SEP 29 1933

Library, L. M. A. L.

TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 471

A COMPLETE TANK TEST OF A MODEL OF A FLYING-BOAT HULL - N.A.C.A. MODEL 16

By James M. Shoemaker
Langley Memorial Aeronautical Laboratory

FILE COPY
To be returned to
the files of the Langley
Memorial Aeronautical
Laboratory.

Washington
September 1933

NASA Technical Library
3 1176 01433 1392

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 471

A COMPLETE TANK TEST OF A MODEL OF A FLYING-BOAT HULL - N.A.C.A. MODEL 16

By James M. Shoemaker

SUMMARY

A model of a 2-step flying-boat hull, of the type generally used in England, was tested according to the complete method described in N.A.C.A. Technical Note No. 464. The lines of this model were taken from offsets given by Mr. William Munro in Flight, May 29, 1931. The data cover the range of loads, speeds, and trim angles that may be of use in applying the hull form to the design of any seaplane. The results are reduced to nondimensional form to aid application to design problems and facilitate comparison with the performance of other hulls.

The water characteristics of Model 16 are compared with those of Model 11-A, which is representative of current American practice. The results show that when the two forms are applied to a given seaplane design under optimum conditions for each, the performance of Model 16 will be somewhat inferior to that of Model 11-A.

INTRODUCTION

The development of flying boats since the World War has been rapid and widespread. Partly because of their military application, exchange of technical information on hull forms has been somewhat restricted. As a result, the designers of the various nations have pursued policies of independent development that have given rise to striking differences in the lines of flying-boat hulls. Although it is probable that the water performance of good examples of the various types will show little difference, direct comparisons are not possible at present because of the scarcity of published test results. Comparison of such results as have been published is unsatisfactory, moreover,

because the tests have usually been made by the hydrovane method. The difficulty of applying such test data to a general study of hull forms, and the advantages of the complete method of testing, are pointed out in reference 1.

As a result of these considerations, the N.A.C.A. has undertaken to test hulls of the various types, so that future development may be concentrated on the forms showing greatest promise. Unfortunately, authentic lines of good hulls are still difficult to obtain, and any attempt to approximate the form of a given hull from such information as is published may result in a model which is not a fair representative of the type. It is to be hoped that hull lines and test data will be exchanged more freely in the future, to the benefit of all concerned.

The lines of Model 16 were faired from offsets given in reference 2. The hull is believed to be representative of current British practice. The tests were made in the N.A.C.A. tank in December 1932, and January 1933.

APPARATUS AND PROCEDURE

Method of Test

The equipment of the N.A.C.A. tank is described in detail in reference 3. The purpose and technic of the complete method used in testing Model 16 are given in reference 1. Briefly, this method consists of determining the resistance, trimming moment, and draft of the model at all combinations of the independent variables - speed, load, and trim angle that lie in the useful range for the model under test. The results can be applied to any seaplane design with assurance that the hull will operate under conditions giving the best performance possible for the particular form chosen.

Description of Model

The lines of Model 16 were obtained by refairing the offsets presented by Mr. William Munro in reference 2. Offsets taken from these refaired lines are given in table I, and a drawing of the principal lines in figure 1. The general form is that in common use in England for large flying-boat hulls. It differs from the form generally used

in this country in that the forebody is relatively shorter, putting the step more nearly under the center of buoyancy; the longer afterbody terminates in a transverse second step rather than in the vertical sternpost or pointed step usual in American designs. The water lines at the bow are also somewhat finer and the forefoot deeper than is usual in American practice.

The model was made of wood, painted and rubbed to give a smooth surface. Its principal dimensions are:

Length, over-all,	100.0	in.
Maximum beam,	15.88	"
Beam at main step,	15.42	"
Depth,	13.32	"
Length of forebody,	37.61	"
Length of afterbody,	39.50	"
Depth of main step,	.85	"
Depth of second step,	1.07	"

The model was made to a tolerance of ±0.02 inch.

RESULTS

Experimental data.- The trimming moment and draft of the model at rest are given in figures 2 and 3 for various loads and trim angles. A positive moment is one that tends to increase the trim angle, that is, raise the bow. These curves may be used to determine the water line at rest for any load and location of the center of gravity. The moment curves are also useful as a measure of the longitudinal stability of the hull at rest.

Table II presents the results of the towing-test measurements on the model. These data can be applied to any size of full-scale hull by the conversion factors implied in Froude's law, as explained in reference 3. The essential data are presented graphically in figures 4 to 8.

These figures are curves of model resistance and trimming moment plotted against speed, with load on the water as a parameter. Each curve sheet gives the characteristics for one trim angle. The center about which the moments are taken is shown on the line drawing (fig. 1). The trim angles are measured between the horizontal and the base line of the model.

Precision.- The precision attained in these tests is approximately as follows:

Load,	±0.3 lb.
Resistance,	± .1 lb.
Trimming moment,	±1.0 lb.-ft.
Trim angle,	± .1°
Speed,	± .1 f.p.s.

Data at best trim angles.- The difficulties caused by the large number of variables, when the data are used for take-off calculations, are pointed out in reference 1. The method outlined in that report for eliminating the trim angle as a variable has been followed here. It consists of cross-fairing the resistance against trim angle to determine the minimum resistance and the best trim angle, i.e., the angle at which the resistance is minimum, for each speed and load. The nondimensional coefficients used in the presentation of the characteristics at the best trim angle are defined as follows:

Load coefficient, $C_\Delta = \frac{\Delta}{w\ b^3}$

Resistance coefficient, $C_R = \frac{R}{w\ b^3}$

Speed coefficient, $C_V = \frac{V}{\sqrt{g\ b}}$

where Δ is the load on the water, lb.

R, resistance of model, lb.

V, speed, f.p.s.

w, weight density of water, lb./cu.ft.

b, beam, ft.

g, acceleration of gravity, ft./sec.^{2}

The curves of C_R at the best trim angle τ_o, plotted against C_V with C_Δ as a parameter, are given in figure 9. The same data are presented in figure 10 as curves of C_R against C_Δ with C_V as a parameter. The first method of plotting the data gives a clearer concept of the behavior of the hull, but the second is somewhat easier to use in the take-off calculation. The best trim angle τ_o, is plotted against C_V with C_Δ as a parameter in figure 11. The dotted line in this figure is the mean value of τ_o to be used in the first approximation of the take-off calculation, as was explained in reference 1.

DISCUSSION

Test results.- The curves of resistance and moment at constant load plotted against speed (figs. 4-8), show the usual trends pointed out in reference 1. The rise in resistance in the high-speed range is rather marked for this model, probably because the large area of the afterbody causes excessive frictional resistance when spray from the main step strikes it. The moments at high speeds and high trim angles, which might be expected to be seriously nose-heavy because of the large second step, are in reality of the same order as those for hulls of the American type. No difficulty in pulling the seaplane up to a reasonable angle for take-off is indicated.

Application of data at best trim angle.- The application of the data for the best trim angles (figs 9-11) to a take-off problem is explained in detail in reference 1. Model 16 may require special treatment at very low speeds because of the rather high value of the best trim angle at speeds below the hump. The positive (tail-heavy) moments which would have to be applied to reach the best angle would not normally be available. This condition is aggravated by the fact that the best angle at the hump is about 7°. The moment here is positive (see fig. 6); hence a

rather large nose-heavy moment must be applied to attain the best angle. The procedure suggested is to locate the center of gravity so that the best trim at the hump can be maintained, and let the angle at low speeds deviate from the best value by the necessary amount. The resulting take-off performance will be only slightly worse than that which would obtain if the best angles were held throughout, because the resistance at low speeds does not change seriously with changes in trim, and the large amount of excess thrust in this region is reduced by a relatively small proportion.

Comparison with Model 11-A.- It has been pointed out that data from complete tests offer a better basis of comparison between hulls of various forms than has been previously available. N.A.C.A. Model 11-A (reference 4) is a good example of current practice in this country; consequently, a comparison between it and Model 16 will give an indication of the relative advantages of the two types. As yet, no method of obtaining a figure of merit for a given hull has been found, because of the great number of variables involved in the application to a seaplane design. Curves of Δ/R against load coefficient at typical values of speed coefficient, however, give a reasonably good comparison. Such curves are shown in figure 12 for Models 16 and 11-A. The value of Δ/R for Model 11-A lies above that for Model 16 at nearly every point, showing that a hull of the form of 11-A when applied to a given seaplane would give a shorter take-off than one using the lines of Model 16. Quantitative comparison of the performance of the two hulls, however, can only be made by carrying through a take-off calculation, because the best size of hull, and consequently the values of C_V and C_Δ at a given speed and load, will be different in the two cases. The curves show that the value of Δ/R for Model 16 is low at high speeds and light loads, but that C_Δ at the hump can be made high without serious reduction in Δ/R. A hull using these lines should therefore be relatively small to give the best compromise. From these considerations the value of C_Δ, based on the load at the hump speed, should probably be about 0.5 for the first trial.

General behavior.- The spray formation of Model 16 is shown in the photographs (fig. 13) for several typical conditions. At low speeds and low angles, with heavy loads, the bow is rather "dirty," as is shown in the bow photograph for $\tau = 3^\circ$ and $V = 5.7$ f.p.s. At planing speeds the spray is light and stays reasonably low, because of the

arched sections of the forebody. Further improvement could no doubt be obtained by means of spray strips. The photographs for $\tau = 5^{\circ}$ and $V = 49.2$ f.p.s. show the blister arising from the main step and striking the afterbody, which causes the pronounced increase of resistance with speed in the high-speed range.

Although no rough-water tests were made to determine the seaworthiness of this model, the photographs of figure 13 indicate that the seaworthiness will probably be satisfactory except at taxying speeds, where the heavy bow wave may result in a wet boat. This condition will be made somewhat worse if the high beam loading and forward location of the center of gravity, which have been mentioned as necessary to best take-off performance, are adopted.

The problem of predicting porpoising characteristics from towing experiments has not been satisfactorily solved. Tests by the complete method, run at fixed-trim angles as they are in the N.A.C.A. tank, do not give any indication of the tendency to porpoise unless it is sufficiently violent to cause the model to oscillate against the restraint of the moment spring. No such tendency was observed for Model 16. A theoretical discussion of the subject of porpoising is given in reference 5. The authors point out that towing tests for the detection of porpoising may be definitely misleading unless the mass, the moment of inertia, and the aerodynamic surfaces are faithfully reproduced in the model. The experimental difficulties of such procedure are great, and obviously are quite insurmountable when the model is intended for general application to any seaplane design. It is hoped that further work will lead to satisfactory criterions defining the conditions under which porpoising may exist so that the measurements may be made on the model to give the designer the data necessary to avoid such conditions.

CONCLUSIONS

The following conclusions may be drawn from a comparison of the results of Model 16 with those of Model 11-A, given in reference 4. However, it should be borne in mind that, although the models are probably representative of the respective types as generally applied, better examples of either type may exist.

When the two forms are applied to a given seaplane design under optimum conditions for each:

1. The hull of the form of Model 16 will have higher resistance throughout the speed range.

2. More difficulty will be found in holding the hull of the form of Model 16 at the best trim angle.

3. The spray thrown while taxying at low speeds will be greater for Model 16.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 10, 1933.

REFERENCES

1. Shoemaker, James M., and Parkinson, John B.: A Complete Tank Test of a Flying-Boat Hull - N.A.C.A. Model No. 11. T.N. No. 464, N.A.C.A., 1933.

2. Munro, William: Hull Design of Flying Boats. Flight, May 29, 1931, pp. 478a-478d.

3. Truscott, Starr: The N.A.C.A. Tank - A High-Speed Towing Basin for Testing Models of Seaplane Floats. T.R. No. 470, N.A.C.A., 1933.

4. Parkinson, John B.: A Complete Tank Test of a Flying-Boat Hull - N.A.C.A. Model No. 11-A. T.N. No. 470, N.A.C.A., 1933.

5. Perring, W. G. A., and Glauert, H.: Stability on the Water of a Seaplane in the Planing Condition. R. & M. No. 1493, British A.R.C., 1933.

TABLE I

OFFSETS OF N.A.C.A. MODEL 16

(Inches)

Station	Distance from bow	Heights above base line							Half-breadths						Deck radius	Sta.
		Keel 0.00	B1 [1]1.65	B2 3.30	B3 4.95	B4 6.60	Chine	Deck	Chine	WL1 [2]1.50	WL2 3.00	WL3 4.50	WL4 6.00	WL5 7.50		
0	0	9.64					9.64	1.11 Rad.	1.11 Rad.							0
1	2.22	2.94	6.49				8.37	12.07	2.93		0.02	0.66	1.39	2.28	2.93	1
2	4.44	1.53	4.05	6.03			7.12	12.67	4.49		.93	2.00	3.27		4.49	2
3	6.66	1.08	2.89	4.50	5.78		6.17	13.02	5.60	0.37	1.76	3.30	5.30		5.60	3
4	10.00	.79	2.10	3.28	4.37	5.10	5.13	13.28	6.68	.88	2.89	5.19			6.47	4
5	13.33	.61	1.67	2.63	3.51	4.22	4.49	13.32	7.31	1.38	3.98				6.67	5
6	16.67	.50	1.42	2.25	3.02	3.69	4.00		7.67	1.80	4.88				6.67	6
7	20.00	.41	1.25	2.02	2.73	3.35	3.68		7.86	2.15	5.64				6.67	7
8	23.33	.33	1.13	1.87	2.53	3.11	3.41		7.93	2.43	6.27				6.67	8
9	26.67	.26	1.04	1.73	2.37	2.91	3.22		7.94	2.71	6.91				6.67	9
10	30.00	.18	.94	1.62	2.24	2.77	3.09		7.89	2.98	7.50				6.67	10
11	33.33	.10	.84	1.51	2.11	2.63	2.93		7.81	3.28					6.67	11
12 for'd	37.61	0	.71	1.38	1.98	2.50	2.77		7.71	3.63					6.67	12 for'd
12 aft	37.61	.85					3.58		7.50						6.67	12 aft
13	42.22	1.26					3.82		7.04						6.67	13
14	46.66	1.69					4.09		6.58						6.50	14
15	50.00	2.06					4.31		6.19						6.19	15
16	53.33	2.44					4.55		5.79						5.79	16
17	56.67	2.83					4.78		5.37						5.37	17
18	60.00	3.23					5.03		4.94						4.94	18
19	63.33	3.60					5.25		4.54						4.54	19
20	66.67	3.95					5.45		4.13						4.13	20
21	70.00	4.27					5.64		3.76						3.76	21
22	73.33	4.56					5.80		3.41						3.41	22
23 for'd	77.11	4.87					5.99		3.07						3.07	23 for'd
23 aft	77.11	5.94					7.06		3.07						3.07	23 aft
24	80.00	6.73					7.76		2.82						2.82	24
25	86.67	8.56					9.36		2.21						2.21	25
26	93.33	10.39					10.91		1.42						1.42	26
27	100.00	12.22					12.38	13.32	.44						.44	27

[1]Distance from center line (plane of symmetry) to buttock (section of hull surface made by plane parallel to plane of symmetry).

[2]Distance from base line to water line (section of hull surface made by a horizontal plane parallel to base line).

TABLE II

Test Data for N.A.C.A. Model No. 16 Flying-Boat Hull

Kinematic viscosity = 0.000015 $\frac{ft.^2}{sec.}$

Water temperature: 48° F.

Tank water density: 63.6 lb. per cu.ft.

Trim angle, τ = 3°				
Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
80	5.7	4.0	-7.7	5.7
	7.2	8.9	13.5	6.1
70	5.7	3.4	-6.0	5.4
	7.2	7.6	12.6	5.65
60	5.7	2.9	-4.3	5.0
	7.2	6.6	14.2	5.25
	24.5	12.5	-	3.0
50	5.7	2.5	-2.4	4.7
	7.2	5.3	13.5	4.85
	24.6	10.0	51.9	2.5
	29.1	10.9	34.3	2.1
40	23.9	8.2	31.7	2.3
	29.2	8.5	24.8	1.9
	34.5	10.4	19.5	1.8
30	23.7	6.3	19.5	2.0
	28.9	7.1	15.1	1.8
	34.2	7.7	13.5	1.5
	38.6	8.2	11.7	1.35
20	24.3	4.7	10.7	1.7
	28.8	4.9	8.1	1.45
	34.2	6.2	7.3	1.35
	38.0	6.6	6.4	1.2
	40.0	7.0	7.3	1.1
	43.4	8.0	6.4	1.05
10	28.8	3.5	3.8	1.3
	34.4	4.5	3.8	1.25
	38.8	5.8	2.9	.9
	43.3	6.9	3.8	.85
	48.5	8.6	3.8	1.0
5	29.3	3.1	1.2	1.0
	34.3	4.2	2.9	.8
	39.7	5.4	2.0	.75
	43.9	5.5	1.1	.75
	48.5	5.8	.3	.7

Trim angle, τ = 5°				
80	6.0	3.6	-34.5	5.5
	7.5	7.6	-11.7	5.7
	9.2	10.4	7.5	5.7
	10.6	11.7	11.1	5.5
	12.0	13.6	18.9	5.5
	13.6	16.2	32.9	5.4
70	6.0	3.3	-29.3	5.2
	7.5	6.9	- 9.3	5.4
	8.7	8.5	5.8	5.4
	10.6	9.7	9.3	5.1
	12.0	11.6	19.6	5.1
	13.6	13.4	32.0	4.9

Trim angle, τ = 5°				
Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
60	6.0	2.9	-24.0	4.8
	7.6	6.2	- 5.7	5.0
	8.9	7.1	3.2	4.9
	10.7	8.2	8.4	4.7
	12.0	9.1	18.2	4.6
	13.6	11.0	30.2	4.5
50	5.9	2.6	-20.6	4.4
	7.6	5.3	- 5.7	4.7
	8.9	5.5	0.5	4.4
	10.8	6.7	8.4	4.2
	12.2	7.7	16.3	4.2
	13.6	8.6	28.5	4.1
	15.8	10.3	53.0	3.8
	16.5	9.8	56.5	3.7
	17.0	9.6	56.5	3.5
	19.0	9.6	48.6	3.2
	21.8	9.3	35.5	2.3
	22.0	9.4	32.9	2.5
	24.4	9.0	27.5	2.2
	24.6	9.1	26.7	2.2
	29.3	9.7	20.6	1.9
40	13.8	6.8	28.5	3.5
	15.6	7.9	41.5	3.3
	15.6	7.8	41.5	3.3
	17.0	7.5	37.3	2.9
	19.2	7.4	27.6	2.6
	20.0	7.3	25.8	2.5
	21.9	6.9	20.5	2.2
	22.0	7.1	22.4	2.1
	24.0	7.6	19.7	2.0
	24.8	7.5	19.5	2.0
	29.6	8.3	15.4	1.7
	35.0	9.0	13.5	1.6
30	22.0	5.7	14.5	2.0
	24.2	6.0	12.6	1.8
	29.5	6.7	10.1	1.6
	34.7	7.5	10.1	1.3
	38.1	8.2	8.3	1.3
20	24.2	4.3	7.4	1.5
	29.4	4.8	5.7	1.3
	33.6	5.6	5.7	1.2
	34.5	6.2	7.4	1.2
	38.5	7.1	4.9	1.1
	43.4	9.2	3.1	1.1
10	29.2	3.6	2.3	1.0
	33.5	4.8	2.3	1.0
	38.5	6.1	2.3	.9
	43.2	8.2	2.3	.8
	49.2	9.5	1.4	.8

TABLE II (Continued)

Test Data for N.A.C.A. Model No. 16 Flying-Boat Hull

Kinematic viscosity = 0.000015 $\frac{ft.^2}{sec.}$

Water temperature: 48° F.

Tank water density: 63.6 lb. per cu.ft.

Trim angle, τ = 5°				
Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
5	29.2	3.1	1.3	0.8
	33.5	4.3	1.4	.7
	35.5	4.3	2.3	.7
	38.6	5.8	1.4	.7
	40.0	6.5	.5	.8
	43.8	7.5	.5	.6
	48.6	8.4	-.6	.7
	49.6	8.4	1.4	.7
Trim angle, τ = 7°				
80	6.2	3.6	-	5.2
	8.0	7.1	-35.9	5.35
	9.5	9.4	-22.1	5.05
	11.0	11.2	-15.0	5.0
	12.0	11.6	- 6.4	5.0
	13.9	13.9	15.5	4.8
70	6.2	3.4	-	4.9
	8.0	6.3	-34.4	4.9
	9.8	8.4	-18.6	4.7
	11.0	9.3	-14.3	4.65
	12.2	10.1	- 2.7	4.55
	13.7	12.1	18.3	4.4
	14.0	12.0	17.4	4.3
	16.0	14.0	48.7	4.0
	17.5	14.3	-	3.95
	19.5	14.3	63.8	3.4
60	6.3	3.2	-51.7	4.5
	7.9	5.6	-30.6	4.55
	9.3	6.8	-21.2	4.45
	11.0	7.8	-12.5	4.3
	12.2	8.7	- 3.7	4.2
	13.6	9.2	.7	4.1
	13.7	10.2	18.3	3.9
	16.0	12.3	41.9	3.6
	17.2	12.3	51.5	3.4
	19.3	11.9	46.3	3.0
	22.6	11.3	33.2	2.4
	24.7	11.5	26.2	2.0
50	6.4	3.0	-40.5	4.0
	7.9	4.7	-26.4	4.1
	9.7	5.6	-17.7	4.0
	10.9	6.5	-12.5	3.9
	12.4	7.5	.7	3.7
	13.7	8.3	1.5	3.6
	14.5	8.8	18.3	3.3
	16.0	9.7	27.8	3.2
	17.6	9.2	34.9	1.9
	19.4	9.6	30.5	2.6
	22.0	9.4	21.7	2.2
	24.7	9.8	19.3	1.9
	28.3	9.5	17.4	1.6
	28.9	10.5	15.5	1.65

Trim angle, τ = 7°				
Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
40	12.7	6.6	0.7	3.15
	14.8	7.3	13.0	2.9
	16.0	7.8	20.9	2.6
	17.7	7.6	20.1	2.3
	19.3	7.7	20.1	2.2
	22.0	7.4	14.7	1.9
	24.8	7.9	14.7	1.7
	28.2	7.9	12.2	1.5
	29.4	8.2	11.3	1.5
	33.9	9.7	10.3	1.25
	34.0	10.5	10.3	1.3
30	21.9	6.0	10.3	1.75
	24.2	6.25	9.4	1.55
	28.0	7.0	7.7	1.4
	29.4	7.6	7.7	1.4
	34.0	8.9	6.0	1.15
	39.0	10.88	4.3	1.0
20	24.6	4.9	5.2	1.3
	29.7	6.4	3.4	1.1
	34.0	8.1	3.4	.9
	39.0	10.0	3.4	.9
	43.0	12.5	- .3	.9
	43.4	12.8	2.5	.9
10	29.1	5.8	1.4	.9
	29.2	5.1	.7	.9
	30.6	6.1	.7	-
	34.0	7.2	1.5	.8
	39.0	10.1	1.5	.8
	42.5	13.0	1.5	.8
5	29.6	5.2	1.5	.75
	30.6	5.8	1.4	.7
	34.1	6.9	1.5	.7
	39.4	10.2	2.5	.6
	43.5	12.8	3.4	.7
Trim angle, τ = 9°				
80	11.0	9.9	-38.6	4.45
	12.4	11.8	-28.8	4.2
70	10.9	8.6	-37.6	3.95
	12.5	10.4	-28.0	3.8
	14.3	13.1	- 2.7	3.65
	16.2	14.2	18.4	3.3
	17.5	15.0	19.3	3.1
	20.1	14.9	27.2	2.7
60	10.9	7.4	-35.9	3.55
	12.3	9.2	-28.0	3.4
	14.2	11.1	- 2.7	3.2
	16.1	12.2	7.9	2.8
	17.1	12.3	10.4	2.7
	19.2	13.1	13.2	2.35
	22.0	13.3	16.6	2.1
	25.0	12.9	19.3	1.8

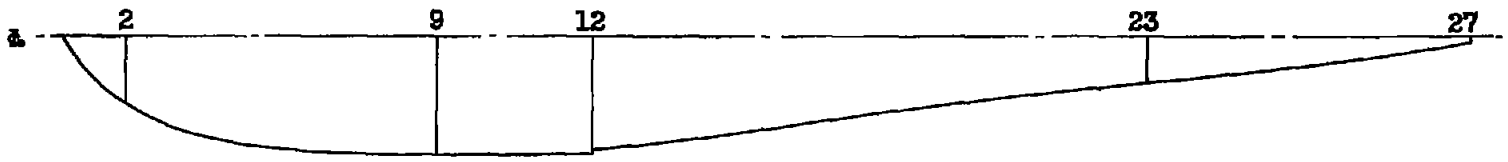
TABLE II (Continued)

Test Data for N.A.C.A. Model No. 16 Flying-Boat Hull

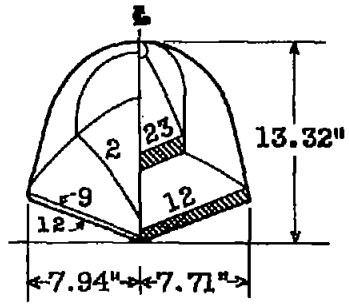
Kinematic viscosity = 0.000015 $\frac{ft.^2}{sec.}$

Water temperature: 48° F.
Tank water density: 63.6 lb. per cu.ft.

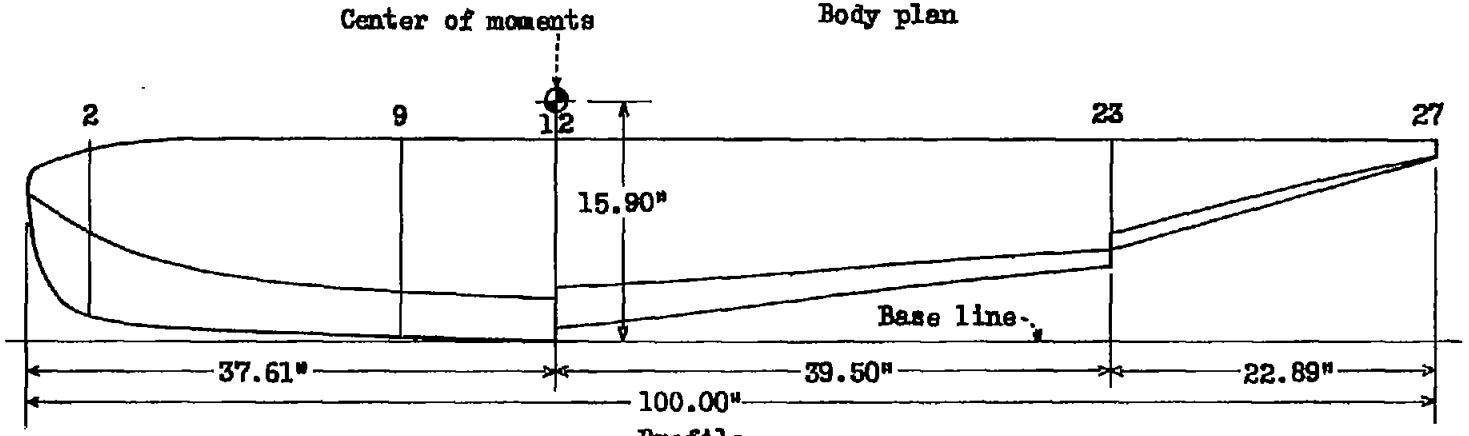
Trim angle, τ = 9°									
Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft,	Draft at step in.	Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
50	10.8	6.5	-35.9	3.0	20	23.5	6.2	-10.6	1.1
	12.4	8.2	-25.5	2.95		28.8	8.6	- 6.1	1.1
	14.4	9.2	- 7.0	2.7		29.0	9.3	- 2.8	1.1
	16.1	10.1	- 3.6	2.5	10	28.3	2.2	-27.2	- .5
	17.4	10.3	0.1	2.3					
	19.2	10.6	3.5	2.2	5	28.5	2.4	-12.4	- .7
	22.0	10.5	10.5	1.9					
	24.8	11.1	14.0	1.7	Trim angle, τ = 11°				
	28.7	12.1	13.2	1.5					
	29.0	11.2	13.2	1.5	70	15.0	14.2	-19.9	2.7
40	12.6	6.9	-22.0	2.4		16.3	14.9	-16.4	2.4
	14.5	7.5	-14.0	2.2		18.0	15.0	-20.7	2.3
	16.2	8.0	-10.6	2.05		20.0	15.1	-25.1	2.15
	18.0	7.8	- 8.6	2.0	60	15.0	12.1	-27.7	2.3
	19.4	8.3	- 3.6	1.95		16.4	12.5	-25.9	2.0
	22.0	8.5	6.2	1.7		18.0	12.6	-28.5	1.95
	24.4	9.1	8.8	1.6		20.0	12.7	-31.2	1.8
	28.8	11.1	5.3	1.35	50	14.9	9.4	-33.8	1.9
	29.1	10.5	7.9	1.3		16.5	9.9	-33.8	1.7
	33.5	13.3	3.4	1.25		18.0	9.5	-36.6	1.75
30	22.0	7.0	- 2.7	1.6		20.0	10.1	-38.2	1.6
	24.7	7.8	4.4	1.4	40	14.8	6.9	-40.8	1.5
	29.0	9.8	1.6	1.2		16.4	7.5	-40.8	1.35
	33.8	12.5	- .8	1.1		18.1	7.5	-49.6	1.3
						20.0	7.8	-51.2	1.1



Half-breadth



Body plan



Profile

Figure 1.- Lines of N.A.C.A. Model No.16

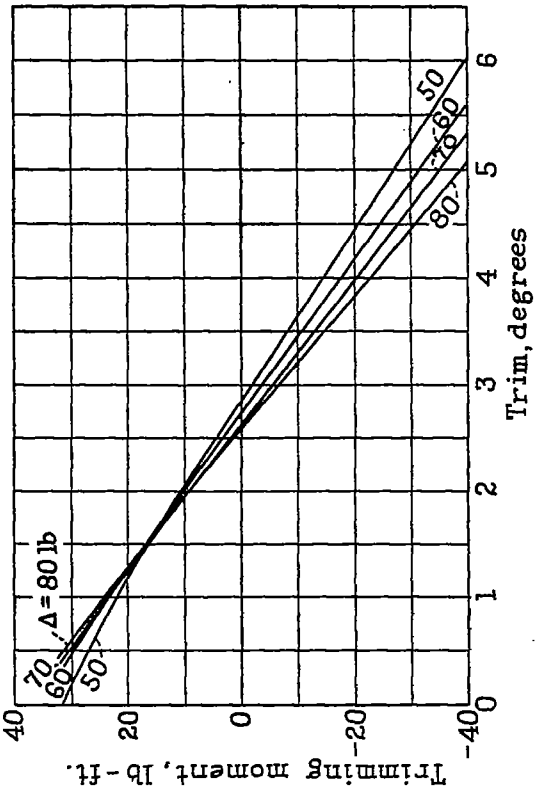


Figure 2.-Trimming moments at rest

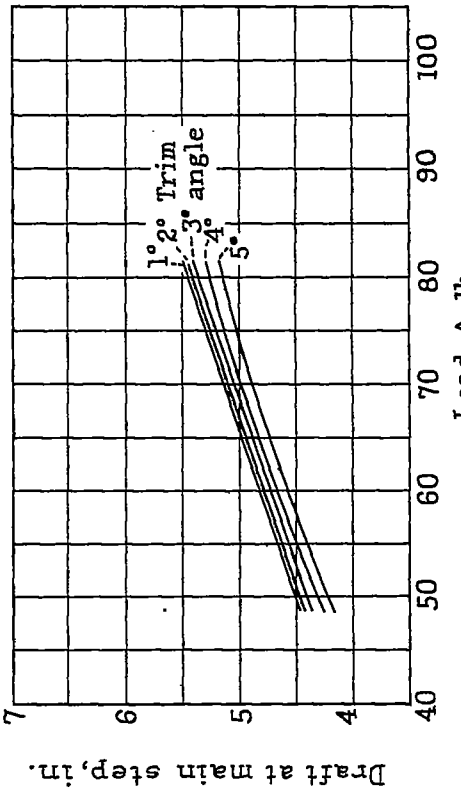


Figure 3.-Draft at rest

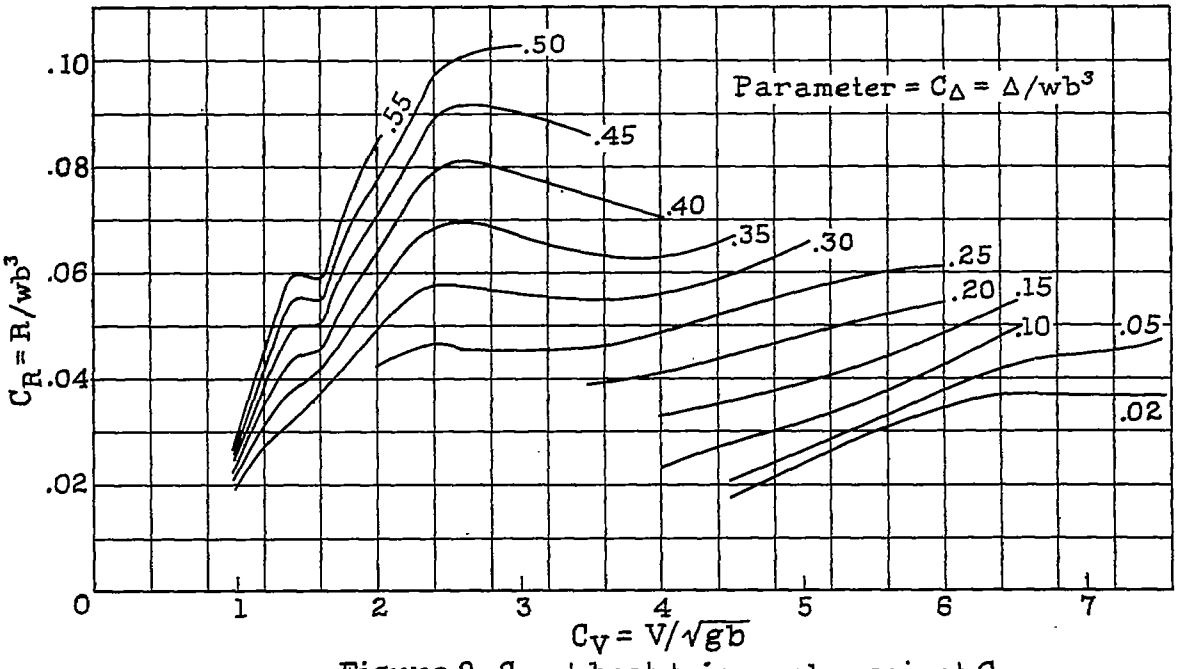


Figure 9.-C_R at best trim angle against C_V

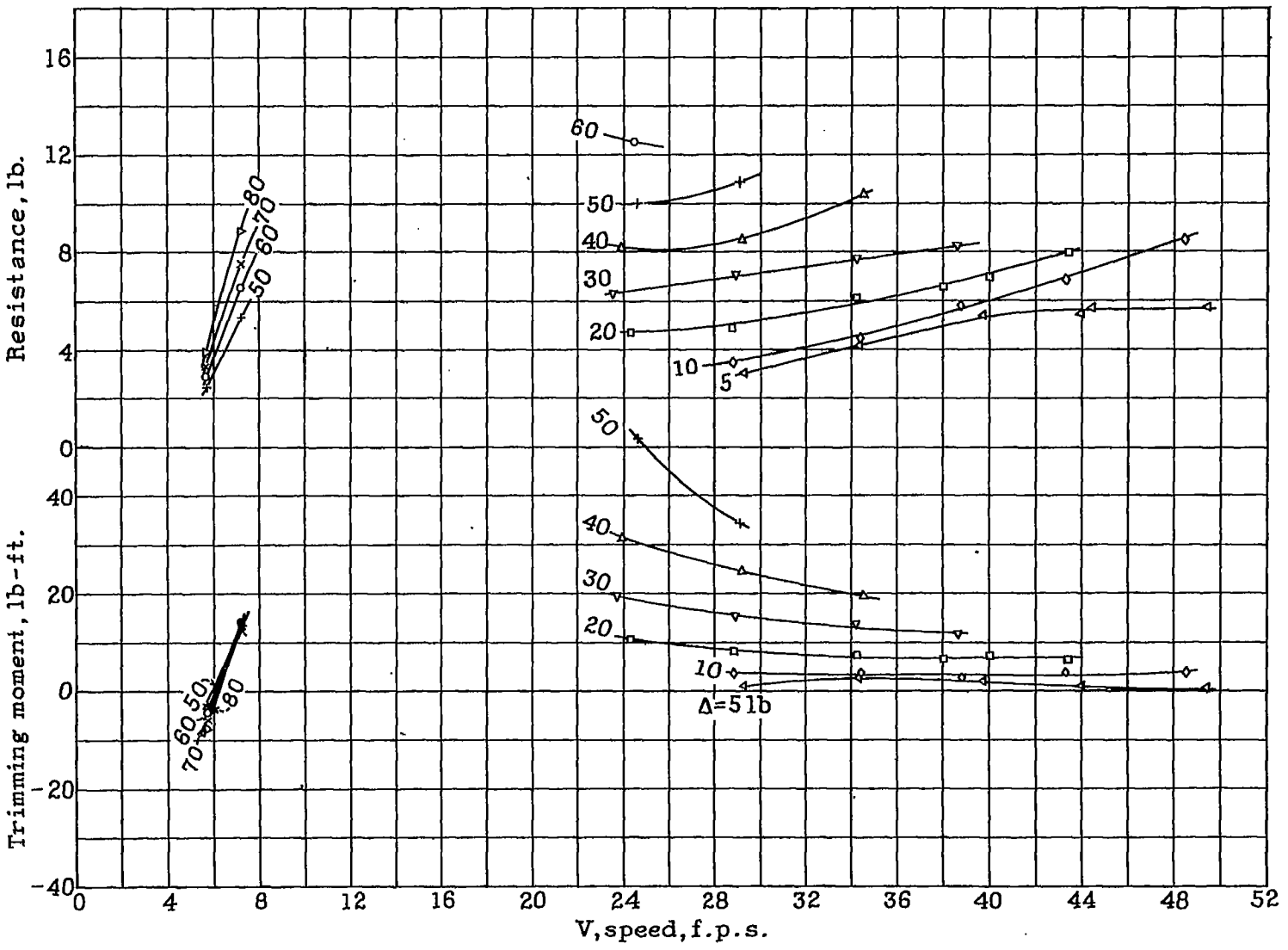


Figure 4.-Model resistance and trimming moment, $\tau = 3^{\circ}$

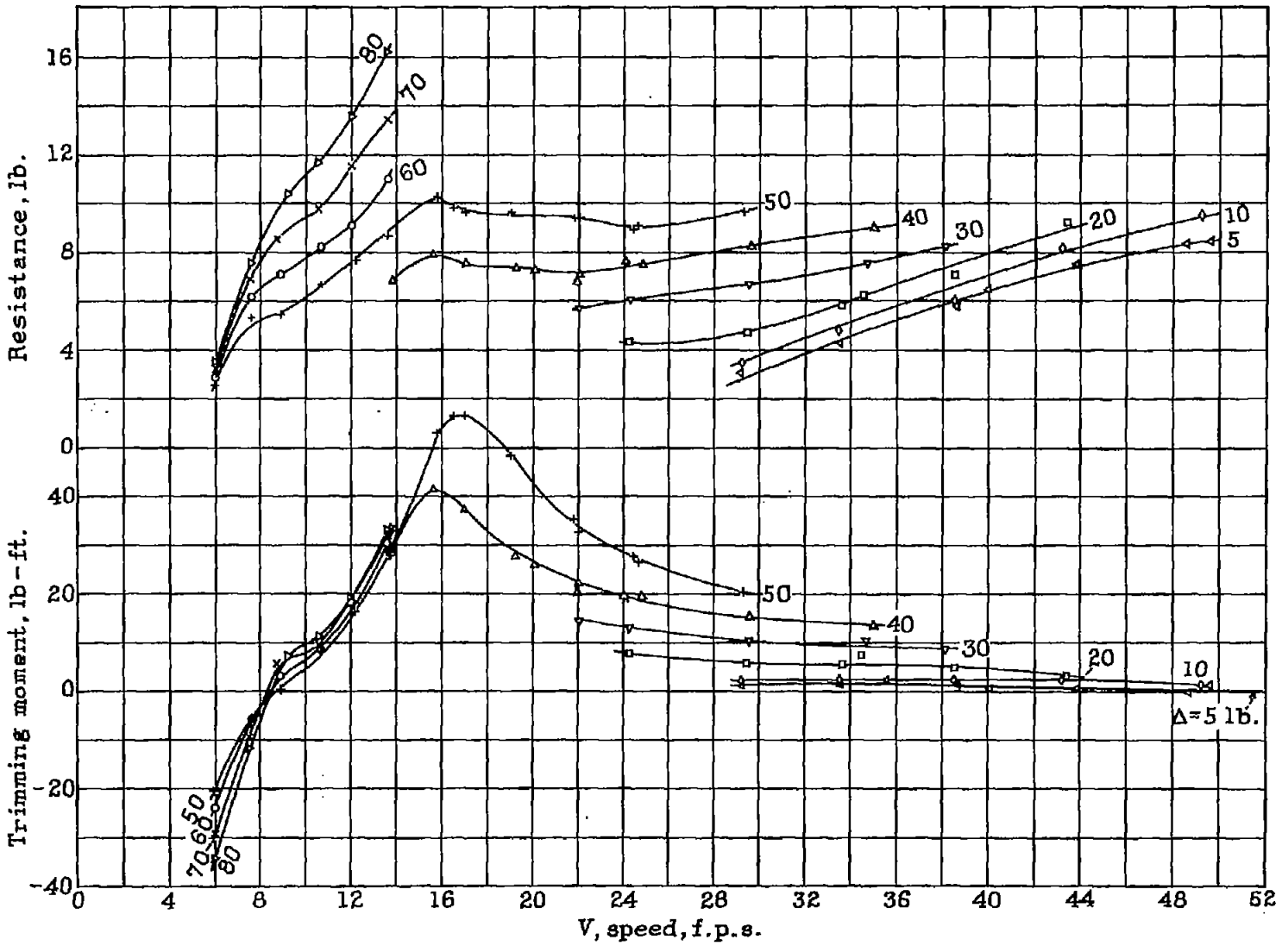


Figure 5.-Model resistance and trimming moment, $\tau = 5°$

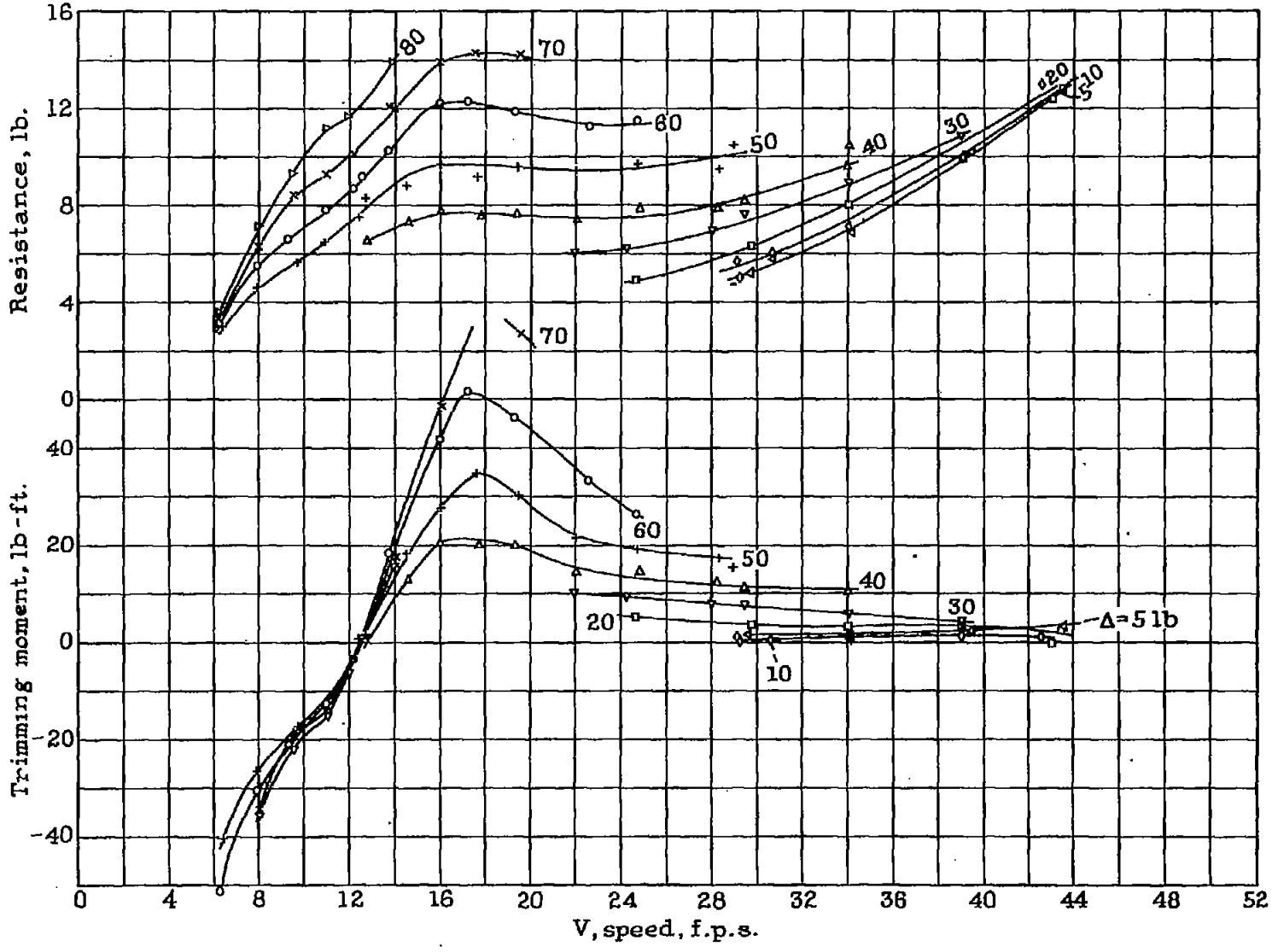


Figure 6.-Model resistance and trimming moment, $\tau = 7°$

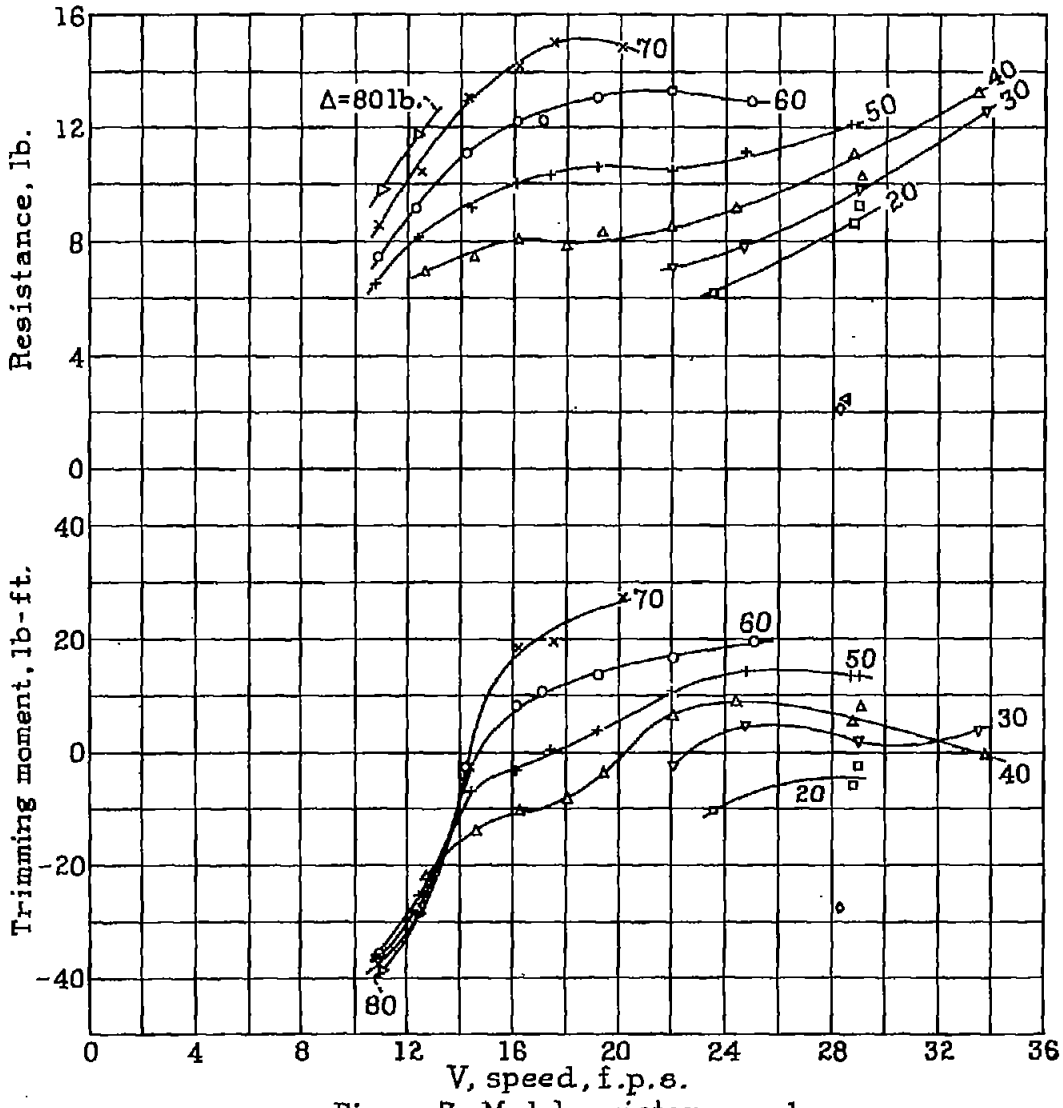


Figure 7.-Model resistance and trimming moment, τ=9°

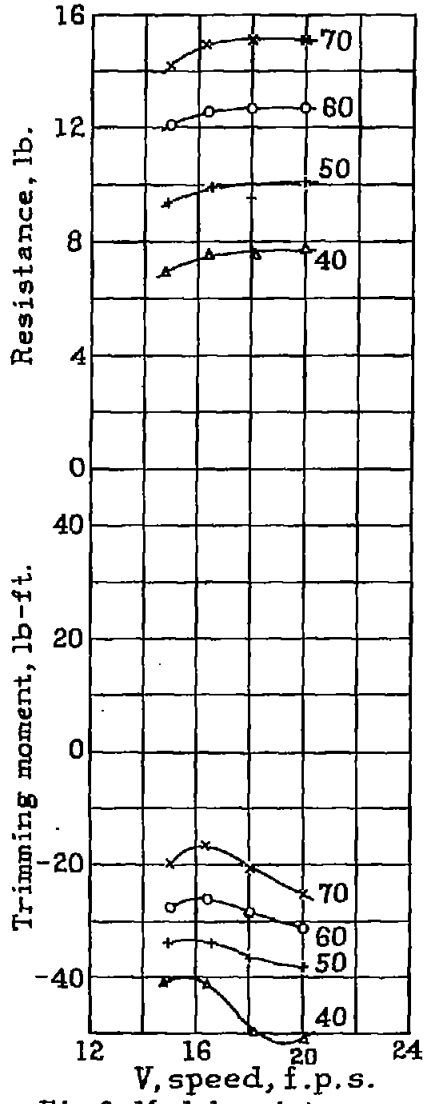


Fig.8-Model resistance and trimming moment, τ=11°

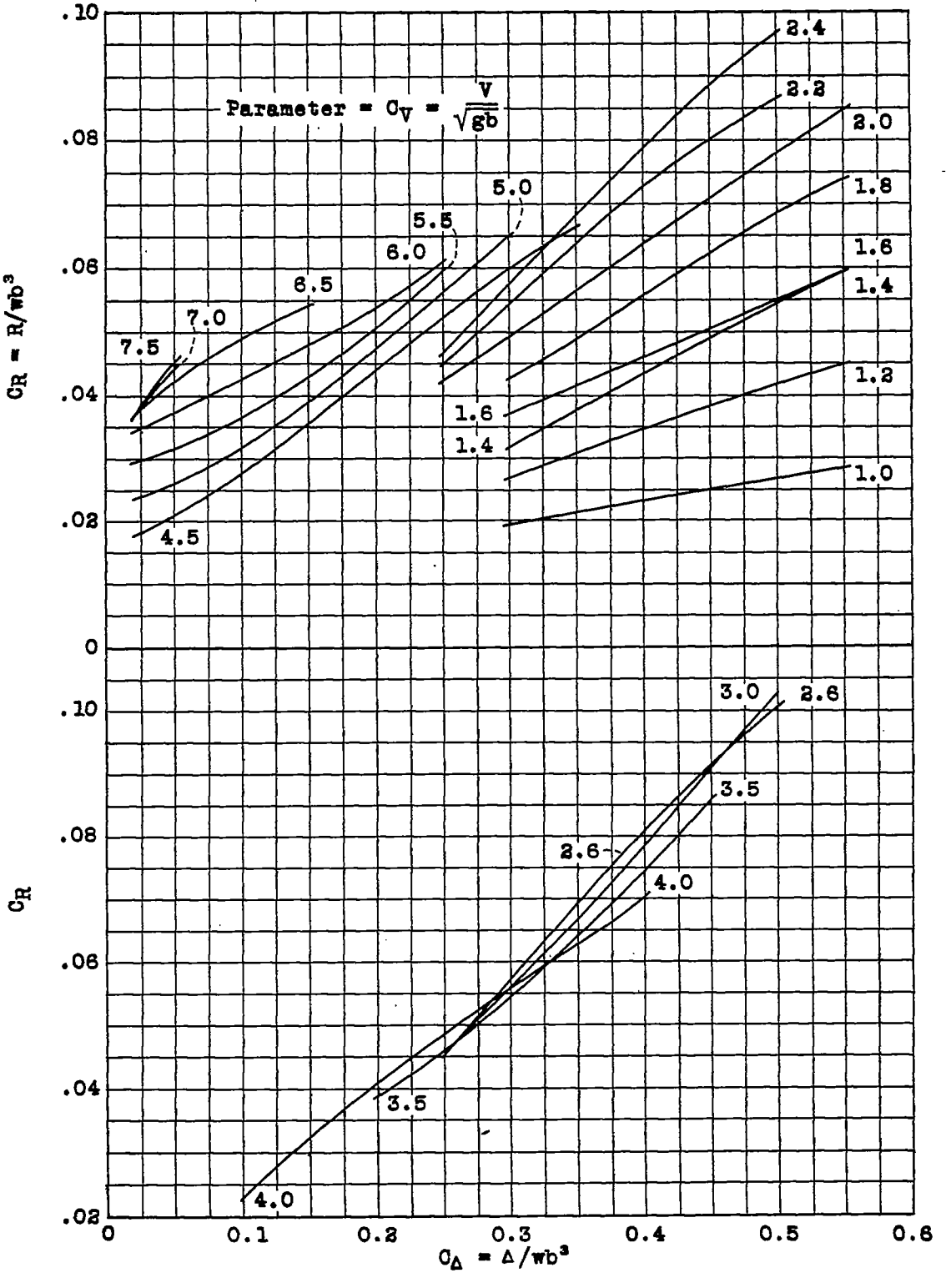


Figure 10. C_R at best trim angle against C_Δ

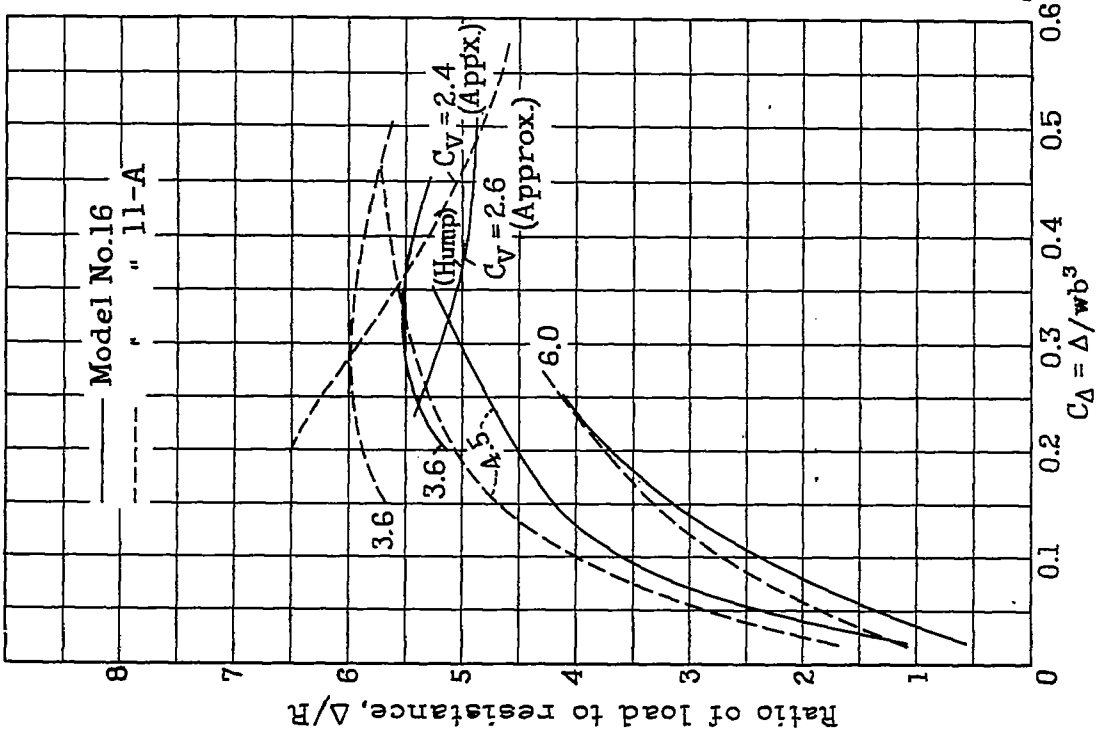


Figure 12.- Δ/R at best trim angle against C_Δ

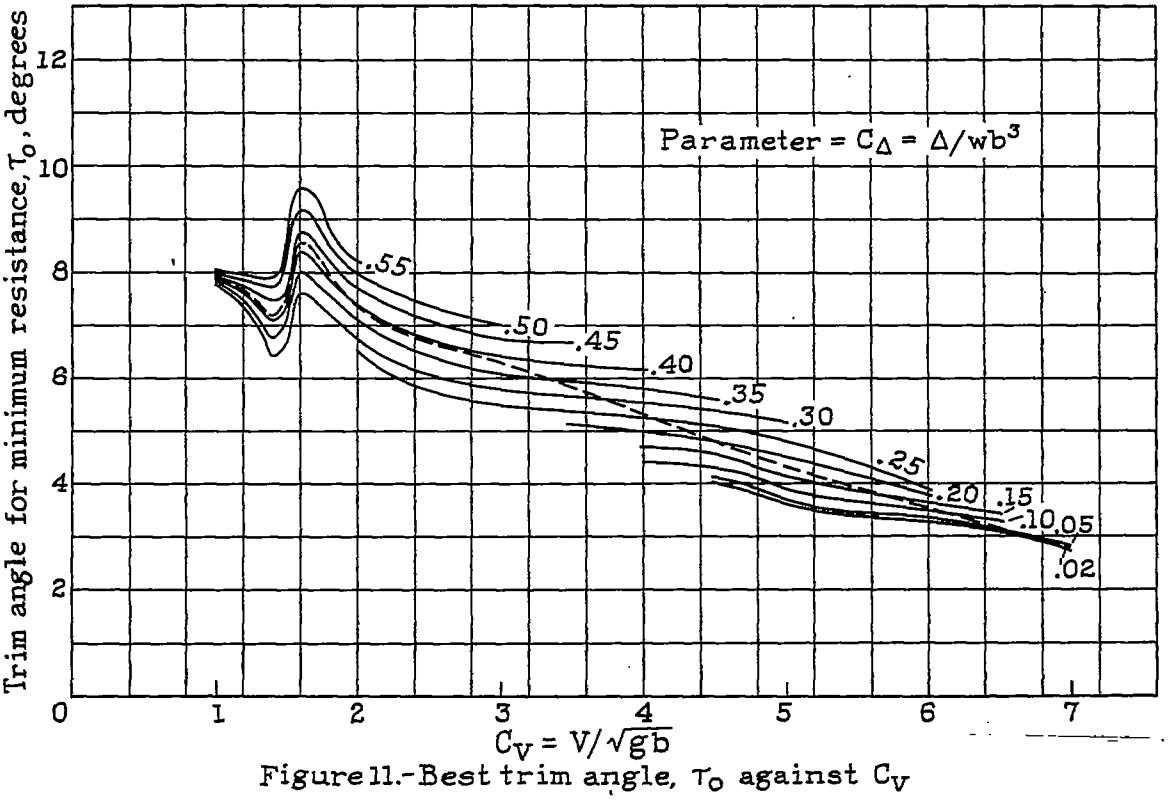
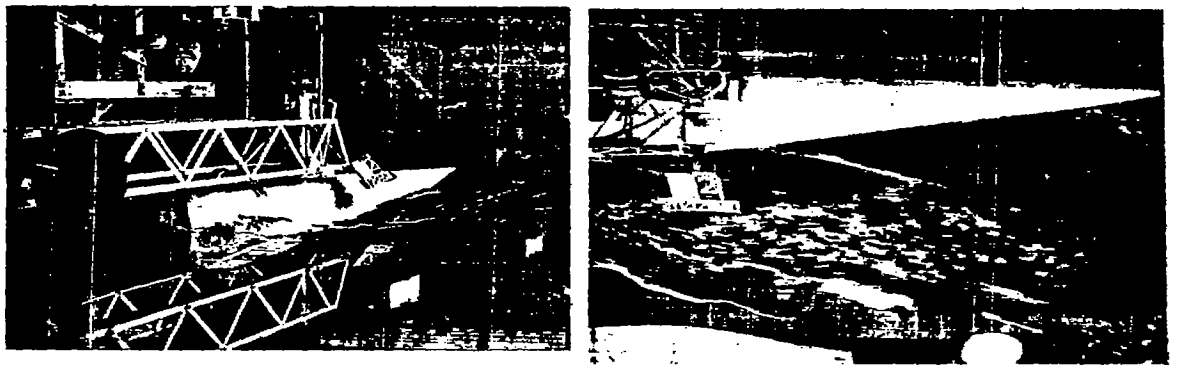
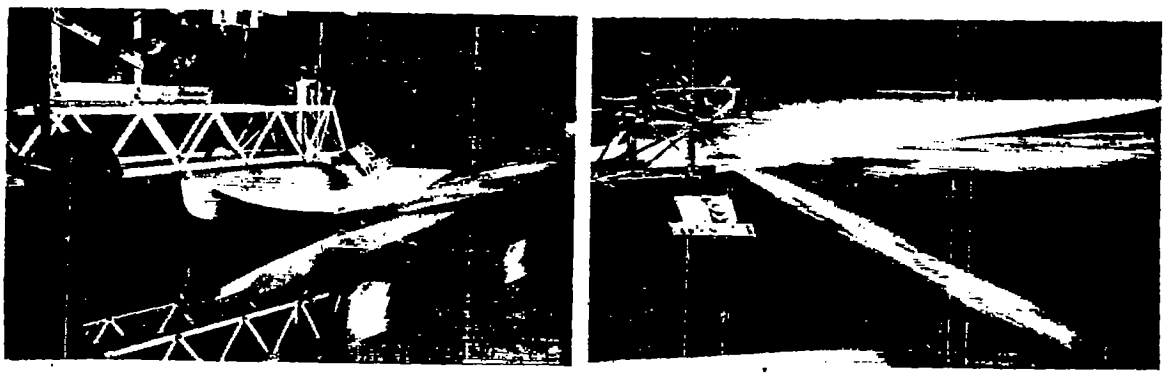


Figure 11.- Best trim angle, τ_o against C_V



Trim angle 3°. Load 80 lb. Speed 5.7 f.p.s.

Trim angle 7°. Load 70 lb. Speed 17.5 f.p.s.



Trim angle 5°. Load 10 lb. Speed 49.2 f.p.s.

Figure 13.-Typical photographs of Model No.16 under way.