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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 449

RESULTS OF AERODYNAMIC TESTS ON SLOTTED AIRFOILS IN THE AEROTECHNICAL LABORATORY (S.T.Aé.) OF RHODE ST. GENESE, BRUSSELS

From Bulletins Nos. 1 & 4, April and July, 1927
of the "Service Technique de L'Aérotechnique Belge"

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM NO. 449.

RESULTS OF AERODYNAMIC TESTS ON SLOTTED AIRFOILS IN THE AEROTECHNICAL LABORATORY (S.T.Aé.) OF RHODE ST. GENESE, BRUSSELS.

By Paul Puvrez.

A.- On a Series of Slotted Airfoils (40 A - 40 G) Derived from a Symmetrical Airfoil (No. 40).*

The phenomenon of the increase in the maximum lift of a wing, obtained by providing the wing with a slot of suitable form, is now well known. The great drag of such wings, however, constitutes the chief obstacle to their use. We have investigated the maximum lift obtainable with slotted airfoils derived from a symmetrical airfoil. These should have a smaller profile drag than other slotted airfoils. Moreover, with a symmetrical profile having a fixed center of lift, it is interesting to see whether the derived slotted airfoil has the same properties.

The tests, which gave the following numerical results, show that:

1. When the two parts of the airfoil are placed adjacent, there remains a narrow slot between them which, although very small, acts in the same sense as a slot of finite width;

*From Bulletins Nos. 1 and 4, April and July, 1927, of the "Service Technique de L'Aérotechnique Belge."

2. The maximum lift approaches $C_L = 1.30$;

3. The minimum drag of each profile of the series is still quite large (.015-.03);

4. The center of lift travels contrary to the usual direction (i.e., toward the rear), as the angle of attack is increased. This phenomenon seems strange at first thought. It agrees, however, with the slotted airfoil tests made at Göttingen (See Report II of "Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen"). It can be demonstrated that the C_M curves are nearer the C_L axis for slotted airfoils than for the ordinary airfoils from which they were derived. If we start with a symmetrical profile, it is natural for the C_M curve to cross the C_L axis in its positive portion;

5. The increase in C_D for $C_L = 0$, starting from said position of the closed slot, is practically proportional to the width of the slot;

6. The increase in the maximum C_L is greater when we pass from a zero slot to a 2 mm (0.08 in.) slot, than when the width of the slot is still further increased. The increase in C_L thus diminishes as the slot is widened. The maximum C_L of the last three tests, slots of 15, 20, and 25 mm (0.59, 0.79, and 0.98 in.), are very near (respectively 1.2718, 1.2706, and 1.2894). This shows that it would be of interest to test a biconvex dissymmetrical airfoil, which would keep one C_D for $C_L = 0$ of the same order of magnitude, would increase C_L max-

imum and would have a fixed center of lift (See Section B, which follows).

Remark.- The model tested had a span of 1 m (39.37 in.) and a chord of 0.2 m (7.87 in.), when the slot was closed. It was, moreover, by the purely conventional area of 0.2 m² (2.15 sq.ft.), that the stresses for all the wings were divided, in order to obtain the nondimensional coefficients C_D, C_L and C_M. Similarly, all the C_M were calculated for a fictitious chord of 0.2 m (7.87 in.). The angles of attack α, were measured, as indicated on the diagrams, at the leading edge of the airfoils (See Figures 1, 2, and 3).

B.- On a Series of Slotted Airfoils (43 A-43 E) Derived from a Dissymmetrical Airfoil (No. 43).*

No. 1 of "Results of Aerodynamic Tests" shows that an airfoil with a slot of variable width, manifests, as the width of the slot is increased:

a) An increase in C_L maximum;

b) A diminution of C_M such that a symmetrical airfoil becomes stable.

For the purpose of discovering whether these conclusions apply to other profiles, it is important to plot the polars of a series of airfoils derived from a dissymmetrical profile.

*"Laboratoire Aerotechnique de Rhode St. Genese," July, 1927.

The results are represented by the accompanying curves, which show that:

1. The center of lift remains nearly fixed, the airfoil still being stable at normal regimes;

2. The maximum lift attains $C_L = 1.45$, the slot then having a width of 25 mm (0.98 in.) (airfoil No. 43 E);

3. The minimum drag and the profile drag are always only a little above those obtained with the symmetrical airfoil No. 40 (See No. 1 of "Results of Aerodynamic Tests");

4. The effect of the restricted space left, on applying the two parts of the airfoil to one another, is manifest, as in the case of airfoil No. 40;

5. Again, as for airfoil No. 40, the increase from C_D to $C_L = 0$ is practically proportional to the width of the slot;

6. The increase in C_L max is greatest when the slot has a width of 2-5 mm (0.08-0.2 in.). It is still appreciable when the width of the slot is between 15 and 25 mm (0.59 and 0.98 in.).

Remarks.- The slot is produced by the displacement of the rear part parallel to a tangent to the upper camber at the junction of the two parts, its width being measured along this tangent.

The tested model has a span of 1 m (39.37 in.) and a chord of 0.2 m (7.87 in.), when the slot is 2 mm (0.08 in.). The stresses of all the airfoils were divided by an area of 0.2 m² (2.15 sq.ft.), in order to obtain the coefficients C_D, C_L, and C_M.

In the same way, the values of C_M were all calculated for a fictitious chord of 0.2 m (7.87 in.).

The angles of attack α, were measured, as shown on the diagrams, by the relation to a direction indicated at the leading edge of the profiles (See Figures 4, 5, and 6).

Airfoil 40-A Slot closed Chord 200 mm				Airfoil 40-B 2 mm slot Chord 202 mm			
Angles	C_L	C_D	C_M	Angles	C_L	C_D	C_M
- 2.1	-.2281	.0206	-	- 0.1	-.1121	.0185	-.0432
- 0.1	-.0882	.0166	-.0394	2.0	+.0286	.0182	-.0123
2.0	+.0570	.0155	-.0012	4.2	.1822	.0194	.0208
4.1	.1919	.0173	.0286	6.2	.3160	.0243	.0480
6.2	.3390	.0221	.0659	8.2	.4504	.0317	.0800
8.2	.4798	.0316	.1000	10.3	.5957	.0434	.1176
10.3	.6168	.0432	.1325	12.2	.7370	.0562	.1549
12.4	.7726	.0687	.1708	14.4	.9030	.0758	.2005
14.4	.9024	.0783	.2180	16.5	1.0534	.0968	.2455
16.5	1.0018	.1000	.2342	18.5	1.1790	.1252	.2845
18.5	1.0466	.1534	.2867				

Airfoil 40-C 5 mm slot Chord 205.3 mm				Airfoil 40-D 10 mm slot Chord 210.6 mm			
Angles	C_L	C_D	C_M	Angles	C_L	C_D	C_M
- 0.1	-.1393	.0187	-	- 0.1	-.1019	.0221	-
+ 2.0	.0013	.0194	-.0211	2.0	+.0013	.0229	-.0299
4.1	.1431	.0208	+.0093	4.2	.1268	.0236	+.0005
6.2	.2788	.0243	.0415	6.2	.2670	.0269	.0440
8.2	.4306	.0311	.0795	8.2	.4203	.0331	.0851
10.1	.5710	.0422	.1146	10.3	.0577	.0445	.1301
12.4	.7438	.0580	.1600	12.4	.7435	.0586	.1744
14.4	.8906	.0754	.2031	14.4	.8950	.0762	.2173
16.5	1.0440	.0971	.2423	16.5	1.0542	.0981	.2629
18.6	1.2041	.1242	.2900	18.6	1.2396	.1233	.3035
20.5	1.1780	.1768	-	20.6	1.2354	.1600	-

Airfoil 40-E 15 mm slot Chord 216 mm				Airfoil 40-F 20 mm slot Chord 221 mm			
Angles	C_L	C_D	C_M	Angles	C_L	C_D	C_M
– 0.1	–.1633	.0243	–.0645	– 0.1	–.1892	.0278	–.0642
2.0	–.0428	.0254	–.0285	2.0	–.0508	.0292	–.0329
4.1	+.0929	.0274	+.0010	4.1	+.0886	.0306	.0061
6.2	.2457	.0285	.0410	6.2	.2429	.0317	.0435
8.2	.3946	.0351	.0812	8.2	.3803	.0370	.0241
10.3	.5403	.0418	.1216	10.3	.5374	.0452	.1308
12.4	.7181	.0572	.1749	12.4	.6996	.0582	.1775
14.4	.8749	.0756	.2228	14.4	.8648	.0746	.2258
16.5	1.0348	.0958	.2773	16.5	1.0274	.0948	.2789
18.5	1.1968	.1225	.3279	18.5	1.1968	.1225	.3340
20.6	1.2718	.1780	.3935	20.6	1.2706	.1755	.3960

Airfoil 40-G
25 mm slot
Chord 226.5 mm

Angles	C_L	C_D	C_M	Angles	C_L	C_D	C_M
– 0.1	=.1779	.0298	–.0567	12.4	.7058	.0604	.2010
2.0	–.0479	.0315	–.0279	14.4	.8772	.0773	.2475
4.1	.1000	.0330	+.0065	16.5	1.0418	.0979	.3009
6.2	.2420	.0349	.0480	18.5	1.1946	.1246	.3520
8.2	.3859	.0389	.0979	20.6	1.2894	.1667	.4060
10.3	.5440	.0479	.1465				

Airfoil 43-A Slot closed Chord 198 mm				Airfoil 43-B 2 mm slot Chord 200 mm			
Angles	C_L	C_D	C_M	Angles	C_L	C_D	C_M
− 2.0	−.0222	.0146	−.0070	− 2.0	−.0743	.0165	−.0280
− 0.1	.0827	.0145	+.0190	− 0.1	+.0437	.0158	+.0005
+ 1.9	.2098	.0156	.0525	1.9	.1530	.0175	.0280
3.9	.3323	.0199	.0790	3.9	.2944	.0214	.0660
5.9	.4784	.0277	.1130	5.9	.4274	.0285	.1010
7.9	.6394	.0405	.1510	7.9	.5893	.0392	.1380
9.9	.7774	.0541	.1840	9.9	.7400	.0532	.1770
11.9	.9131	.0694	.2150	11.9	.8831	.0682	.2200
13.7	1.0047	.0861	.2340	13.7	1.0162	.0869	.2420
16.0	1.0844	.1098	.2525	16.0	1.1431	.1089	.2720
18.0	1.0808	.1410	.2640	18.0	1.1667	.1341	.2870

Airfoil 43-C 5 mm slot Chord 202 mm				Airfoil 43-D 15 mm slot Chord 210 mm			
Angles	C_L	C_D	C_M	Angles	C_L	C_D	C_M
- 2.0	-.0857	.0179	-.0310	- 2.0	-.1263	.0230	-.0440
- 0.1	.0398	.0169	+.0040	- 0.1	+.0026	.0228	-.0080
1.9	.1727	.0192	.0380	1.9	.1312	.0239	+.0280
3.9	.3177	.0243	.0790	3.9	.2773	.0272	.0750
5.9	.4695	.0329	.1210	5.9	.4282	.0337	.1220
7.9	.6108	.0436	.1640	7.9	.6100	.0438	.1760
9.9	.7716	.0585	.2020	9.9	.7613	.0574	.2220
11.9	.9104	.0735	.2390	11.9	.9111	.0738	.2620
13.7	1.0410	.0909	.2680	13.7	1.0525	.0939	.2980
16.0	1.1858	.1158	.3010	16.0	1.1966	.1196	.3310
18.0	1.2305	.1419	.3170	18.0	1.3102	.1474	.3640
				20.1	1.3940	.1757	.3850
				21.1	1.4040	.1936	.3930

Airfoil 43-E
25 mm slot
Chord 221 mm

A

Angles	C_L	C_D	C_M
- 2.0	-.1652	.0316	-
- 0.1	-.0259	.0308	-.0190
+ 1.9	+.1067	.0302	+.0320
3.9	.2417	.0324	.0765
5.9	.4036	.0380	.1230
7.9	.5552	.0450	.1730
9.9	.7174	.0561	.2190
11.9	.8668	.0711	.2760
13.9	1.0116	.0893	.3130
16.0	1.1440	.1128	.3550
18.0	1.2899	.1427	.3960
20.1	1.4038	.1708	.4200
21.1	1.4517	.1910	.4420

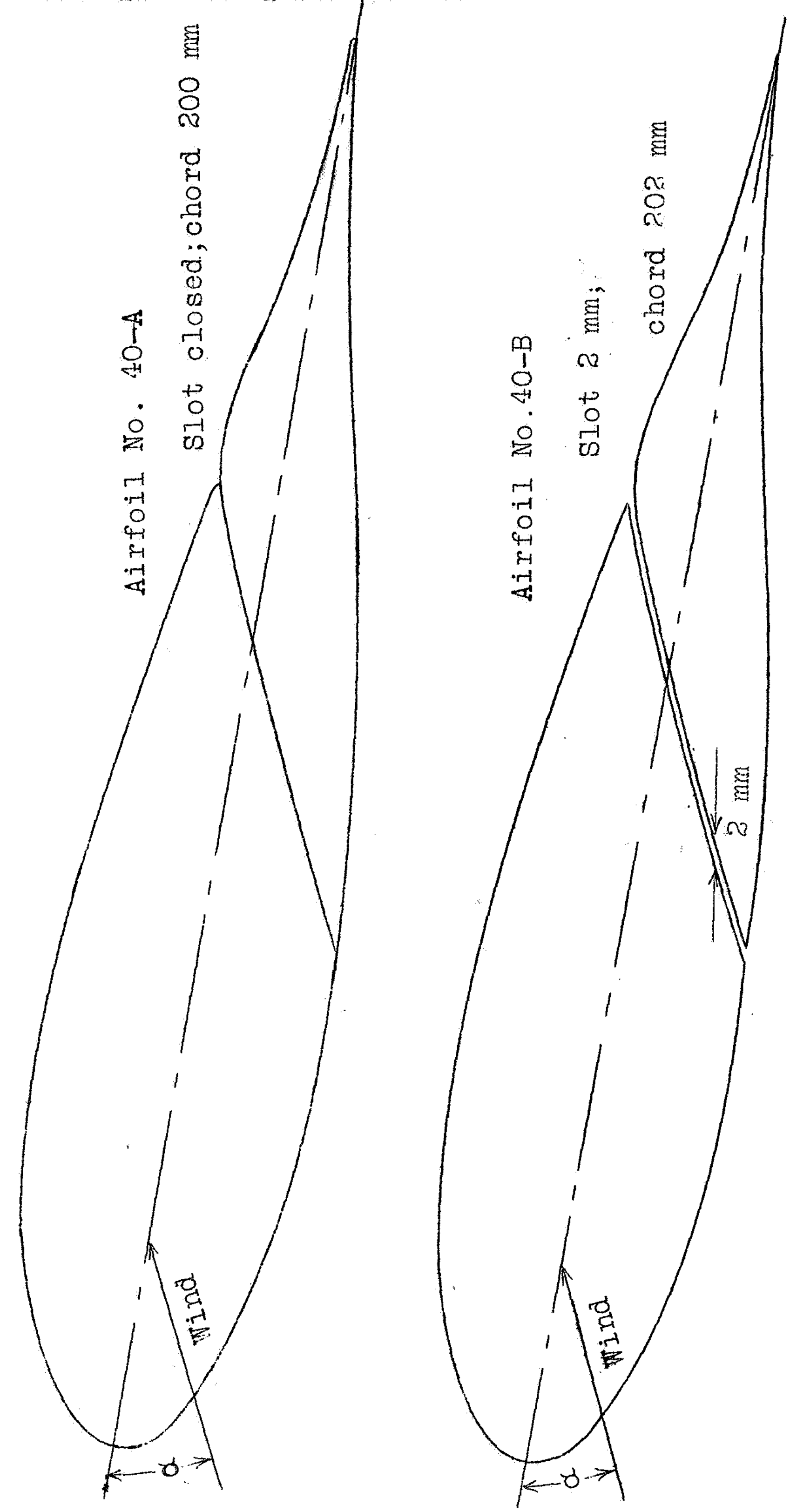

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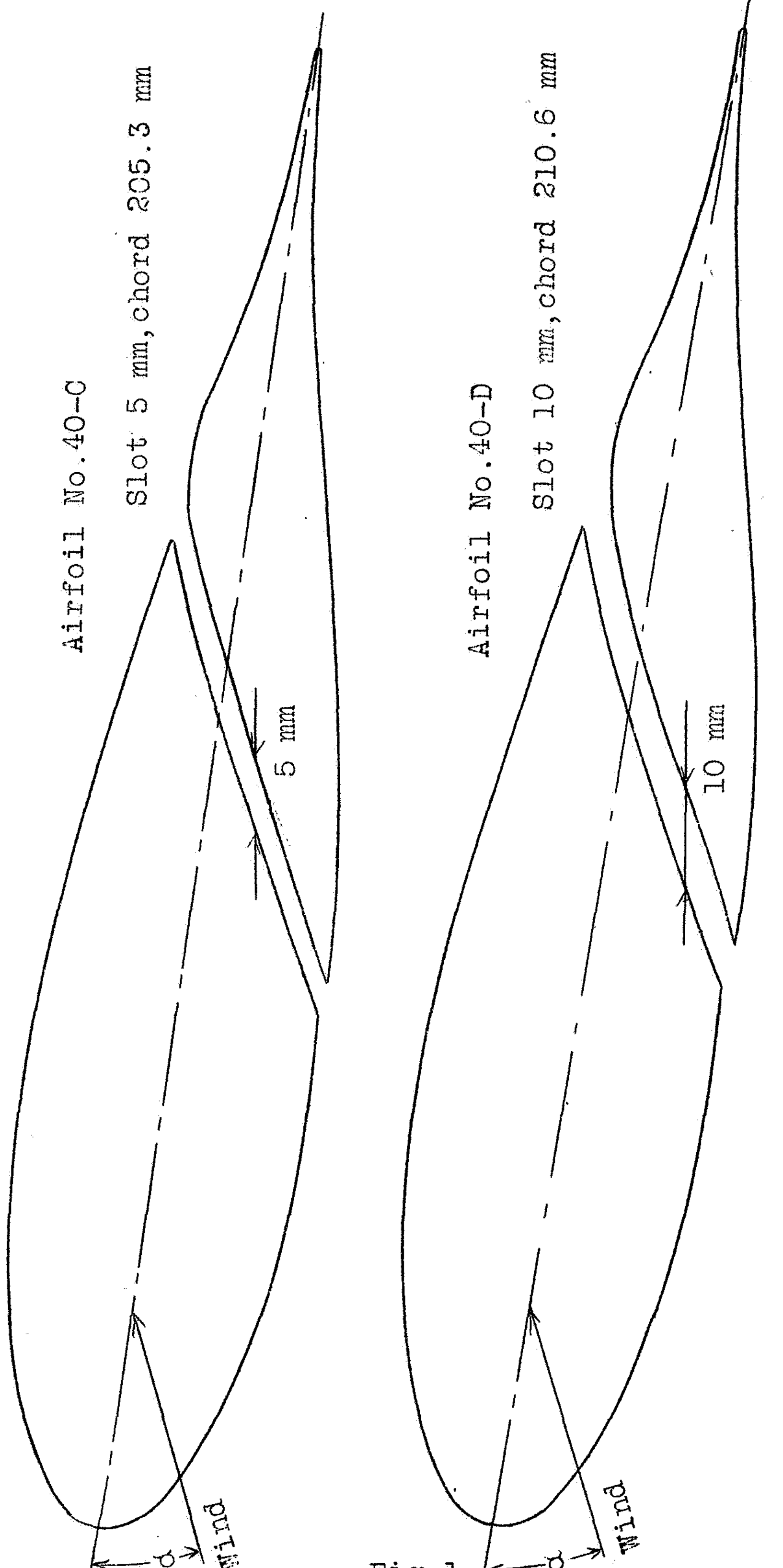
Fig.1



Continuation of Fig. 1

Fig.1
(Continuation)

Fig.1
(Continuation)

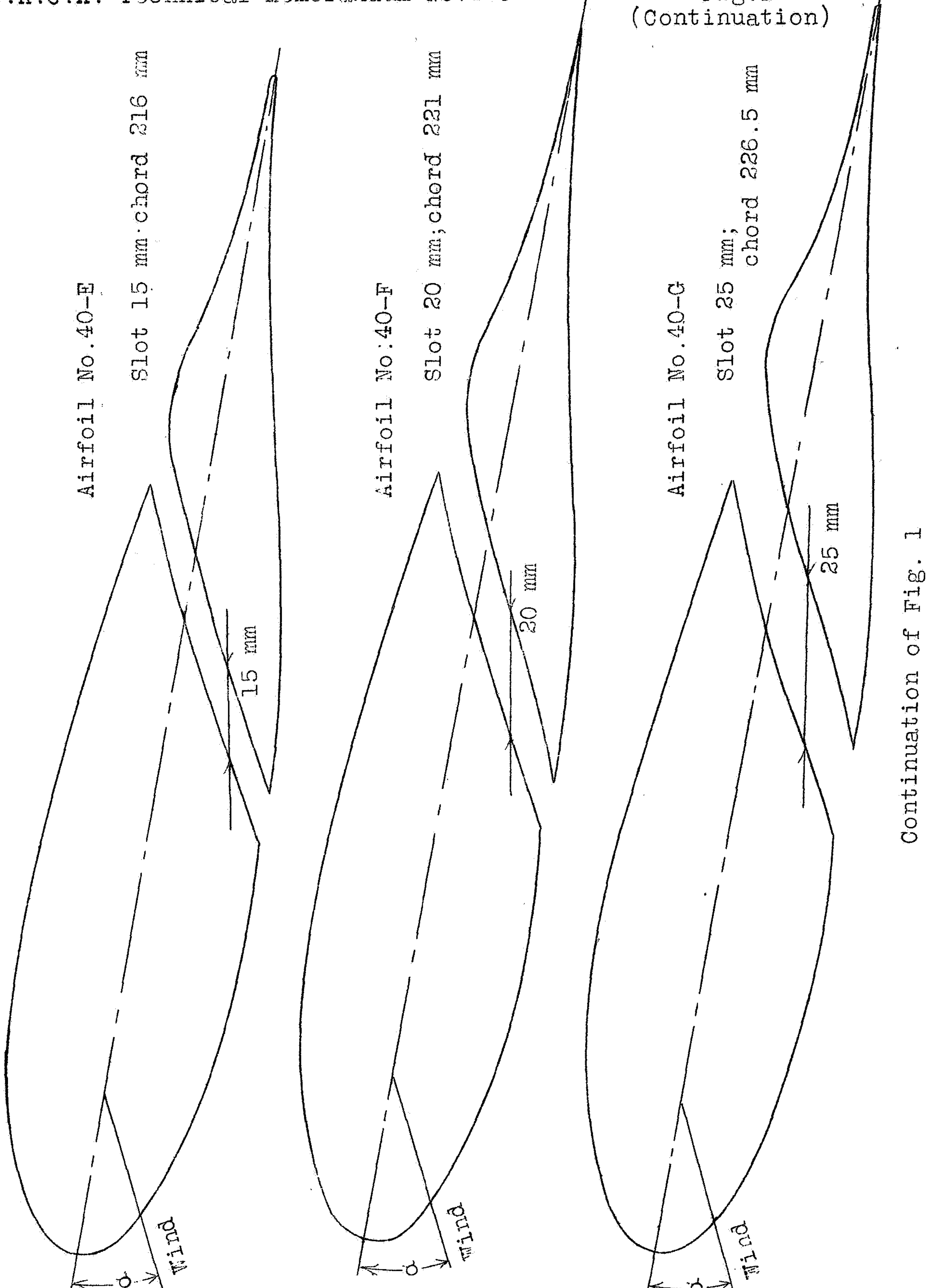
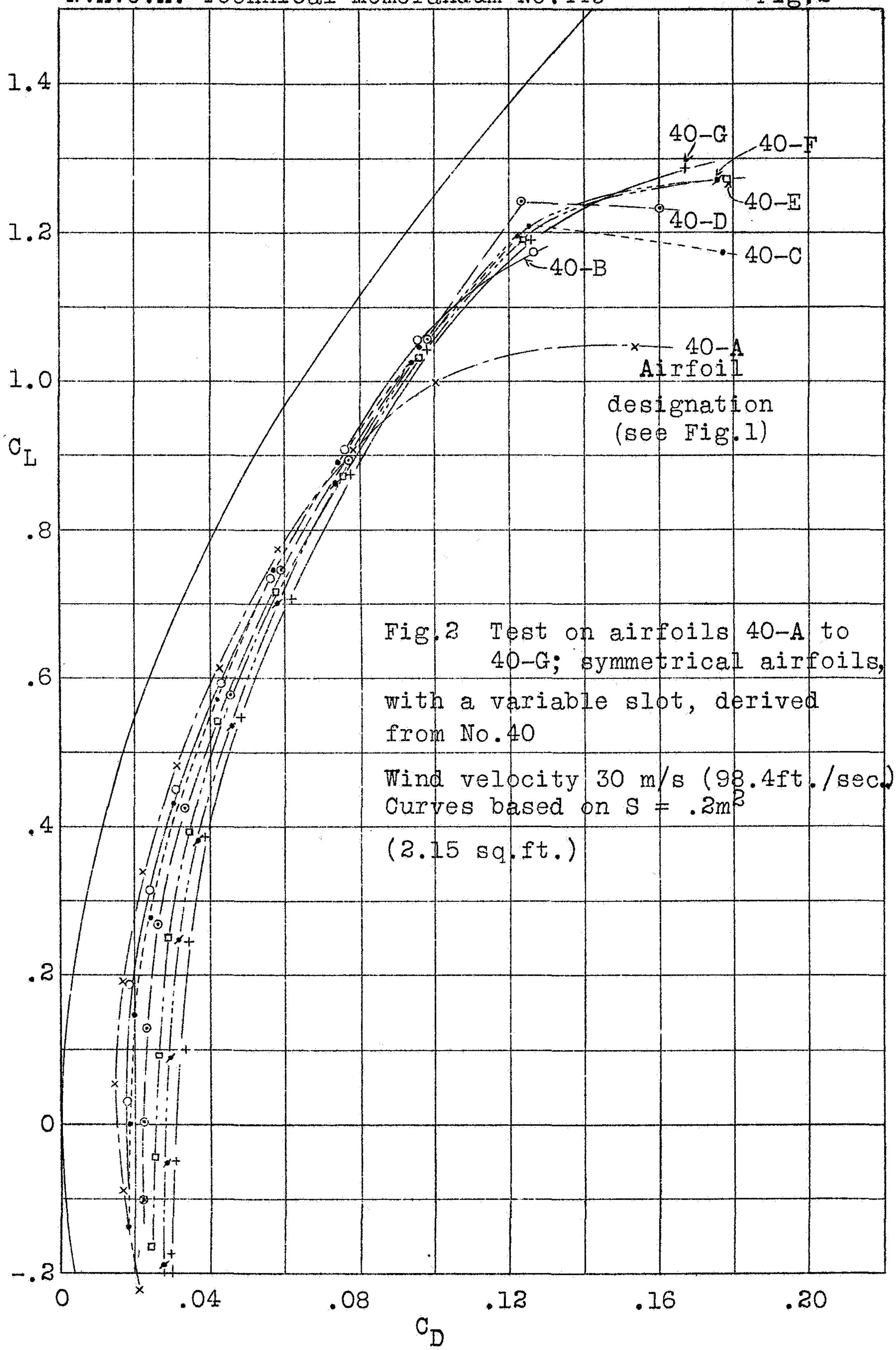


Fig.1
(Continuation)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1.2
1.0
.8
.6
.4
.2
0
-.2
C_L
0
.04
.08
.12
.16
.20
C_D
40-G
40-F
40-E
40-D
40-C
40-B
40-A
Airfoil designation (see Fig.1)
Fig.2 Test on airfoils 40-A to 40-G; symmetrical airfoils, with a variable slot, derived from No.40
Wind velocity 30 m/s (98.4ft./sec.)
Curves based on S = .2m²
(2.15 sq.ft.)

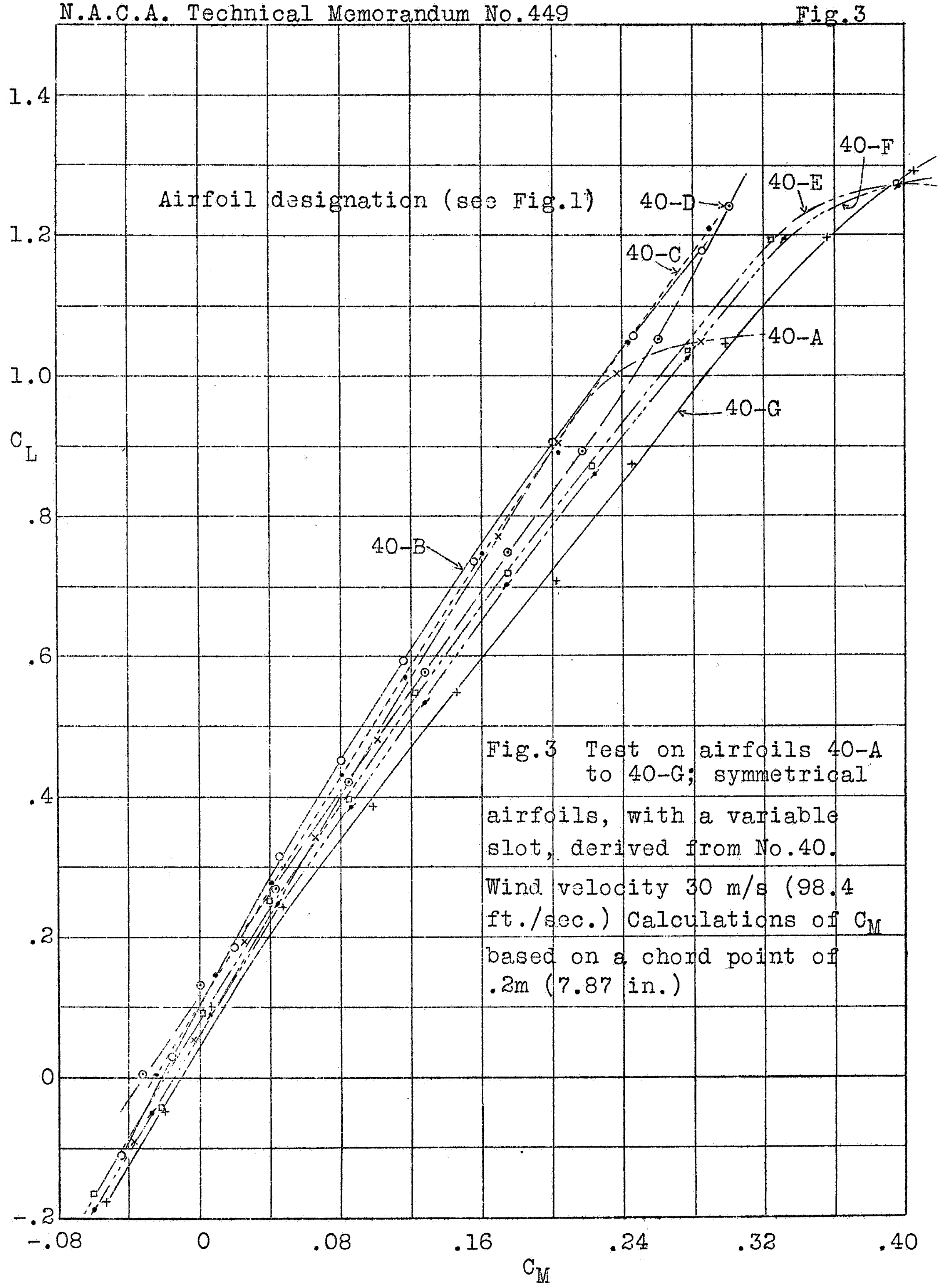

Fig.3 Test on airfoils 40-A to 40-G; symmetrical airfoils, with a variable slot, derived from No.40. Wind velocity 30 m/s (98.4 ft./sec.) Calculations of C_M based on a chord point of .2m (7.87 in.)

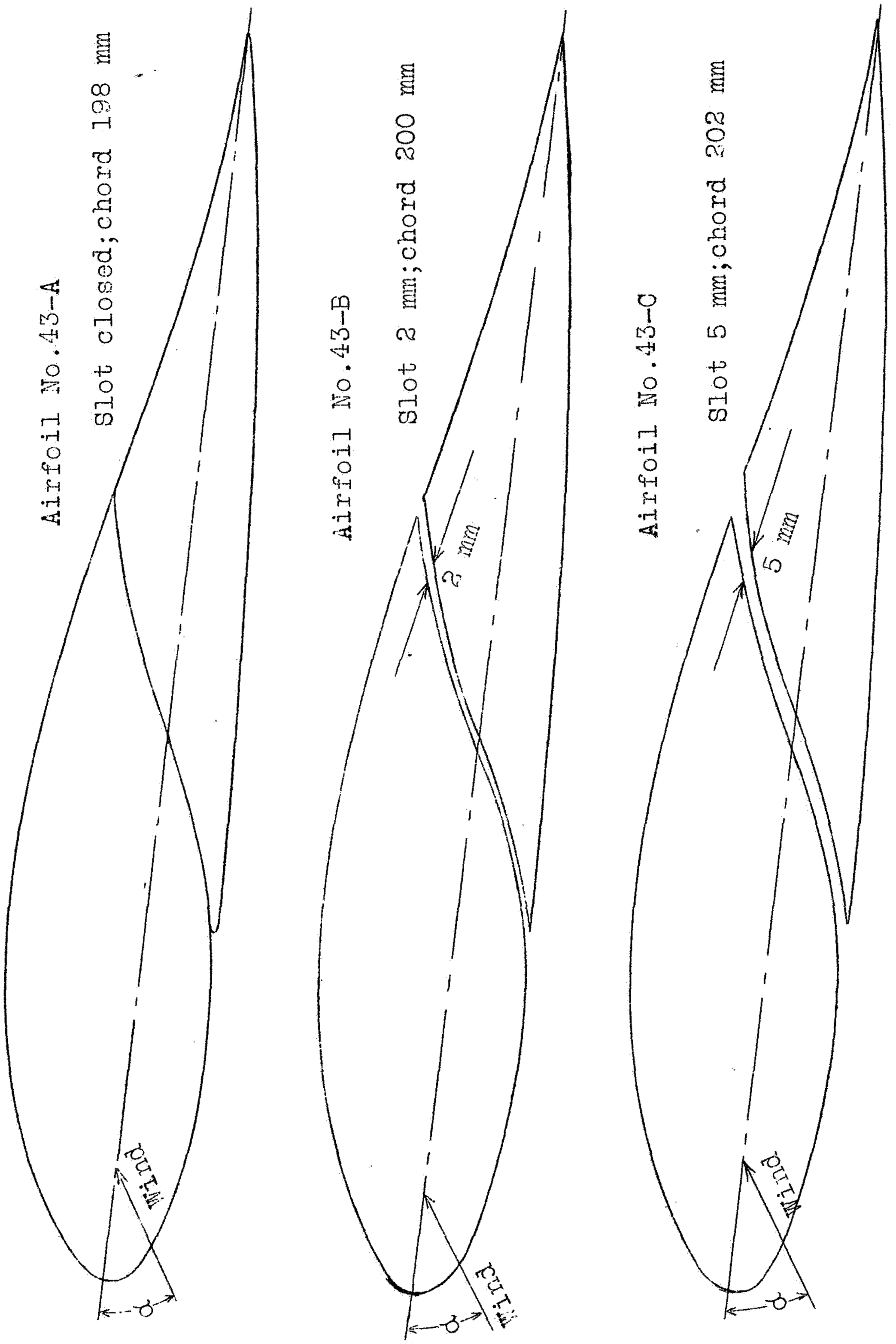

Fig.4 (Continued on next page)

Fig.4

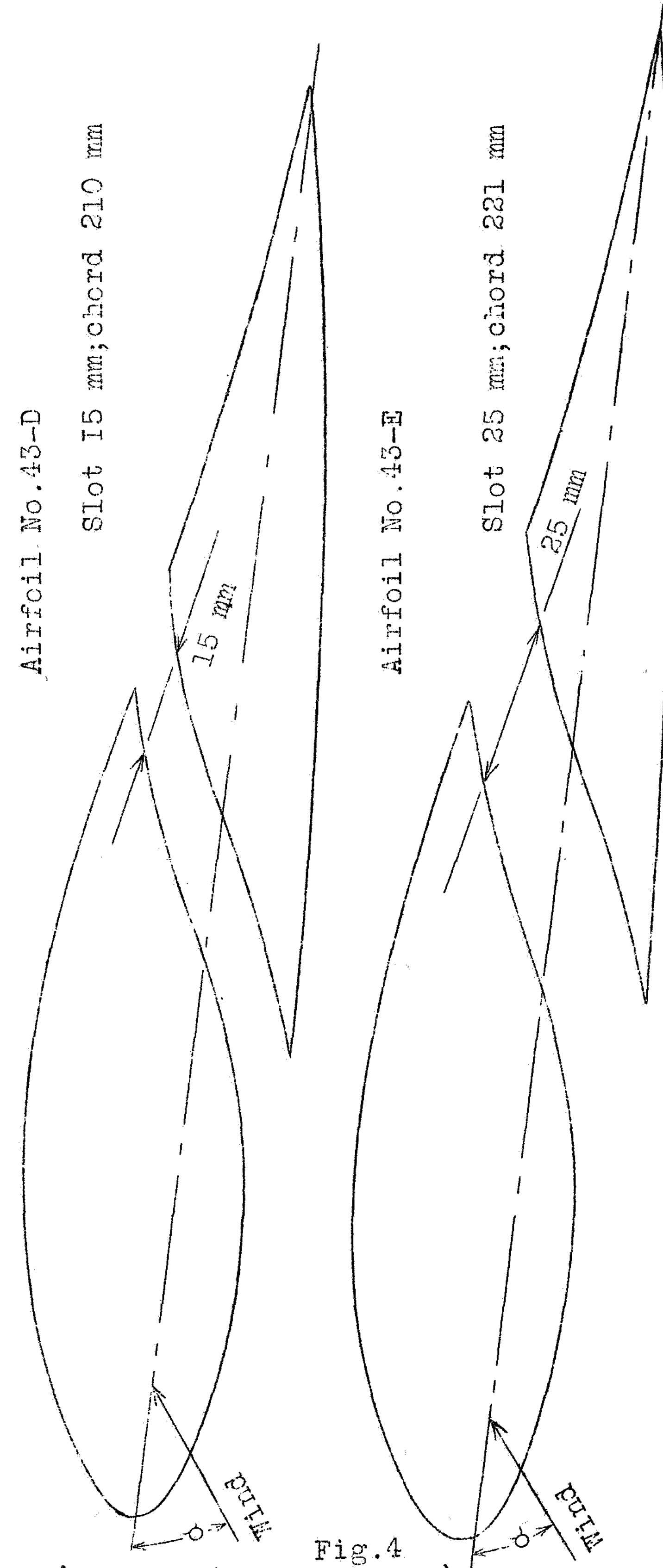

Fig.4
(Continuation)

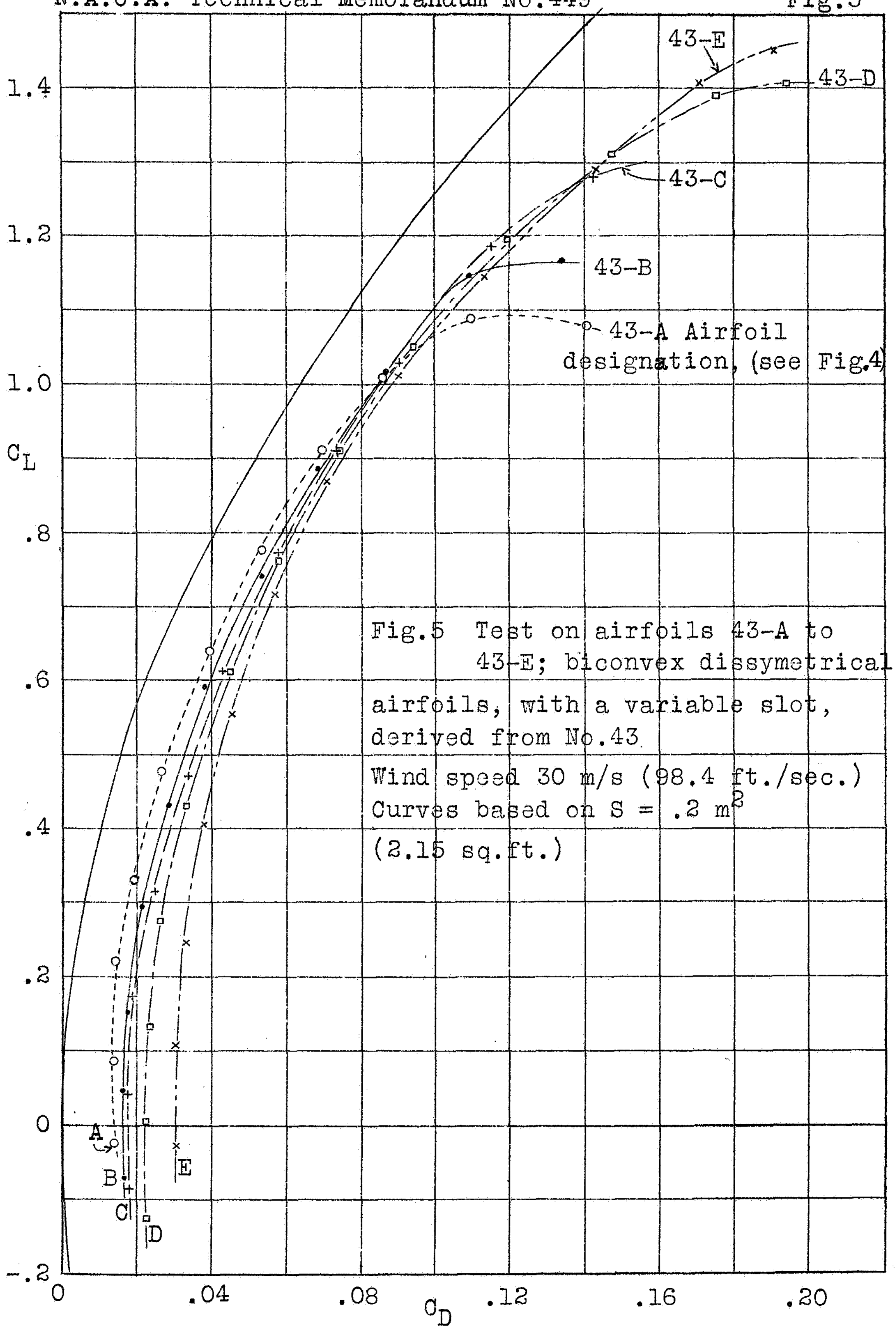

Fig.5 Test on airfoils 43-A to 43-E; biconvex dissymetrical airfoils, with a variable slot, derived from No.43
Wind speed 30 m/s (98.4 ft./sec.)
Curves based on S = .2 m^2 (2.15 sq.ft.)

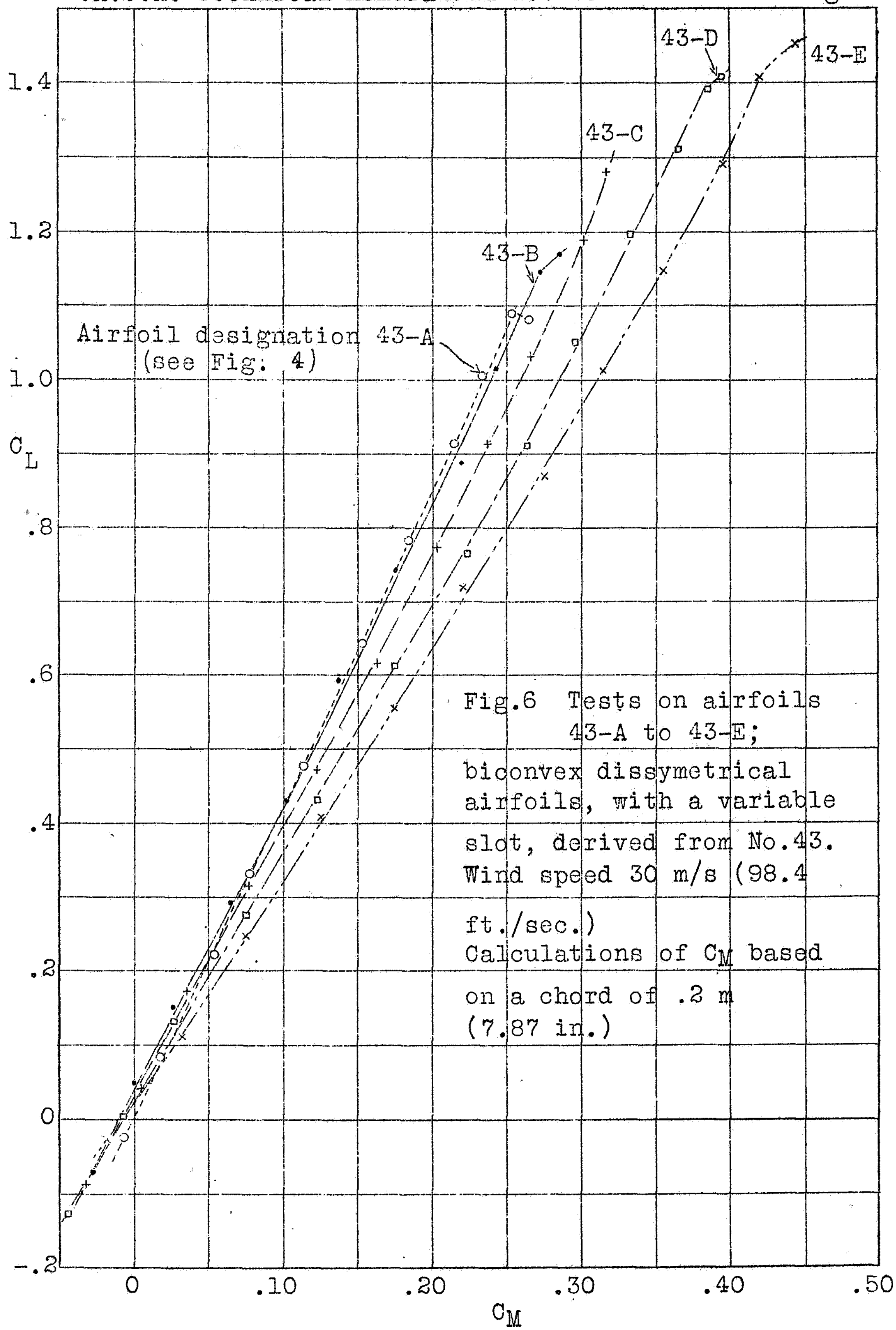

Fig.6 Tests on airfoils 43-A to 43-E; biconvex dissymetrical airfoils, with a variable slot, derived from No.43. Wind speed 30 m/s (98.4 ft./sec.) Calculations of C_M based on a chord of .2 m (7.87 in.)