TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 264

TESTS OF THE N.P.L. AIRSHIP MODELS IN THE VARIABLE DENSITY WIND TUNNEL

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Summary

Tests have been conducted in the variable density wind tunnel of the National Advisory Committee for Aeronautics, on two airship models, known as the "N.P.L. Standardization Models, Long and Short." The resistance or shape coefficients were determined for each model through a range of Reynolds Numbers from 110,000 to 5,000,000. Comparison is made with previous tests on these models and other airship models.

Introduction

During the years of 1922 and 1923, comparative tests were made on two N.P.L. airship models in six American atmospheric wind tunnels to determine their resistance with particular reference to scale effect. These tests were made for the purpose of determining some idea of the "standardization of wind tunnels." The models used were developed and furnished by the British Aeronautical Research Committee.

It was desired that further tests on these models be made and, as the models had been returned to England, replicas were made at the Washington Navy Yard by the wind tunnel division of the Bureau of Construction and Repair. It was of particular importance that a greater "scale" or Reynolds Number be reached; simplicity in the method of support for the models was also recommended for the further tests.

The Navy replicas of the N.P.L. airship models were therefore forwarded to the Langley Memorial Aeronautical Laboratory for testing in the variable density wind tunnel where a Reynolds Number fifteen times that of the original tests could be obtained. The actual tests in the variable density tunnel were not performed until June, 1927.

These consisted of determining the resistance at the angle of zero pitch for both models through a range of Reynolds Numbers from 110,000 to 5,000,000.

Apparatus and Method of Test

The airship models used in these tests were cast of aluminum and turned in a lathe to specified ordinates measured on the original N.P.L. models. The model, designated as "long," is a 1/225 size replica of the "H.M.A.-R 33." The second model, designated as "short," is similar to the first in the shape of the nose and tail, but 1.5 diameters or 6.3 inches shorter in the cylindrical mid-portion. The actual dimensions of the two models are given in Table I. Here, also, is given the volume as determined by Simpson's rule and used in the computations. Photographs of the models are given in Figure 1.

The models were mounted in the test section of the variable density wind tunnel (Reference 1) in the manner shown in Figure 2. The suspension consisted of streamlined wires .025 inch by .094 inch in cross section. Two wires were screwed into the model 4 inches aft of the nose 90° apart and making 45° to the vertical. The outer ends of these wires were attached through small knife edges to the tunnel walls. Streamlined fairings covered the outer 16 inches and protected that portion of the suspension from the air stream. A single wire at the tail fastened by a pivot to a short 2-inch sting supported the rear of the models in a similar manner as the nose. A round wire, 0.043 inch in diameter, attached to a plug screwed in at the nose, transmitted the drag forces through a bell crank to the auxiliary drag balance (for use where resistance only is to be measured (Figure 3)). A similar round wire attached to the tail sting led through a bell crank to a counterweight. This served the purpose of keeping the system taut and maintaining a slight initial load on the balance. The lengths of these horizontal wires were adjusted by small turnbuckles at the ends away from the model so the model might assume its own position, thus eliminating any error due to a component of its weight exerting a force on the balance.

Each model was tested at a velocity of about 50 miles an hour and at densities ranging from that equivalent to 1/2 atmosphere to 20 atmospheres pressure, absolute. Using the $(\text{volume})^{1/3}$ as a characteristic length, the range in Reynolds Number covered was from 110,000 to 5,000,000. Readings of the resistance were obtained at six densities.

Results and Discussion

The results of the tests on these two airship models are given in Table II, and are plotted in Figures 4 and 5. Resistance or shape coefficients have been computed and plotted against Reynolds Number, where

$$D = C_S \, q \, (\text{Vol.})^{2/3}$$

$$\text{R.N.} = \frac{\rho V}{\mu} (\text{Vol.})^{1/3}$$

D = drag

q = dynamic pressure, $\frac{1}{2} \rho V^2$

R.N. = Reynolds Number

Vol. = volume of airship model

ρ = density of air

V = velocity of air

μ = viscosity of air

Figure 4 shows the values of C_S for the two models with reference to the change in R.N. In each case, the curve of C_S is regular, decreasing in value as the "scale" is increased and apparently approaching a minimum at the upper limit of the range tested. The 20-atmosphere run on the long model was irregular and the value of the C_S is too high. This is due to insufficient counterweight on the suspension system, which allowed the model to become unsteady and to oscillate. The value of the Reynolds Number of the "H.M.A.-R 33" cruising at 50 miles an hour is 60,500,000. Even though the scale reached is 1/10 that of full scale, these curves indicate that extrapolation to determine a full-scale value of C_S is perhaps unreliable.

In this same chart there are shown the C_S curves obtained for the N.P.L. originals of these same models in tests made at six American atmospheric wind tunnels. The range of R.N. covered by these tests is only about 1/15 that of the variable density tunnel. The curves are very widely scattered, particularly at the lower R.N. There is a decided tendency to converge as the scale is increased, approaching values of the same magnitude as obtained in the variable density tunnel.

The results from the Washington Navy Yard agree the best with those from the present tests; both are high compared to the average and it is possible that this is due to the relatively high degree of turbulence present in both wind tunnels.

The method of support used in the present tests was such that the tare drag amounted to about 45 per cent of the net drag and that interference to the model was small (see Fig. 2).

In Figure 5 there is shown a chart of C_S versus $\frac{\text{length}}{\text{diameter}}$

ratio, where a curve has been plotted representing the results of tests on other airships in the variable density tunnel at a Reynolds Number corresponding to 20 atmospheres. The values of C_S for the N.P.L. models are shown as points. The agreement is very good.

Conclusion

The shape or resistance coefficient of the N.P.L. airship models, as tested in the variable density wind tunnel, decreases in value as the scale or Reynolds Number is increased, tending to approach a minimum as the upper limit of the test range is reached. The results of these tests in comparison with tests at low scale in other wind tunnels show that further work is necessary in the standardization of wind tunnels. The values of resistance for these models are in accordance with other airship models tested in this wind tunnel.

Reference

1. Munk, Max M. and Miller, E. W. : The Variable Density Wind Tunnel of the National Advisory Committee for Aeronautics. N.A.C.A. Technical Report No. 227. (1926)

TABLE I.

Dimensions of N.P.L. Airship Models
in Inches.

Long Model				Short Model			
Sta.	Diam.	Sta.	Diam.	Sta.	Diam.	Sta.	Diam.
0.0	.000	15.0	4.200	0.0	.000	13.0	4.158
.5	1.320	16.0	4.199	.5	1.294	14.0	4.101
1.0	1.866	17.0	4.198	1.0	1.849	15.0	4.010
1.5	2.266	18.0	4.194	1.5	2.266	16.0	3.889
2.0	2.577	19.0	4.173	2.0	2.580	17.0	3.724
2.5	2.846	20.0	4.128	2.5	2.847	18.0	3.532
3.0	3.074	21.0	4.047	3.0	3.073	19.0	3.326
3.5	3.223	22.0	3.931	3.5	3.268	20.0	3.098
4.0	3.438	23.0	3.777	4.0	3.439	21.0	2.845
4.5	3.586	24.0	3.602	4.5	3.585	22.0	2.554
5.0	3.714	25.0	3.396	5.0	3.711	23.0	2.236
6.0	3.919	26.0	3.169	6.0	3.916	24.0	1.883
7.0	4.066	27.0	2.927	7.0	4.059	25.0	1.502
8.0	4.149	28.0	2.667	8.0	4.150	26.0	1.068
9.0	4.188	29.0	2.363	9.0	4.188	27.0	.592
10.0	4.200	30.0	2.013	10.0	4.196	27.953	.000
11.0	4.200	31.0	1.638	11.0	4.195		
12.0	4.2005	32.0	1.222	12.0	4.184		
13.0	4.2005	33.0	.752				
14.0	4.201	34.0	.217				
		34.280	.000				

Long model:

Total length = 34.280 in.

Vol. = .00535 m^3

$(\text{Vol.})^{2/3}$ = .0360 m^2

$(\text{Vol.})^{1/3}$ = .1748 m

Short model:

Total length = 27.953 in.

Vol. = .00391 m^3

$(\text{Vol.})^{2/3}$ = .02485 m^2

$(\text{Vol.})^{1/3}$ = .1577 m

TABLE II.

Resistance or Shape Coefficients.

$$C_S = \frac{\text{Drag}}{q\ (\text{Vol.})^{2/3}}$$

Long Model		Short Model	
R.N.	C_S	R.N.	C_S
118,000	.0372	108,500	.0341
118,000	.0368	108,500	.0341
254,000	.0346	228,000	.0327
254,000	.0348	228,000	.0328
254,000	.0350	545,000	.0290
254,000	.0349	545,000	.0292
610,000	.0294	1,175,000	.0257
610,000	.0294	1,175,000	.0257
1,285,000	.0260	2,320,000	.0231
1,285,000	.0261	2,320,000	.0230
2,570,000	.0233	4,550,000	.0209
2,570,000	.0233	4,550,000	.0213
5,050,000	.0236	4,550,000	.0213
5,050,000	.0238		

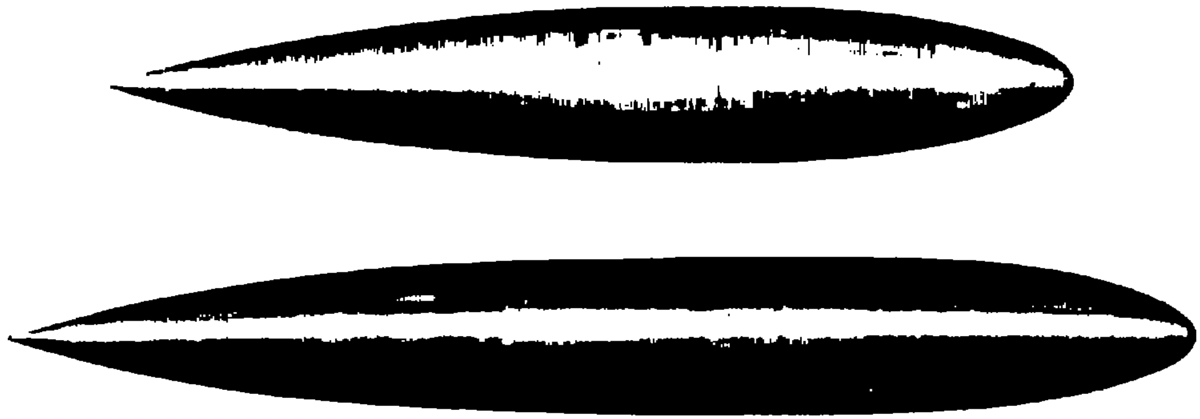

Fig.1 N.P.L. Standard airship models. U.S.N. replicas

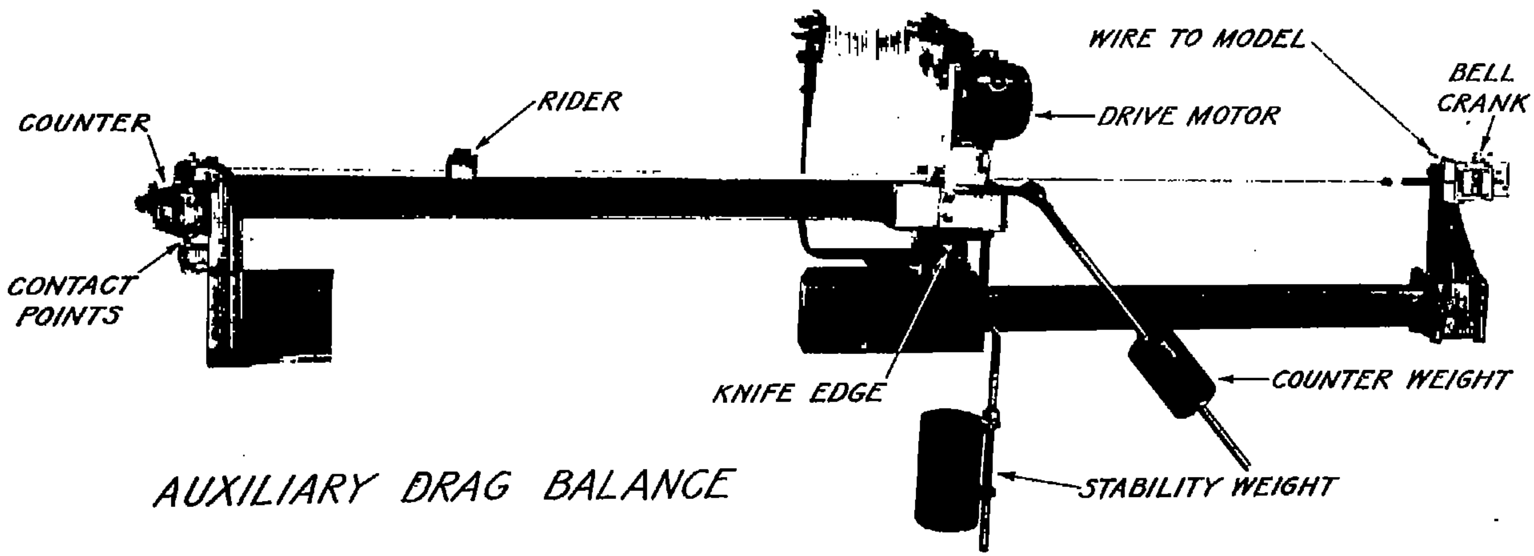

Fig.3 Auxiliary drag balance. Variable density tunnel.

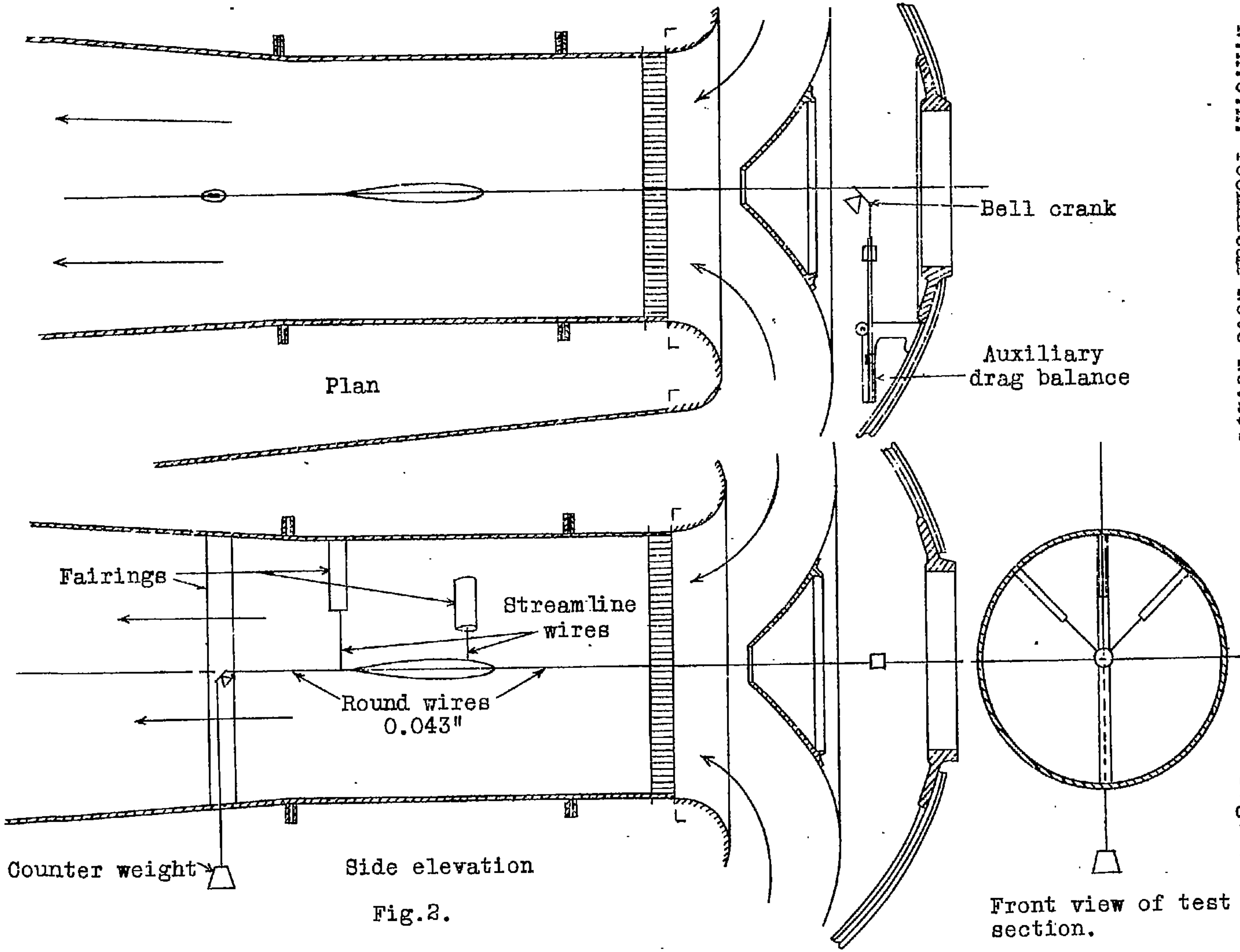
Bell crank
Auxiliary
drag balance
Plan
Fairings
Streamline
wires
Round wires
0.043"
Counter weight
Side elevation
Front view of test
section.

Fig.2.

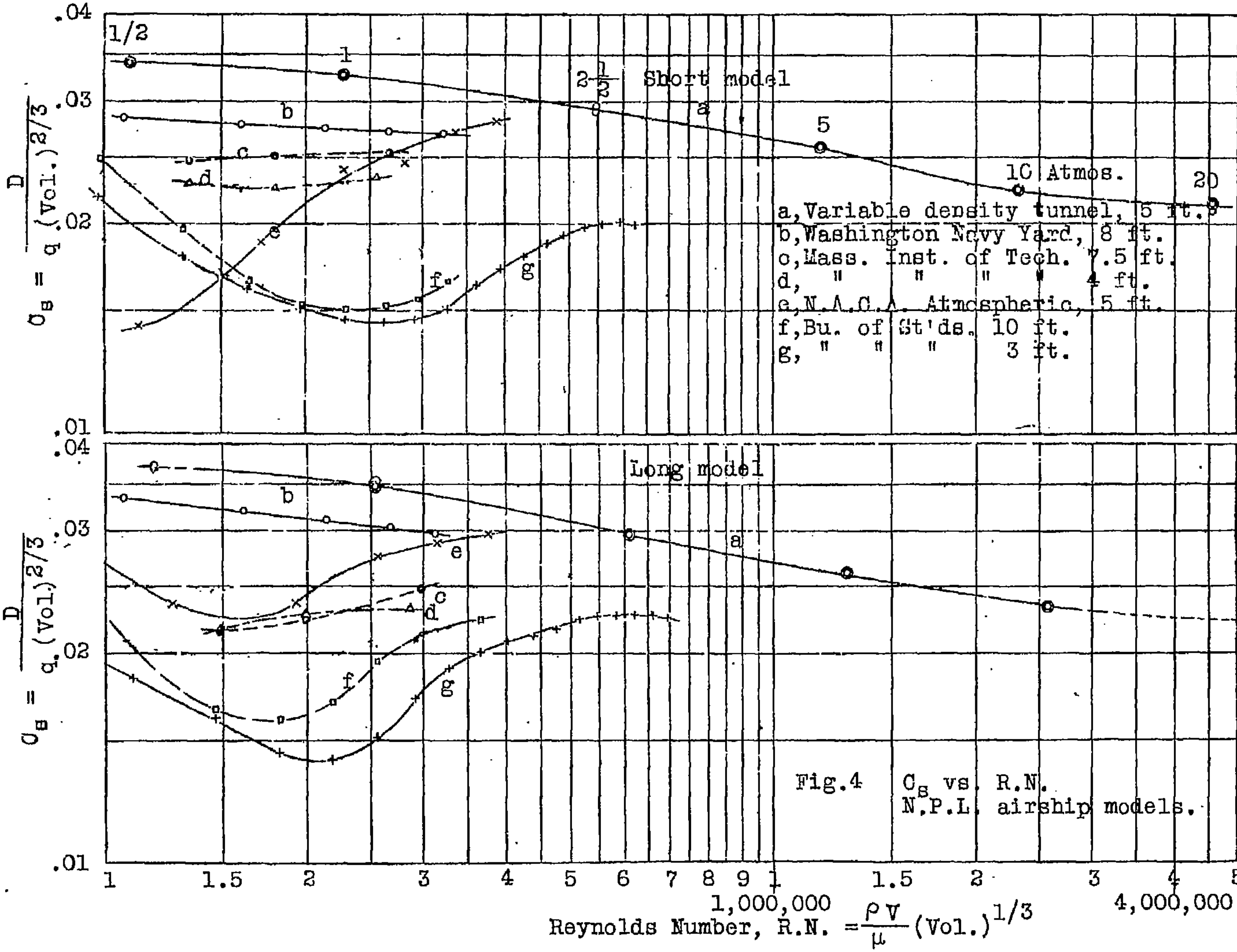

Fig.4 C_s vs. R.N.
N.P.L. airship models.

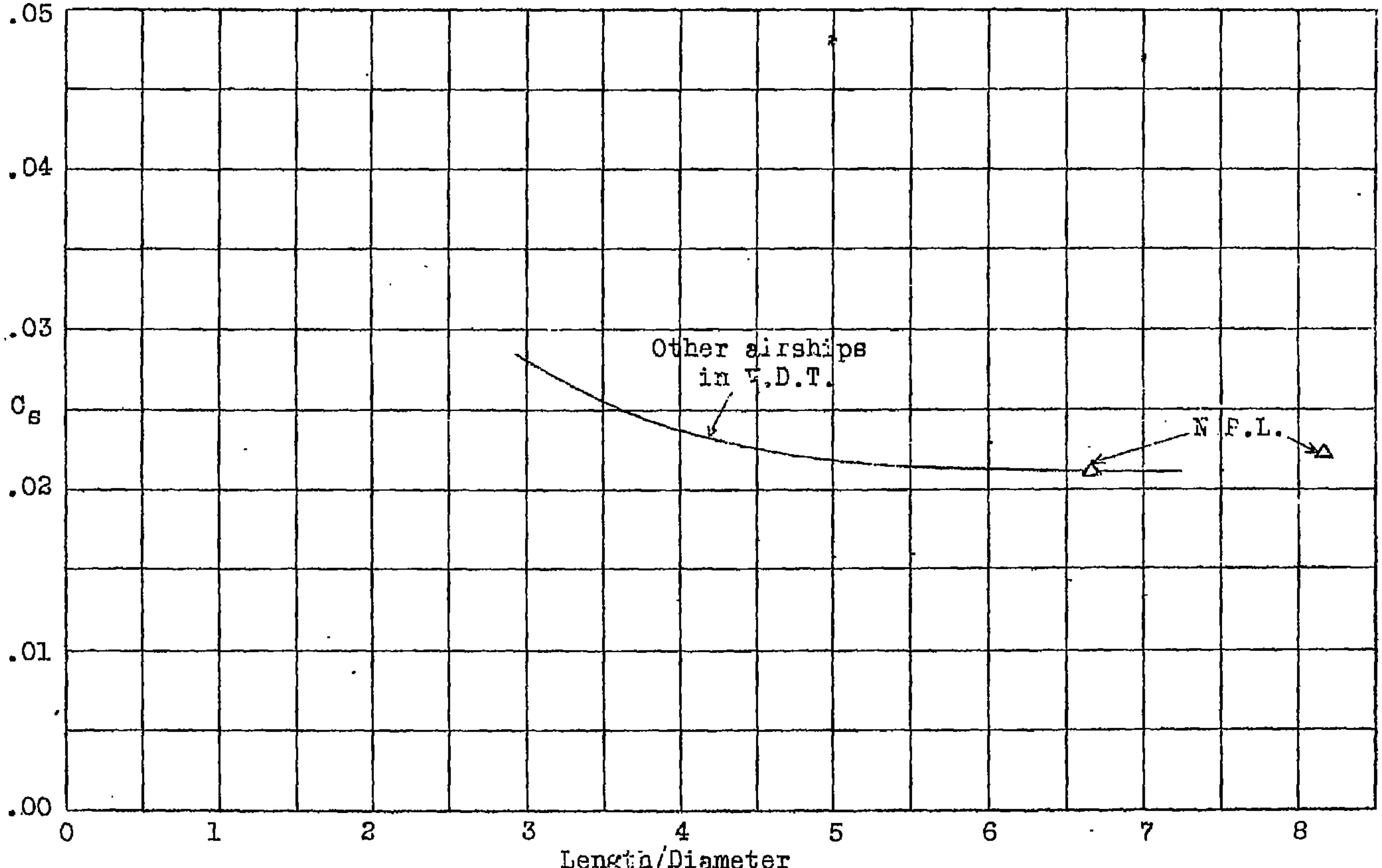

Fig.5 C_s vs. Length/Diameter. N.P.L. airship models.