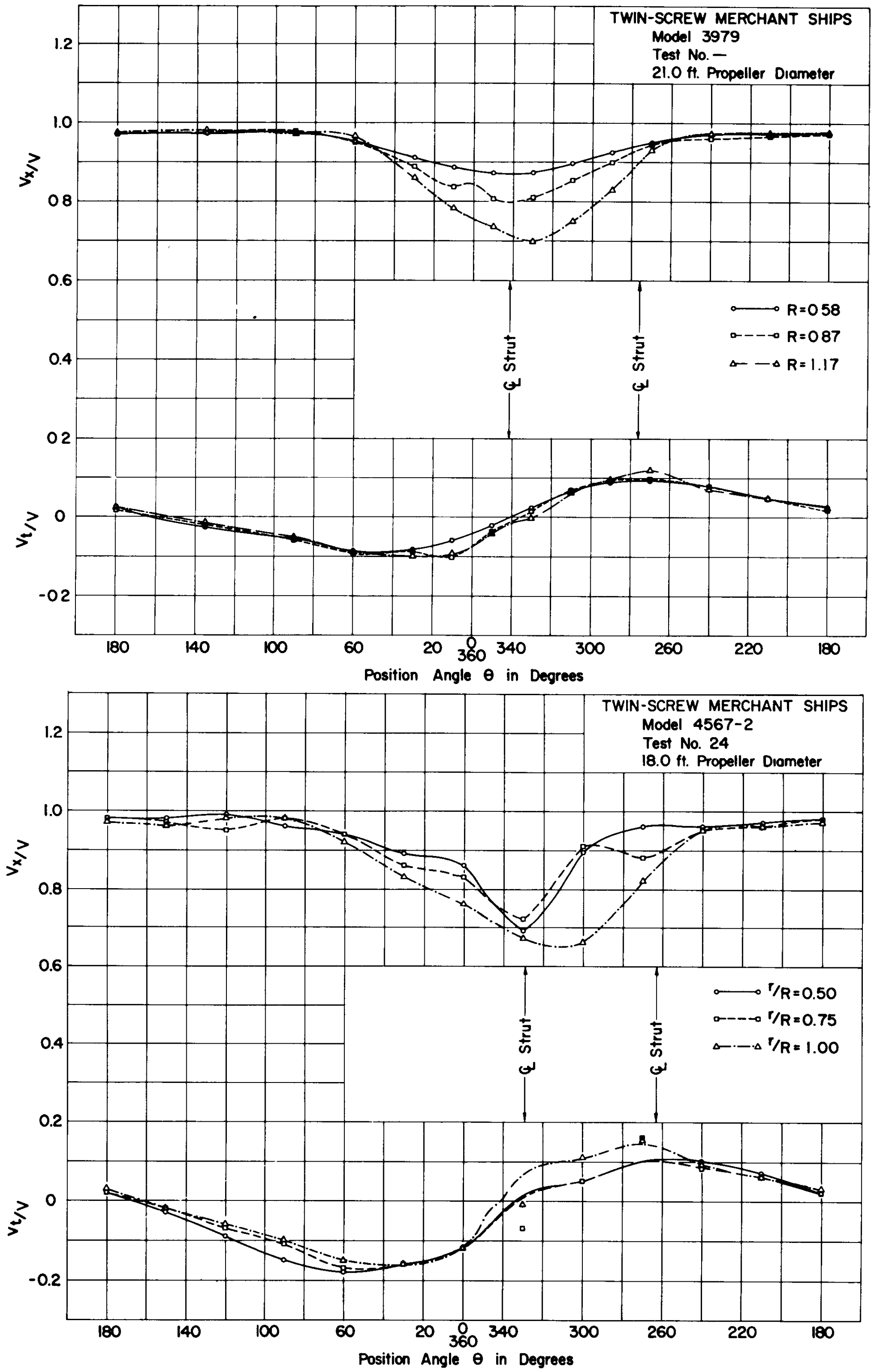
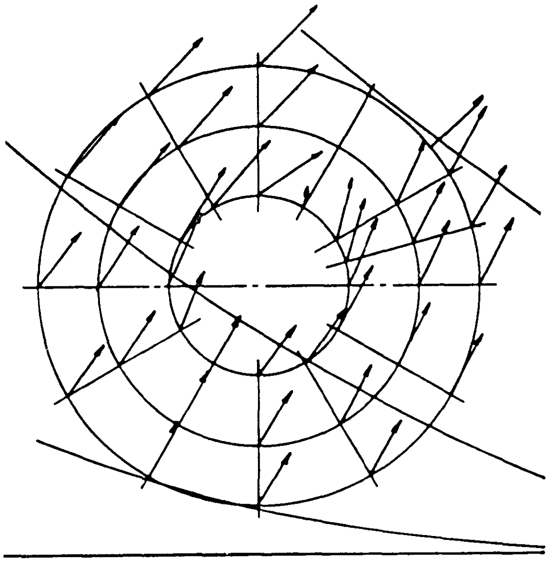
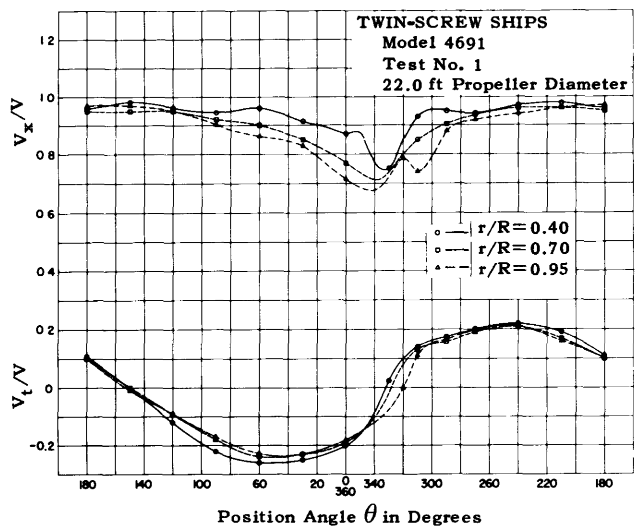
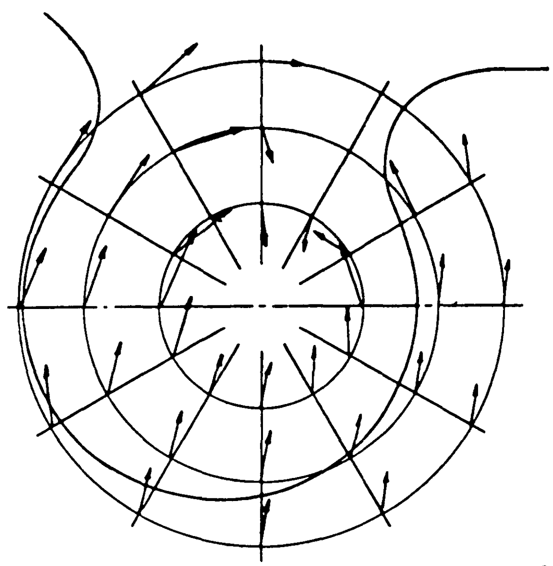


Figure 6 - Circumferential Distributions of Longitudinal (V_x/V) and Tangential (V_t/V) Velocity Components, Stern with Struts, Models 3979 and 4567-2



TWIN SCREW SHIP
Model 4691 Test No. 1
22.0 Ft. Propeller Diameter





TWIN SCREW SHIP
Model 4833 Test No. 9
22.0 Ft. Propeller Diameter

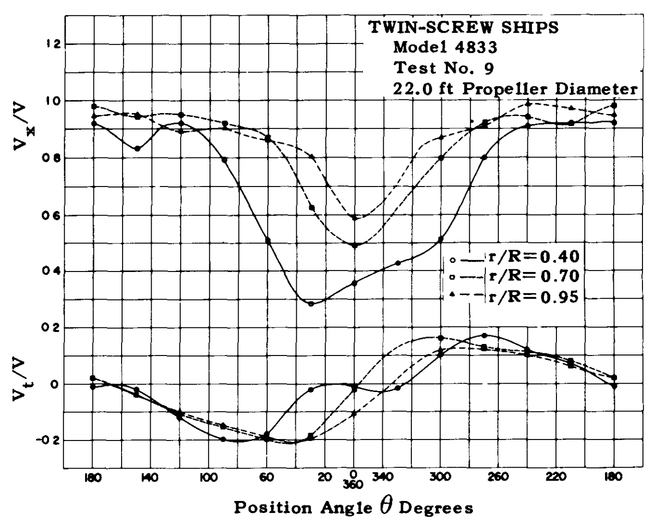


Figure 7 - Circumferential Distributions of Longitudinal (V_x/V) and Tangential (V_t/V) Velocity Components, Stern with Strut Versus Special TMB Stern

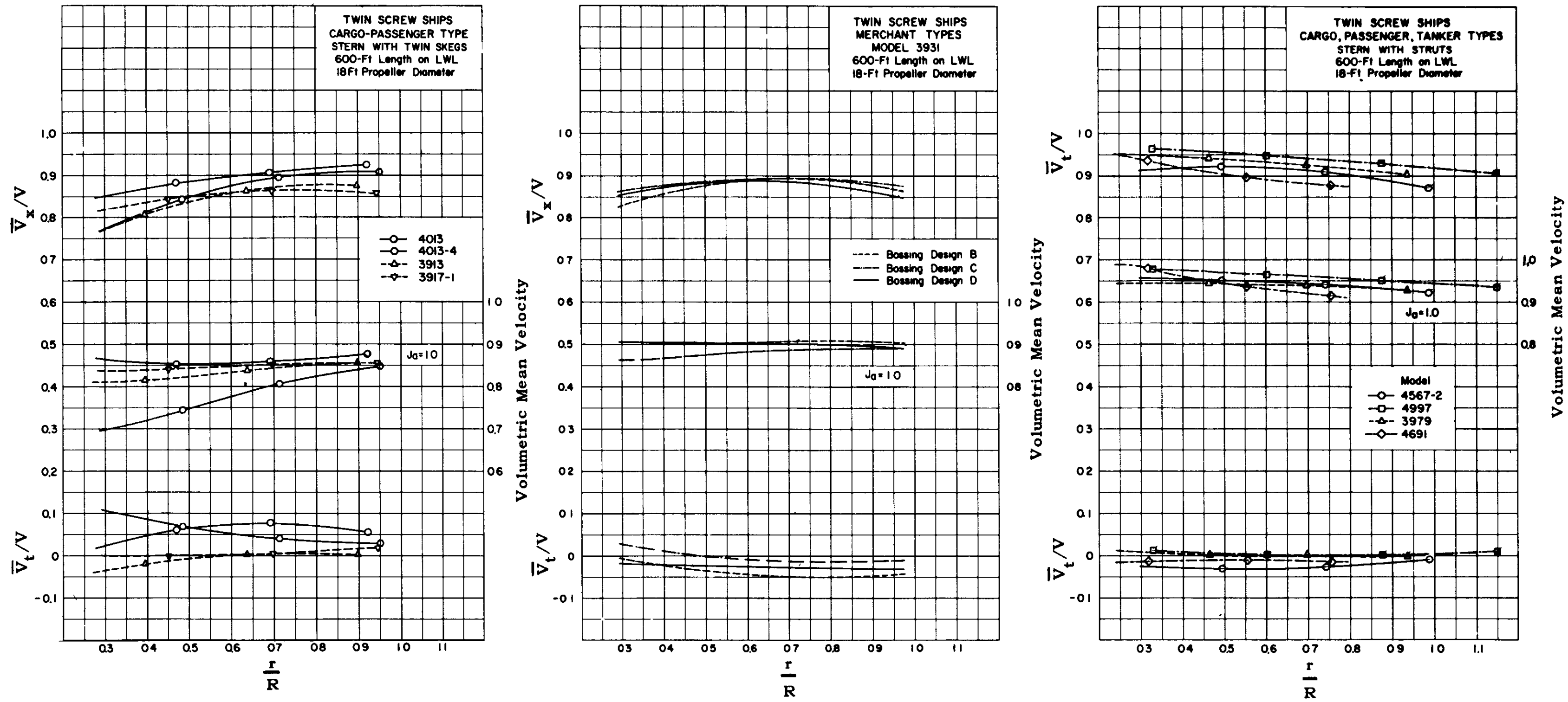


Figure 8 - Mean Longitudinal ($\overline{V}_x/V$) Velocity, Mean Tangential ($\overline{V}_t/V$) Velocity, and Volumetric Mean Velocity, Twin-Screw Merchant Types

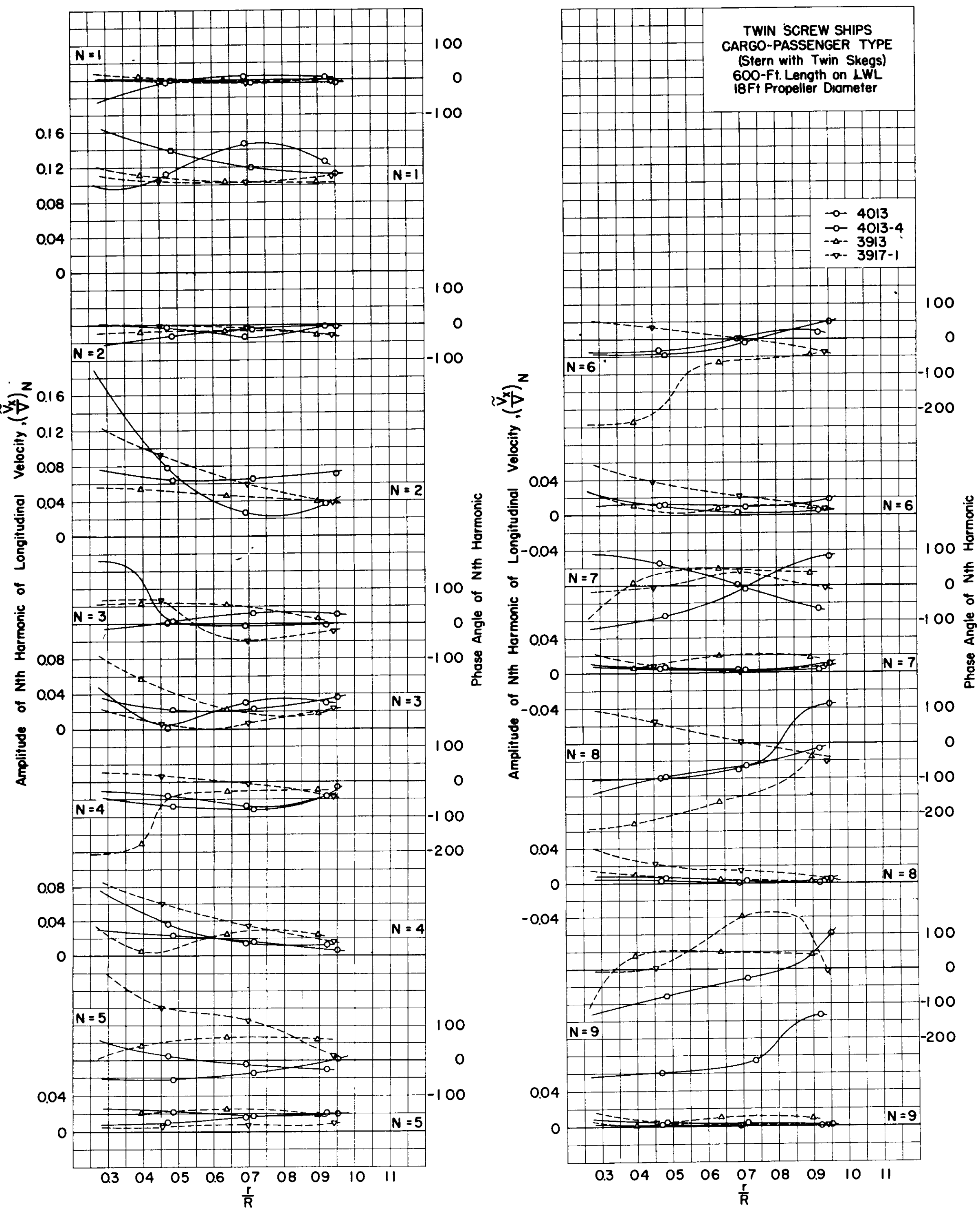


Figure 9 - Amplitudes and Phase Angles of Longitudinal $(\tilde{V}_x/V)$ Velocity, Twin-Screw Merchant Types, Stern with Skegs

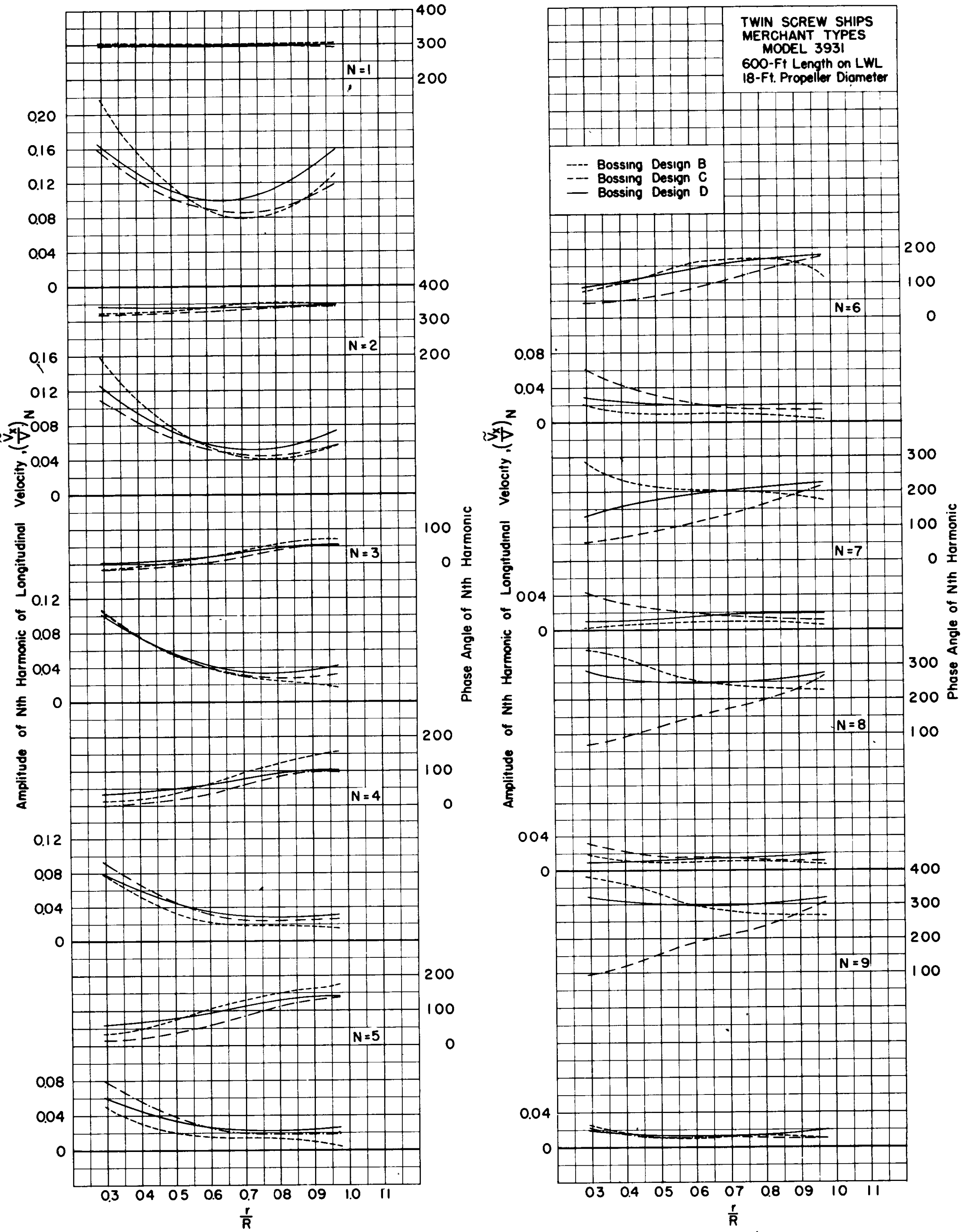


Figure 10 - Amplitudes and Phase Angles of Longitudinal $(\tilde{V}_x/V)$ Velocity, Twin-Screw Merchant Types, Stern with Bossings

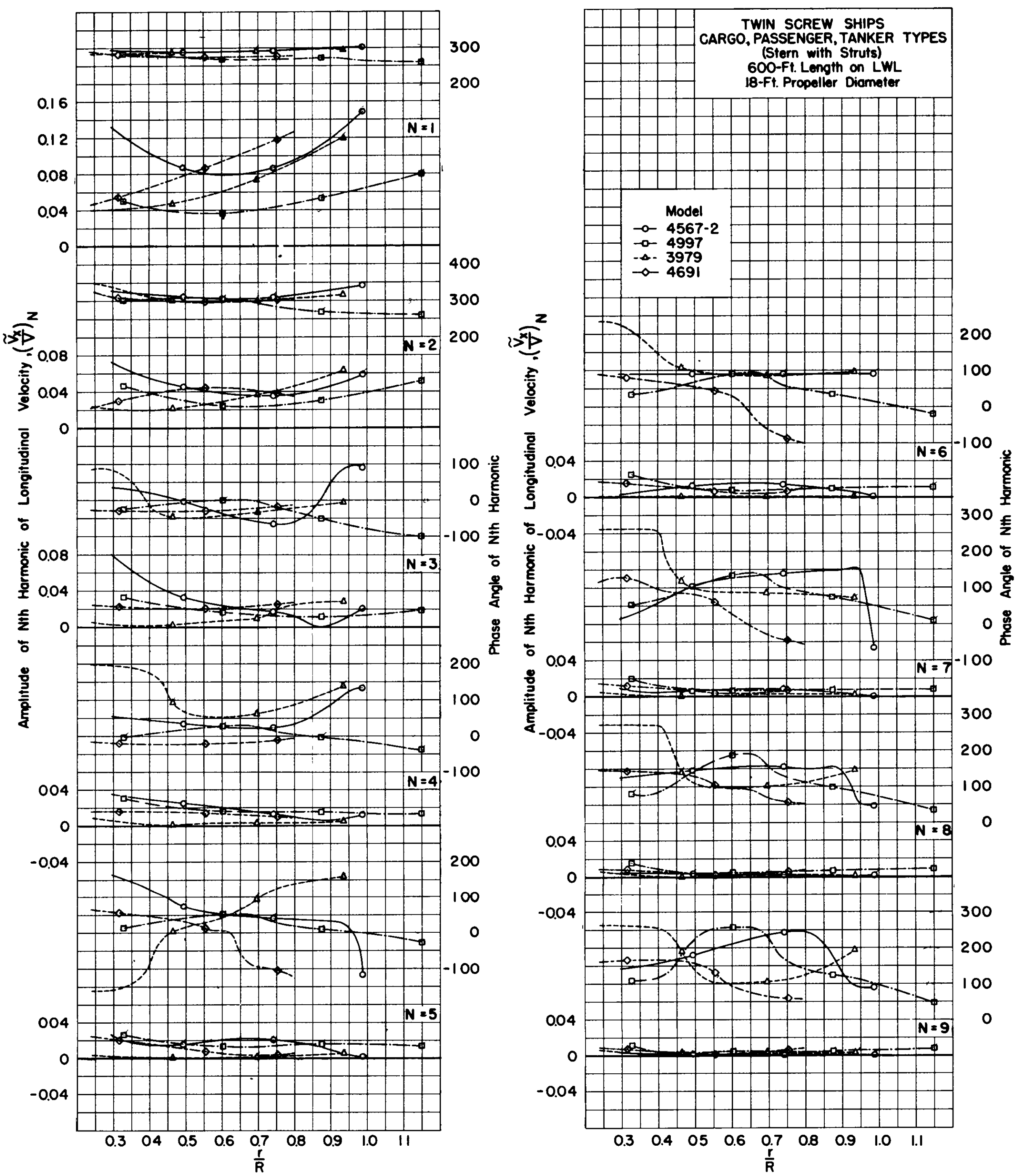


Figure 11 - Amplitudes and Phase Angles of Longitudinal $(\tilde{V}_x/V)$ Velocity, Twin-Screw Merchant Types, Stern with Struts

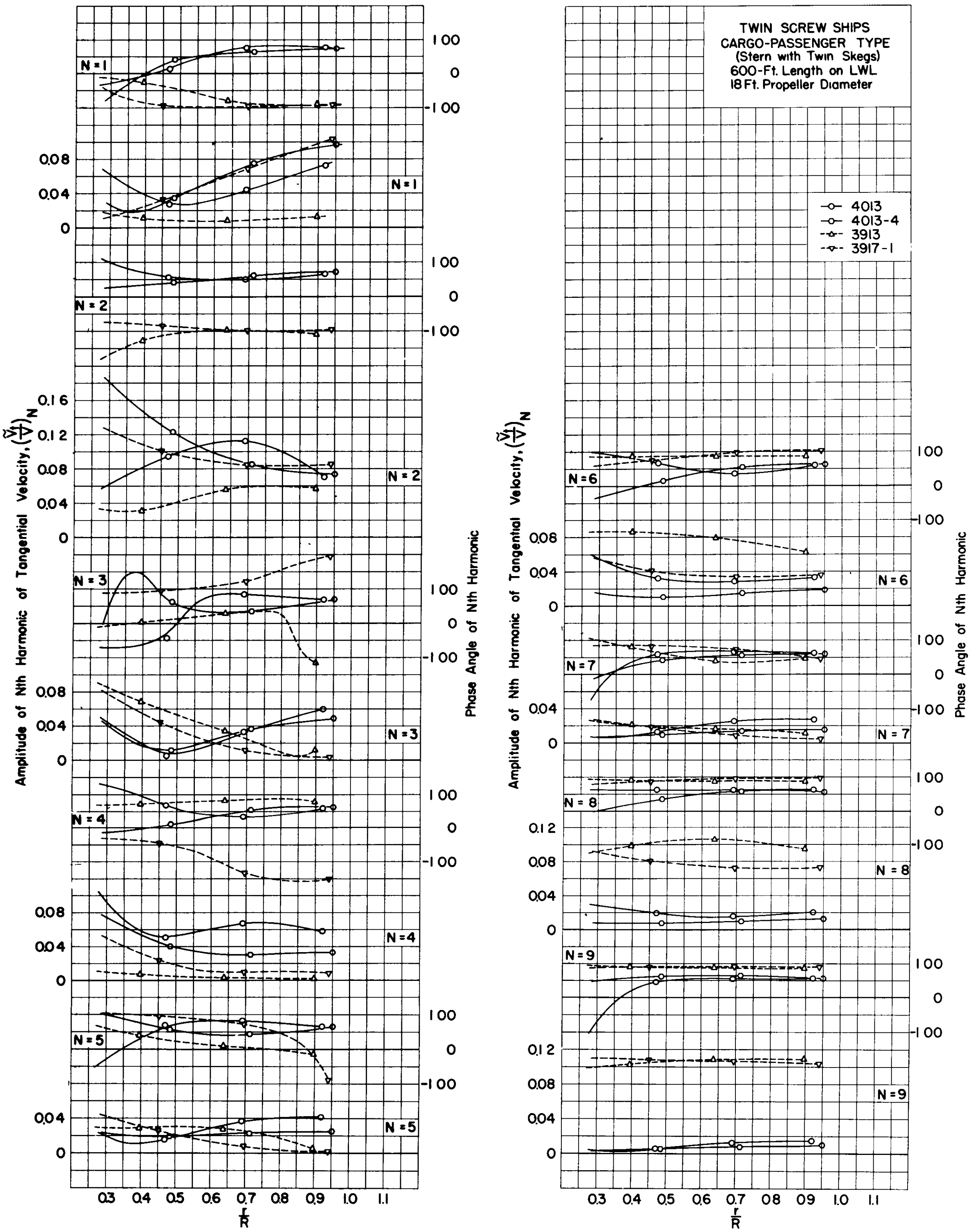


Figure 12 - Amplitudes and Phase Angles of Tangential $(\tilde{V}_t/V)$ Velocity, Twin-Screw Merchant Types, Stern with Skegs

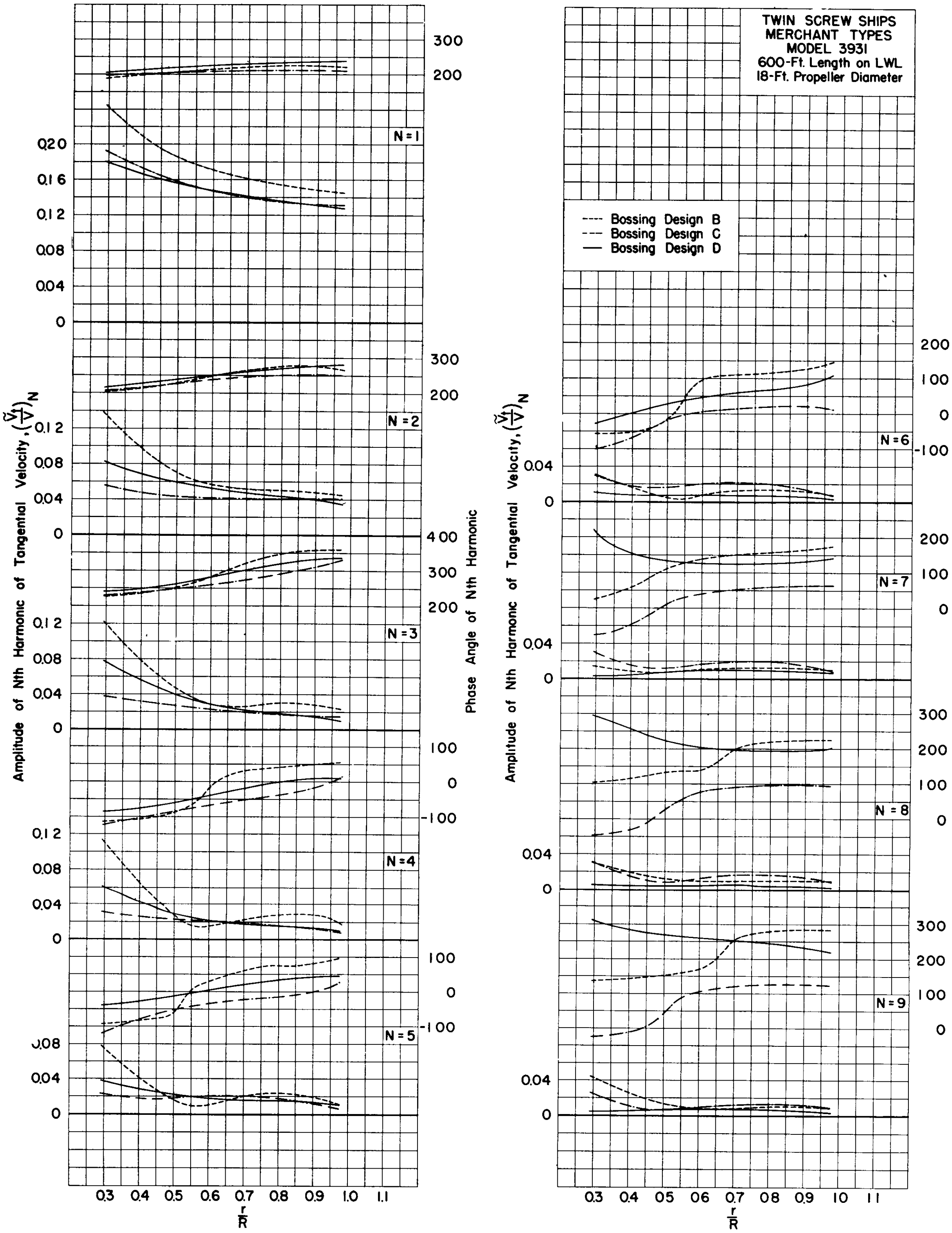


Figure 13 - Amplitudes and Phase Angles of Tangential $(\tilde{V}_t/V)$ Velocity, Twin-Screw Merchant Types, Stern with Bossings

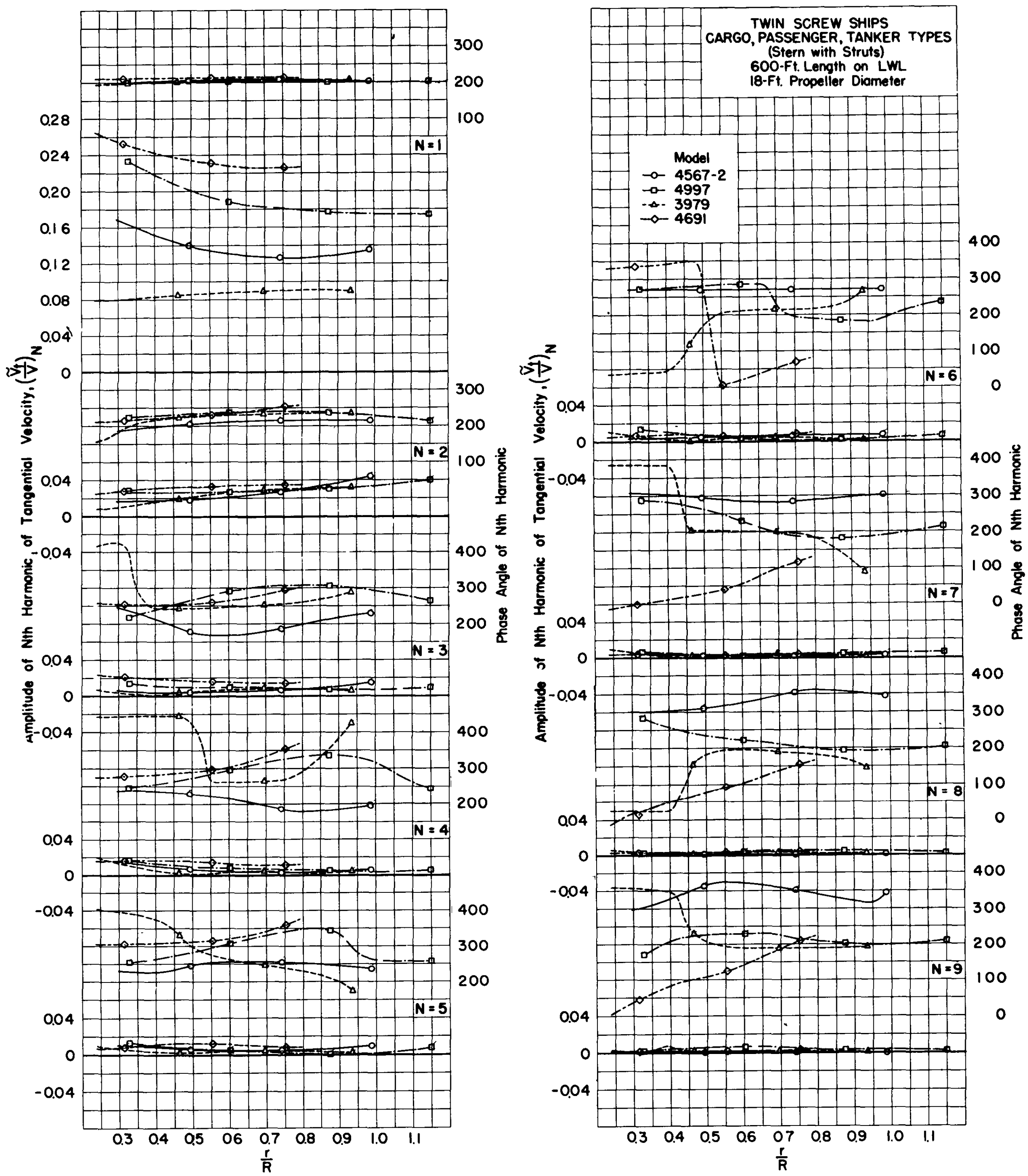


Figure 14 - Amplitudes and Phase Angles of Tangential $(\tilde{V}_t/V)$ Velocity, Twin-Screw Merchant Types, Stern with Struts

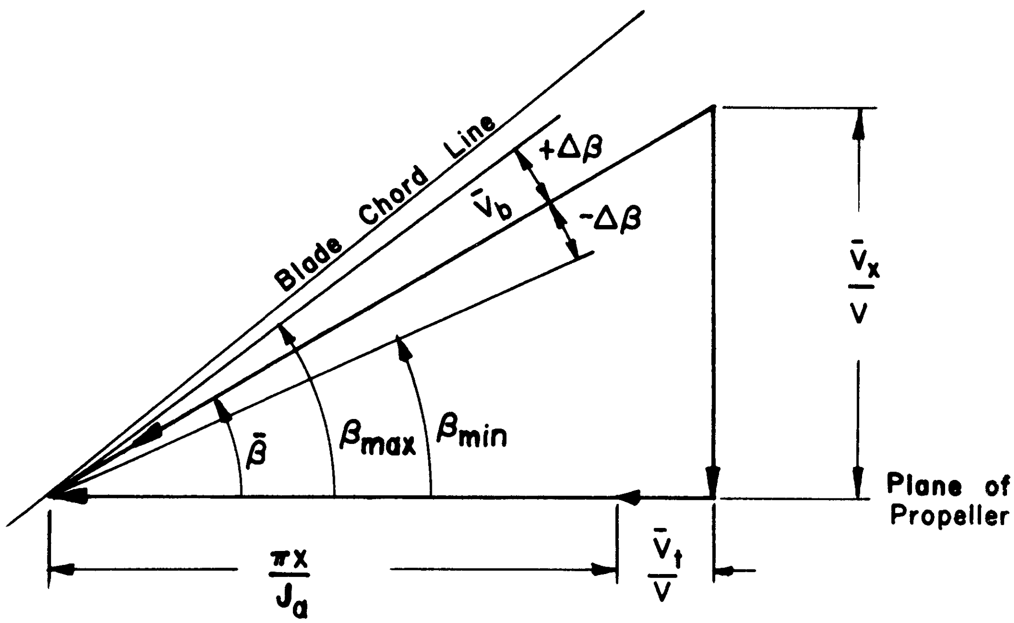


Figure 15 - Velocity Diagram

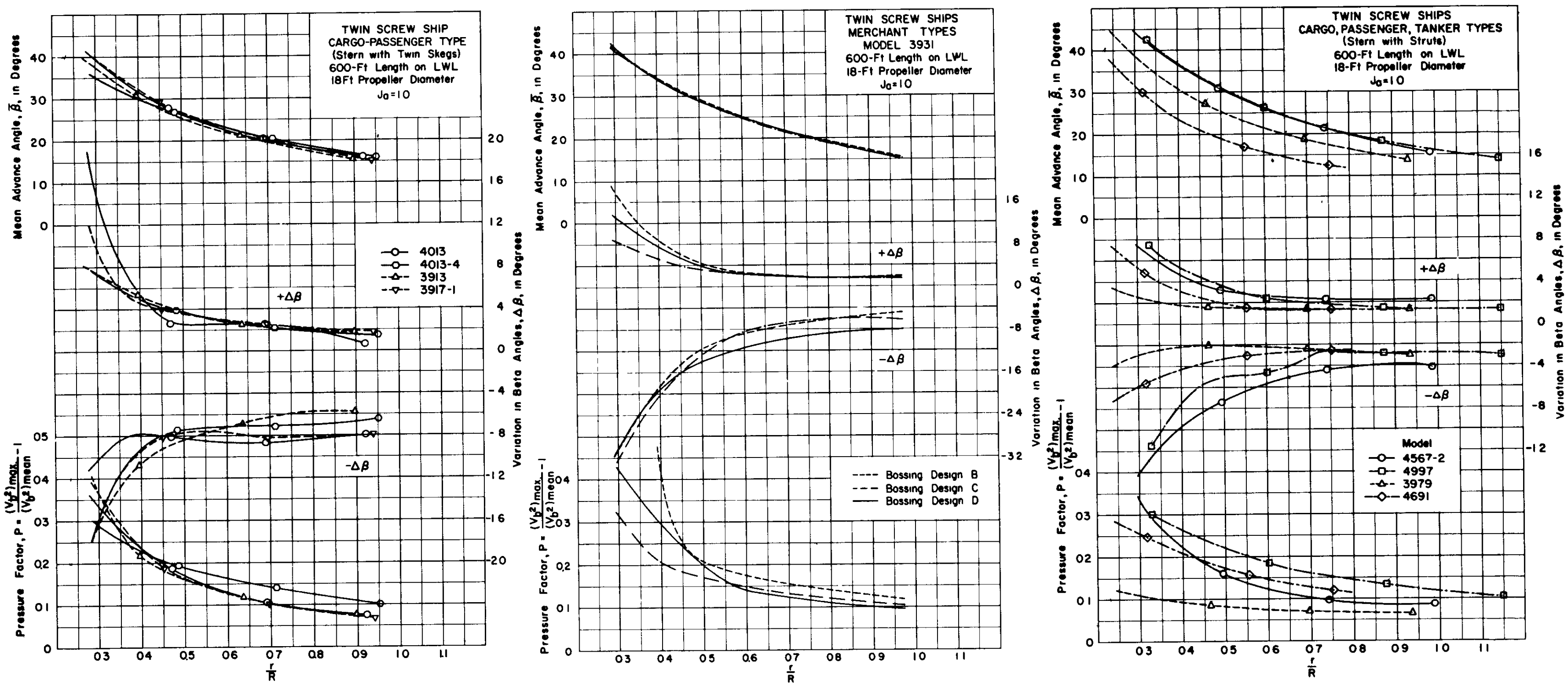


Figure 16 - Mean Advance Angle ($\bar{\beta}$), Variation in Beta Angles ($\Delta\beta$)
and Pressure Factor (P), Twin-Screw Merchant Types

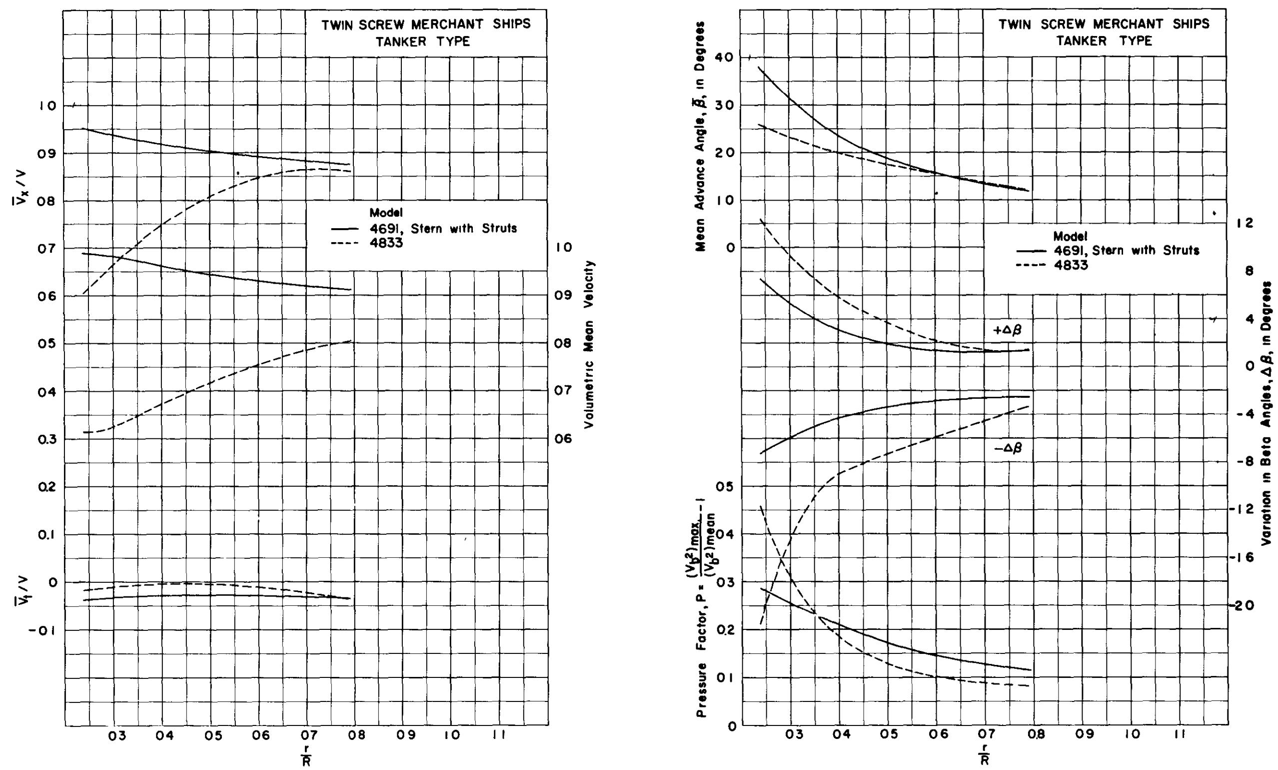


Figure 17 - Comparative $\bar{V}_x/V$, $\bar{V}_t/V$, Volumetric Mean Velocity, $\bar{\beta}$, $\Delta\beta$, and P, Conventional Stern with Struts Versus Special TMB Stern

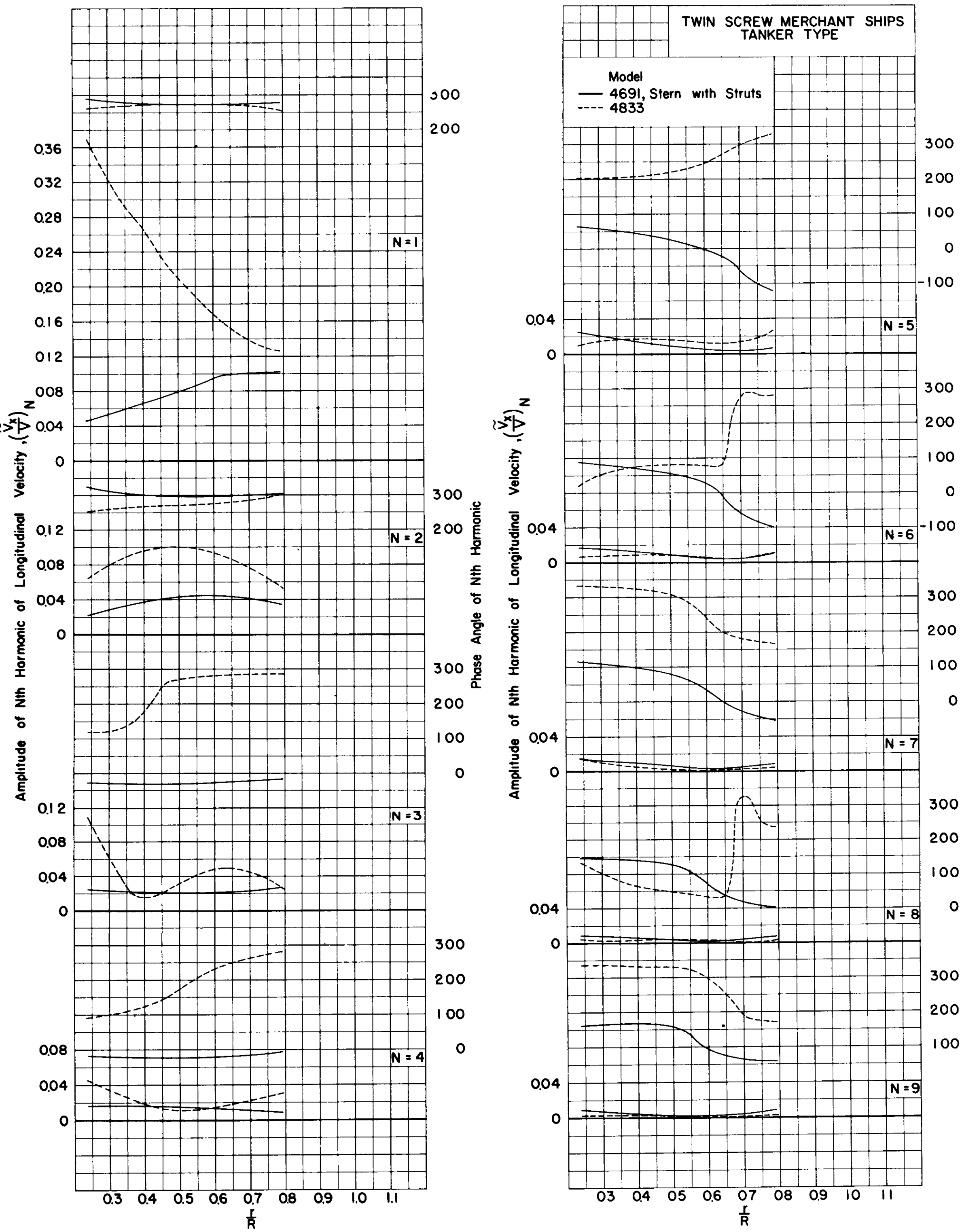


Figure 18 - Comparative Amplitudes and Phase Angles of Longitudinal ($\tilde{V}_x/V$) Velocity, Conventional Stern with Struts Versus Special TMB Stern

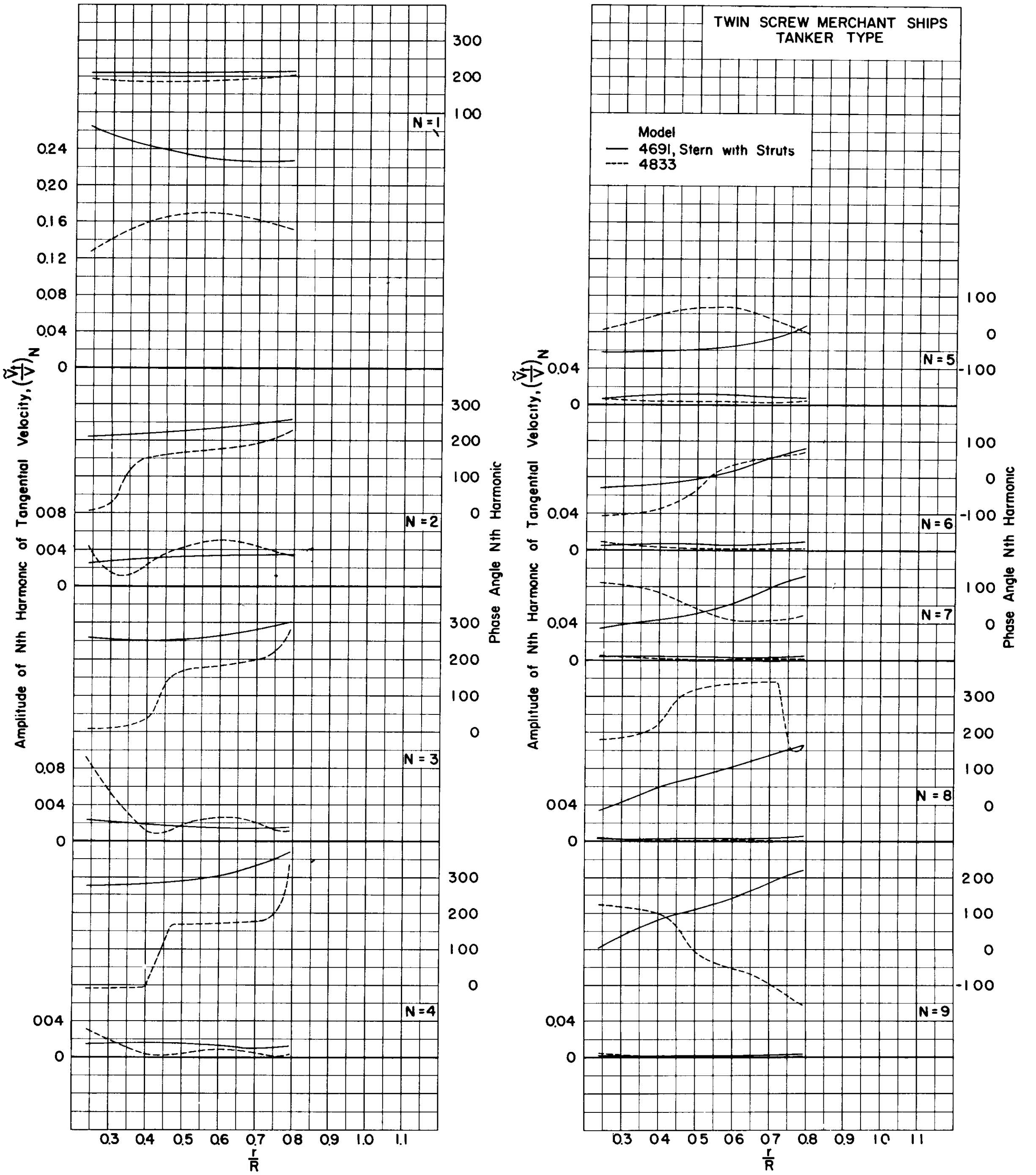


Figure 19 - Comparative Amplitudes and Phase Angles of Tangential ($\tilde{V}_t$/V) Velocity, Conventional Stern with Struts Versus Special TMB Stern

APPENDIX

TEST DATA

The figures given in this Appendix present the test data of the various twin-screw models; see Figures 20 through 30. These figures also show the transverse velocity vectors in the plane of the propeller at the various test radii as well as the body plan in the proximity of the propeller plane and the propeller shaft supports.

VELOCITY SURVEY IN WAY OF THE PROPELLER CARGO - PASSENGER SHIP MODEL 3913		
MODEL DIMENSIONS		
LENGTH (LWL)	20.00	FT
BEAM	2.415	FT
DRAFT	0 81	FT
DISPLACEMENT	0.64	TONS F W.
PROPELLER DIAMETER	0.536	FT
SPEED	4.10	KT
TEST APRIL 1945		

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R).

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION.

V IS THE SHIP SPEED.

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE.

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr}/V.

THE VELOCITY MEASUREMENTS WERE MADE IN A PLANE WHICH IS PERPENDICULAR TO THE CENTERLINE OF THE PROPELLER SHAFT AND INTERSECTS THE SHAFT LINE AT STATION 18-3/4

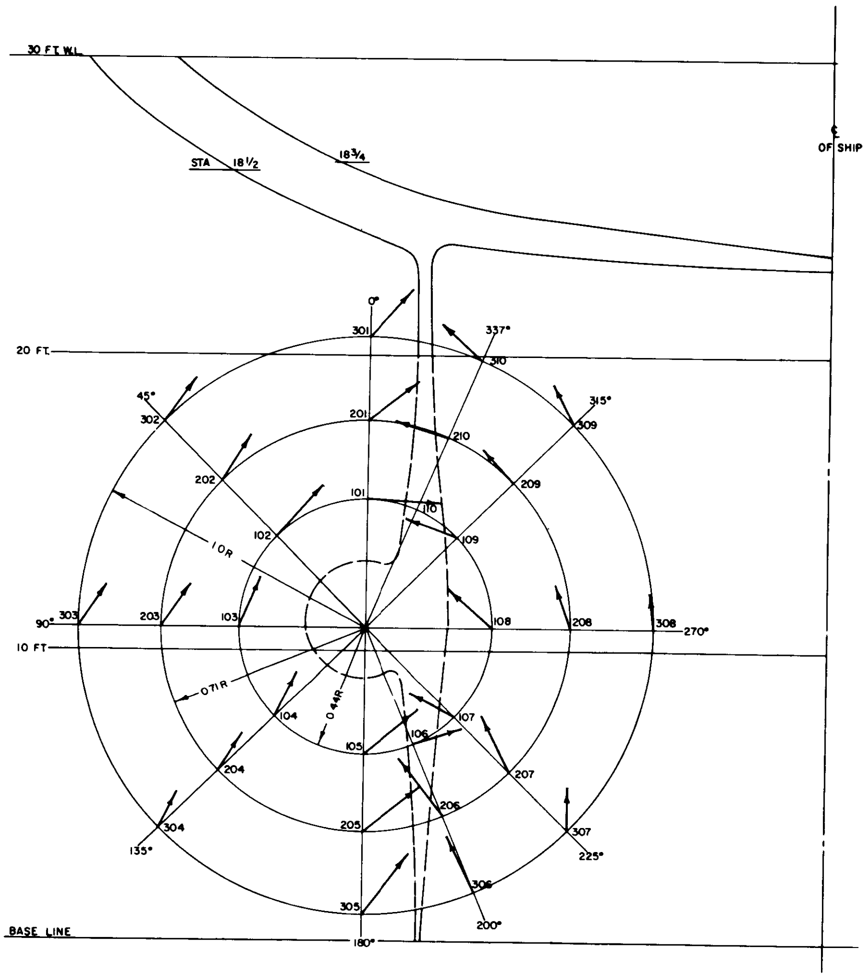


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x/V	V_t/V	V_r/V
101	0.74	-0 16	0 01
102	0.85	-0.15	-0.01
103	0 92	-0 11	0 05
104	0.94	-0.04	0.10
105	0.90	0.11	0 10
106	0.71	0 11	-0 01
107	0.67	-0 03	0 10
108	0 82	0 09	0.10
109	0 71	0.11	0.05
110	0.52	0	0.02
201	0.68	-0.11	-0.08
202	0.84	-0 11	-0.03
203	0.93	-0.09	0.06
204	0.95	-0.03	0 09
205	0.93	0 12	0.10
206	0 82	-0.04	0.16
207	0.91	0.05	0.14
208	0.92	0.10	0.03
209	0.84	0.10	0
210	0 62	0.12	0.01
301	0.57	-0.09	-0 10
302	0.81	-0.12	-0.02
303	0.95	-0.09	0.06
304	0.95	-0 03	0.09
305	0.96	0.10	0 14
306	0.96	-0 01	0 14
307	0.93	0.07	0 07
308	0.94	0.08	0.01
309	0.88	0 10	-0.04
310	0.73	0.12	-0 04

Figure 20 - Wake Velocity Diagram and Test Data, Model 3913

VELOCITY SURVEY IN WAY OF THE PROPELLER CARGO - PASSENGER SHIP MODEL 3917-1	
MODEL DIMENSIONS	
LENGTH (LWL)	20.00 FT
BEAM	2.415 FT
DRAFT	0.81 FT
DISPLACEMENT	0.64 TONS F.W.
PROPELLER DIAMETER	0 565 FT
SPEED	4.1 KT
TEST - OCTOBER 1945	

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R).

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION.

V IS THE SHIP SPEED.

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION.

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION.

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr}/V

THE VELOCITY MEASUREMENTS WERE MADE AT PROPELLER RAKE

r/R = 0.48 1.94 FT AFT OF STATION 18-3/4
r/R = 0.74 2.42 FT AFT OF STATION 18-3/4
r/R = 1.00 2.91 FT AFT OF STATION 18-3/4

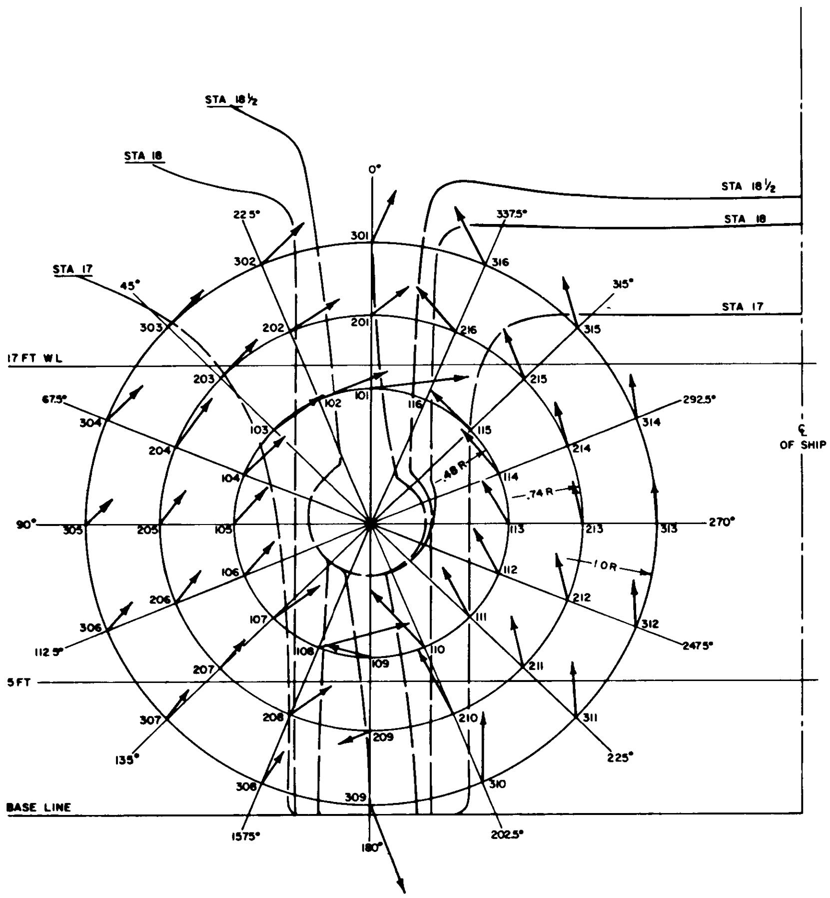


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x/V	V_t/V	V_r/V
101	0 60	-0 22	-0 03
102	0 77	-0 17	-0 01
103	0 85	-0 14	0 02
104	0 91	-0 12	0 04
105	0 92	-0 09	0 07
106	0 94	-0 05	0 09
107	0 94	0 01	0 13
108	0 83	0 16	0 14
109	0 62	-0 11	0 04
110	0 91	-0 06	0 18
111	0 93	0 05	0 14
112	0 93	0 08	0 10
113	0 93	0 11	0 60
114	0 91	0 14	0 04
115	0 86	0 14	0
116	0 73	0 17	0
201	0.47	-0 08	-0 07
202	0 74	-0 14	-0 04
203	0 83	-0 12	-0 01
204	0 92	-0 13	0 03
205	0 94	-0.08	0 06
206	0 94	-0 05	0 07
207	0 93	-0 01	0 08
208	0 92	0 05	0 10
209	0 72	-0 08	-0 03
210	0 92	-0 02	0 17
211	0 94	0 06	0 11
212	0 94	0 09	0 07
213	0 94	0 11	0 02
214	0 93	0 11	-0 01
215	0 89	0 12	-0.05
216	0 78	0 13	-0.07
301	0 40	-0 04	-0.11
302	0 71	-0 12	-0 06
303	0 83	-0 12	0
304	0 90	-0.11	0 04
305	0 94	-0 07	0.06
306	0 95	-0.04	0.07
307	0.94	-0 02	0 08
308	0 93	0.02	0 09
309	0.76	0.08	-0.20
310	0 94	0.07	0 15
311	0 94	0.08	0.10
312	0 94	0.10	0 05
313	0 94	0.11	0.02
314	0.91	0.11	-0.03
315	0 84	0.12	-0.06
316	0 75	0.12	-0.11

Figure 21 - Wake Velocity Diagram and Test Data, Model 3917-1

VELOCITY SURVEY IN WAY OF THE PROPELLER PASSENGER - TRAILER TYPE MODEL 4013	
MODEL DIMENSIONS	
LENGTH (LWL)	20.49 FT
BEAM	3.13 FT
DRAFT	0.83 FT
DISPLACEMENT	0.744 TONS F.W.
PROPELLER DIAMETER	0.566 FT
SPEED	4.85 KT
TEST JUNE 1947	

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R).

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION

V IS THE SHIP SPEED.

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION.

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION.

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE.

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr}/V.

THE VELOCITY MEASUREMENTS WERE MADE IN A PLANE WHICH IS PERPENDICULAR TO THE CENTERLINE OF THE PROPELLER SHAFT AND INTERSECTS .. 3.69 FT AFT OF STATION 1/4

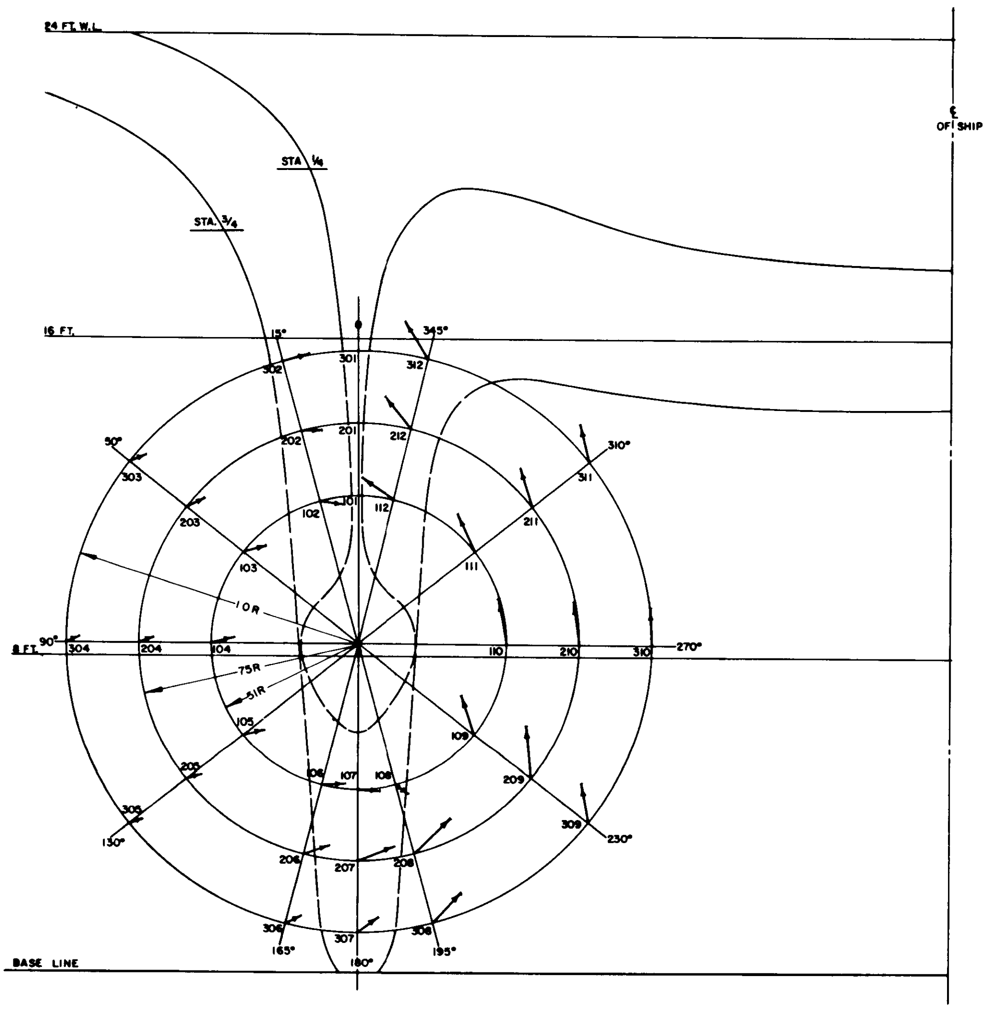


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x/V	V_t/V	V_r/V
101	0.58	0.02	0.02
102	0.79	-0.09	0.08
103	0.86	-0.09	0.07
104	0 92	-0.03	0.11
105	0 94	0.04	0.10
106	0.81	0.11	0.04
107	0.71	0.10	0
108	0.81	0.02	-0.02
109	0.94	0 10	0.15
110	0.95	0.21	0.04
111	0.94	0.16	-0.11
112	0.82	0.15	-0.12
201	0.49	0	-0.03
202	0.72	-0.09	0 05
203	0 94	-0.08	0.05
204	0.98	-0.03	0.07
205	0.97	0.02	0.07
206	0.95	0.11	0.07
207	0.85	0.18	0.07
208	0.77	0.21	0.12
209	0.97	0.18	0.17
210	0.96	0.20	0.02
211	0.95	0.14	-0.12
212	0.82	0.11	-0.16
301	0.45	-0.02	-0.05
302	0.77	-0.12	0 05
303	0.97	-0.08	0.04
304	0.96	-0.03	0.06
305	0.98	0.02	0.07
306	0.97	0.07	0.06
307	0.95	0.10	0.07
308	0.94	0.15	0.10
309	0.97	0.12	0.14
310	0.94	0.18	0.01
311	0.95	0.13	-0.12
312	0.79	0.09	-0.18

Figure 22 - Wake Velocity Diagram and Test Data, Model 4013

VELOCITY SURVEY IN WAY OF THE PROPELLER
PASSENGER - TRAILER TYPE
MODEL 4013-4

MODEL DIMENSIONS	
LENGTH (LWL)	20.49 FT
BEAM	3.13 FT
DRAFT	0.83 FT
DISPLACEMENT	0.744 TONS F.W.
PROPELLER DIAMETER	0.585 FT
SPEED	5.01 KT

TEST 16
APRIL 1950

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R).

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION.

V IS THE SHIP SPEED.

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION.

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION.

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE.

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r.

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr}/V.

THE VELOCITY MEASUREMENTS WERE MADE IN A PLANE WHICH IS PERPENDICULAR TO THE CENTERLINE OF THE PROPELLER SHAFT AND INTERSECTS ... AT STATION 1/8

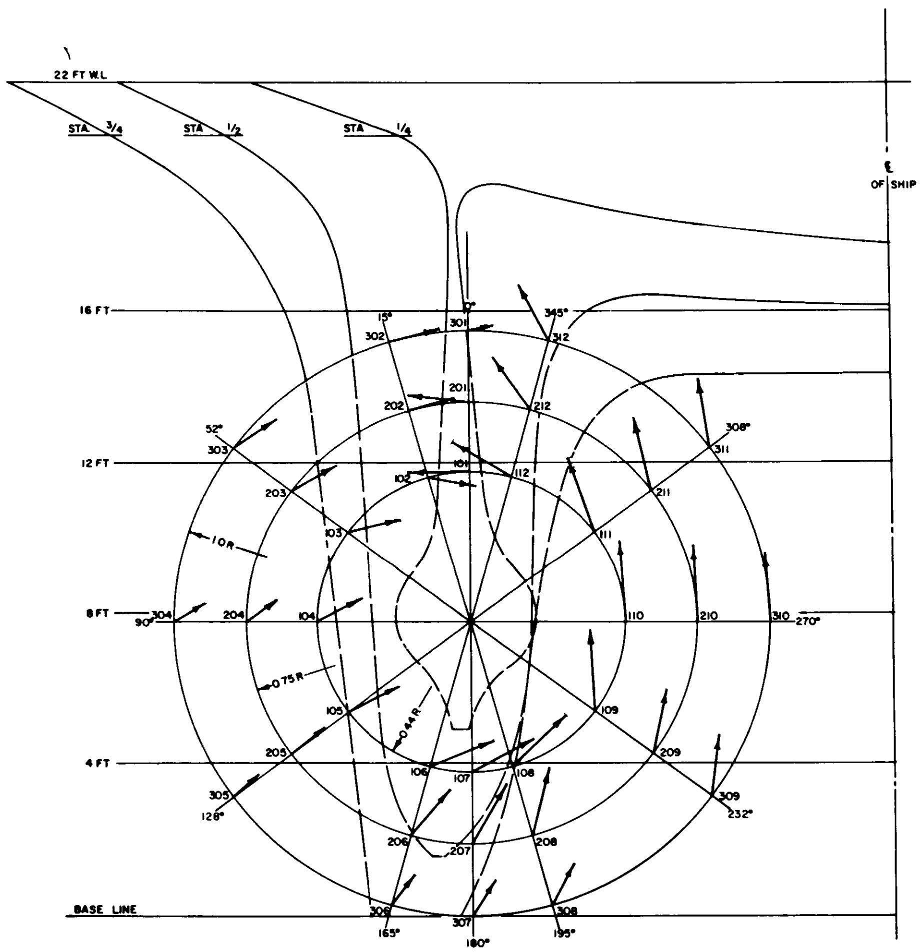


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x/V	V_t/V	V_r/V
101	0.60	0.14	0.01
102	0.63	-0.10	0.05
103	0.82	-0.10	0.08
104	0.92	-0.06	0.11
105	0.92	0.02	0.13
106	0.84	0.13	0.10
107	0.78	0.14	0.08
108	0.72	0.15	0.09
109	0.94	0.15	0.12
110	0.94	0.20	0.01
111	0.92	0.18	-0.07
112	0.80	0.16	-0.05
201	0.56	0.14	-0.02
202	0.70	-0.11	0
203	0.89	-0.11	0.05
204	0.96	-0.05	0.08
205	0.96	0	0.10
206	0.89	0.06	0.13
207	0.90	0.08	0.14
208	0.92	0.08	0.14
209	0.96	0.15	0.07
210	0.95	0.19	0
211	0.92	0.16	-0.08
212	0.79	0.11	-0.10
301	0.52	-0.06	-0.01
302	0.72	-0.12	0
303	0.93	-0.11	0.04
304	0.97	-0.05	0.07
305	0.96	0	0.08
306	0.96	0.03	0.09
307	0.96	0.05	0.08
308	0.96	0.07	0.08
309	0.96	0.13	0.07
310	0.95	0.17	0.01
311	0.91	0.16	-0.08
312	0 75	0.10	-0.11

Figure 23 - Wake Velocity Diagram and Test Data, Model 4013-4

VELOCITY SURVEY IN WAY OF THE PROPELLER
CARGO - PASSENGER SHIP
MODEL 3931 (BOSSING DESIGN B)

MODEL DIMENSIONS	
LENGTH (LWL)	20.00 FT
BEAM	2 74 FT
DRAFT	0.923 FT
DISPLACEMENT	0.845 TONS F.W
PROPELLER DIAMETER	0.585 FT
SPEED	4.03 KT

TEST 0.1
NOVEMBER 1945

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R).

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION

V IS THE SHIP SPEED.

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION.

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE.

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr}/V

THE VELOCITY MEASUREMENTS WERE MADE IN A PLANE WHICH IS PERPENDICULAR TO THE CENTERLINE OF THE PROPELLER SHAFT AND INTERSECTS . 0.74 FEET FORWARD OF FRAME 228

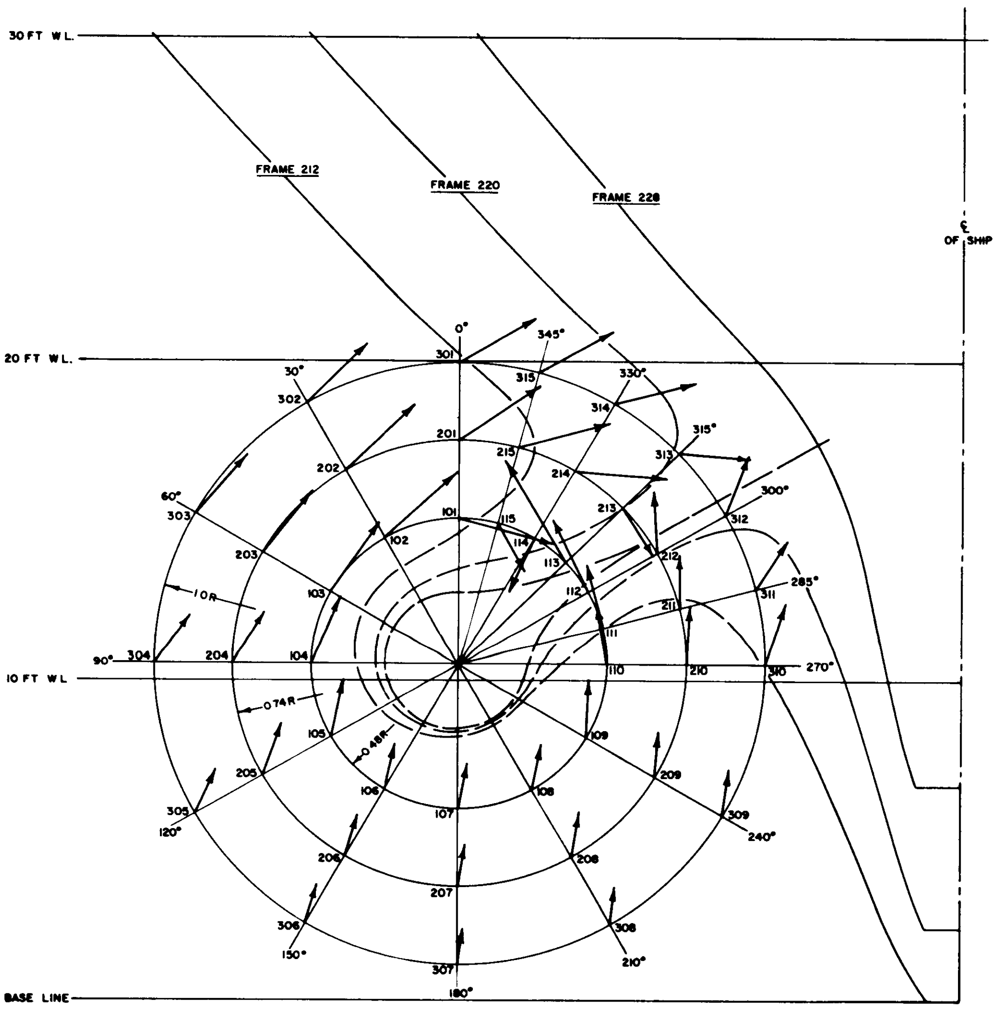


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x/V	V_t/V	V_r/V
101	0.78	-0.31	0.08
102	0.90	-0.22	-0.06
103	0.92	-0 20	0 02
104	0.93	-0 16	0.07
105	0.94	-0.10	0 09
106	0 95	-0 04	0 10
107	0.95	0.02	0.11
108	0.94	0.07	0.08
109	0.94	0.12	0.06
110	0.91	0 14	0 02
111	0.88	0.15	0
112	0 84	0.19	-0.02
113	0.57	0.27	-0.07
114	0.56	-0.16	0.14
115	0 59	-0 09	0.09
201	0.85	-0.18	-0.13
202	0.89	-0.21	-0.06
203	0.92	-0.18	0.02
204	0.92	-0.12	0.07
205	0.94	-0.09	0.10
206	0.95	-0.02	0.10
207	0.95	0.17	0.10
208	0.94	0.07	0 08
209	0.93	0 10	0 05
210	0.91	0.14	-0.01
211	0.84	0.12	-0.03
212	0.78	0.13	-0.06
213	0.57	-0.13	0.03
214	0.79	-0 19	-0.09
215	0.83	-0.18	-0.12
301	0.76	-0 16	-0.12
302	0.84	-0.19	-0 06
303	0.92	-0 18	0.03
304	0.92	-0.12	0.06
305	0 94	-0.07	0 10
306	0.95	-0.02	0.09
307	0.95	0.01	0.06
308	0 94	0.06	0 07
309	0.93	0.10	0.04
310	0.83	0.15	-0.05
311	0.71	0.10	-0.10
312	0.70	0.10	-0.12
313	0.57	-0.13	-0.11
314	0.71	-0.14	-0 14
315	0.74	-0.14	-0.14

Figure 24 - Wake Velocity Diagram and Test Data, Model 3931 (Bossing Design B)

VELOCITY SURVEY IN WAY OF THE PROPELLER CARGO - PASSENGER SHIP MODEL 3931 (BOSSING DESIGN C)	
MODEL DIMENSIONS	
LENGTH (LWL)	20.00 FT
BEAM	2.74 FT
DRAFT	0.923 FT
DISPLACEMENT	0 845 TONS F.W.
PROPELLER DIAMETER	0 585 FT
SPEED	4.03 KT
TEST 0.2 OCTOBER 1946	

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R).

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION.

V IS THE SHIP SPEED.

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION.

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION.

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE.

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r.

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr}/V

THE VELOCITY MEASUREMENTS WERE MADE IN A PLANE WHICH IS PERPENDICULAR TO THE CENTERLINE OF THE PROPELLER SHAFT AND INTERSECTS ... 2.17 FEET FORWARD OF STATION 19

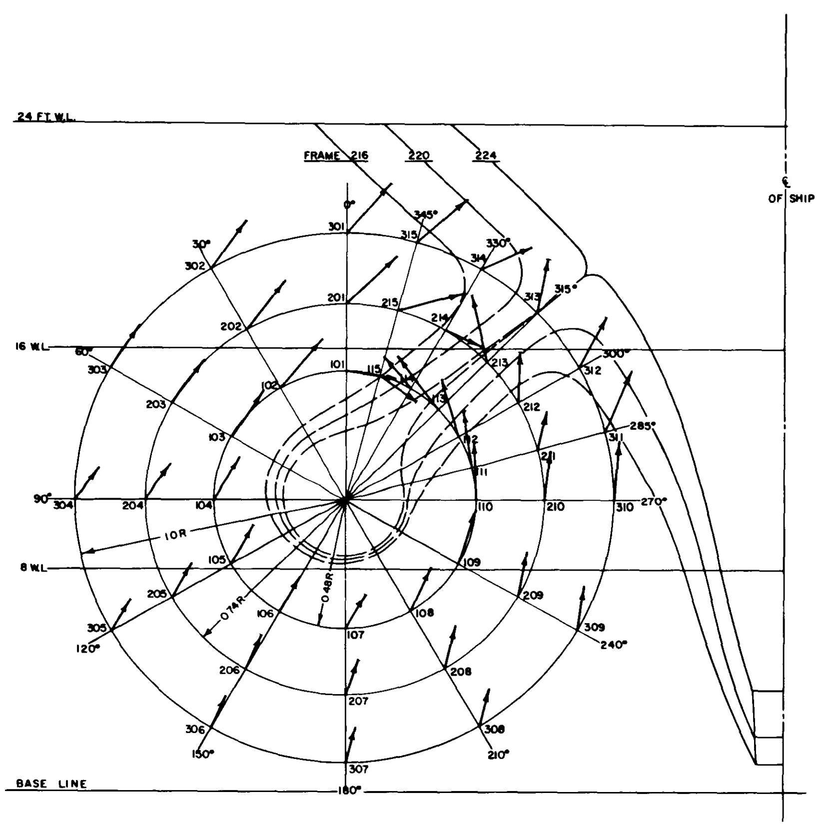


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x/V	V_t/V	V_r/V
101	0 83	-0.13	0 02
102	0.89	-0.16	-0 06
103	0.91	-0.14	0.01
104	0.94	-0 12	0.07
105	0.95	-0 06	0.10
106	0.95	0	0 10
107	0.95	0.05	0.09
108	0 94	0 11	0.07
109	0.93	0.14	0.03
110	0.91	0.16	0
111	0.89	0.15	-0 02
112	0.87	0 16	-0.04
113	0 79	0.17	-0 03
114	0 46	0 11	-0 04
115	0.58	-0.11	0 04
201	0.84	-0.13	-0.12
202	0 87	-0.15	-0.07
203	0.92	-0 14	0 02
204	0.94	-0.10	0 07
205	0.95	-0.05	0 09
206	0.95	-0.01	0 10
207	0.95	0.03	0 09
208	0.94	0.08	0 09
209	0.93	0 12	0.04
210	0.92	0.13	-0.01
211	0.85	0.09	-0.05
212	0 84	0.11	-0 07
213	0.70	0.15	-0.10
214	0.64	-0.10	-0.01
215	0.81	-0.16	-0 09
301	0.80	-0 11	-0 13
302	0 84	-0.14	-0.06
303	0.91	-0.13	0.01
304	0 94	-0 09	0 06
305	0.95	-0.05	0 09
306	0.95	0	0.10
307	0 96	0.03	0 09
308	0 95	0 07	0.07
309	0.95	0.11	0.05
310	0 89	0.16	-0 02
311	0.81	0.14	-0.10
312	0.74	0.08	-0.13
313	0.54	0.08	-0 12
314	0.72	-0 09	-0.11
315	0 77	-0.10	-0.14

Figure 25 - Wake Velocity Diagram and Test Data, Model 3931 (Bossing Design C)

VELOCITY SURVEY IN WAY OF THE PROPELLER CARGO - PASSENGER SHIP MODEL 3931 (BOSSING DESIGN D)	
MODEL DIMENSIONS	
LENGTH (LWL)	20 00 FT
BEAM	2.74 FT
DRAFT	0 923 FT
DISPLACEMENT	0.845 TONS F.W
PROPELLER DIAMETER	0 585 FT
SPEED	4.83 KT
TEST 0.3 MARCH 1948	

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R)

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION.

V IS THE SHIP SPEED

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION.

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr}/V

THE VELOCITY MEASUREMENTS WERE MADE IN A PLANE WHICH IS PERPENDICULAR TO THE CENTERLINE OF THE PROPELLER SHAFT AND INTERSECTS . . 3/4-INCH FORWARD OF FRAME 227

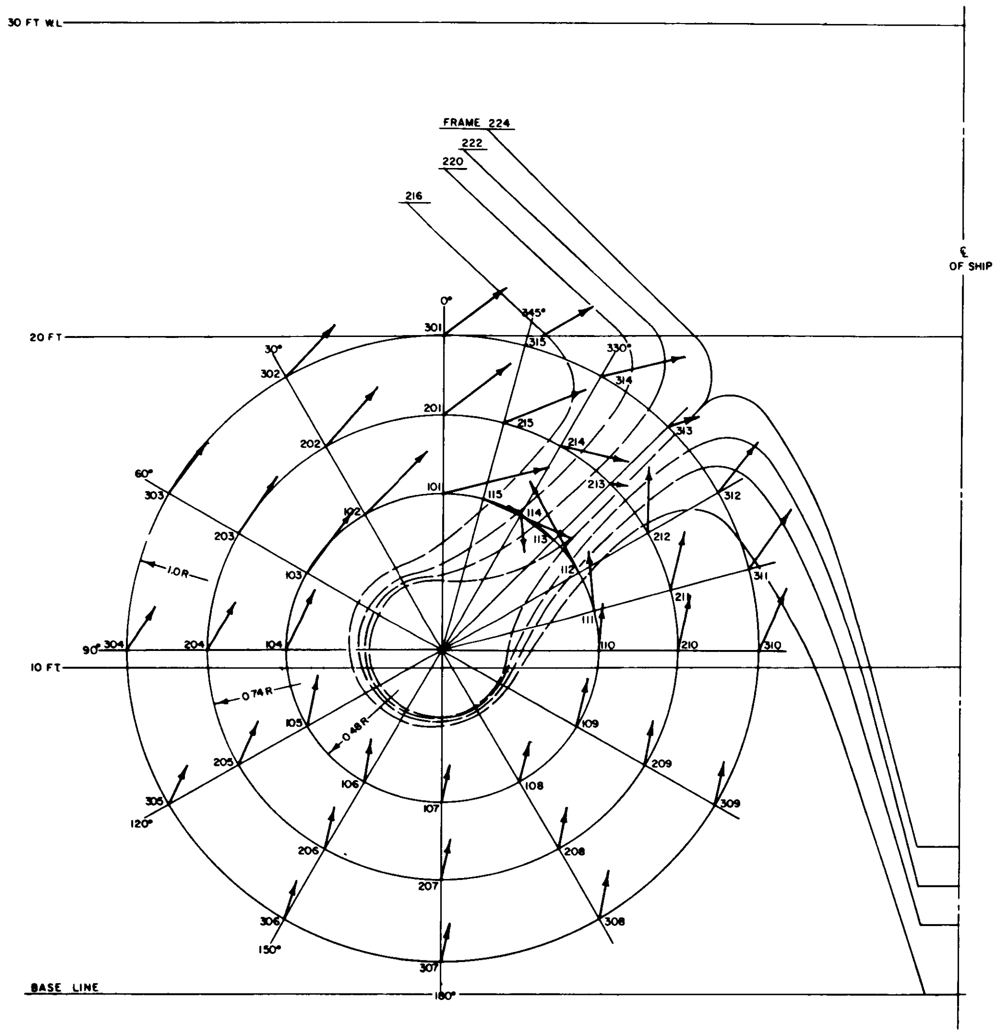


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x/V	V_t/V	V_r/V
101	0 86	-0.24	0 03
102	0.89	-0.20	0 02
103	0.92	-0 16	0.08
104	0.94	-0.11	0 11
105	0.94	-0.06	0.11
106	0 96	0	0 10
107	0 96	0.05	0 07
108	0.95	0.09	0.04
109	0.94	0 11	0
110	0.91	0.10	-0.04
111	0 89	0 12	-0.06
112	0.83	0 21	-0.09
113	0.45	0 12	-0 03
114	0.57	-0 02	0.08
115	0.67	-0.19	0.11
201	0 82	-0 18	-0.06
202	0.86	-0.17	0
203	0.91	-0 14	0 07
204	0.94	-0.08	0 10
205	0.95	-0.03	0 10
206	0.95	0 01	0 09
207	0 95	0.05	0.08
208	0.95	0.09	0.05
209	0 94	0 11	0
210	0 89	0 10	-0 07
211	0.85	0.12	-0.10
212	0.80	0 21	-0.11
213	0.46	0.12	-0.01
214	0 71	-0 02	0 01
215	0 80	-0.19	0.06
301	0 75	-0 17	-0.05
302	0 81	-0 16	0.01
303	0.90	-0.13	0.06
304	0 93	-0.07	0 09
305	0.95	-0 03	0.09
306	0.96	0.01	0.09
307	0.95	0.05	0.07
308	0 95	0 08	0 04
309	0.93	0.10	0
310	0.84	0.07	-0.11
311	0.73	0.06	-0.15
312	0.70	0	-0.15
313	0.39	-0 06	-0.05
314	0.66	-0.18	-0.07
315	0.71	-0.16	-0 08

Figure 26 - Wake Velocity Diagram and Test Data, Model 3931 (Bossing Design D)

VELOCITY SURVEY IN WAY OF THE PROPELLER CARGO - PASSENGER TYPE MODEL 3979	
MODEL DIMENSIONS	
LENGTH (LWL)	20 00 FT
BEAM	1.97 FT
DRAFT	0.71 FT
DISPLACEMENT	0.44 TONS F.W
PROPELLER DIAMETER	0.48 FT
SPEED	4 53 KT
TEST AUGUST 1946	

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R)

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION

V IS THE SHIP SPEED

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr} V

THE VELOCITY MEASUREMENTS WERE MADE IN A PLANE WHICH IS PERPENDICULAR TO THE CENTERLINE OF THE PROPELLER SHAFT AND INTERSECTS THE SHAFT LINE AT 10 FT FWD OF STATION 19

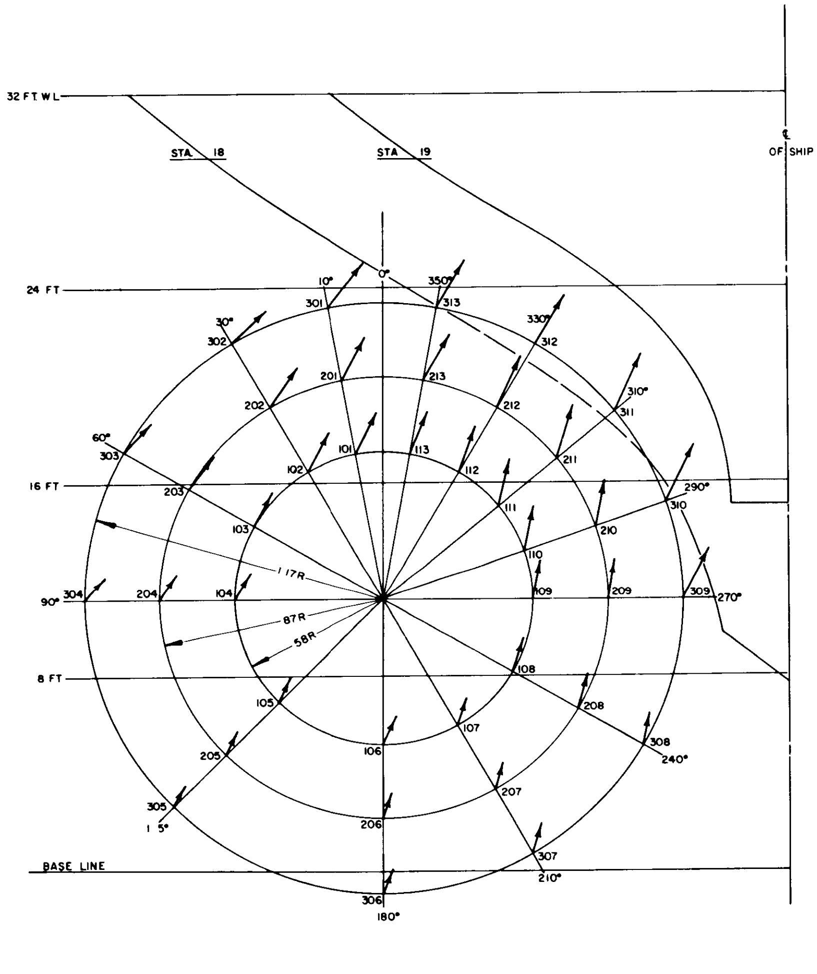


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x V	V_t V	V_r V
101	0 89	-0 06	-0 08
102	0 91	-0 08	-0 06
103	0 95	-0 09	0
104	0 97	-0 06	0 03
105	0 97	-0 03	0 06
106	0 97	0 03	0 06
107	0 97	0 05	0 05
108	0 97	0 08	0.02
109	0 95	0 09	-0 02
110	0.92	0 09	-0 05
111	0 90	0 06	-0 09
112	0 87	0.02	-0.11
113	0 87	-0 02	-0 10
201	0 84	-0 11	-0 09
202	0 89	-0.09	-0 05
203	0 95	-0 09	0 01
204	0 98	-0 06	0 04
205	0.97	-0 02	0 05
206	0 97	0 02	0 06
207	0 96	0 05	0 05
208	0.96	0 08	0 02
209	0 94	0 10	-0 02
210	0 90	0 09	-0 06
211	0 85	0 07	-0 10
212	0 81	0 01	-0 13
213	0 81	-0.04	-0 11
301	0 78	-0 09	-0 08
302	0 86	-0 10	-0 03
303	0 96	-0 09	0 02
304	0 97	-0 05	0 05
305	0 98	-0 02	0 05
306	0 98	0 02	0 06
307	0 97	0 05	0.05
308	0 97	0 07	0 02
309	0 93	0 12	-0 06
310	0 83	0 09	-0 09
311	0 75	0 06	-0 13
312	0 70	-0 01	-0 13
313	0 74	-0.04	-0 12

Figure 27 - Wake Velocity Diagram and Test Data, Model 3979

VELOCITY SURVEY IN WAY OF THE PROPELLER CARGO - PASSENGER SHIP MODEL 4567-2	
MODEL DIMENSIONS	
LENGTH (LWL)	19.67 FT
BEAM	2.80 FT
DRAFT	0.901 FT
DISPLACEMENT	0.81 TONS F.W
PROPELLER DIAMETER	0.583 FT
SPEED	4.01 KT
TEST 24 JANUARY 1956	

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R)

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION

V IS THE SHIP SPEED.

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION.

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION.

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE.

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr}/V.

THE VELOCITY MEASUREMENTS WERE MADE IN A PLANE WHICH IS PERPENDICULAR TO THE CENTERLINE OF THE PROPELLER SHAFT AND INTERSECTS . 35 FT FORWARD OF STATION 20

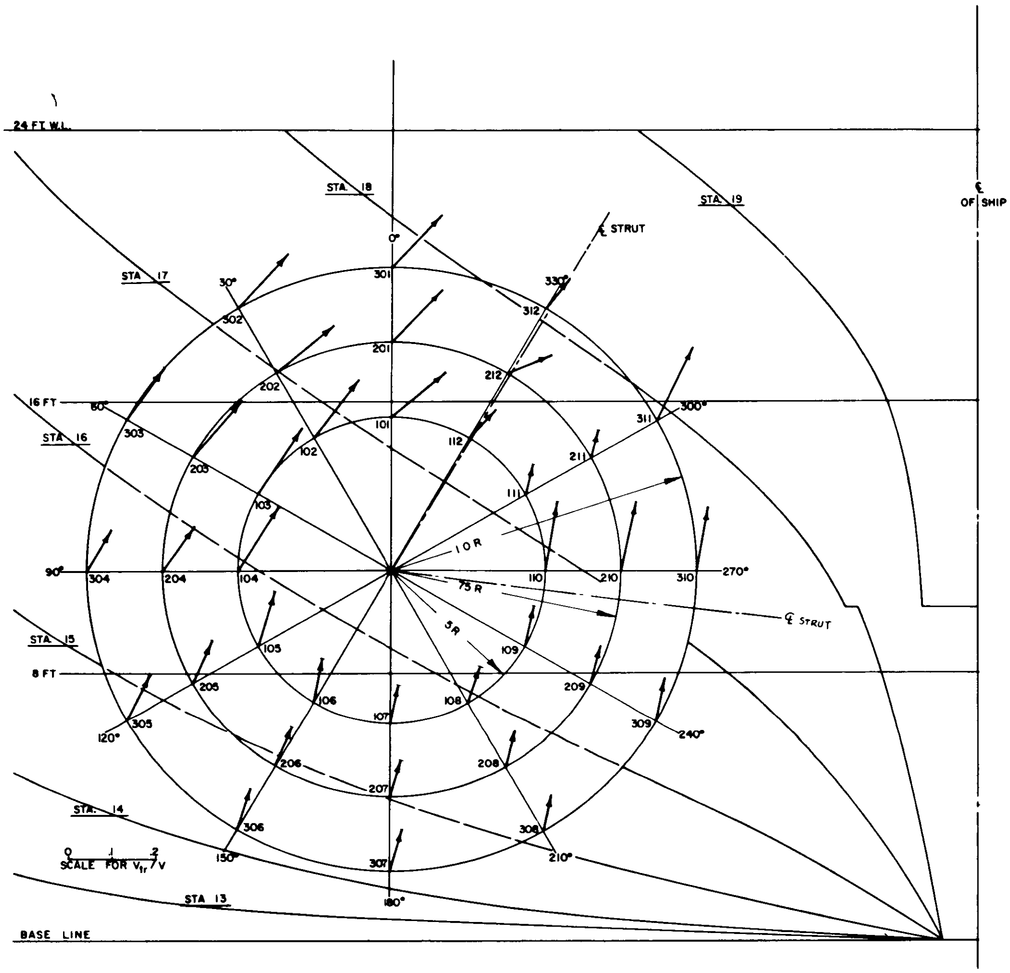


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x/V	V_t/V
101	0 86	-0 12
102	0 89	-0.16
103	0.94	-0.18
104	0 96	-0.15
105	0.99	-0 09
106	0.98	-0 03
107	0.98	0.02
108	0.97	0.07
109	0 96	0 10
110	0 96	0.16
111	0 90	0.05
112	0.69	-0.01
201	0.83	-0.12
202	0.86	-0.16
203	0.94	-0.17
204	0.98	-0.11
205	0.95	-0.07
206	0.97	-0.02
207	0.98	0.02
208	0 96	0 06
209	0.95	0.08
210	0 88	0.16
211	0.91	0.05
212	0.72	-0.07
301	0 76	-0.12
302	0 83	-0.16
303	0.92	-0.15
304	0.98	-0.10
305	0.98	-0.06
306	0.96	-0.02
307	0.97	0.03
308	0.96	0 06
309	0.95	0.09
310	0.82	0.15
311	0.66	0 11
312	0.67	-0.01

Figure 28 - Wake Velocity Diagram and Test Data, Model 4567-2

VELOCITY SURVEY IN WAY OF THE PROPELLER
TANKER SHIP
MODEL 4691

MODEL DIMENSIONS

LENGTH (LWL)	24.54	FT
BEAM	3.50	FT
DRAFT	1.301	FT
DISPLACEMENT	2.47	TONS F.W.
PROPELLER DIAMETER	0.583	FT
SPEED	2.93	KT

TEST 1
DECEMBER 1960

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R)

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION.

V IS THE SHIP SPEED.

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION.

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION.

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE.

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r.

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr}/V.

THE VELOCITY MEASUREMENTS WERE MADE IN A PLANE WHICH IS PERPENDICULAR TO THE CENTERLINE OF THE PROPELLER SHAFT AND INTERSECTS THE SHAFT LINE AT 2.2 FT FWD OF STA. 19-1/2

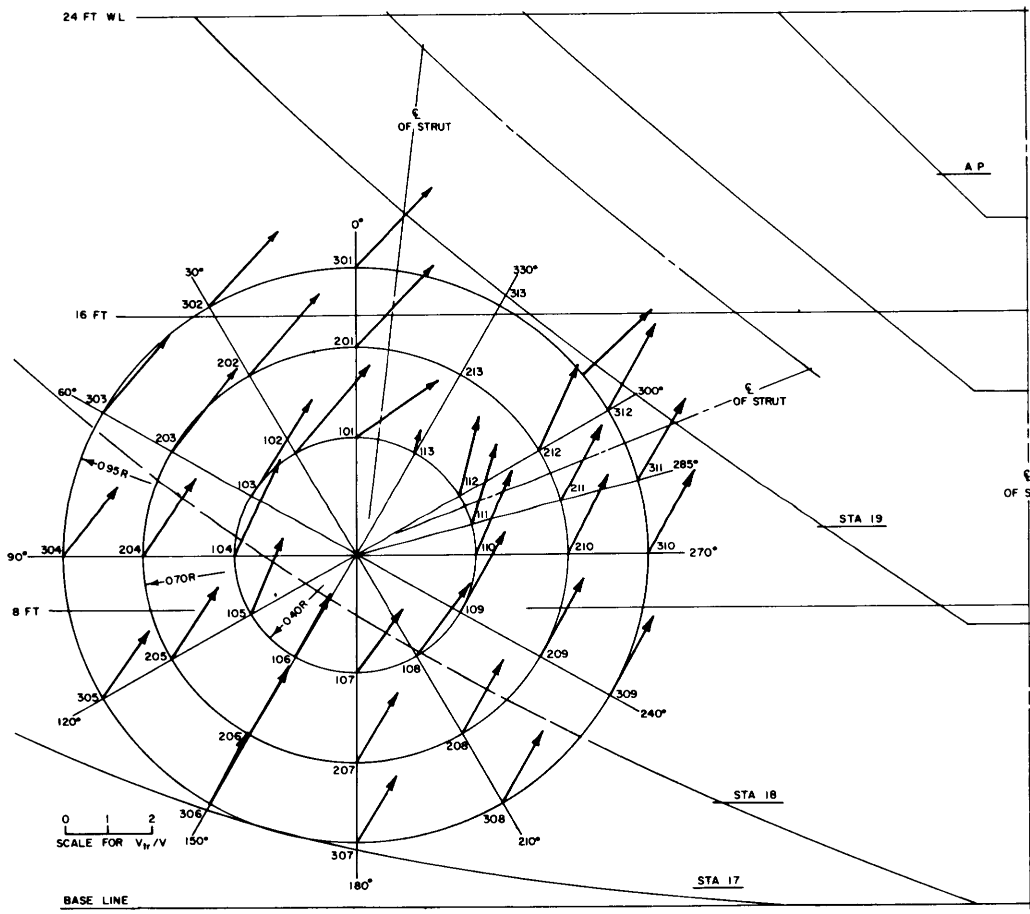


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x/V	V_t/V
101	0 87	-0.20
102	0 91	-0.25
103	0.96	-0.26
104	0.94	-0.22
105	0.96	-0.12
106	0.98	0
107	0.96	0 11
108	0 98	0.19
109	0 97	0.22
110	0.94	0.20
111	0.95	0.18
112	0.96	0 16
113	0 75	0.02
201	0.77	-0.19
202	0.85	-0.23
203	0.90	-0.24
204	0.92	-0.18
205	0.95	-0 09
206	0.95	0
207	0.95	0.10
208	0.96	0.17
209	0 94	0.21
210	0 92	0.19
211	0.91	0.16
212	0.88	0.15
213	-	-
301	0.71	-0.18
302	0.83	-0.23
303	0.86	-0 23
304	0.90	-0 17
305	0 95	-0.09
306	0.97	-0.01
307	0.97	0.10
308	0.96	0.16
309	0 94	0.21
310	0 92	0.20
311	0.90	0.17
312	0.79	0.15
313	-	-

Figure 29 - Wake Velocity Diagram and Test Data, Model 4691

VELOCITY SURVEY IN WAY OF THE PROPELLER	
TANKER SHIP	
MODEL 4833	
MODEL DIMENSIONS	
LENGTH (LWL)	24.54 FT
BEAM	3.50 FT
DRAFT	1.301 FT
DISPLACEMENT	2.47 TONS F.W.
PROPELLER DIAMETER	0.583 FT
SPEED	2 93 KT
TEST 9	
JUNE 1960	

r/R IS THE DISTANCE FROM THE PROPELLER AXIS (r) EXPRESSED AS A RATIO OF THE PROPELLER RADIUS (R)

θ IS THE ANGLE MEASURED FROM THE TOP OF THE PROPELLER DISK IN A COUNTERCLOCKWISE DIRECTION.

V IS THE SHIP SPEED.

V_x IS THE LONGITUDINAL (NORMAL TO THE PLANE OF SURVEY) COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE ASTERN DIRECTION.

V_t IS THE TANGENTIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE IN THE COUNTERCLOCKWISE DIRECTION.

V_r IS THE RADIAL COMPONENT OF THE WATER VELOCITY AND IS POSITIVE TOWARD THE SHAFT CENTERLINE.

V_{tr} IS THE TRANSVERSE COMPONENT OF THE WATER VELOCITY AND IS THE VECTOR SUM OF V_t AND V_r.

THE VECTOR SHOWN IN THE DIAGRAM IS IN THE DIRECTION OF V_{tr} WITH A MAGNITUDE EQUAL TO V_{tr}/V.

THE VELOCITY MEASUREMENTS WERE MADE IN A PLANE WHICH IS PERPENDICULAR TO THE CENTERLINE OF THE PROPELLER SHAFT AND INTERSECTS THE SHAFT LINE AT 1.8 FT FWD OF STATION 20

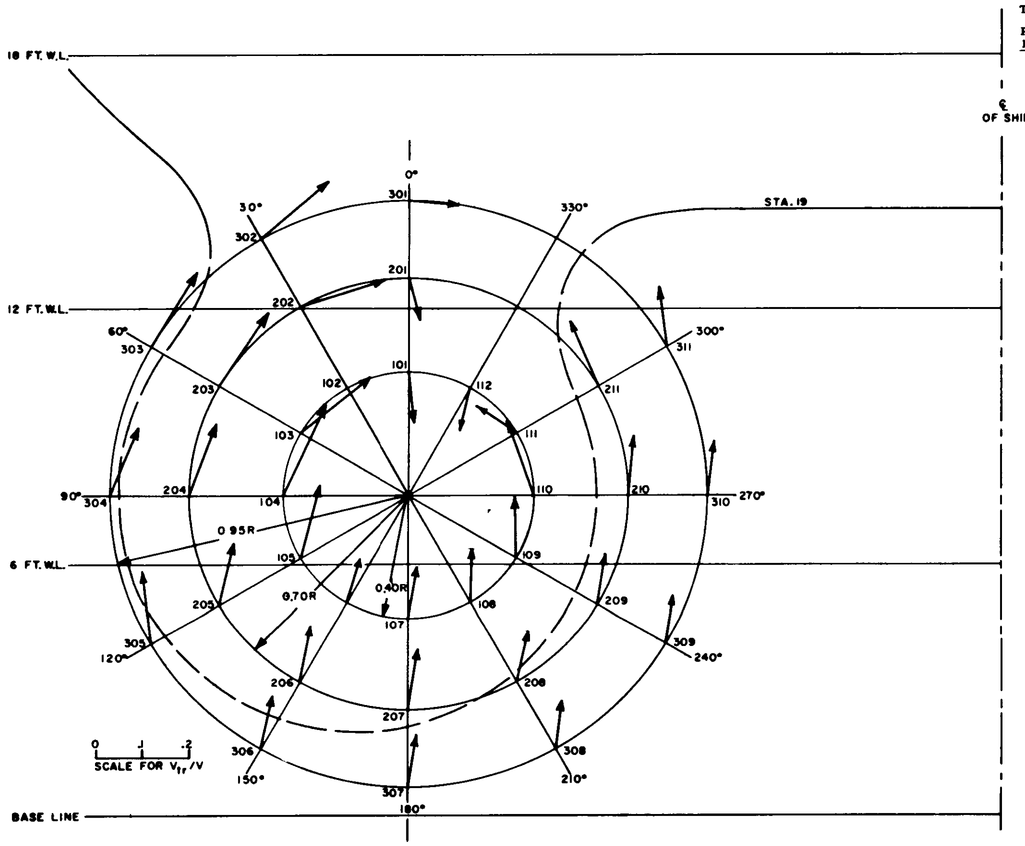


TABLE OF COMPONENT RATIOS

POSITION NUMBER	V_x/V	V_t/V
101	0.36	-0.01
102	0.28	-0.02
103	0.51	-0.18
104	0.79	-0.20
105	0.92	-0.12
106	0.83	-0.02
107	0.92	-0.01
108	0.92	0.07
109	0.91	0.12
110	0.80	0.17
111	0.51	0.10
112	0.43	-0.02
201	0.49	-0.02
202	0.63	-0.19
203	0.87	-0.20
204	0.92	-0.16
205	0.95	-0.11
206	0.94	-0.04
207	0.98	0.02
208	0.91	0.08
209	0.94	0.11
210	0.92	0.13
211	0.80	0.16
212	-	-
301	0.59	-0.11
302	0.80	-0.20
303	0.86	-0.19
304	0.90	-0.15
305	0.89	-0.10
306	0.95	-0.04
307	0.95	0.02
308	0.97	0.06
309	0.98	0.10
310	0.91	0.12
311	0.87	0.12
312	-	-

Figure 30 - Wake Velocity Diagram and Test Data, Model 4833

REFERENCES

1. Cheng, H.M. and Hadler, J.B., "Wake Analysis of Ship Models; Single-Screw DE Type," David Taylor Model Basin Report 1849 (Jun 1964).

2. Cheng, H.M. and Hadler, J.B., "Wake Analysis of Ship Models; Twin-Screw Military Types," David Taylor Model Basin Report 1928 (Dec 1964).

3. Cheng, H.M. and Hadler, J.B., "Wake Analysis of Ship Models; Single-Screw Merchant Types," David Taylor Model Basin Report 2076 (Sep 1965).

4. Frisby, R.E. and Wilson, C.J., "Tests of a 20-Foot Model of a Proposed Twin-Screw Passenger and Trailership to Determine Shaft Horsepower," David Taylor Model Basin Report 639 (Mar 1948).

5. Harper, M.S., "Twin-Screw Passenger and Trailership Model 4013-4. Wake Survey in Way of Propeller and at Two Locations Aft," David Taylor Model Basin Report 722 (Jul 1950).

6. Harper, M.S., "The Effect of Bossing Design on the Effective Horsepower, Shaft Horsepower, and Wake for a Twin-Screw Passenger Vessel, Bethlehem Steel Design PR-1534, as Predicted from Tests with Model 3931," David Taylor Model Basin Report 602 (Jun 1948) PROPRIETARY.

7. Weaver, A.H., Jr., "Powering Characteristics for a 100,000-Ton Deadweight Tanker Represented by Model 4691," David Taylor Model Basin Report 1225 (Jun 1958) PROPRIETARY.

8. Hadler, J.B. et al., "Advanced Propeller Propulsion for High-Powered Single-Screw Ships," Transactions, the Society of Naval Architects and Marine Engineers, Vol 2 (1964).

INITIAL DISTRIBUTION

Copies	
13	CHBUSHIPS
	3 Tech Lib (Code 210L)
	1 Appl Res (Code 340)
	1 Prelim Des (Code 420)
	1 Mach Sci & Res (Code 436)
	1 Hull Des (Code 440)
	1 Prop Shaft & Brng (Code 644)
	1 Lab Mgt (Code 320)
	1 Ship Silencing Br (Code 345)
	1 Cruisers and Destroyers Br (Code 523)
	2 Sci & Res (Code 442)
1	CHBUWEPS
	1 Library (DLI-3)
3	CHONR
	2 Fluid Dyn Br (Code 438)
	1 Library (Code 740)
1	SUPT, USNAVPGSCOL
1	DIR, ORL
1	ADMIN, MARAD
20	DDC
1	SNAME
1	HD, NAME, MIT
1	DIR, Iowa Inst. of Hydraulic Res
1	DIR, St. Anthony Falls Hydrau Lab
1	HD, Dept NAME, Univ of Mich
1	ADMIN, Inst NAVARCH, Webb
1	DIR, Inst of Eng Res, Univ of Calif
1	DIR, Hydronautics, Inc.
1	Bethlehem Steel Corp, Shipbldg Div
1	Ingalls Shipbldg Corp
1	NNS & DD Co
1	Sun Shipbldg & DD Co
1	Friede and Goldman, Inc.
1	Gibbs & Cox

Copies	
1	George G. Sharpe Co
1	Avondale Shipyards, Inc.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* David Taylor Model Basin, Dept of Navy, Washington, D.C., 20007	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b GROUP

3. REPORT TITLE

Wake Analysis of Ship Models; Twin-Screw Merchant Types

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Fourth of Series

5. AUTHOR(S) *(Last name, first name, initial)*

Cheng, H.M.
Hadler, J.B.

6. REPORT DATE October 1965	7a. TOTAL NO. OF PAGES 41	7b. NO. OF REFS 8

8a. CONTRACT OR GRANT NO. b. PROJECT NO. S-R011 01 01 c. Task 0401 d.	9a. ORIGINATOR'S REPORT NUMBER(S) DTMB Report 2074 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. AVAILABILITY/LIMITATION NOTICES

Distribution of This Document is Unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Department of the Navy Bureau of Ships Washington, D.C.

13. ABSTRACT

This report, the fourth in a series on studies of the wake in the propeller plane of ship models, presents the results of the wake of twin-screw merchant-type ship models using the IBM-7090 computer. The data presented are the interpolated longitudinal and tangential velocity distributions, their computer mean values, the harmonic contents of these velocity components, the maximum variations in the resultant inflow velocity, and the advance angles and their variations. Also included are the calculated volumetric wake velocities.

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Wake Propeller Cavitation Vibration Merchant Ships Digital Computer						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ___________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ___________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ___________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.