UNITED STATES
EXPERIMENTAL MODEL BASIN

NAVY YARD, WASHINGTON, D.C.

COMPARATIVE EFFECTS OF RUDDER TYPES ON PROPULSION AND STEERING AS DETERMINED BY TRIALS ON U.S.S. SALINAS CLASS

EXPERIMENTAL MODEL BASIN
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Object of Test

To determine the influence of various rudders on the power, speed and maneuverability of a single screw vessel, a number of comparative full-scale tests were made with vessels of the auxiliary oiler class of the U.S. Navy. These are single screw vessels of the following characteristics:—

length between perpendiculars . . .	463 ft. 3 in.
beam	60 ft.
mean draft	26 ft. 2 in.
block coefficient	0.825
displacement	16,800 tons

The first of this series of trials was held on the Rockland course during August of 1929. The U.S.S. PATOKA, fitted with an Oertz type rudder, was standardized first, immediately followed by the U.S.S. SALINAS fitted with its original plate rudder.

The differences in powers for equal speeds, as determined by this first trial, were far greater than had been anticipated. To check these results, model experiments, duplicating full-scale tests, were made which indicated a saving in power for the vessel with the Oertz rudder, although not as pronounced as in the case of the ship.

As these comparative trials were conducted with vessels of similar design and characteristics, it was concluded that due to the inherent differences to be found even in vessels of similar design—differences in condition of ship's surface, in propeller surface, etc.—the results obtained from this first set of trials were not truly comparable. Accordingly, it was planned to conduct trials on individual vessels fitted first with their original plate rudders and then with other types of stream-line rudders. The rudders selected were the original plate, the fair form (Bureau of Construction and Repair design), the Oertz, and the Contra rudder, illustrated in Figs. 1 to 4 respectively. Fig. 5 shows graphically, the major differences in these rudders.

Procedure

Each vessel was standardized first with the original plate rudder at 8 knots, 9 knots, 10 knots, and maximum speed. Standardization runs with stream-lined types of rudders were then made at the same engine revolutions developed during the trials of that vessel when fitted with its original plate rudder. The displacement for all runs was limited to the range of 16,600 to 16,900 tons (full load condition).

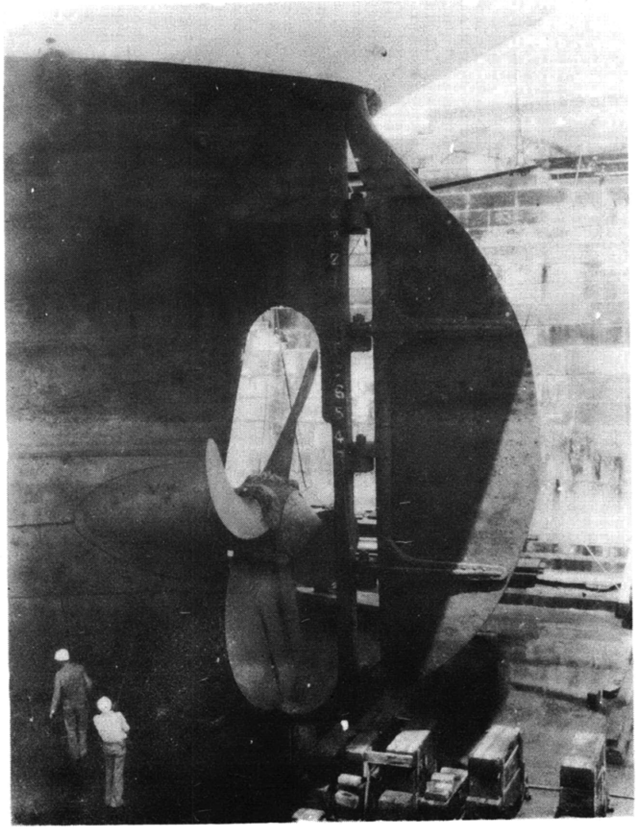


FIG. 1— PLATE RUDDER INSTALLATION

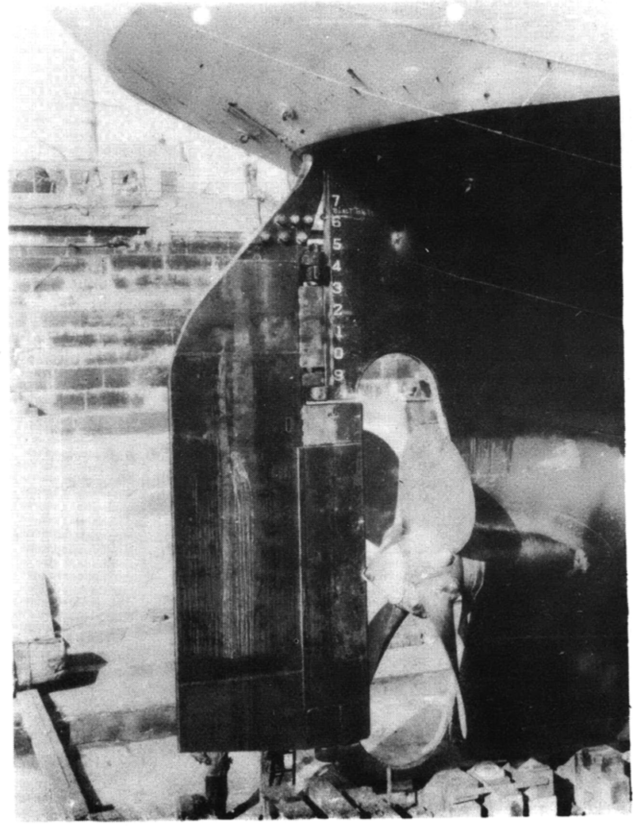


FIG. 2— FAIRFORM RUDDER INSTALLATION

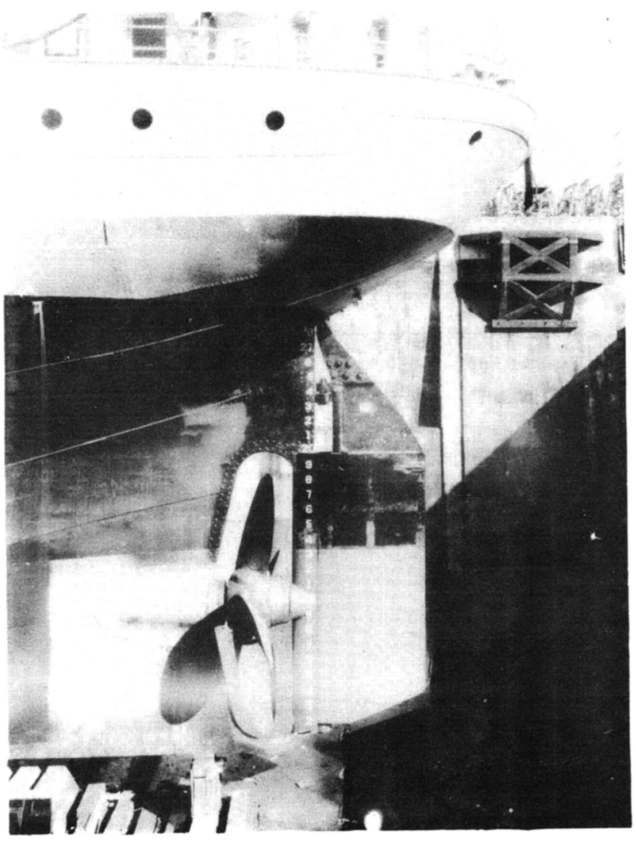


FIG. 3— OERTZ RUDDER INSTALLATION

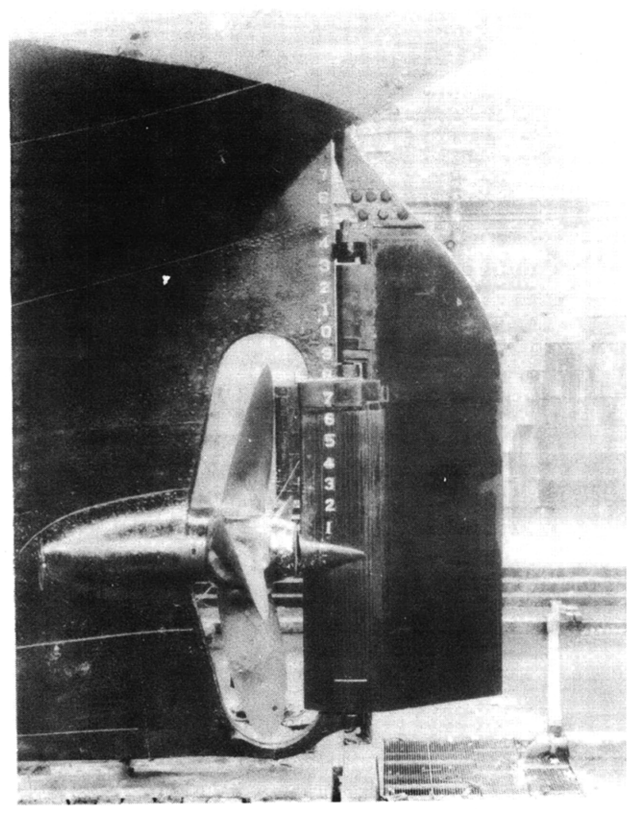
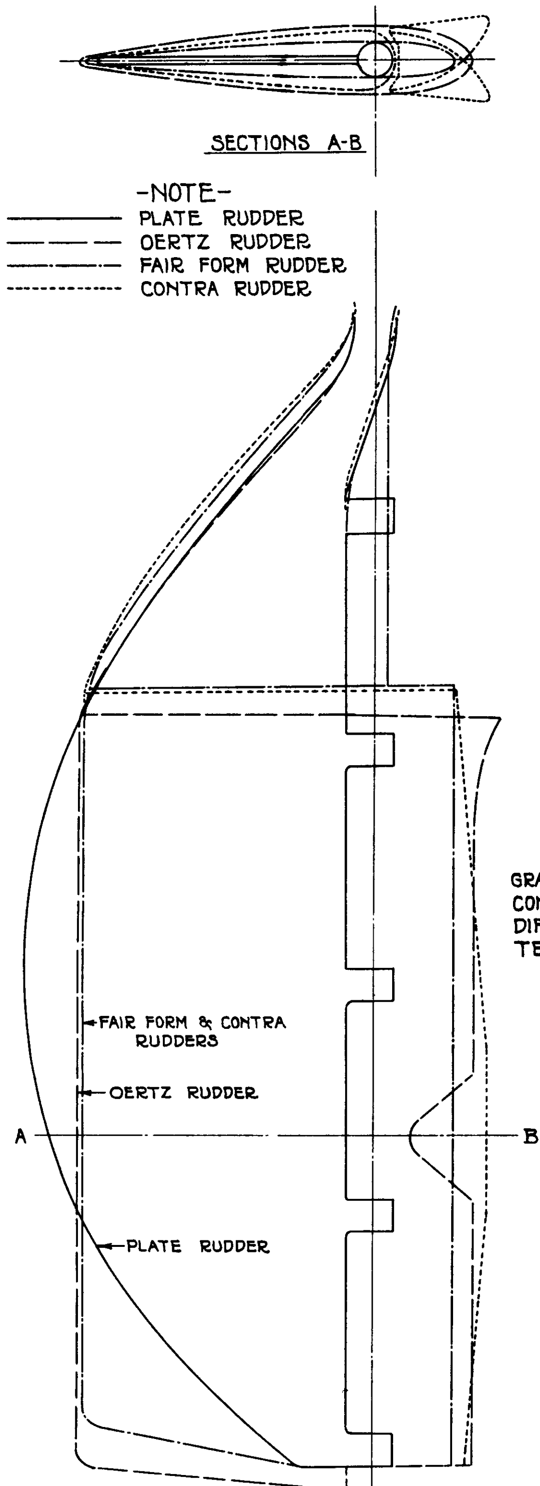


FIG. 4—CONTRA RUDDER INSTALLATION



GRAPHICAL COMPARISON OF CONTOUR AND SECTION OF DIFFERENT RUDDERS TESTED

FIG. 5

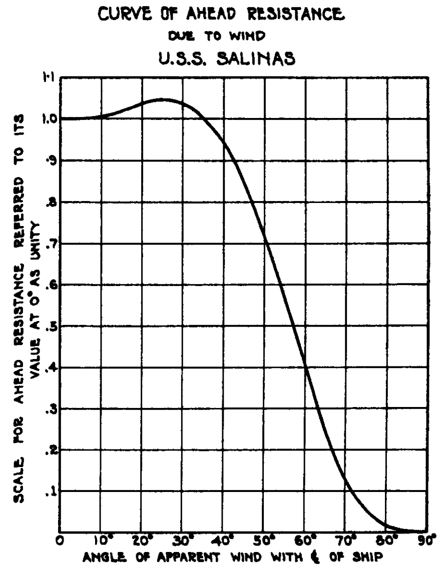


FIG. 6

In addition to the standardization trials, maneuvering tests were made. These comprised observations of turning circles and special evolutions for measuring the time for the vessel to change heading with a definite rudder angle. With the vessel steady on a base course, the rudder was placed 15° left. The times required for the vessel to swing 10°, 20°, and 30° were noted. At this latter angle, the rudder was then shifted to 15° right, noting the maximum angle attained and the time required to return to base course. With the vessel still swinging, the times required to swing 10°, 20°, and 30° to the opposite hand were noted. At this latter angle, the rudder was shifted to 15° left, noting the maximum angle attained and the time required to steady on base course. The foregoing evolution was repeated, beginning with a rudder angle of 15° right.

Trial Data and Methods of Analysis

For ready reference, all comparative trials are grouped and designated by the following symbols:—

Group A	USS SALINAS	– fitted with original plate rudder
	USS PATOKA	– fitted with Oertz rudder
Group B	USS RAMAPO	– fitted with original plate rudder
	USS RAMAPO	– fitted with fair form rudder
Group C	USS SAPELO	– fitted with original plate rudder
	USS SAPELO	– fitted with Oertz rudder
Group D	USS SALINAS	– fitted with original plate rudder
	USS SALINAS	– fitted with fair form rudder
	USS SALINAS	– fitted with Contra rudder

Measurements of power, for all trials, were obtained by indicator cards. To convert these values to equivalent shaft horse power, the overall mechanical efficiency of the engine plant was taken as 0.90.

Since no wind data were observed and recorded on the comparative trials of Groups A and B, it was not possible to make a complete correction for the wind resistance. Partial corrections were made as shown on pages 21, 22, 23, and 24 of the appendix for Groups A and B respectively.

To make corrections for wind resistance in the case of Groups C and D, a model of the upper works of the U.S.S. SALINAS was towed inverted in the basin. Fig. 6 is taken from this experiment, the complete data for which will be found in Experimental Model Basin Report No. 345. The calculations for corrections to the observed data will be found on pages 25, 26, 27, and 28 of the appendix.

Since the model experiments were made at a displacement corresponding to 16,900 tons, an additional correction was applied to all trial data to make them comparable. The observed trial data corrected to a basis of no wind were plotted on an enlarged scale and faired. The faired curves were then shifted on the assumption that, for small changes in actual displacement, the shaft horse power varied directly as the displacement.

No attempt was made to establish a comparative basis for analyzing the turning circle data, chiefly because of the impossibility of correcting for the effect of tidal and other currents. For those vessels given the maneuvering test, comparative curves have been prepared to study rudder action by plotting change of heading on time.

Discussion of Results—Standardization Trials

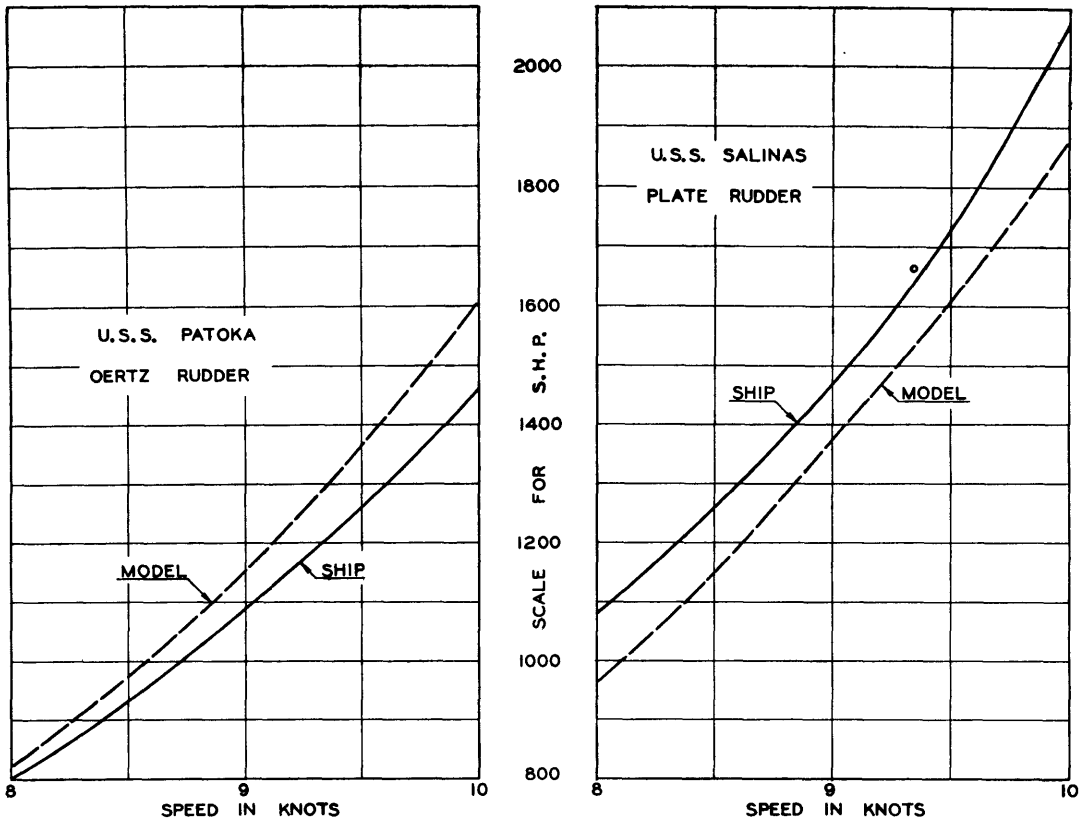
Graphic comparison of shaft horse power characteristics for Groups A, B, C, and D, will be found in Figs. 7, 8, 9, and 10.

To effect a logical comparison, it appears that the following steps should be observed;—first, the corrected results of each trial must be compared with results from corresponding model tests, second, the corrected results of each group of trials must be compared with results from corresponding group model tests, and third, the corrected results of each trial for the same type of rudder, but of different vessels, must be compared. This procedure is essential for indicating not only the character of the results, but their reliability as well. Accordingly the data are presented in three tables, indicated below as Table I, II, and III respectively.

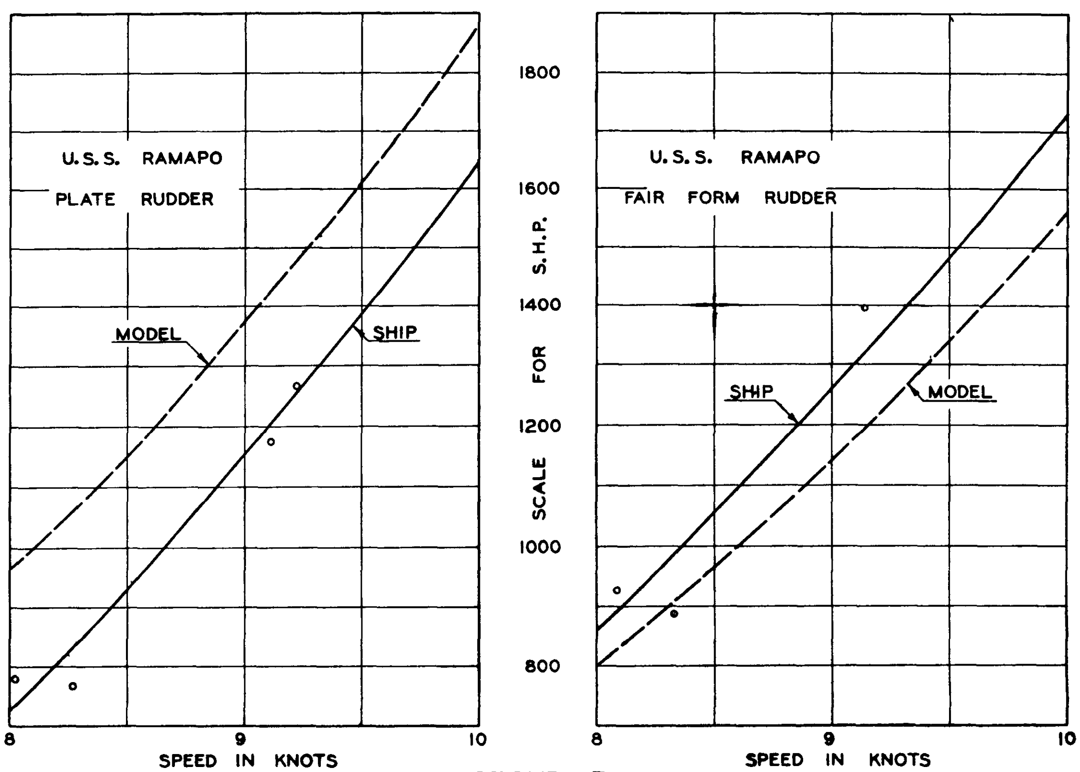
TABLE I

SHAFT HORSE POWER COMPARISON—TRIAL WITH MODEL

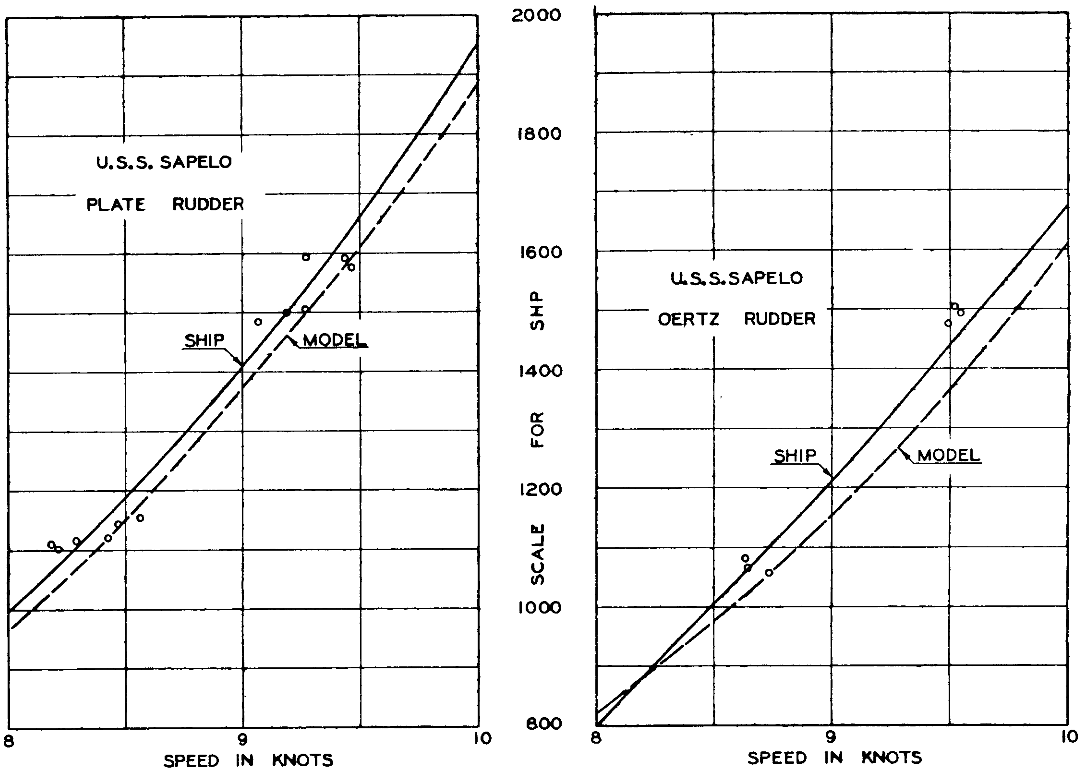
Group	Vessel	Type of Rudder	Variation of Trial SHP from model SHP per cent
A	USS SALINAS	Plate	+10.5
A	USS PATOKA	Oertz	− 5.3
B	USS RAMAPO	Plate	−16.6
B	USS RAMAPO	Fair Form	+11.0
C	USS SAPELO	Plate	+ 4.0
C	USS SAPELO	Oertz	+ 3.7
D	USS SALINAS	Plate	− 6.5
D	USS SALINAS	Fair Form	− 0.4
D	USS SALINAS	Contra	+ 3.5



GROUP A
FIG. 7

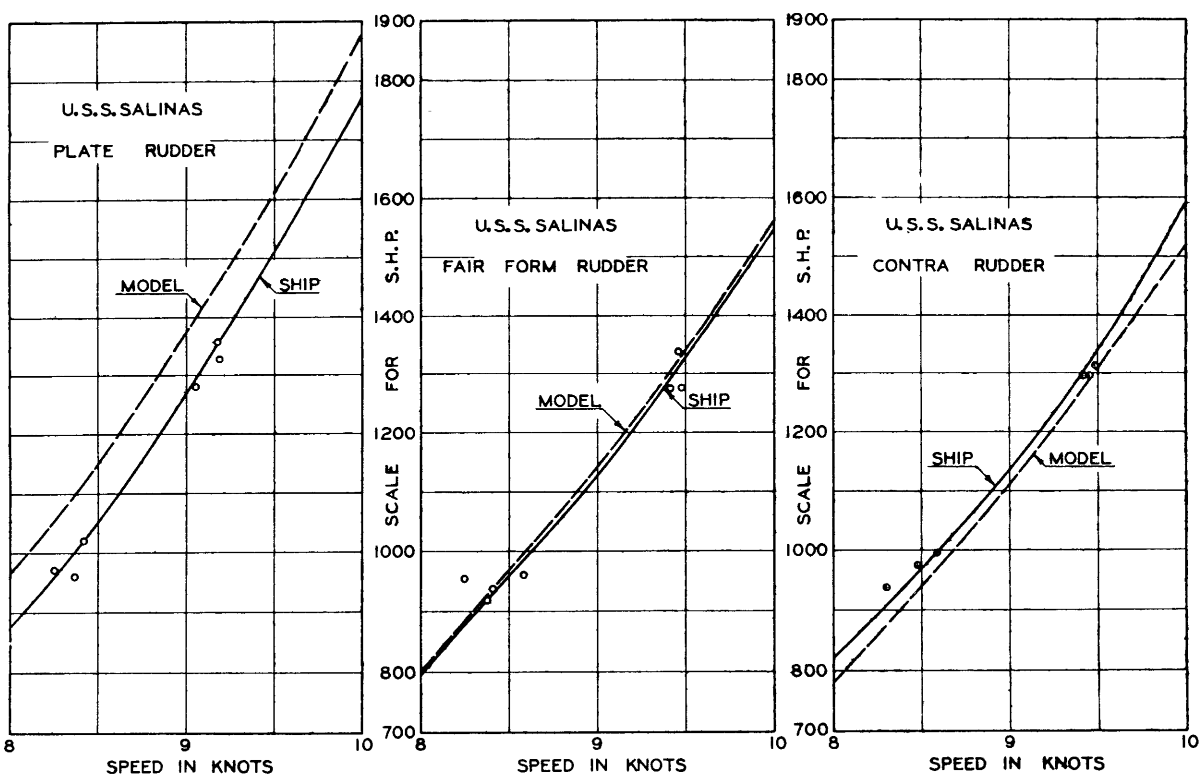


GROUP B
FIG. 8



GROUP C

FIG. 9



GROUP D

FIG. 10

TABLE II

SHAFT HORSE POWER COMPARISON—TRIALS in GROUP vs MODEL TEST in GROUP

Group	Vessel	Rudder	Corrected Trial SHP of vessel fitted with	Model SHP of vessel fitted with
A	USS PATOKA USS SALINAS	Oertz vs Plate	Oertz 27.3 per cent less than Plate	Oertz 15.2 per cent less than Plate
B	USS RAMAPO	Fair Form vs Plate	Fair Form 10.9 per cent more than Plate	Fair Form 16.8 per cent less than Plate
C	USS SAPELO	Oertz vs Plate	Oertz 15.4 per cent less than Plate	Oertz 15.2 per cent less than Plate
D	USS SALINAS	Fair Form vs Plate	Fair Form 11.4 per cent less than Plate	Fair Form 16.8 per cent less than Plate
		Contra vs Plate	Contra 10.1 per cent less than Plate	Contra 19.0 per cent less than Plate

TABLE III

SHAFT HORSE POWER for TRIALS with SAME TYPE RUDDER

Group	Vessel	Variation of Trial SHP from Model SHP per cent
	PLATE RUDDER	
A	USS SALINAS	+10.5
B	USS RAMAPO	+16.6
C	USS SAPELO	+ 4.0
D	USS SALINAS	− 6.5
	OERTZ RUDDER	
A	USS PATOKA	− 5.3
C	USS SAPELO	+ 3.7
	FAIR FORM RUDDER	
B	USS RAMAPO	+11.0
D	USS SALINAS	− 0.4
	CONTRA RUDDER	
D	USS SALINAS	+ 3.5

Since no wind data were observed and only partial corrections made in the trials of Groups A and B, it is worthy of note that the widest discrepancies between trial and model results are found in these trials. Although it is not certain that all of this difference is due to the lack of wind observation, the nature of the results warrant their exclusion since no other logical explanation can be found for the wide differences.

Turning next to Groups C and D, where wind data were observed and corrections made, the comparisons established in Tables I and II for Group C are consistent with model predictions, but similar comparisons for Group D show the results to be discordant. Table I, in the case of Group D, indicates that the plate rudder trial of the SALINAS shows the widest variation from model results. Since the comparisons effected in Table II, for Group D, are based on the plate rudder trial results given in Table I, this deviation is reflected in the tabulated results of Table II. Accordingly, some consideration must be given this in analyzing the other trials of this group. Assuming, for purposes of discussion, that the variations in SHP for plate rudder trials of the SALINAS were of the same order as in the case for the SAPELO, Group C, the comparisons established in Table II for Group D would be more consistent with model test results.

Table III is given primarily to study the differences in performance of the various trials for the same type of rudder. Since the data obtained in the case of trials for Groups A and B are unreliable, much of the value of the comparison is lost. There are, however, many significant conclusions that may be drawn from this comparison even as it stands.

Despite the fact that wind observations were recorded in the case of Groups C and D, the plate rudder trial results in the case of the SAPELO and SALINAS show an overall difference of approximately ten per cent. This feature serves to emphasize further the care that must be employed in establishing the final comparison.

Discussion of Results—Maneuvering Tests

Since it is impossible to derive any comparison of value from the data of Table IV, curves have been prepared to show the effects of the various types of rudders from the special maneuvering tests of Groups B, C, and D. Figs. 11 and 12 have been prepared from the results of Group B tests, Fig. 13 from tests of Group C, and Fig. 14 from tests of Group D. With the aid of these curves, the rate of change of heading—the vessel being initially steady on a base course—has been tabulated in Tables V and VI.

Figs. 11 and 12 indicate the characteristics of rudder action for both plate and fair form rudders as well as the influence of speed upon these characteristics.

In general, for a single screw vessel fitted with a right hand propeller, the effect of the slip stream is such that the vessel's head will fall to the left at a greater rate than to the right. This general condition, however, may be modified by the presence of sea and wind, depending upon their magnitude and relative direction. For this reason, in analyzing the influence of rudder action from Tables V and VI, consideration must be given to the conditions surrounding each particular test.

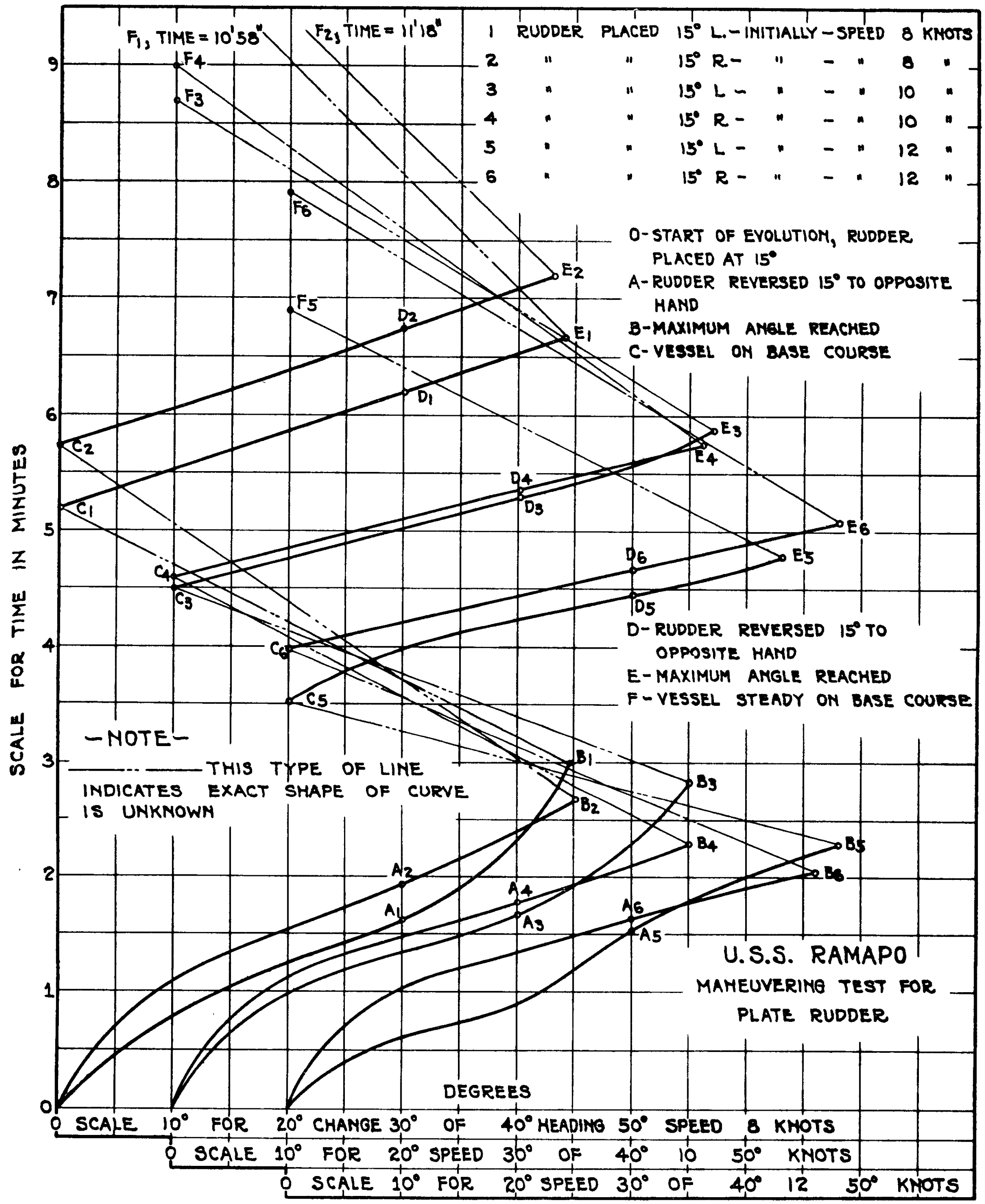

F1, TIME = 10'58"
F2, TIME = 11'18"
1 RUDDER PLACED 15° L. – INITIALLY – SPEED 8 KNOTS
2 " " 15° R. – " – " 8 "
3 " " 15° L. – " – " 10 "
4 " " 15° R. – " – " 10 "
5 " " 15° L. – " – " 12 "
6 " " 15° R. – " – " 12 "
O - START OF EVOLUTION, RUDDER PLACED AT 15°
A - RUDDER REVERSED 15° TO OPPOSITE HAND
B - MAXIMUM ANGLE REACHED
C - VESSEL ON BASE COURSE
D - RUDDER REVERSED 15° TO OPPOSITE HAND
E - MAXIMUM ANGLE REACHED
F - VESSEL STEADY ON BASE COURSE
— NOTE —
THIS TYPE OF LINE INDICATES EXACT SHAPE OF CURVE IS UNKNOWN
U.S.S. RAMAPO
MANEUVERING TEST FOR PLATE RUDDER
SCALE FOR TIME IN MINUTES
DEGREES
0 SCALE 10° FOR 20° CHANGE 30° OF 40° HEADING 50° SPEED 8 KNOTS
0 SCALE 10° FOR 20° SPEED 30° OF 40° 10 50° KNOTS
0 SCALE 10° FOR 20° SPEED 30° OF 40° 12 50° KNOTS

FIG. 11

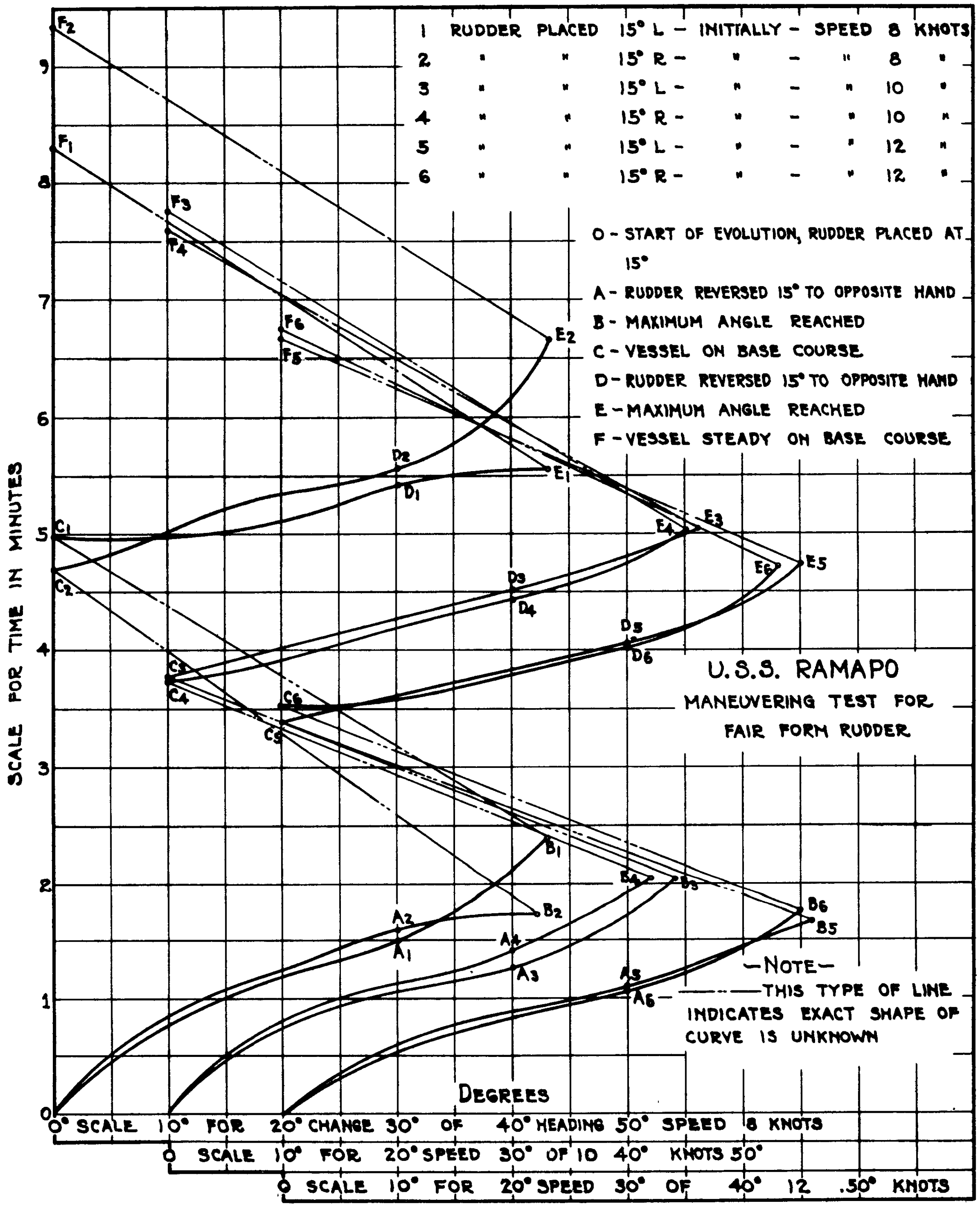

1 RUDDER PLACED 15° L – INITIALLY – SPEED 8 KNOTS
2 " " 15° R – " – " 8 "
3 " " 15° L – " – " 10 "
4 " " 15° R – " – " 10 "
5 " " 15° L – " – " 12 "
6 " " 15° R – " – " 12 "
O – START OF EVOLUTION, RUDDER PLACED AT 15°
A – RUDDER REVERSED 15° TO OPPOSITE HAND
B – MAXIMUM ANGLE REACHED
C – VESSEL ON BASE COURSE
D – RUDDER REVERSED 15° TO OPPOSITE HAND
E – MAXIMUM ANGLE REACHED
F – VESSEL STEADY ON BASE COURSE
U.S.S. RAMAPO
MANEUVERING TEST FOR FAIR FORM RUDDER
—NOTE—
THIS TYPE OF LINE INDICATES EXACT SHAPE OF CURVE IS UNKNOWN
SCALE FOR TIME IN MINUTES
DEGREES
0° SCALE 10° FOR 20° CHANGE 30° OF 40° HEADING 50° SPEED 8 KNOTS
0 SCALE 10° FOR 20° SPEED 30° OF 10 40° KNOTS 50°
0 SCALE 10° FOR 20° SPEED 30° OF 40° 12 50° KNOTS

FIG. 12

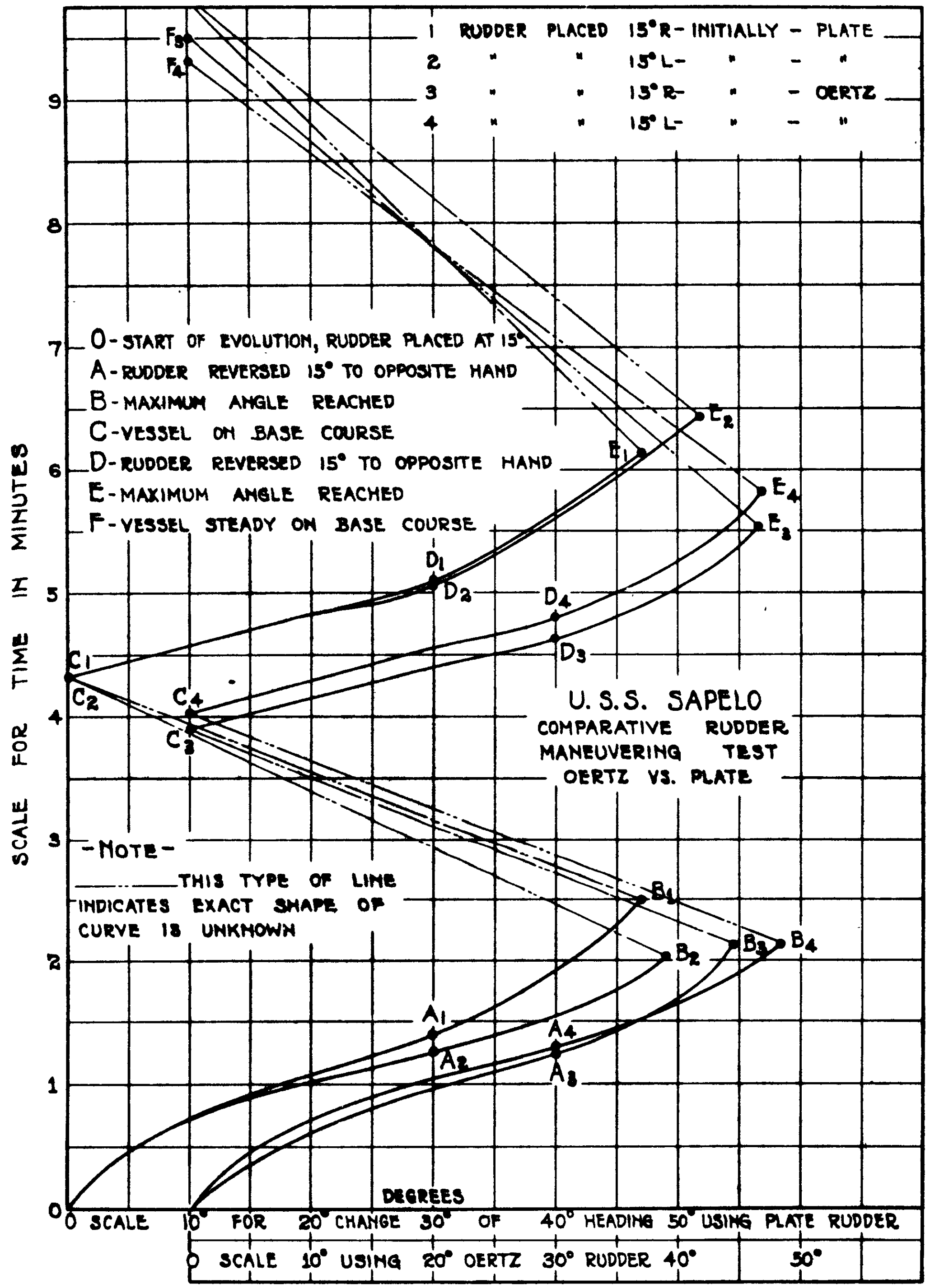

1 RUDDER PLACED 15° R - INITIALLY - PLATE
2 " " 15° L - " - "
3 " " 15° R - " - OERTZ
4 " " 15° L - " - "
O - START OF EVOLUTION, RUDDER PLACED AT 15°
A - RUDDER REVERSED 15° TO OPPOSITE HAND
B - MAXIMUM ANGLE REACHED
C - VESSEL ON BASE COURSE
D - RUDDER REVERSED 15° TO OPPOSITE HAND
E - MAXIMUM ANGLE REACHED
F - VESSEL STEADY ON BASE COURSE
U. S. S. SAPELO
COMPARATIVE RUDDER MANEUVERING TEST
OERTZ VS. PLATE
- NOTE -
THIS TYPE OF LINE INDICATES EXACT SHAPE OF CURVE IS UNKNOWN
SCALE FOR TIME IN MINUTES
DEGREES
0 SCALE 10° FOR 20° CHANGE 30° OF 40° HEADING 50° USING PLATE RUDDER
0 SCALE 10° USING 20° OERTZ 30° RUDDER 40° 50°

FIG. 13

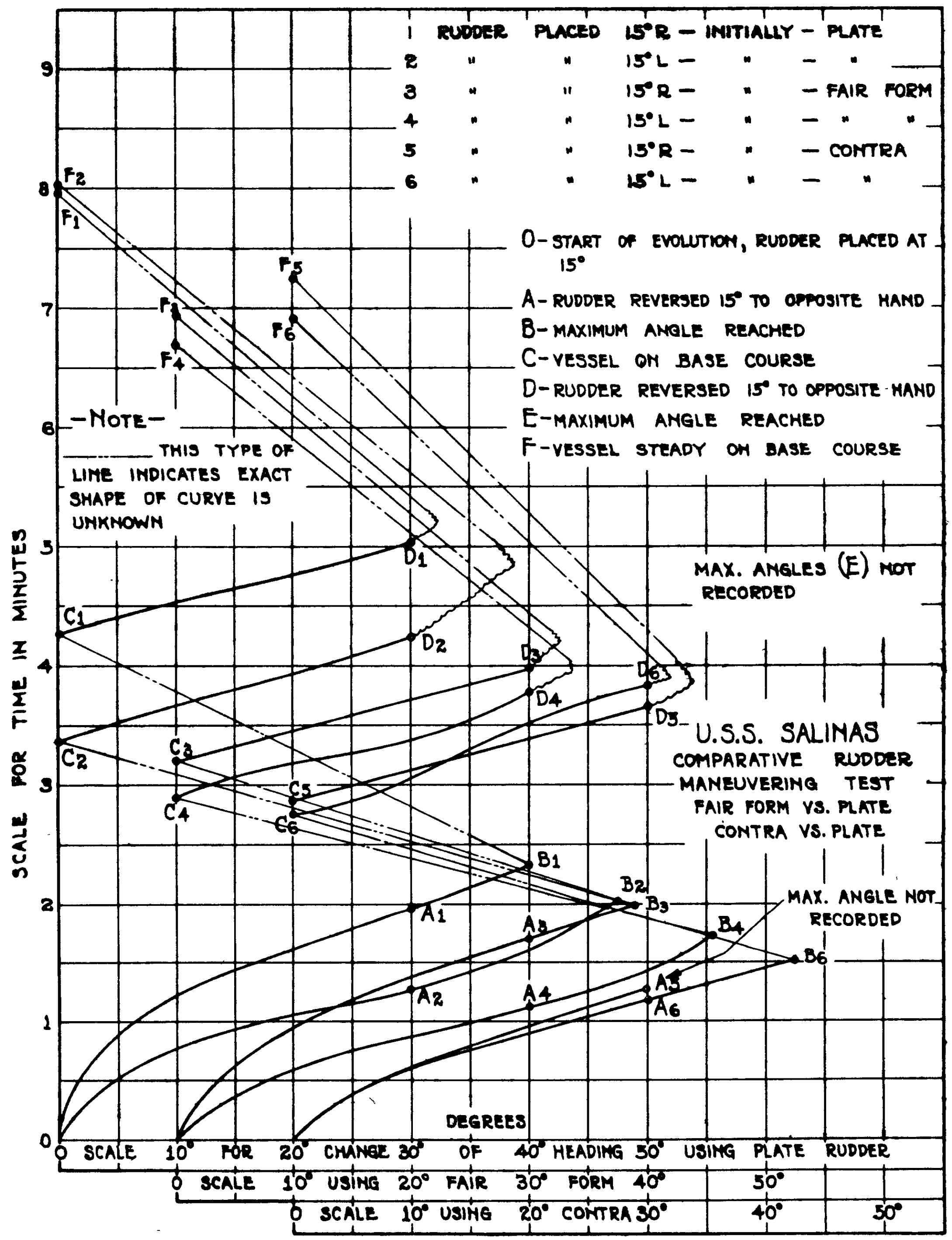

1 RUDDER PLACED 15° R — INITIALLY — PLATE
2 " " 15° L — " — "
3 " " 15° R — " — FAIR FORM
4 " " 15° L — " — " "
5 " " 15° R — " — CONTRA
6 " " 15° L — " — "
O- START OF EVOLUTION, RUDDER PLACED AT 15°
A- RUDDER REVERSED 15° TO OPPOSITE HAND
B- MAXIMUM ANGLE REACHED
C- VESSEL ON BASE COURSE
D- RUDDER REVERSED 15° TO OPPOSITE HAND
E- MAXIMUM ANGLE REACHED
F- VESSEL STEADY ON BASE COURSE
—NOTE—
———— THIS TYPE OF LINE INDICATES EXACT SHAPE OF CURVE IS UNKNOWN
MAX. ANGLES (E) NOT RECORDED
U.S.S. SALINAS
COMPARATIVE RUDDER MANEUVERING TEST
FAIR FORM VS. PLATE
CONTRA VS. PLATE
MAX. ANGLE NOT RECORDED
SCALE FOR TIME IN MINUTES
DEGREES
0 SCALE 10° FOR 20° CHANGE 30° OF 40° HEADING 50° USING PLATE RUDDER
0 SCALE 10° USING 20° FAIR 30° FORM 40° 50°
0 SCALE 10° USING 20° CONTRA 30° 40° 50°

FIG. 14

TABLE IV

TACTICAL DATA

SHIP	SPEED or RPM	RUDDER ANGLE	TYPE	TACT. DIAM. feet	ADVANCE feet	TRANSFER feet
SALINAS	Full	L.R.	Plate	1436		
SALINAS	Full	L.R.	Oertz	1442		
SALINAS	Full	R.R.	Plate	1748		
SALINAS	Full	R.R.	Oertz	1610		
RAMAPO	76 RPM	33° L	Plate	1674	1518	999
RAMAPO	76 RPM	33° L	Fair Form	1560	1319	822
RAMAPO	76 RPM	33° R	Plate	1707	1494	906
RAMAPO	75.6	33° R	Fair Form	1644	1347	786
SAPELO	66.9	35° R	Plate	1685	1720	765
SAPELO	64.8	35° R	Oertz	1630	1635	625
SAPELO	64.5	35° L	Plate	1650	1450	1105
SAPELO	66.0	35° L	Oertz	1650	1021	875
SALINAS	64.5	25° R	Plate	2370	2020	1320
SALINAS	61.2	25° R	Fair Form	2170	1450	1150
SALINAS	66.8	25° R	Contra	1820	1290	990
SALINAS	67.7	25° L	Plate	1840	1610	1010
SALINAS	61.7	25° L	Fair Form	1510	1490	760
SALINAS	65.6	25° L	Contra	1670	1310	910

TABLE V

RATE of INITIAL SWING—FROM MANEUVERING TESTS

See Figs. 11, 12.

Vessel		RAMAPO					
Column		1	2	3	4	5	6
Speed		8 kts.	8 kts.	10 kts.	10 kts.	12 kts.	12 kts.
Sea		choppy	slight	choppy	slight	choppy	slight
Wind Dir. Relative		85° on star.bow	40° on star.bow	ahead	40° on star.bow	35° on port bow	40° on star.bow
Wind Force		1	2	1	2	1	2
Type Rudder		Plate	Fair Form	Plate	Fair Form	Plate	Fair Form
Elapsed time from shifting rudder from zero	R.Angle 15° L	Change in heading from base course.					
30 sec.		5.5°	6.5°	3.5°	6.0°	7.5°	7.5°
45 sec.		9.5°	10.0°	6.5°	11.0°	16.0°	14.0°
60 sec.		14.0°	15.0°	10.5°	18.0°	22.0°	26.0°
Elapsed time from shifting rudder from zero	R.Angle 15° R	Change in heading from base course.					
30 sec.		3.0°	5.0°	2.5°	5.0°	3.0°	9.5°
45 sec.		5.5°	8.5°	5.0°	9.5°	5.5°	17.0°
60 sec.		8.5°	13.0°	8.0°	15.0°	9.5°	27.5°

TABLE VI

RATE of INITIAL SWING— FROM MANEUVERING TESTS

See Figs. 13, 14.

Vessel	SAPELO	SAPELO	SALINAS	SALINAS	SALINAS
Column	1	2	3	4	5
RPM	67	67	62	62	64
(approx. speed)	10 kts.	10.5 kts.	9.5 kts.	10 kts.	10.2 kts.
Sea	Smooth	Smooth	Smooth	Moderate on port bow	Light swell 2 pts. aft of star beam
Wind Dir. Relative	40° on star.bow	60° on star.bow	75° on star.bow	46° on port bow	36° on star quarter
Wind Force	0–1	2–3	0–1	5	3
Type Rudder	Plate	Oertz	Plate	Fair Form	Contra
Elapsed time from shifting rudder from zero R.Angle 15° L	Change in heading from base course				
30 sec.	5.5°	5.75°	5.0°	8.0°	7.5°
45 sec.	10.5°	11.0°	10.5°	15.0°	15.0°
60 sec.	19.5°	18.5°	17.5°	26.0°	23.0°
Elapsed time from shifting rudder from zero R.Angle 15° R	Change in heading from base course				
30 sec.	5.5°	7.7°	1.6°	3.5°	7.5°
45 sec.	10.5°	13.5°	3.5°	6.5°	13.5°
60 sec.	18.0°	21.5°	6.5°	11.0°	21.0°

With this in mind, the differences in change of heading between left and right, taken from columns 1, 3, and 5 of Table V, are given below.

TABLE VII

DIFFERENCES in CHANGE of HEADING between LEFT and RIGHT

Elaspsed Time	Col. 1	Col. 3	Col. 5
30 sec.	2.5° L	1.0° L	4.5° L
45 sec.	4.0° L	1.5° L	10.5° L
60 sec.	5.5° L	2.5° L	12.5° L

Since the relative wind is dead ahead in column 3, the wind effect is eliminated. Hence, the difference in rate to the left is caused by the slip stream effect upon the unequal rudder areas above and below the propeller axis (see Fig. 5 where AB is at the propeller axis). The differences in columns 1 and 5 are both greater than those in column 3. Considering force and direction of wind effect alone, the differences are consistent in column 1 but inconsistent in column 5. Since the direction of the sea is not given, it appears that its direction is not the same as that of the relative wind. This fact makes it impossible to state whether columns 1 and 5 are definitely consistent or inconsistent with column 3.

The differences in change of heading between left and right, taken from columns 2, 4, and 6 of Table V for the fair form rudder, show the following characteristics:

TABLE VIII

DIFFERENCES in CHANGE of HEADING between LEFT and RIGHT

Elapsed Time	Col. 2	Col. 4	Col. 6
30 sec.	1.5° L	1.0° L	2.0° R
45 sec.	1.5° L	1.5° L	3.0° R
60 sec.	2.0° L	3.0° L	1.5° R

As the sea is recorded as slight in these three cases, its effect may be neglected. The wind is the same for all three speeds. These differences are not consistent, since the directions of column 6 are opposite to those of columns 2 and 4.

Despite a lack of complete uniformity, it is believed that the data of Table V indicate a gain in action for the stream-lined rudder over the plate rudder. The average rate of increase varies from approximately 10 per cent upwards.

The results given in columns 1 and 3 of Table VI are comparable to those of columns 1, 3, and 5 of Table V. The differences in change of heading between left and right are negligible in the case of the SAPELO, column 1, but great in the case of the SALINAS, column 3. When these differences are compared to those given in Table VII, the rudder action, considering wind and sea, is consistent for the RAMAPO and SAPELO, but inconsistent for the SALINAS.

Table IX gives the differences in change of heading between left and right, taken from columns 2, 4, and 5 of Table VI:

TABLE IX

DIFFERENCES in CHANGE of HEADING between LEFT and RIGHT

Elapsed Time	Col. 2	Col. 4	Col. 6
30 sec.	2.0° R	4.5° L	0°
45 sec.	2.5° R	8.5° L	1.5° L
60 sec.	3.0° R	15.0° L	2.0° L

In the case of column 2, the center of pressure of the wind effect is aft of the pivoting point. Considering the force of the wind, it is consistent for the vessel to swing right faster than to the left because of the added effort of the wind effect.

Considering column 5, from the given conditions of wind, it appears that the rate of turning left should be less and that of turning right should be greater. In other words, the differences observed are not consistent with anticipated effects from the wind.

In column 5, the force and direction of the relative wind are such as to increase the rate of turning right and to decrease the rate of turning left. This explains the greater rate of turning right in comparison with column 4.

One interesting feature exhibited by all the curves is that approximately the same maximum change in heading is reached for all speeds and types of rudders. The time required to reach this angle is, in general, reduced by the speed and appears to be shortest for the fair form rudder.

Conclusions

On the basis of the above analysis, the following conclusions may be drawn.

1. Every act of comparison involves two considerations—one for purpose of relative evaluation, the other for basic evaluation. In establishing a relative evaluation, any basis may be accepted. For purposes of basic evaluation some standard must be accepted. All things considered, model test results are the only logical standard for propulsion comparisons. Since there is a wide variation in the corrected trial shaft horsepower results, a suspicion of the reported data is raised. It naturally brings into bold relief the question of accuracy of power measurements by means of indicator cards. The mechanical efficiency of not only the same plant, but of identical plants may vary considerably because of differences in the amount of friction found in various parts of the plant. Because of this, it appears that the measurements of power are approximately three per cent plus or three per cent minus in error.

2. Since the corrected trial shaft horse power of certain vessels of this group is in excess of this three per cent deviation, the question arises whether this excess in power is real or apparent. Since no thrust was measured during any one of these trials, no means are available for analyzing comparative propeller performance between model and ship. Had thrust as well as torque been measured, such a comparative analysis could be established—and this analysis would immediately indicate whether or not the observed powers were accurate.

3. Despite the limitations imposed on this analysis, it appears that the use of a stream-line instead of the usual plate rudder will reduce the shaft horse power approximately fifteen per cent.

4. The trial results do not establish definitely the superiority of any one

type of stream-lined rudder over that of another. Such differences as occur may be more the result of other conditions, such as state of sea, condition of vessel's surface, character of propeller performance, etc., than of any inherent superiority in the particular rudder.

5. Because of the difficulty in reducing all conditions peculiar to each maneuvering test to a truly comparative basis, it can not be stated definitely that one type of stream-line rudder is superior to another from the view point of maneuverability. It can be stated that a stream-line rudder is superior to a plate rudder in obtaining a quicker response for a given rudder angle. The rate of increase of this response is a variable quantity that is influenced greatly by wind and sea conditions.

6. In general, a shorter turning circle is obtained with a stream-line rudder than with the usual plate rudder.

— APPENDIX —

SHEET 1

TRIAL ANALYSIS OF U.S.S. SALINAS & U.S.S. PATOKA

GENERAL DATA U.S.S. SALINAS

DATE OF TRIALS, 26,27 AUG., 1929
LOCATION OF TRIALS, ROCKLAND, ME.
DATE OF LAST DOCKING,
DAYS OUT DOCK,
LOCATION OF SHIP,
LENGTH, FT. 458
BEAM, FT. 60

TRIAL DATA U.S.S. SALINAS

ITEM	SHIP	MODEL
DISPLACEMENT,	16,700.1	16,900
DRAFT,	26'-1½"	26'.08
TRIM,	1'-1" × STERN	E.K.
TEMP. OF WATER,		
SP. G. OF WATER,		
APPENDAGES,	BILGE KEELS & PLATE RUDDER	
MODEL NO.,		2285
TEST NO.,		8

PROPELLER DATA

DIAMETER, 17.5 FT.
PITCH, DESIGNED, 18.0 FT.
PITCH, MEASURED,
NO. OF BLADES, 4
M.W.R., .214
B.T.F., .0423
P.A./D.A., .356
DIR. OF ROTATION, R.H.
TIPS BELOW SURFACE, 7.39 FT.
NO. OF PROPELLERS, 1
MODEL NOS., 914

OBSERVED DATA

1 RUN NO. & DIR.	2 TIME TO MIDDLE RUN	3 R.P.M. N	4 OBS. SPEED V	5 I.H.P. TOTAL	6 .9 I.H.P. = S.H.P.	7 THRUST T	8 APPAR. WIND VEL. W_a	8 APPAR. WIND DIR.
U.S.S. SALINAS FITTED WITH PLATE RUDDER								
1-S	7.00	53.76	8.02	1209	1088			
2-N	7.72	53.58	7.34	1140	1026			
3-S	8.21	52.61	7.57	1136	1023			
			7.57					
4-N	8.69	63.27	9.09	1852	1666			
5-S	9.01	62.95	8.93	1920	1728			
6-N	9.50	63.63	9.24	1912	1711			
			9.05					
7-S	9.94	74.99	10.65	3146	2831			
8-N	10.32	75.56	11.25	3138	2822			
9-S	10.67	75.03	10.37	3148	2832			
			10.88					
10-N	11.16	45.85	6.99	741	667			
11-S	11.68	45.42	5.77	723	651			
12-N	12.20	45.99	7.26	716	644			
			6.45					
U.S.S. PATOKA FITTED WITH OERTZ RUDDER								
1-S	10.21	50.66	7.96	920	828			
2-N	10.72	49.84	7.76	916	824			
3-S	11.25	49.72	7.66	842	758			
			7.76					
4-N	12.07	63.52	9.91	1694	1525			
5-S	12.44	62.93	9.88	1739	1565			
6-N	12.81	62.99	9.88	1640	1476			
			9.89					
7-S	14.04	74.56	11.86	2936	2642			
8-N	14.45	75.35	11.99	3026	2723			
9-S	14.87	73.77	11.71	2930	2637			
			11.89					
10-N	15.40	38.27	5.99	439	395			
11-S	15.96	39.37	6.17	492	443			
12-N	16.63	39.14	5.46	442	398			
			5.95					

FORMULAE & COLUMN DESIGNATIONS METHOD I

COL. 9- THRUST CORRECTED FOR SHAFT DRAG

COL. 10- $C_T^* = \frac{T}{\rho P^2 D^2 n^2} = \text{---} \frac{T}{N^2}$

COL. 11- $C_Q^* = \frac{SHP \times 33000 \times 3600}{\rho N^3 \times 2\pi \times P^3 \times D^2} = 10.32 \frac{SHP}{N^3}$

COL. 12- $S = m\,C_Q - a = 10.14 C_Q - .36$

COL. 13- $V_a = \frac{PN(1-S)}{101.33} = .1776\,N(1-S)$

COL. 14- WAKE, $\omega = \frac{V - V_a}{V}$

COL. 15- SPEED THRU WATER, $V_1' = \frac{V_a}{1-\omega}$

COL. 16- CURRENT, $C = V - V_1'$

COL. 17- K, FROM EXPERIMENT DATA

COL. 18- INCREMENT OF H.P. FROM WIND, ΔSHP

COL. 19- FROM $\frac{dEHP}{dV}$ CURVE

COL. 20- CORRECTED ΔV = COL. 18 ÷ COL. 19

COL. 21- CORR. SPEED OVER GR'D, $V'' = V + \Delta V$

COL. 22- RPM/KNT, COL. 3 ÷ COL. 21, = N AVE. ÷ V''

COL. 23- CORR. SP'D THRU WATER, V''' = COL. 3/COL. 22

COL. 24- CURRENT, $C = V'' - V'''$

COL. 25- ACT. SP'D THRU WATER, $V_2' = V''' - \Delta V$

COL. 26- MEAN SP'D THRU WATER, $V' = (V_1' + V_2') \div 2$

COL. 27- SPEED THRU WATER, BASIS NO WIND

COL. 28- TORQUE COEFF., BASIS NO WIND

COL. 29- SHP, BASIS NO WIND

COL. 30- THRUST COEFF., BASIS NO WIND

COL. 31- THRUST H.P., BASIS NO WIND

COL. 32- THRUST DEDUCTION

COL. 33- EHP, BASIS NO WIND

*N = REV. PER MIN., T = THRUST (LBS.), n = REV./SEC., P = PITCH, D = DIAM. (FT.), ρ = SPECIFIC GRAVITY OF S.W.

GENERAL DATA U.S.S. PATOKA

DATE OF TRIALS 25, 26 AUG., 1929
LOCATION OF TRIALS ROCKLAND, ME.
LENGTH, FT. 458
BEAM, FT. 60

TRIAL DATA U.S.S. PATOKA

	SHIP	MODEL
DISPLACEMENT	16,803.4	16,900
DRAFT	26'-3"	26'.08
TRIM	1'-2" × STERN	E.K.
APPENDAGES	BILGE KEELS & OERTZ RUDDER	
MODEL NO.		2285
TEST NO.		5

REDUCTION OF TRIAL DATA U.S.S. SALINAS & U.S.S. PATOKA

SHEET 2

METHOD I

1	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	Corr. Thrust	C_T	C_Q	S	V_a	ω	V_1'	C	K	ΔSHP	[illegible]	ΔV	V''	[illegible]	V'''	C	V_2'	V'	V_o	C_{Q_o}	SHP_o	C_{T_o}	THP_o	t	EHP_o
	TORQUE METHOD								POWER METHOD										CORRECTED RESULTS						
U.S.S. SALINAS FITTED WITH PLATE RUDDER																									
1-S			.0722	.372	6.00	.193	7.44	.58-S																	
2-N			.0688	.338	6.30	.193	7.81	.47-S											7.81		1026				
3-S			.0724	.374	5.85	.193	7.25	.32-S																	
					6.11																				
4-N			.0678	.327	7.56	.190	9.34	.25-S											9.34		1666				
5-S			.0714	.364	7.12	.190	8.79	.14-S																	
6-N			.0686	.335	7.52	.190	9.28	.04-S											9.28		1711				
					7.33																				
7-S			.0693	.342	8.77	.179	10.69	.04-N																	
8-N			.0674	.323	9.08	.179	11.06	.19-N											11.06		2822				
9-S			.0692	.342	8.78	.179	10.70	.33-N																	
					8.93																				
10-N			.0748	.298	5.80	.166	6.95	.04-N																	
11-S			.0716	.366	5.12	.166	6.14	.37-N																	
12-N			.0682	.331	5.46	.166	6.54	.72-N											6.54		644				
					5.38																				
U.S.S. PATOKA FITTED WITH OERTZ RUDDER																									
1-S			.0657	.306	6.24	.217	7.97	.01-N											7.97		828				
2-N			.0687	.336	5.88	.217	7.51	.25-N																	
3-S			.0637	.286	6.31	.217	8.06	.40-N											8.06		758				
					6.08																				
4-N			.0614	.262	8.32	.181	10.16	.25-S											10.16		1525				
5-S			.0647	.296	7.86	.181	9.60	.28-S																	
6-N			.0610	.258	8.30	.181	10.14	.26-S											10.14		1476				
					8.10																				
7-S			.0660	.309	9.16	.231	11.91	.05-N																	
8-N			.06565	.305	9.30	.231	12.10	.11-S											12.10		2723				
9-S			.0678	.327	8.82	.231	11.47	.27-S																	
					9.15																				
10-N			.0726	.376	4.22	.277	5.84	.16-N																	
11-S			.0748	.398	4.21	.277	5.82	.32-S																	
12-N			.0684	.348	4.54	.277	6.28	.62-S											6.28		398				
					4.30																				

SHEET 1

TRIAL ANALYSIS OF U.S.S. RAMAPO

GENERAL DATA PLATE RUDDER

DATE OF TRIALS: 12 FEB., 1931
LOCATION OF TRIALS: WEST COAST
DATE OF LAST DOCKING:
DAYS OUT DOCK:
LOCATION OF SHIP:
LENGTH: 458
BEAM: 60

TRIAL DATA PLATE RUDDER

ITEM	SHIP	MODEL
DISPLACEMENT	16,765	16,900
DRAFT	26'-2"	26'.08
TRIM	11" STERN	E.K.
TEMP. OF WATER		
SP. G. OF WATER		
APPENDAGES	BILGE KEEL & PLATE RUDDER	
MODEL NO.		2285
TEST NO.		8

PROPELLER DATA

DIAMETER: 17.5 FT.
PITCH, DESIGNED: 18.0 FT.
PITCH, MEASURED:
NO. OF BLADES: 4
M.W.R.: .214
B.T.F.: .0423
P.A./D.A.: .356
DIR. OF ROTATION: R.H.
TIPS BELOW SURFACE: 7.39 FT.
NO. OF PROPELLERS: 1
MODEL NOS.: 914

FORMULAE & COLUMN DESIGNATIONS METHOD I

COL. 9 - THRUST CORRECTED FOR SHAFT DRAG
COL. 10 - $C_T^* = \frac{T}{\rho P^2 D^2 n^2} = \_\_\_ \frac{T}{N^2}$
COL. 11 - $C_Q^* = \frac{SHP \times 33000 \times 3600}{\rho N^3 \times 2\pi \times P^3 \times D^2} = 10.32 \frac{SHP}{N^3}$
COL. 12 - $S = m\, C_Q - a = 10.14\, C_Q - .36$
COL. 13 - $V_a = \frac{PN(1-S)}{101.33} = .1776\, N(1-S)$
COL. 14 - WAKE, $\omega = \frac{V - V_a}{V}$
COL. 15 - SPEED THRU WATER, $V_1' = \frac{V_a}{1-\omega}$
COL. 16 - CURRENT, $C = V - V_1'$
COL. 17 - K, FROM EXPERIMENT DATA
COL. 18 - INCREMENT OF H.P. FROM WIND, ΔSHP
COL. 19 - FROM $\frac{dEHP}{dV}$ CURVE
COL. 20 - CORRECTED ΔV = COL. 18 ÷ COL. 19
COL. 21 - CORR. SPEED OVER G'RD, $V'' = V + \Delta V$
COL. 22 - RPM/KNT, COL. 3 ÷ COL. 21, = N AVE. ÷ V''
COL. 23 - CORR. SP'D THRU WATER, $V''' = $ COL. 3/COL. 22
COL. 24 - CURRENT, $C = V'' - V'''$
COL. 25 - ACT. SP'D THRU WATER, $V_2' = V''' - \Delta V$
COL. 26 - MEAN SP'D THRU WATER, $V' = (V_1' + V_2') \div 2$
COL. 27 - SPEED THRU WATER, BASIS NO WIND
COL. 28 - TORQUE COEFF., BASIS NO WIND
COL. 29 - SHP, BASIS NO WIND
COL. 30 - THRUST COEFF., BASIS NO WIND
COL. 31 - THRUST H.P., BASIS NO WIND
COL. 32 - THRUST DEDUCTION
COL. 33 - EHP, BASIS NO WIND

* N = REV. PER MIN., T = THRUST (LBS.), n = REV./SEC., P = PITCH, D = DIAM. (FT.), ρ = SPECIFIC GRAVITY OF S.W.

OBSERVED DATA

1 RUN NO. & DIR.	2 TIME TO MIDDLE RUN	3 R.P.M. N	4 OBS. SPEED V	5 I.H.P. TOTAL	6 .9 I.H.P. = S.H.P.	7 THRUST T	8 APPAR. WIND VEL. Wa	8 APPAR. WIND DIR.
U.S.S. RAMAPO WITH PLATE RUDDER								
2-S	8.32	51.73	8.03	989	890			
3-N	9.02	50.90	7.94	866	779			
4-S	9.80	51.19	7.94	854	768			
			7.96					
5-N	10.41	57.36	9.01	1305	1174			
6-S	11.03	58.63	9.10	1407	1266			
7-N	11.60	57.07	8.83	1379	1241			
			9.01					
8-S	12.21	64.98	10.15	2117	1903			
9-N	12.75	66.15	10.24	2018	1815			
10-S	13.31	65.74	9.92	2107	1895			
			10.14					
11-N	14.05	76.58	11.90	3362	3028			
12-S	14.52	75.90	11.40	3300	2970			
13-N	15.00	76.12	11.76	3231	2909			
14-S	15.56	75.76	11.50	3237	29[illegible]1			
15-N	16.09	76.29	11.84	3288	2957			
			11.63					
U.S.S. RAMAPO WITH FAIR FORM RUDDER								
1-N		52.17	7.70	1030	927			
2 S		51.57	8.14	1033	930			
3-N		51.99	7.77	986	887			
			7.94					
4-S		59.91	9.59	1603	1442			
5-N		59.46	8.59	1550	1394			
6-S		59.93	9.75	1593	1432			
			9.13					
7-N		66.30	9.63	2144	1930			
8-S		66.33	10.83	2112	1900			
9-N		65.92	9.36	2092	1884			
			10.16					
10-S		76.26	12.50	3207	2885			
11-N		75.65	10.71	3142	2828			
12-S		76.04	12.41	3378	3038			
13-N		75.89	10.79	3129	2815			
14-S		75.99	12.36	3129	2815			
			11.61					

GENERAL DATA FAIR FORM RUDDER

DATE OF TRIALS: 11 JUNE, 1931
LOCATION OF TRIALS: WEST COAST
LENGTH: 458
BEAM: 60

TRIAL DATA FAIR FORM RUDDER

	SHIP	MODEL
DISPLACEMENT	16,719.2	16,900
DRAFT	26'-1"	26'-0"
TRIM	8" STERN	E.K.
APPENDAGES	BILGE KEELS & FAIR FORM RUDDER	
MODEL NO.		2285
TEST NO.		6

REDUCTION OF TRIAL DATA U.S.S. RAMAPO

SHEET 2

METHOD I

				TORQUE METHOD					POWER METHOD										CORRECTED RESULTS						
1	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	CORR. THRUST	C_T	C_Q	S	V_a	ω	V_1'	C	K	ΔSHP	ΔSHP/ΔV	ΔV	V''	N ок/V''	V'''	C	V_2'	V'	V_o	C_{Qo}	SHP_o	C_{To}	THP_o	t	EHP_o
U.S.S. RAMAPO WITH PLATE RUDDER																									
2-S			.0663	.312	6.32	.162	7.54	.49-S																	
3-N			.0610	.258	6.71	.162	8.01	.07-S																	
4-S			.0591	.239	6.92	.162	8.26	.32-N											8.26		768				
					6.67																				
5-N			.0642	.290	7.23	.206	9.11	.10-S											9.11		1174				
6-S			.0648	.297	7.32	.206	9.22	.12-S											9.22		1266				
7-N			.0689	.338	6.71	.206	8.45	.38-N																	
					7.15																				
8-S			.0714	.364	7.34	.223	9.45	.70-S																	
9-N			.0647	.296	8.27	.223	10.65	.41-S											10.65		1815				
10-S			.0688	.338	7.73	.223	9.95	.03-N																	
					7.90																				
11-N			.0695	.344	8.92	.231	11.60	.30-N											11.60		3028				
12-S			.0700	.350	8.76	.231	11.40	0																	
13-N			.0680	.329	9.08	.231	11.81	.05-S											11.81		2909				
14-S			.0691	.340	8.88	.231	11.55	.05-N																	
15-N			.0687	.336	9.00	.231	11.70	.14-N											11.70		2957				
					8.94																				
U.S.S. RAMAPO WITH FAIR FORM RUDDER																									
1-N			.0673	.322	6.28	.223	8.08	.38-S											8.08		927				
2-S			.0699	.348	5.97	.223	7.69	.45-S																	
3-N			.0651	.300	6.46	.223	8.32	.55-S											8.32		887				
					6.17																				
4-S			.0691	.340	7.02	.227	9.08	.51-S																	
5-N			.0683	.332	7.06	.227	9.13	.54-S											9.13		1394				
6-S			.0685	.335	7.08	.227	9.16	.59-S																	
					7.06																				
7-N			.0683	.332	7.87	.211	9.97	.34-S																	
8-S			.0670	.309	8.14	.211	10.31	.52-S											10.31		1900				
9-N			.0678	.328	7.87	.211	9.97	.61-S																	
					8.01																				
10-S			.0670	.320	9.21	.223	11.86	.64-S																	
11-N			.0674	.323	9.10	.223	11.71	1.00-S																	
12-S			.0713	.363	8.60	.223	11.07	1.34-S																	
13-N			.0664	.313	9.26	.223	11.91	1.11-S											11.91		2815				
14-S			.0662	.311	9.30	.223	11.96	.40-S											11.96		2815				
					9.00																				

SHEET 1

TRIAL ANALYSIS OF U.S.S. SAPELO

GENERAL DATA PLATE RUDDER

DATE OF TRIALS, 16 & 17 DEC., 1931
LOCATION OF TRIALS, ROCKLAND, ME.
DATE OF LAST DOCKING,
DAYS OUT DOCK,
LOCATION OF SHIP,
LENGTH, FT. 458
BEAM, FT. 60

TRIAL DATA PLATE RUDDER

ITEM	SHIP	MODEL
DISPLACEMENT,	16 DEC. 17 DEC. 16,715 - 16,797	16,900
DRAFT,	26'-1" - 26'-2"	26'.08
TRIM,	10" STERN - 10" STERN	E.K.
TEMP. OF WATER,		
SP. G. OF WATER,	1.0260 - 1.0254	
APPENDAGES,	BILGE KEELS & PLATE RUDDER	
MODEL NO.,		2285
TEST NO.,		8

PROPELLER DATA

DIAMETER, 17.5 FT.
PITCH, DESIGNED, 18.0 FT.
PITCH, MEASURED,
NO. OF BLADES, 4
M.W.R., .214
B.T.F., .0423
P.A./D.A., .356
DIR. OF ROTATION, R.H.
TIPS BELOW SURFACE, 7.39 FT.
NO. OF PROPELLERS, 1
MODEL NOS., 914

OBSERVED DATA - PLATE RUDDER

1	2	3	4	5	6	7	8	
RUN NO. & DIR.	TIME TO MIDDLE RUN	R.P.M. N	OBS. SPEED V	I.H.P. TOTAL	.9 I.H.P. = S.H.P.	THRUST T	APPAR. WIND VEL. Wo	DIR.
1-S	7.17	56.33	8.79	1309	1178		10.5	F-5-S
2-N	7.71	56.41	7.74	1240	1116		1.3	A-10-P
3-S	8.24	56.19	8.34	1275	1148		15.7	F-10-S
		56.34	8.15					
4-N	8.86	62.00	8.93	1685	1507		6.0	A-10-P
5-S	9.51	62.19	9.54	1679	1512		10.2	F-5-P
6-N	10.15	62.08	8.83	1622	1460		14.7	A-25-S
		62.12	9.21					
7-S	10.77	67.84	10.24	2224	2002		14.1	F-40-S
8-N	11.41	68.43	10.05	2237	2013		5.3	A-80-P
9-S	12.04	67.63	8.99	2347	2112		38.7	F-40-S
		68.08	9.83					
10-N	12.75	49.85	7.87	903	813		27.8	A-80-P
11-S	13.59	49.72	6.20	981	883		33.2	F-40-S
		49.79	7.04					
1-S	6.81	49.98	7.77	860	774		12.7	F-45-S
2-N	7.60	50.01	7.04	908	817		9.7	F-80-P
3-S	9.15	50.33	7.60	929	837		12.6	F-45-S
		50.08	7.36					
4-N	9.80	55.82	8.24	1247	1122		3.0	F-50-P
5-S	10.19	56.05	8.29	1293	1164		21.4	F-40-S
6-N	11.00	56.14	8.41	1268	1141		15.2	A-70-P
		56.02	8.31					
7-S	11.60	68.24	9.70	2317	2085		23.2	F-40-S
8-N	12.08	68.55	10.35	2322	2090		13.6	A-70-P
9-S	12.62	68.26	9.40	2372	2135		24.4	F-20-S
		68.40	9.95					
10-N	13.19	62.21	9.70	1741	1567		10.2	A-70-P
11-S	13.81	62.03	8.25	1824	1642		29.3	F-30-S
12-N	14.39	62.31	9.74	1767	1590		16.7	A-20-P
		62.15	9.24					

OBSERVED DATA - OERTZ RUDDER

1	2	3	4	5	6	7	8	
1-S	7.16	50.01	7.05	937	834		29.0	F-50-S
2-N	7.89	50.27	7.83	875	787		18.1	A-85-P
3-S	9.48	50.29	7.42	950	855		29.9	F-35-S
		50.21	7.53					
4-N	10.13	55.96	8.39	1148	1033		20.5	A-80-P
5-S	10.70	56.52	8.36	1343	1209		30.5	F-45-S
6-N	11.34	56.24	8.26	1195	1076		23.0	A-80-P
		56.31	8.34					
7-S	11.89	62.11	9.36	1746	1571		29.0	F-50-S
8-N	12.53	62.29	9.08	1652	1487		15.5	A-70-P
9-S	13.11	62.48	9.90	1733	1560		19.3	F-50-S
		62.29	9.36					
10-N	13.65	68.41	10.00	2181	1963		12.8	F-60-P
11-S	14.15	68.45	10.70	2165	1949		16.7	F-50-S
12-N	14.68	68.94	10.14	2185	1967		10.8	F-35-P
		68.56	10.39					

FORMULAE & COLUMN DESIGNATIONS
METHOD I

COL. 9 - THRUST CORRECTED FOR SHAFT DRAG

COL. 10 - $C_T^* = \frac{T}{\rho P^2 D^2 n^2} = \text{---} \frac{T}{N^2}$

COL. 11 - $C_Q^* = \frac{SHP \times 33000 \times 3600}{\rho N^3 \times 2\pi \times P^3 \times D^2} = \underline{10.32} \frac{SHP}{N^3}$

COL. 12 - $S = m\,C_Q - a = 10.14\,C_Q - .36$

COL. 13 - $V_a = \frac{PN(1-S)}{101.33} = \underline{.1776}\,N(1-S)$

COL. 14 - WAKE, $\omega = \frac{V - V_a}{V}$

COL. 15 - SPEED THRU WATER, $V_1' = \frac{V_a}{1-\omega}$

COL. 16 - CURRENT, $C = V - V_1'$

COL. 17 - K, FROM EXPERIMENT DATA

COL. 18 - INCREMENT OF H.P. FROM WIND, ΔSHP

COL. 19 - FROM $\frac{dEHP}{dV}$ CURVE

COL. 20 - CORRECTED ΔV = COL. 18 ÷ COL. 19

COL. 21 - CORR. SPEED OVER G'R'D, $V'' = V + \Delta V$

COL. 22 - RPM/KNT, COL. 3 ÷ COL. 21, = N AVE. ÷ V''

COL. 23 - CORR. SP'D THRU WATER, V''' = COL. 3/COL. 22

COL. 24 - CURRENT, $C = V'' - V'''$

COL. 25 - ACT. SP'D THRU WATER, $V_2' = V''' - \Delta V$

COL. 26 - MEAN SP'D THRU WATER, $V' = (V_1' + V_2') \div 2$

COL. 27 - SPEED THRU WATER, BASIS NO WIND

COL. 28 - TORQUE COEFF., BASIS NO WIND

COL. 29 - SHP, BASIS NO WIND

COL. 30 - THRUST COEFF., BASIS NO WIND

COL. 31 - THRUST H.P., BASIS NO WIND

COL. 32 - THRUST DEDUCTION

COL. 33 - EHP, BASIS NO WIND

* N = REV. PER MIN., T = THRUST (LBS.), n = REV./SEC., P = PITCH, D = DIAM. (FT.), ρ = SPECIFIC GRAVITY OF S.W.

GENERAL DATA - OERTZ RUDDER

DATE OF TRIALS, 20 JAN., 1932
LOCATION OF TRIALS, ROCKLAND, ME.
LENGTH, FT. 458
BEAM, FT. 60

REDUCTION OF TRIAL DATA U.S.S. SAPELO

SHEET 2

METHOD I

				TORQUE METHOD					POWER METHOD										CORRECTED RESULTS						
1	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	CORR. THRUST	C_T	C_Q	S	V_a	ω	V_1'	C	K	ΔSHP	ΔSHP/ΔV	ΔV	V''	MAX V''	V'''	C	V_2'	V'	V_o	C_{Qo}	SHP_o	C_{To}	THP_o	t	EHP_o
1-S			.0680	.329	6.85	.145	8.02	.77-S	1.00	23.9	216	.111	8.90		8.23	.67-S	8.12	8.07	8.18		1110				
2-N			.0641	.290	7.12	.145	8.33	.59-S	-1.01	-.38			7.74		8.25	.51-S	8.25	8.23	8.29		1116				
3-S			.0668	.318	6.81	.145	7.97	.37-S	1.01	53.6	220	.244	8.54		8.21	.37-S	7.97	7.97	8.21		1102				
					6.97								8.24	6.84						.0641					
4-N			.06565	.305	7.65	.149	8.98	.05-S	-1.01	-8.8	283	-.031	8.90		9.18	.28-S	9.21	9.10	9.07		1484				
5-S			.0649	.298	7.86	.149	9.24	.30-S	1.00	25.9	313	.083	9.62		9.21	.41-S	9.13	9.19	9.27		1505				
6-N			.0629	.277	7.97	.149	9.36	.53-S	-1.045	-57.0	325	-.175	8.65		9.20	.56-S	9.38	9.37	9.19		1500				
					7.84								9.20	6.75						.0646					
7-S			.0661	.310	8.32	.1536	9.83	.41-S	.94	49.6	359	.138	10.38		10.10	.28-S	9.96	9.90	10.04		1952				
8-N			.0645	.294	8.58	.1536	10.14	.09-S	-.02				10.05		10.19	.14-S	10.19	10.17	10.17		2013				
9-S			.07035	.353	7.78	.1536	9.20	.21-N	.94	35.0	343	1.020	10.01		10.06	.05-N	9.04	9.12	10.14		1948				
					8.32								10.12	6.73						.0645					
10-N			.06755	.325	5.98	.1916	7.40	.47-N	-.02				7.87		7.64	.23-N	7.64	7.62	7.62		813				
11-S			.0740	.390	5.39	.1916	6.67	.47-N	.94	186.5	158	1.180	7.38		7.63	.25-N	6.45	6.57	7.75		806				
					5.69								7.63	6.52						.06755					
1-S			.0639	.288	6.32	.1645	7.56	.21-S	.85	28.0	183	.153	7.92		7.44	.48-S	7.29	7.43	7.58		826				
2-N			.06735	.323	6.02	.1645	7.20	.16-S	.02				7.04		7.44	.40-S	7.44	7.32	7.32		817				
3-S			.06535	.304	6.22	.1645	7.44	.16-S	.85	27.1	176	.153	7.75		7.49	.26-S	7.34	7.39	7.54		859				
					6.15								7.44	6.72						.06735					
4-N			.0667	.316	6.78	.189	8.36	.12-S	.72	1.46	235	.005	8.25		8.47	.22-S	8.46	8.41	8.42		1120				
5-S			.06805	.330	6.67	.189	8.22	.07-S	.94	93.7	245	.334	8.68		8.50	.18-S	8.11	8.17	8.56		1155				
6-N			.0664	.313	6.85	.189	8.45	.04-S	-.13	-6.85	246	-.026	8.38		8.52	.14-S	8.55	8.50	8.47		1145				
					6.74								8.50	6.59						.06655					
7-S			.06855	.335	8.06	.180	9.84	.14-N	.94	133.8	367	.364	10.06		10.11	.05-N	9.75	9.80	10.16		2040				
8-N			.0670	.319	8.29	.180	10.11	.24-N	-.13	-6.56	375	-.017	10.33		10.16	.17-N	10.18	10.15	10.13		2090				
9-S			.0692	.341	7.99	.180	9.74	.34-N	1.035	162.0	365	.444	9.84		10.11	.27-N	9.67	9.71	10.15		2070				
					8.16								10.14	6.75						.0671					
10-N			.0670	.319	7.53	.212	9.56	.14-N	-.13	-3.5	332	-.01	9.69		9.30	.39-N	9.31	9.44	9.43		1591				
11-S			.0708	.358	7.08	.212	8.98	.73-N	1.035	215.5	315	.684	8.93		9.28	.35-N	8.60	8.79	9.47		1576				
12-N			.06785	.328	7.44	.212	9.44	.30-N	-1.035	-73.6	332	-.222	9.52		9.31	.21-N	9.53	9.49	9.27		1592				
					7.28								9.29	6.69						.0680					

REDUCTION OF TRIAL DATA - OERTZ RUDDER

1	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1-S			.0687	.336	5.90	.186	7.25	.20-N	.72	118.4	180	.657	7.71		7.93	.22-N	7.27	7.26	7.92		774				
2-N			.0638	.286	6.38	.186	7.84	.01-S	-.005				7.83		7.97	.14-S	7.97	7.91	7.91		787				
3-S			.0694	.343	5.87	.186	7.21	.21-S	1.00	174.0	190	.916	8.34		7.98	.36-S	7.06	7.14	8.06		785				
					6.13								7.93	6.31						.0638					
4-N			.0609	.257	7.38	.163	8.82	.43-S	-.02	-2.0	275	-.007	8.38		8.64	.26-S	8.65	8.74	8.73		1049				
5-S			.06905	.340	6.63	.163	7.93	.43-S	.84	167.2	237	.706	9.07		8.72	.35-S	8.01	7.97	8.68		1082				
6-N			.0624	.272	7.28	.163	8.70	.44-S	-.02	-2.59	265	-.009	8.25		8.68	.43-S	8.69	8.70	8.69		1066				
					6.98								8.69	6.48						.0618					
7-S			.0677	.326	7.44	.173	9.00	.36-S	.72	147.4	307	.480	9.84		9.49	.35-S	9.01	9.01	9.49		1477				
8-N			.0635	.284	7.92	.173	9.59	.51-S	-.13	-8.08	335	-.024	9.05		9.51	.46-S	9.53	9.56	9.54		1492				
9-S			.0660	.309	7.67	.173	9.28	.62-S	.72	66.4	320	.208	10.11		9.54	.57-S	9.33	9.31	9.52		1505				
					7.74								9.51	6.55						.0637					
10-N			.06335	.282	8.61	.181	10.51	.51-S	.41	19.06	405	.047	10.05		10.80	.75-S	10.75	10.63	10.68		1932				
11-S			.0627	.275	8.82	.181	10.76	.06-S	.72	58.4	428	.137	10.84		10.80	.04-S	10.66	10.71	10.85		1936				
12-N			.06195	.268	8.95	.181	10.93	.79-S	1.00	34.4	440	.078	10.22		10.87	.65-S	10.79	10.86	10.94		1980				
					8.80								10.49	6.34						.0623					

TRIAL DATA - OERTZ RUDDER

	SHIP	MODEL
DISPLACEMENT,	BEGIN. 16,784 - END. 16,745	16,900
DRAFT,	26'-2"	26.08
TRIM,	4" × STERN	E.K.
SP. G. OF WATER,	1.0252	
APPENDAGES,	BILGE KEELS & OERTZ RUDDER	
MODEL NO.		2285
TEST NO.		5

SHEET 1

TRIAL ANALYSIS OF U.S.S. SALINAS

GENERAL DATA - PLATE RUDDER

DATE OF TRIALS, 5 AUG., 1932
LOCATION OF TRIALS, ROCKLAND, ME.
DATE OF LAST DOCKING,
DAYS OUT DOCK,
LOCATION OF SHIP,
LENGTH, 458
BEAM, 60

TRIAL DATA - PLATE RUDDER

ITEM	SHIP	MODEL
DISPLACEMENT,	BEG. 16,730; END 16,661	16,900
DRAFT,	26'-1½"	26.08'
TRIM,	7" x STERN	E.K.
TEMP. OF WATER,	58°	
SP. G. OF WATER,	1.024	
APPENDAGES,	BILGE KEELS & PLATE RUDDER	
MODEL NO.,		2285
TEST NO.,		8

PROPELLER DATA

DIAMETER, 17.5 FT.
PITCH, DESIGNED, 18.0 FT.
PITCH, MEASURED,
NO. OF BLADES, 4
M.W.R., .214
B.T.F., .0423
P.A./D.A., .356
DIR. OF ROTATION, R.H.
TIPS BELOW SURFACE, 7.39 FT.
NO. OF PROPELLERS, 1
MODEL NOS., 914

FORMULAE & COLUMN DESIGNATIONS
METHOD I

COL. 9- THRUST CORRECTED FOR SHAFT DRAG
COL. 10- $C_T^* = \frac{T}{\rho P^2 D^2 n^2} = \_\_\_ \frac{T}{N^2}$
COL. 11- $C_Q^* = \frac{SHP \times 33000 \times 3600}{\rho N^3 \times 2\pi \times P^3 \times D^2} = \underline{10.32} \frac{SHP}{N^3}$
COL. 12- $S = m\,C_Q - a = 10.14\,C_Q - .36$
COL. 13- $V_a = \frac{PN(1-S)}{101.33} = \underline{.1776}\,N(1-S)$
COL. 14- WAKE, $\omega = \frac{V - V_a}{V}$
COL. 15- SPEED THRU WATER, $V_1' = \frac{V_a}{1-\omega}$
COL. 16- CURRENT, $C = V - V_1'$
COL. 17- K, FROM EXPERIMENT DATA
COL. 18- INCREMENT OF H.P. FROM WIND, ΔSHP
COL. 19- FROM $\frac{dEHP}{dV}$ CURVE
COL. 20- CORRECTED ΔV = COL. 18 ÷ COL. 19
COL. 21- CORR. SPEED OVER G'RD, $V'' = V + \Delta V$
COL. 22- RPM/KNT, COL. 3 ÷ COL. 21, = N AVE. ÷ V''
COL. 23- CORR. SP'D THRU WATER, V''' = COL. 3/COL. 22
COL. 24- CURRENT, $C = V'' - V'''$
COL. 25- ACT. SP'D THRU WATER, $V_2' = V''' - \Delta V$
COL. 26- MEAN SP'D THRU WATER, $V' = (V_1' + V_2') \div 2$
COL. 27- SPEED THRU WATER, BASIS NO WIND
COL. 28- TORQUE COEFF., BASIS NO WIND
COL. 29- SHP, BASIS NO WIND
COL. 30- THRUST COEFF., BASIS NO WIND
COL. 31- THRUST H.P., BASIS NO WIND
COL. 32- THRUST DEDUCTION
COL. 33- EHP, BASIS NO WIND

* N = REV. PER MIN., T = THRUST (LBS.), n = REV./SEC., P = PITCH, D = DIAM. (FT.), ρ = SPECIFIC GRAVITY OF S.W.

OBSERVED DATA - PLATE RUDDER

1 RUN NO. & DIR.	2 TIME TO MIDDLE RUN	3 R.P.M. N	4 OBS. SPEED V	5 I.H.P. TOTAL	6 .9 I.H.P. = S.H.P.	7 THRUST T	8 APPAR. WIND VEL. Wo	8 APPAR. WIND DIR.
2-S	8.51	48.55	7.00	790	711		9.8	F-27-S
3-N	9.65	48.24	7.60	771	694		2.6	F-17-S
4-S	10.85	48.32	6.86	790	711		14.9	F-12-S
		48.34	7.26					
5-N	11.90	54.45	8.55	1115	1004		3.4	A-60-P
6-S	12.91	54.11	7.84	1098	988		16.6	F-20-S
7-N	13.92	54.64	8.25	1103	993		11.0	A-60-P
		54.33	8.11					
8-S	14.78	66.69	10.16	2011	1810		22.6	F-25-S
9-N	15.71	66.89	9.42	2016	1814		11.1	A-77-P
10-S	16.42	66.58	10.55	2011	1810		19.9	F-33-S
		66.76	9.89					
11-N	17.27	60.91	8.48	1522	1370		11.6	A-77-P
12-S	18.19	59.76	9.34	1462	1316		18.6	F-35-S
13-N	19.08	60.52	8.68	1461	1315		10.4	A-84-P
		60.21	8.96					
U.S.S. SALINAS TRIALS FAIR FORM RUDDER — 17-18 AUG., 1932 — ROCKLAND, ME.								
1-S	12.32	47.32	6.91	730	657		21.7	F
2-N	13.43	48.08	7.40	706	635		8.0	A-5-P
3-S	14.51	47.31	7.40	714	643		18.5	F-2P
		47.70	7.28					
4-N	15.51	54.09	8.14	1041	937		1.9	A-20-S
5-S	16.49	53.70	8.41	1052	947		18.2	F-2P
		53.90	8.28					
4-S	12.61	59.98	8.76	1438	1294		22.1	F-27-P
5-N	13.48	60.94	9.54	1482	1334		11.5	A-57-P
6-S	14.36	59.94	9.10	1459	1313		22.9	F-30-P
		60.45	9.24					
7-N	15.19	66.53	10.09	1891	1702		12.1	A-70-P
8-S	15.99	65.44	10.14	1880	1692		24.7	F-35-P
9-N	16.78	66.56	10.17	1923	1730		15.0	A-67-P
		65.99	10.13					
10-S	17.68	53.67	7.96	1067	960		25.5	F-35-P
11-N	18.58	53.76	8.61	1059	953		15.6	A-55-S
		53.72	8.29					
U.S.S. SALINAS TRIALS CONTRA RUDDER — 7-8 SEPT., 1932 — ROCKLAND, ME.								
1-S	9.78	53.68	8.72	1054	949		11.4	A-55-S
2-N	10.76	54.08	8.13	1116	1004		15.0	F-20-P
3-S	11.73	54.47	8.43	1083	975		1.4	A-25-S
		54.08	8.35					
4-N	12.60	60.01	9.37	1499	1349		18.4	F-5-P
5-S	13.46	60.27	9.37	1455	1310		5.0	F-70-S
6-N	14.31	60.07	9.21	1482	1334		14.3	F-3-P
		60.16	9.33					
7-S	15.15	65.81	10.35	1930	1737		3.8	F-70-P
8-N	15.94	65.79	9.96	1946	1751		13.9	F-13-P
9-S	16.73	65.75	10.52	1900	1710		5.4	F-75-S
		65.79	10.20					
1-S	5.96	47.95	8.25	722	650		10.8	A-42-P
2-N	7.12	47.75	6.29	762	686		16.2	F-35-S
3-S	8.23	48.14	8.26	744	670		11.1	A-65-P
		47.90	7.27					

REDUCTION OF TRIAL DATA U.S.S. SALINAS

SHEET 2

METHOD I

			TORQUE METHOD						POWER METHOD										CORRECTED RESULTS						
1	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	CORR. THRUST	C_T	C_Q	S	V_a	ω	V'_1	C	K	ΔSHP	ΔSHP/ΔV	ΔV	V''	PLOT V''	V'''	C	V'_2	V'	V_o	C_{Q_o}	SHP_o	C_{T_o}	THP_o	t	EHP_o
2-S			.0632	.280	6.22	.1446	7.27	.27-N	1.045	19.85	170	.116	7.12		7.40	.28-N	7.28	7.28	7.40		701				
3-N			.06275	.276	6.20	.1446	7.25	.35-N	1.025	1.34			7.60		7.35	.25-N	7.33	7.29	7.29		688				
4-S			.06505	.299	6.02	.1446	7.04	.18-N	1.010	42.80	152	.281	7.14		7.37	.23-N	7.07	7.06	7.34		681				
					6.11								7.37	6.56						.0623					
5-N			.0640	.289	6.87	.147	8.06	.49-N	-.41	-1.03			8.55		8.43	.12-N	8.43	8.25	8.25		970				
6-S			.0643	.291	6.82	.147	8.00	.16-N	1.035	61.30	220	.278	8.12		8.38	.26-S	8.10	8.05	8.33		960				
7-N			.0608	.256	7.22	.147	8.47	.22-S	-.41	-11.40	250	-.045	8.20		8.46	.26-S	8.41	8.43	8.38		1020				
					6.92								8.25	6.46						.06245					
8-S			.0633	.282	8.50	.1335	9.81	.35-S	1.045	141.60	364	.388	10.55		10.04	.51-S	9.65	9.73	10.12		1797				
9-N			.0627	.275	8.62	.1335	9.95	.53-S	-.04	-1.30			9.42		10.06	.54-S	10.06	10.01	10.01		1814				
10-S			.0632	.280	8.52	.1335	9.83	.72-S	1.020	107.1	364	.294	10.84		10.03	.81-S	9.74	9.79	10.08		1795				
					8.57								10.06	6.64						.06265					
11-N			.0625	.272	7.88	.135	9.12	.64-S	-.04				8.48		9.21	.73-S	9.21	9.17	9.17		1355				
12-S			.0636	.285	7.58	.135	8.77	.57-S	1.00	81.9	284	.288	9.63		9.04	.59-S	8.75	8.76	9.05		1280				
13-N			.0612	.259	7.94	.135	9.19	.51-S	-.005				8.68		9.16	.48-S	9.16	9.18	9.18		1328				
					7.75								9.11	6.61						.06185					

DISPLACEMENT—
SHIP, 17 AUG.-16,760.3 TO 16,774.4;
18 AUG.- 16,795
MODEL, 16,900

U.S.S. SALINAS
TRIALS
FAIR FORM RUDDER

DRAFT- SHIP, 17 AUG., 26'-2"; 18 AUG., 26'-2½"
MODEL, 26'-0"
TRIM- SHIP, 17 AUG., 1 FT.×STERN; 18 A., 9"×STERN
MODEL, E.K.

1	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1-S			.06395	.289	5.97	.1386	6.93	.02-N	1.00	87.6	155	.584	7.49		7.43	.06-S	6.85	6.89	7.47		612				
2-N			.0589	.237	6.51	.1386	7.56	.16-S	-1.00	-12.81	185	-.069	7.33		7.55	.22-S	7.62	7.59	7.52		642				
3-S			.0627	.276	6.09	.1386	7.07	.33-S	1.00	63.8	160	.400	7.80		7.43	.37-S	7.03	7.05	7.45		612				
					6.27								7.49	6.37						.0596					
4-N			.06105	.260	7.11	.1556	8.42	.28-S	1.035				8.14		8.31	.17-S	8.31	8.37	8.37		937				
5-S			.06305	.282	6.86	.1556	8.12	.29-S	1.00	71.6	230	.311	8.72		8.24	.48-S	7.93	8.03	8.34		917				
					6.99								8.43	6.51						.0610					
4-S			.0618	.266	7.82	.144	9.14	.38-N	1.045	123.4	315	.392	9.15		9.34	.19-N	8.95	9.05	9.44		1275				
5-N			.0607	.256	8.06	.144	9.42	.12-N	-.50	-16.5	325	-.051	9.49		9.48	.01-N	9.53	9.48	9.43		1338				
6-S			.0629	.278	7.69	.144	8.99	.11-S	1.035	128.5	305	.421	9.52		9.33	.19-S	8.91	8.95	9.37		1274				
					7.91								9.41	6.425						.0609					
7-N			.0596	.244	8.94	.1402	10.40	.31-S	-.13	-15.2	405	-.038	10.05		10.42	.37-S	10.46	10.43	10.39		1720				
8-S			.0622	.271	8.48	.1402	9.87	.27-S	1.00	158.0	370	.427	10.57		10.25	.32-S	9.82	9.85	10.28		1635				
9-N			.0605	.253	8.93	.1402	10.39	.22-S	-.20	-11.7	390	-.030	10.15		10.42	.27-S	10.45	10.42	10.39		1722				
					8.71								10.34	6.38						.0602					
10-S			.0641	.290	6.78	.1834	8.30	.34-N	1.00	142.3	255	.558	8.52		8.31	.21-S	7.75	8.03	8.59		960				
11-N			.0642	.291	6.76	.1834	8.28	.33-N	-.58	-30.8	245	-.126	8.48		8.32	.16-N	8.45	8.37	8.24		952				
					6.77								8.50	6.46						.0640					

DISPLACEMENT—
SHIP, 7 SEP.- 16,866 TO 16,879
8 SEP.- 16,837
MODEL, 16,900

U.S.S. SALINAS
TRIALS
CONTRA RUDDER

DRAFT- SHIP,- 7 SEPT., 26'-4"; 8 SEPT., 26'-3½"
MODEL- 26.'08
TRIM- SHIP,- 7 SEPT., 8"×STERN; 8 SEPT., 7"× STERN
MODEL- E.K.

1	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1-S			.06415	.291	6.74	.186	8.28	.46-S	-.570	-16.2		-.069	8.65		8.38	.27-S	8.45	8.37	8.30		939				
2-N			.0654	.303	6.70	.186	8.23	.10-S	1.035	50.4	235	.214	8.34		8.44	.10-S	8.23	8.23	8.47		973				
3-S			.0621	.270	7.06	.186	8.68	.25-N	1.045				8.43		8.50	.07-N	8.50	8.59	8.59		996				
					6.80								8.44	6.41						.0635					
4-N			.0643	.292	7.55	.174	9.14	.23-N	1.000	85.0	307	.277	9.65		9.42	.23-N	9.15	9.15	9.45		1296				
5-S			.0618	.266	7.82	.174	9.47	.10-N	.130				9.37		9.46	.09-N	9.46	9.47	9.47		1313				
6-N			.0635	.284	7.64	.174	9.25	.04-N	1.000	49.8	310	.161	9.37		9.43	.09-S	9.27	9.26	9.42		1296				
					7.71								9.44	6.37						.0619					
7-S			.0628	.278	8.43	.173	10.20	.15-S	.130				10.35		10.29	.06-S	10.29	10.25	10.25		1727				
8-N			.0634	.283	8.39	.173	10.15	.19-S	1.010	52.1	377	.138	10.10		10.28	.18-S	10.14	10.15	10.29		1725				
9-S			.0621	.270	8.53	.173	10.31	.21-S	.060				10.52		10.27	.25-S	10.27	10.29	10.29		1721				
					8.44								10.27	6.40						.0625					
1-S			.0608	.256	6.34	.157	7.52	.73-S	-.910	-21.8	200	-.109	8.14		7.39	.75-S	7.50	7.51	7.40		644				
2-N			.0650	.299	5.95	.157	7.06	.77-S	1.000	50.1	170	.295	6.59		7.36	.77-S	7.06	7.06	7.36		633				
3-S			.0619	.268	6.26	.157	7.43	.83-S	-.250	-5.96	164	-.036	8.22		7.42	.80-S	7.46	7.45	7.41		656				
					6.13								7.39	6.49						.0603					