TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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A GENERAL TANK TEST OF A MODEL OF THE HULL OF THE P3M-1

FLYING BOAT INCLUDING A SPECIAL WORKING CHART FOR

THE DETERMINATION OF HULL PERFORMANCE

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SUMMARY

The results of a general tank test of a 1/6-full-size
model of the hull of the P3M-1 flying boat (N.A.C.A. model
18) are given in nondimensional form. In addition to the
usual curves, the results are presented in a new form that
makes it possible to apply them more conveniently than in
the forms previously used.

The resistance was compared with that of N.A.C.A.
models 11-C and 26 (Sikorsky S-40) and was found to be
generally less than the resistance of either.

INTRODUCTION

The research program for the N.A.C.A. tank includes
the testing of models of hulls that have been successfully
used in actual flying boats. The data accumulated from
such a series of tests should indicate the relative merits
of the various types of hull that have been developed.
Previous tests have included models of a number of hulls
of foreign design as well as some of those developed in
this country.

Because some difficulty had been experienced with the
spray from the hull of the Navy P3M-1 flying boat, a 1/6
full-size model of this hull was tested with several forms
of spray strips; the results of the tests, which were made
for only one load and get-away speed, are reported in ref-
erence 1. In these first tests, the spray thrown by the
model did not appear to be excessive and the water resist-
ance compared favorably with the resistance of other mod-
els. On account of the satisfactory results obtained in

the tests with one load, a general tank test has been made
with this model to obtain more complete data regarding its
performance.

The manner in which the results of general tank tests
have usually been presented has a number of disadvantages.
These disadvantages can be overcome to some extent by plot-
ting the data with a different arrangement of the varia-
bles. In order to demonstrate the advisability of present-
ing the data in this new manner, the data from the present
tests will be presented in both the old and the new forms.

THE MODEL

The model as tested consisted of the same wooden model
of the main hull that was used in the tests reported in
reference 1. The lines of the model are shown in figure 1
and the offsets are given in table I. The position of the
center of moments shown in figure 1 was used in the pres-
ent tests.

The particulars of the model and of the full-size
flying boat are as follows:

	Model	Full-size
Length:		
Over-all	117.50 in.	58 ft. 9 in.
Of forebody to main step. .	50.83 in.	25 ft. 5 in.
Maximum beam	16.84 in.	8 ft. 5 in.
Center of moments forward of step	8.33 in.	4 ft. 2 in.
Center of moments above keel	13.18 in.	6 ft. 7 in.
Depth of step	0.64 in.	3-7/8 in.
Angle of keel aft of step to base line	6° 15'	
Linear ratio of model to full size	1/6	

Beam:

   Percentage of over-all length 14.33
   Percentage of forebody length 33.13

Forebody:

   Percentage of over-all length 43.26

Center of moments, distance forward
 of the step:

   Percentage of over-all length 7.09
   Percentage of forebody length 16.39

Center of moments, distance above the keel:

   Percentage of over-all length 11.22
   Percentage of forebody length 25.95

APPARATUS AND PROCEDURE

The apparatus and procedure for the general tank test
are described in reference 2. A general free-to-trim test
was made and the results were published in reference 3.
In a general test, the water resistance of a model for a
number of constant loads is obtained throughout the speed
range considered practicable. In the general fixed-trim
test, the trim is fixed and trimming moments are measured,
tests being made at a sufficient number of trims to deter-
mine the trim for minimum resistance, i.e., best trim. In
the general free-to-trim test the model is balanced to
bring the center of gravity to the desired position and
allowed to pivot freely about a transverse axis through
the center of gravity; trim is measured for each load and
speed tested.

Most of the present tests were made in the fall of
1936. Analysis of the data having indicated that addition-
al data would be desirable, further tests were made in the
fall of 1937. Some differences were obtained at speed co-
efficients greater than 7.0, and, since it was believed
that the tares (which increase with speed coefficient) were
obtained more accurately in the later tests, all test
points obtained in the 1936 tests at speed coefficients

greater than 7.0 were repeated in 1937; the 1936 data in this region are omitted from the present report. The differences obtained in the two tests in this high-speed region would not, in general, greatly affect performance calculations.

RESULTS

. The nondimensional coefficients commonly in use at the N.A.C.A. tank are defined as

Load coefficient, $C_\Delta = \dfrac{\Delta}{wb^3}$

Resistance coefficient, $C_R = \dfrac{R}{wb^3}$

Speed coefficient, $C_V = \dfrac{V}{\sqrt{gb}}$

Trimming-moment coefficient, $C_M = \dfrac{M}{wb^4}$

Draft coefficient, $C_d = \dfrac{d}{b}$

where Δ is load on water, lb.

w,   specific weight of water, lb./cu. ft. (w = 63.3 lb./cu. ft. in these tests).

b,   beam of hull, ft.

V,   speed, f.p.s.

M,   trimming moment, lb.-ft.

g,   acceleration of gravity, ft./sec.²

d,   draft at step, ft.

Any consistent system of units may be employed.

The air drag of the model is included in the water resistance. Moments tending to raise the bow are considered positive.

The fixed-trim data are presented in figures 2 to 7, in which resistance coefficient and trimming-moment coefficient are plotted against speed coefficient with load

coefficient as parameter, each figure being for one trim τ. Trim is the angle between the horizontal and the base line (fig. 1).

The original free-to-trim data are shown in figure 8 in which resistance coefficient and trim are plotted against speed coefficient with load coefficient as parameter. This figure is from figure 5 of reference 3.

The static data are presented in figure 9 in which trimming-moment coefficient and draft coefficient are plotted against load coefficient with trim as parameter.

Owing to the number of independent variables in a general tank test, it is customary to eliminate the variable, trim, by finding the trim that gives minimum resistance for each speed and load tested. This best trim has been found in the usual manner (see reference 4) for the present data and the usual curves obtained are shown in figures 10 to 13. Figure 10 shows the resistance coefficient at best trim plotted against speed coefficient with load coefficient as parameter. Figure 11 shows the same data plotted against load coefficient with speed coefficient as parameter. In figure 12, best trim τ_o is plotted against speed coefficient and, in figure 13, the trimming-moment coefficient obtained at best trim is plotted against speed coefficient, load coefficient being the parameter in both cases.

Plotting the best-trim data in this manner allows the ready finding of the least resistance that would be obtained from the hull under any condition within the range of the test. It also permits the trims required to give the least resistance and the trimming moments necessary to hold those trims to be obtained. If, however, conditions prevent the obtaining of the best trim or circumstances are such that the trim for minimum water resistance will not give a minimum of the sum of the water resistance and the air drag, then the best-trim curves are inadequate. When, because of lack of control, best trim cannot be obtained, an approximation to the condition can sometimes be made by using free-to-trim data. In general, however, when the best-trim data were inadequate, it has been desirable to compute from the curves of original test data the resistance resulting from the conditions assumed. The curves of original data are not very convenient for interpolating for a number of reasons, an important one being

that it frequently is necessary to interpolate for trim
from sheet to sheet. This difficulty in interpolation can
be overcome by referring directly to the group of cross
plots used in obtaining the best trim curves. These plots
have previously been omitted from N.A.C.A. publications
because they seemed to add unnecessarily to the already
bulky sets of data. A method of presenting the data that
increases the convenience of use without increasing the
bulk of the curves is to omit both the curves of original
test data and the curves of best-trim data and to substi-
tute for them the cross plots. All the data found in ei-
ther of the curves that have been omitted can be included
in the cross plots. Apparently the only sacrifice made by
presenting the data in this manner is the loss of a view
of the variation of the dependent variables with speed,
although this view can be obtained by close examination of
the cross plots.

The usual cross plots of resistance coefficient are
shown in figure 14. Resistance coefficient is plotted
against trim with load coefficient as parameter, a set of
curves being made for each of a number of speed coeffi-
cients. Similar plots were made for the trimming-moment
coefficients but the data from those cross plots are shown
in figure 14 in the form of curves of constant trimming-
moment coefficient superposed on the resistance curves.
The speed coefficients used are selected to cover the
range of the tests in such a manner that interpolation for
other speed coefficients may be made without sensible loss
of accuracy. The symbols shown in figure 14 do not indi-
cate test points but denote points taken from the faired
curves of the original test data (figs. 2 to 8).

It should be noted that the data from the general
free-to-trim tests are included in these cross plots be-
cause these data represent the conditions of zero moment.
The line of best trim is shown on the curves of resistance
coefficient. This line aids in the determination of the
best-trim data given in figures 10 to 13. The resistance
coefficient for load coefficients other than those actual-
ly tested has been indicated in figure 14 by broken lines
obtained by cross-plotting resistance coefficient against
load coefficient for each trim. These lines are added to
aid in interpolating for load coefficient and do not dif-
fer sensibly from curves that would have been obtained
had the variation of resistance coefficient with load co-
efficient been assumed to be linear between any two suc-
cessive load coefficients tested.

It is proposed that, except in special cases, curves similar to those of figure 14 shall in future papers be presented to show the results from general tank tests, without the additional plots of figures 2 to 8 and 10 to 13. These curves are, in general, quite adequate for any problem that can be solved with data from a general tank test and, in a great many cases, they give the required answer with the least labor. The resistance corresponding to zero trimming-moment coefficient (free-to-trim) or any other assumed trimming-moment coefficient may be obtained with equal facility. If data are wanted for any center of gravity other than the one corresponding to the center of moments used in the general tests, the trimming-moment coefficient may be corrected for the differences between the two positions by calculation; these curves may then be used to show the results of such changes. The effect of inadequate controlling moment on resistance is probably more readily shown on this type of plot than on any other.

COMPARISONS

The resistance coefficients of N.A.C.A. models 18, 26, and 11-C are compared in figure 15. In this figure, the resistance coefficients at best trim are plotted against speed coefficient for selected load coefficients. The data for models 26 and 11-C are from references 5 and 6. A direct comparison of the curves of figure 15 assumes that, for a given load, the hulls of each of the three models under consideration will have the same beam. If the tail extension, which is used primarily for carrying control surfaces, is neglected, the three models, 18, 11-C, and 26, are of about the same proportions so that comparisons based on equal beams assume that the hulls will be about the same size.

The curves of figure 15 indicate that, under practically all the conditions shown, the resistance of model 18 is less than that of either model 26 or model 11-C. Model 18 appears to have very good resistance characteristics for a hull of its type and proportions.

Langley Memorial Aeronautical Laboratory,
    National Advisory Committee for Aeronautics,
        Langley Field, Va., October 5, 1938.

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       Model of the P3M-1 Flying-Boat Hull. T.N. No. 482,
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2. Allison, John M.: Tank Tests of a Model of the Hull
       of the Navy PB-1 Flying Boat - N.A.C.A. Model 52.
       T.N. No. 576, N.A.C.A., 1936.

3. Dawson, John R.: Tank Tests of Two Models of Flying-
       Boat Hulls to Determine the Effect of Ventilating
       the Step. T.N. No. 594, N.A.C.A., 1937.

4. Shoemaker, James M., and Parkinson, John B.: A Com-
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       N.A.C.A. Model No. 11. T.N. No. 464, N.A.C.A.,
       1933.

5. Dawson, John R.: A Complete Tank Test of the Hull of
       the Sikorsky S-40 Flying Boat - American Clipper
       Class. T.N. No. 512, N.A.C.A., 1934.

6. Dawson, John R.: A General Tank Test of N.A.C.A.
       Model 11-C Flying-Boat Hull, Including the Effect
       of Changing the Plan Form of the Step. T.N. No.
       538, N.A.C.A., 1935.

TABLE I. Offsets for N.A.C.A. Model 18 (P3M-1) Flying-Boat Hull (Inches).

Station	Distance from F.P.	Keel 1_A	B1 $2_{1.83}$	B2 3.67	B3 5.50	Main chine 1_B	Upper chine 1_C	Straight bottom chine 1_E	Cove 1_F	Chine 1_G	Cove 1_H	Bottom tangency 1_J	Deck	WL3 $3_{7.86}$	WL4 5.89	WL5 3.93	Crown radius 1_K
						Distance from base line				Half-breadths							
F.P.	0.00																
1/4	.92	4.18	4.18										3.12			3.09	
1/2	1.83	5.36	5.36										3.46			3.60	
3/4	2.75	6.53	6.53	5.40									3.77		3.43	3.98	
1	3.66	7.40	7.04	6.75		6.75				3.69			4.03		4.03	4.36	
2	7.33	9.78	8.67	7.55	4.35 / 6.96	6.94				5.54			4.87	3.15	5.57	5.42	
4	14.67	11.74				8.32		7.84		7.33		5.07					7.33
6	22.00	12.78				9.80		9.18		8.17		5.53					8.17
8	29.33	13.33				10.52		9.87		8.42		5.67					8.42
10	36.67	13.59				10.81		10.17		8.42		5.67					8.42
12	44.00	13.68				10.94		10.27		8.42		5.67					8.42
14	50.83	13.83 / 13.19				11.08 / 10.42	9.72	10.42 / 9.78	9.72	8.42	8.42	5.67					8.42
16	58.56	↑				9.67	8.53	9.05	8.62	8.32	8.08	5.43					8.32
18	66.29					9.15	7.44	8.72	7.92	8.02	6.70	4.65					8.03
20	74.02	↓				9.10	6.44	8.96	7.77	7.44	4.25	2.97					7.51
22	81.75	9.80 / 8.24				9.80	5.56	9.80	8.24	6.64	.17	.17					6.74
24	89.50	↑					4.77			5.63							5.70
26	97.25						4.03			4.41							4.43
28	105.00						3.43			2.92							2.92
30	112.75	↓					2.90			1.24							1.24
A.P.	117.50	2.57					2.57			.21							.21

[1] Letters refer to dimensions on figure 1.

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

[3] Distance from base line to water line (section of hull surface made by a horizontal plane parallel to base line).
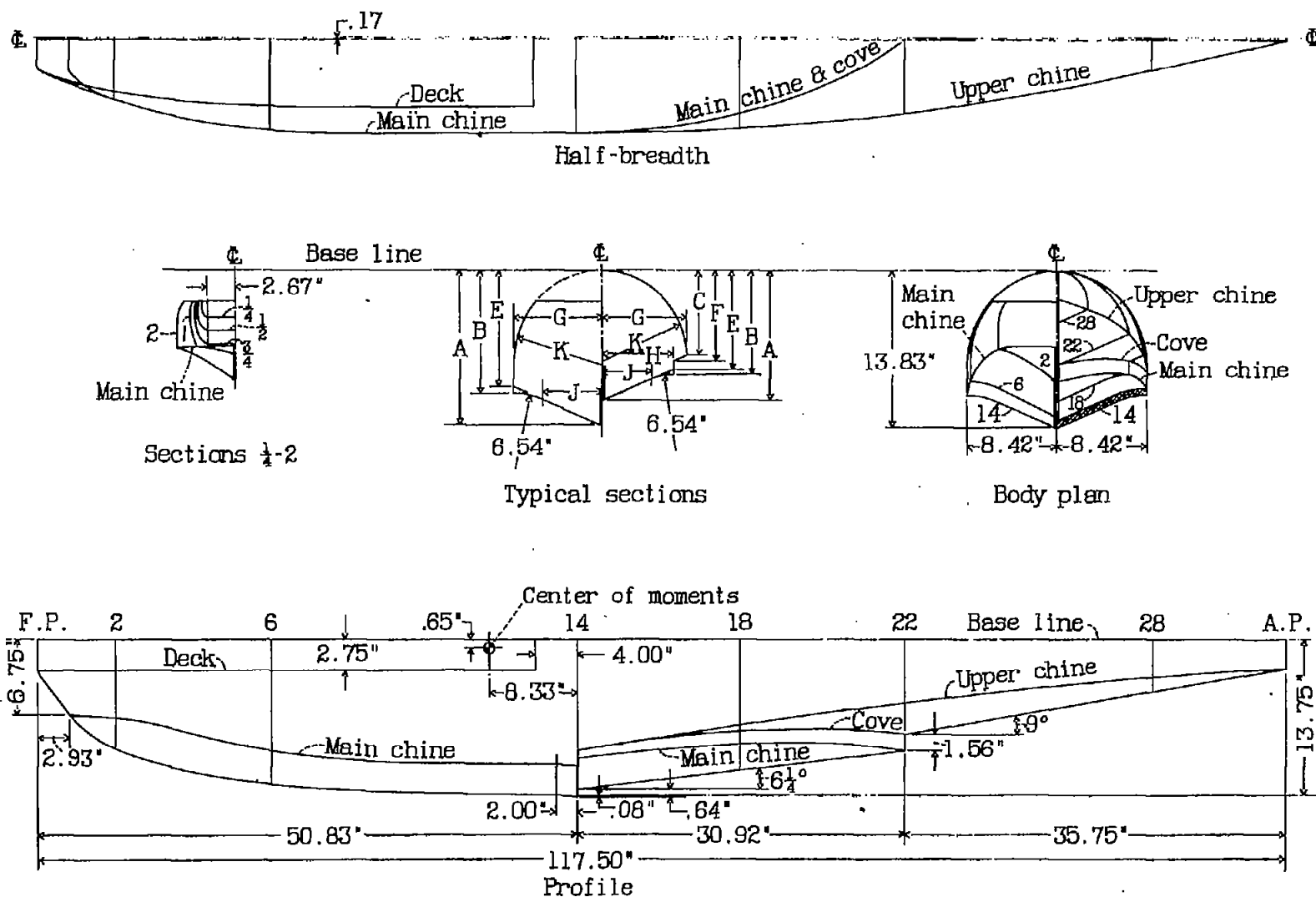
.17

Deck
Main chine
Main chine & cove
Upper chine

Half-breadth

Base line
2.67"

Main chine

Sections ¼-2

A B E G G C F E B A K K H J J

6.54"   6.54"

Typical sections

Main chine
13.83"
Upper chine
Cove
Main chine
28 22 2 6 14 18 14
8.42" 8.42"

Body plan

Center of moments

F.P. 2   6   .65"   14   18   22   Base line   28   A.P.

Deck
2.75"
8.33"
6.75"
4.00"
Upper chine
Cove
Main chine
13.75"
2.93"
Main chine
6¼°
9°
1.56"
2.00" .08" .64"
50.83"   30.92"   35.75"
117.50"

Profile
Figure 1.- Lines of N.A.C.A. model 18 (P3M-1).

Fig. 1

Fig. 2

Figure 2.- Model 18. Variation of resistance coefficient and trimming moment coefficient with speed coefficient. $\tau = 10°$.
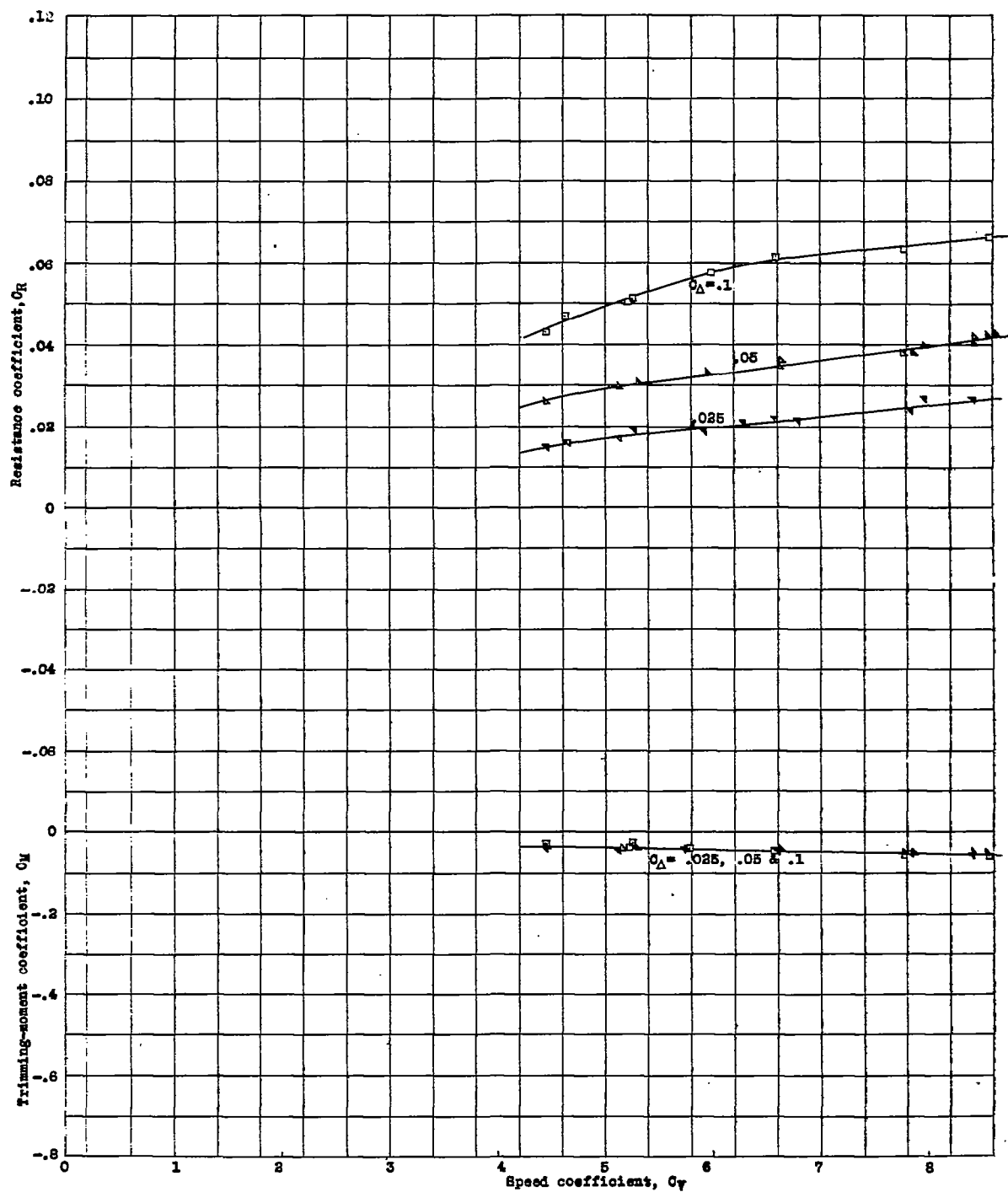
Figure 3.- Model 18. Variation of resistance coefficient and trimming-moment coefficient with speed coefficient. T = 3°.
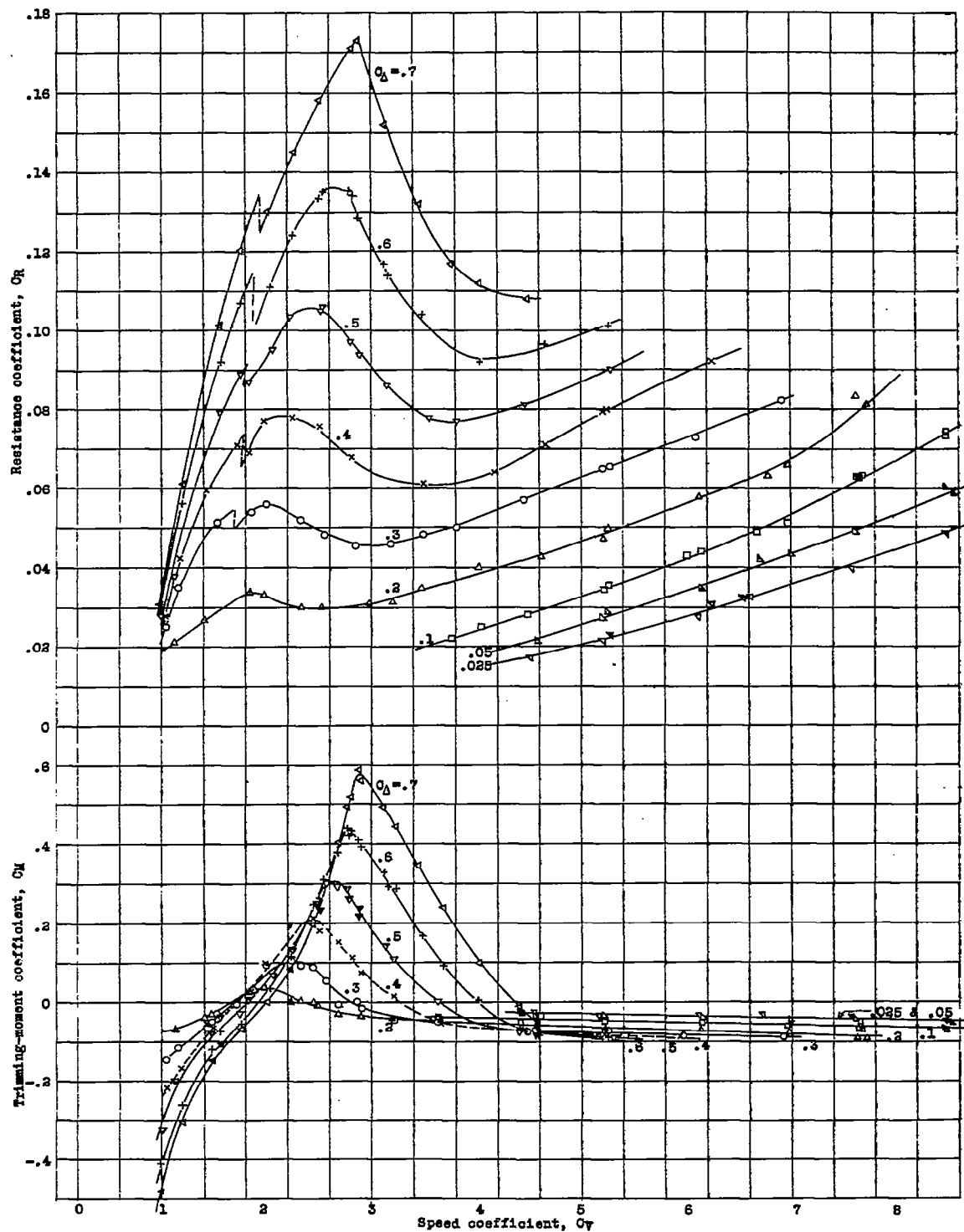
Figure 4.- Model 18. Variation of resistance coefficient and trimming-moment coefficient with speed coefficient. $\tau = 5^o$.

Fig. 5
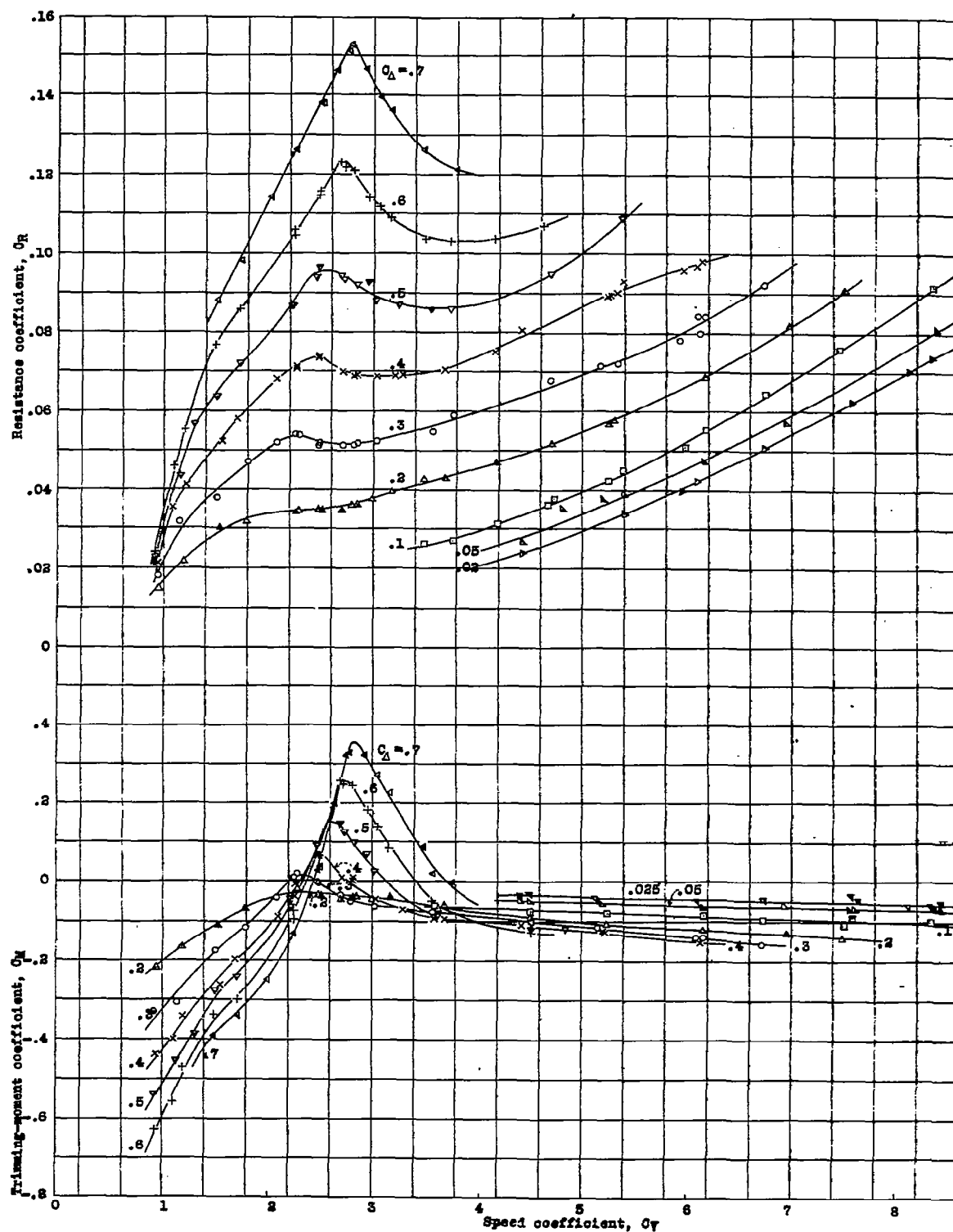
Figure 5.- Model 18. Variation of resistance coefficient and trimming-moment coefficient with speed coefficient. $\tau = 7°$.

Fig. 6
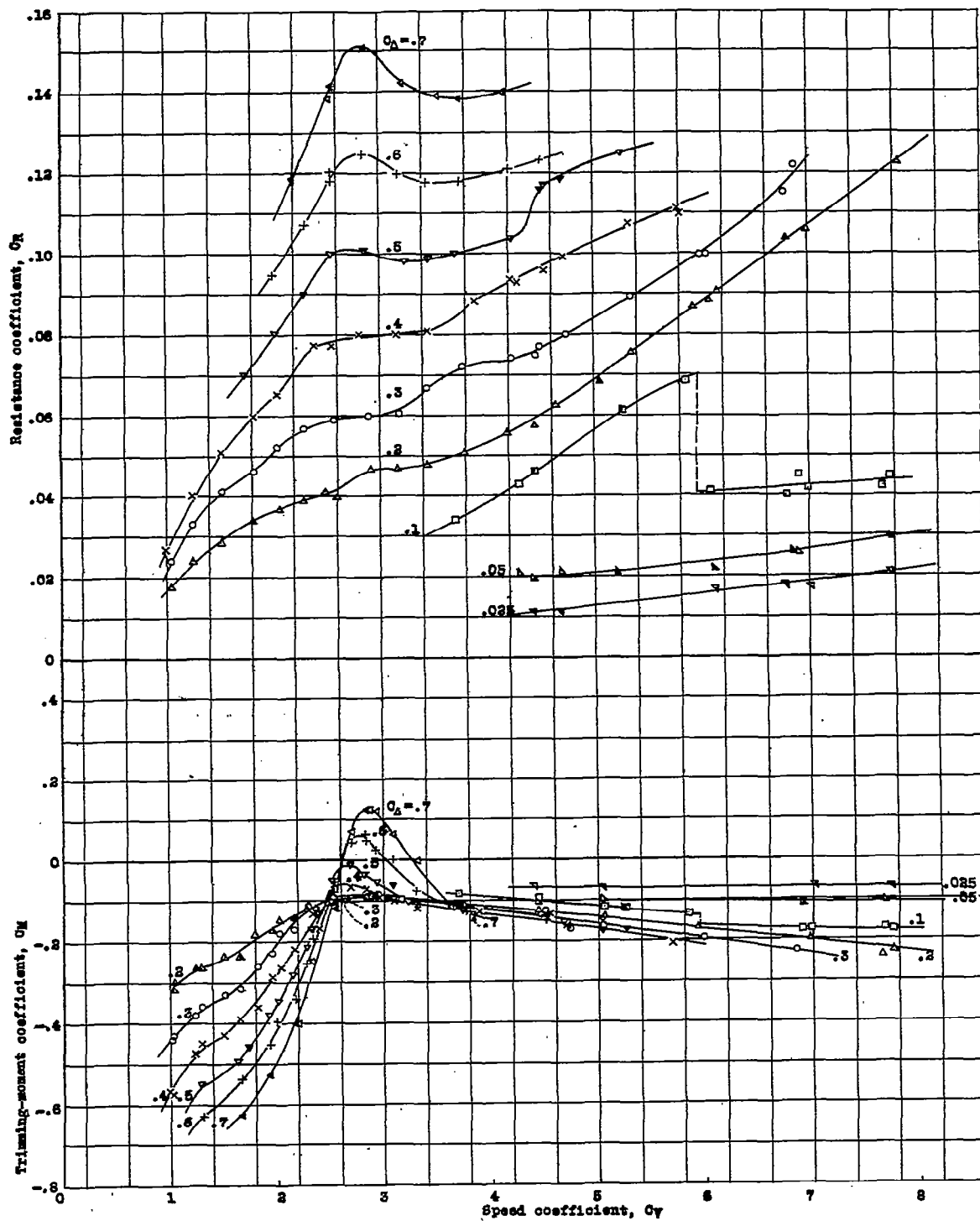
Figure 6.- Model 18. Variation of resistance coefficient and trimming-moment coefficient with speed coefficient. T=9°.

Fig. 7
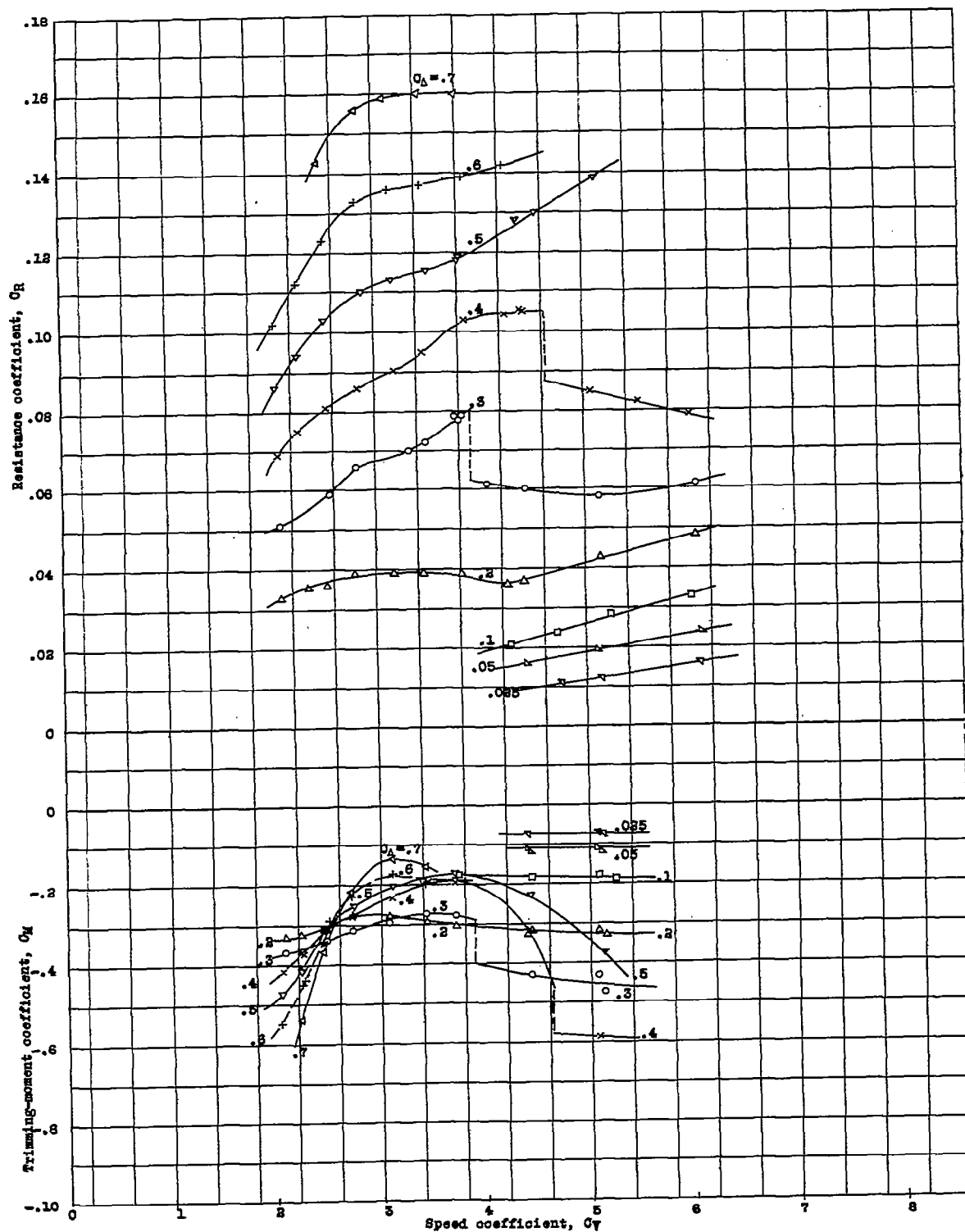
Figure 7.— Model 18. Variation of resistance coefficient and trimming-moment coefficient with speed coefficient. $\tau = 11°$.

Fig. 8
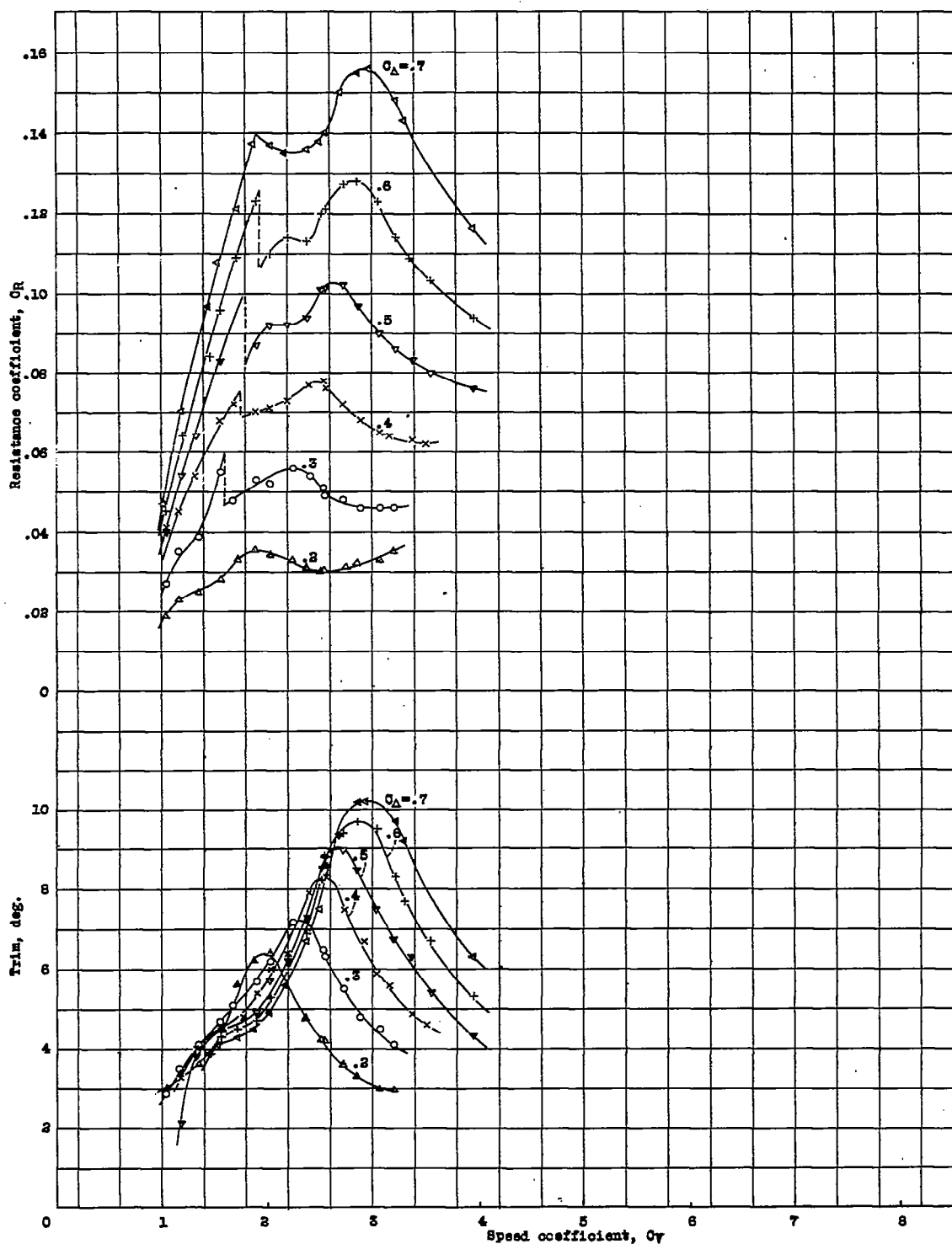
Figure 8.- Model 18. Variation of resistance coefficient and trim with speed coefficient. Free to trim. (From fig. 5, reference 3.)
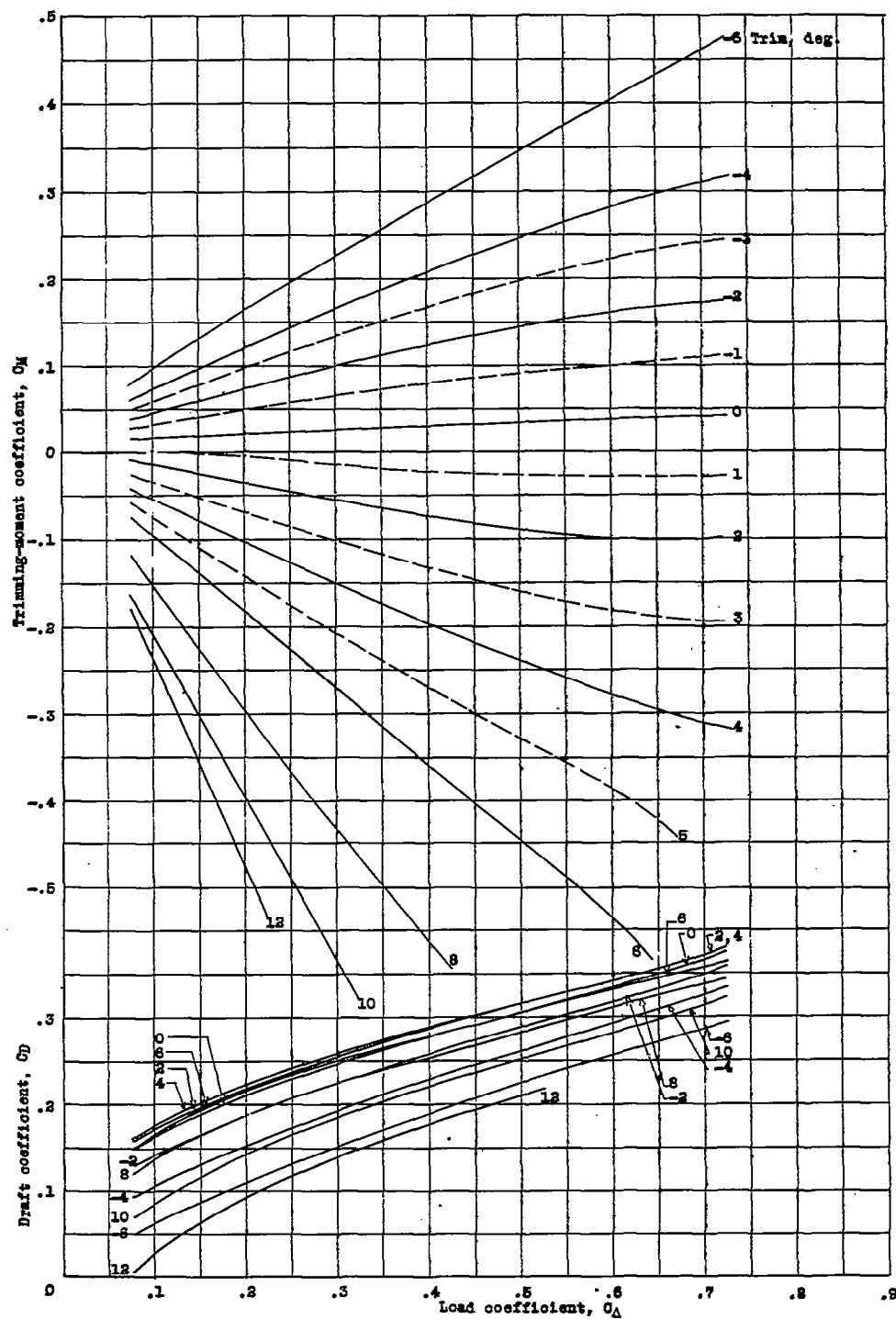
Figure 9.— Model 18. Static properties.
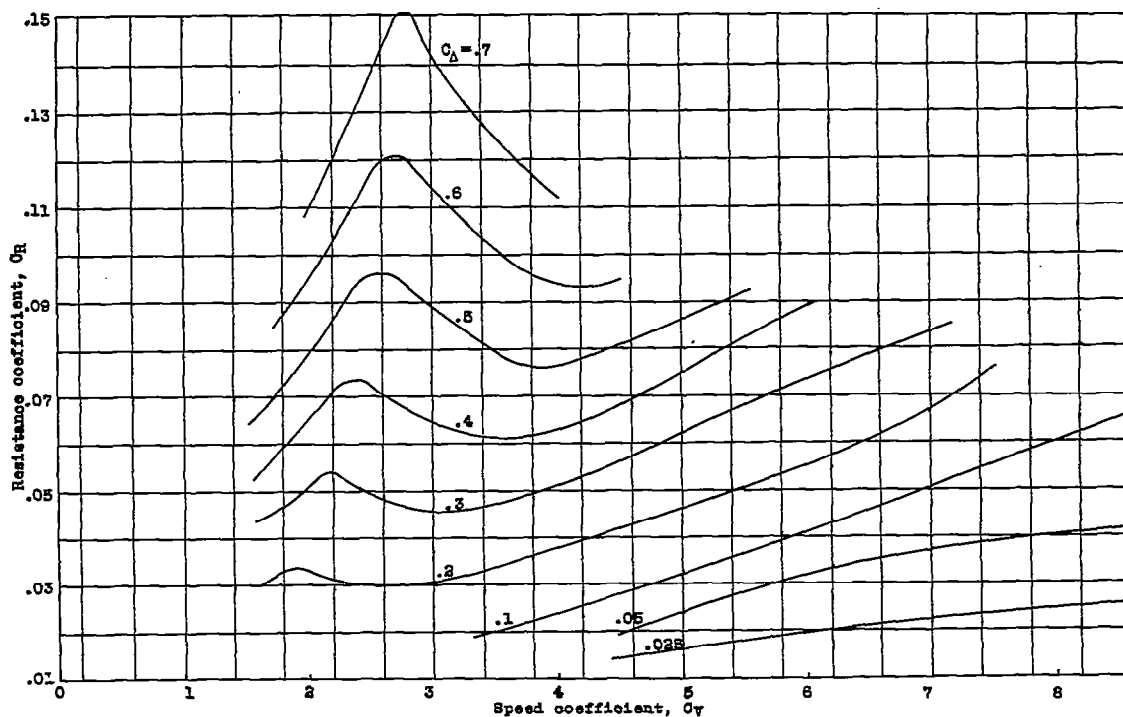
Figure 10.- Model 18. Variation of resistance coefficient at best trim with speed coefficient.
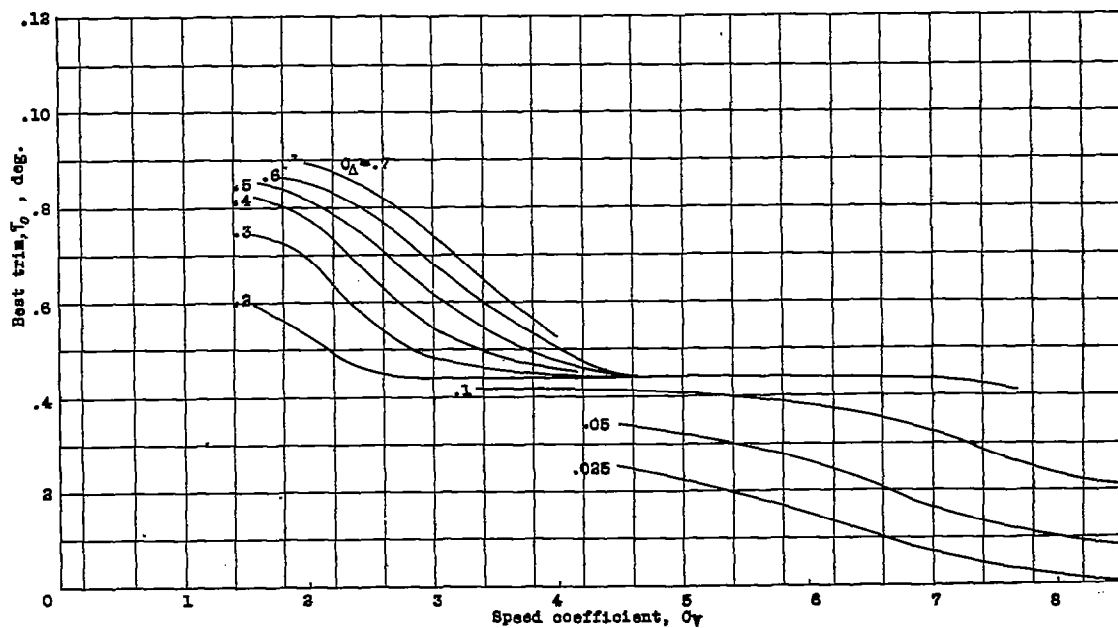
Figure 12.- Model 18. Variation of best trim with speed coefficient.

Fig. 11
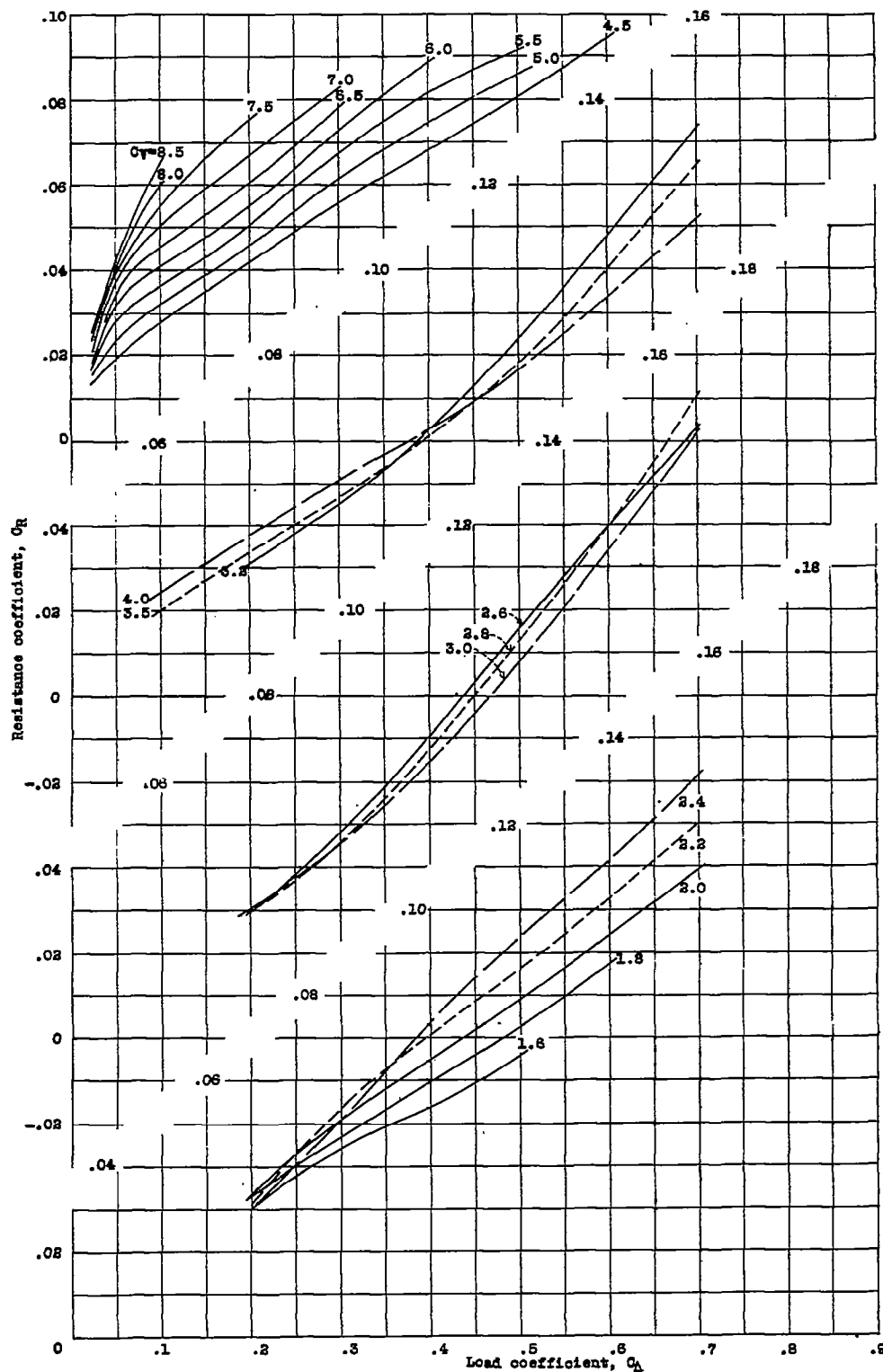
Figure 11.- Model 18. Variation of resistance coefficient at best trim with load coefficient.
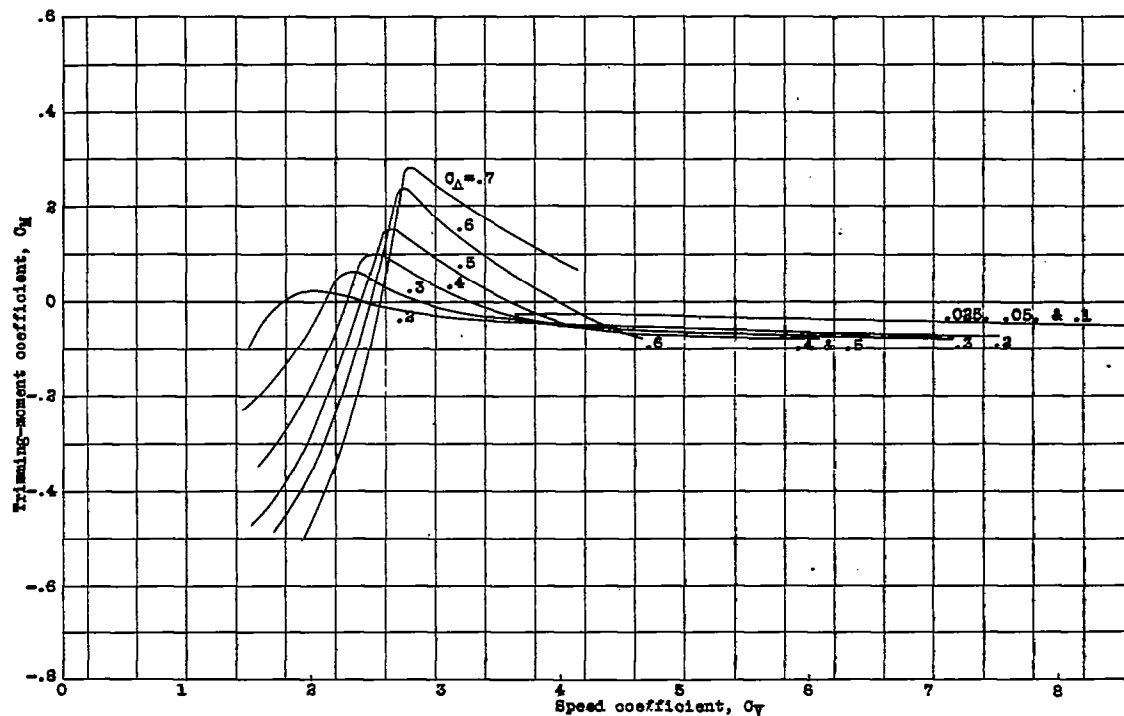
Figure 13.- Model 18. Variation of trimming-moment coefficient at best trim with speed coefficient.
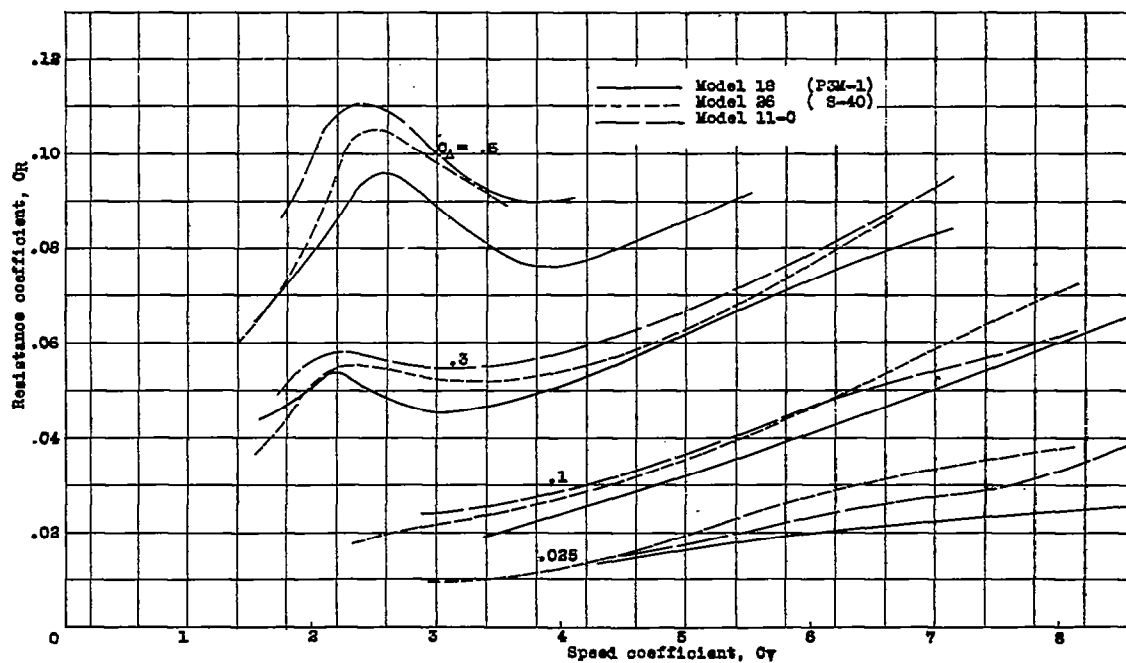
Figure 15.- Comparison of resistance coefficients at best trim of models 18, 26, and 11-C.
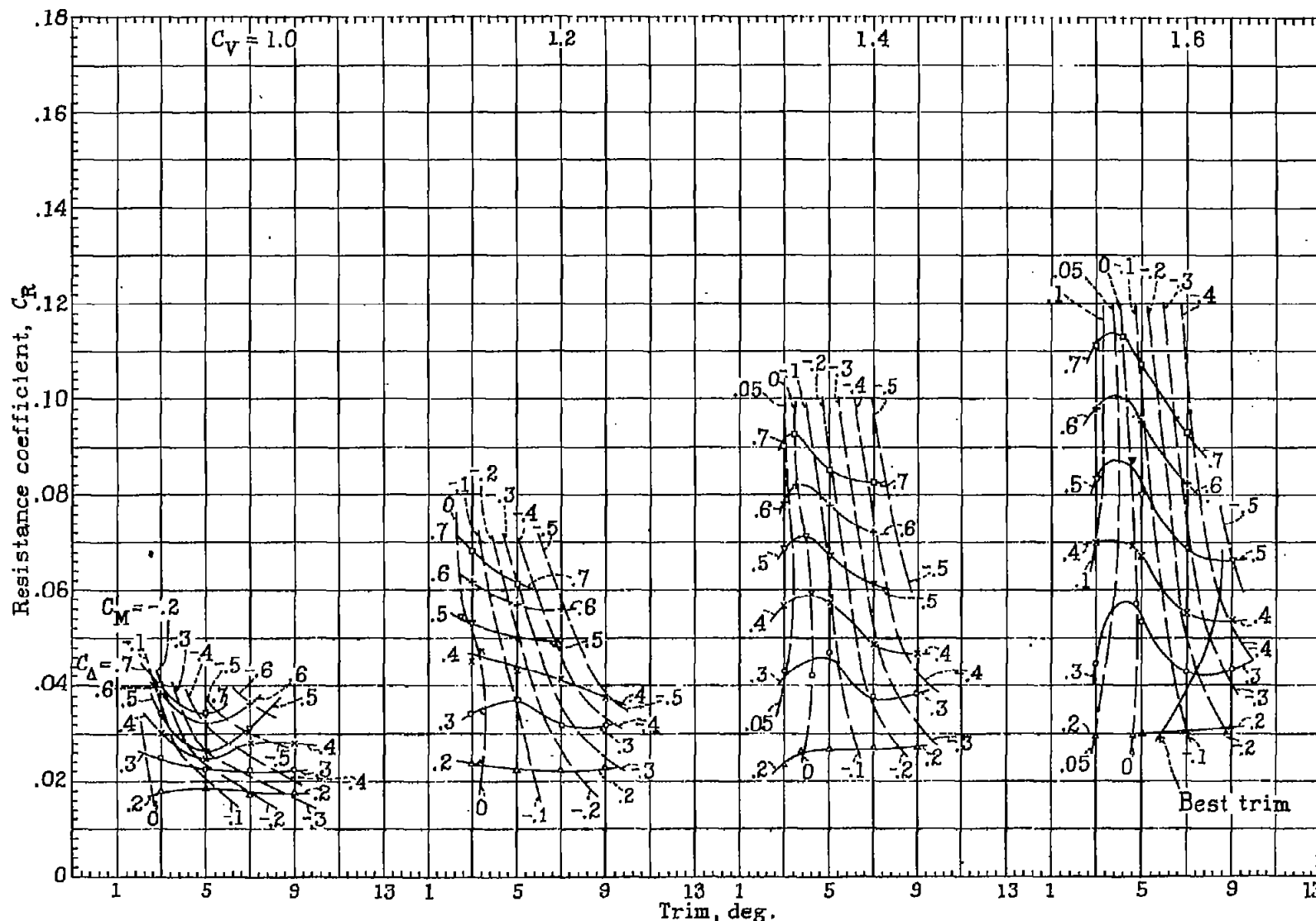
Figure 14a.– Model 18. Working charts for the determination of resistance and trimming moment.
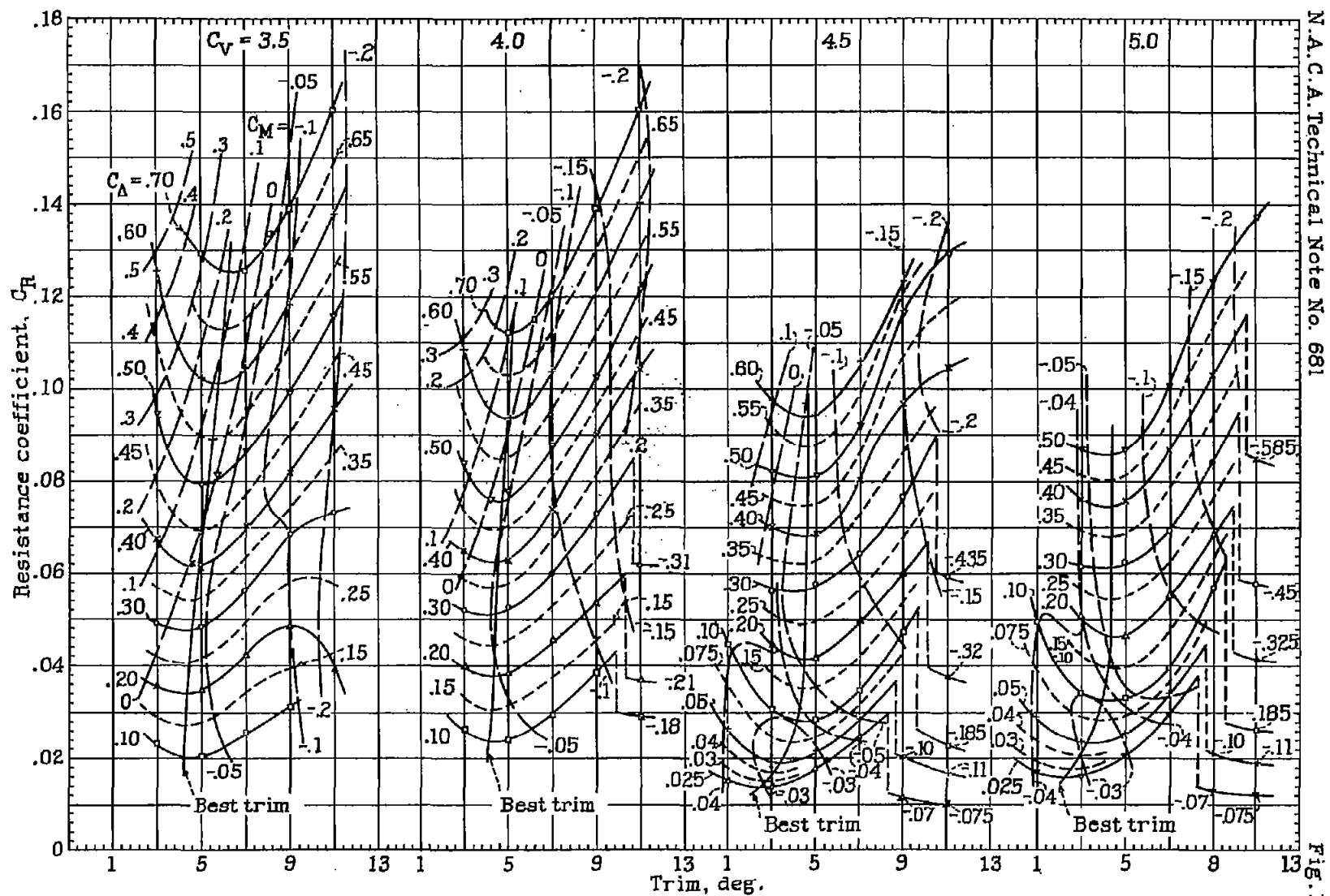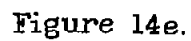
Figure 14b.

Figure 14c.

Figure 14d.

Figure 14e.

Figure 14f.