TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 295

THE EFFECT OF TIP SHIELDS ON A HORIZONTAL TAIL SURFACE

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Summary

A series of experiments made in the wind tunnel of The Daniel Guggenheim School of Aeronautics, New York University, on the effect of tip shields on a horizontal tail surface are described and discussed. It was found that some aerodynamic gain can be obtained by the use of tip shields though it is considered doubtful whether their use would be practical.

Introduction

It is a well-known fact that every wing or lifting surface experiences certain lift losses at the tips. The tip vortices that accompany the loss of lift are at the same time a source of a great portion of the wing drag. Any method reducing this loss of lift and this increase in drag improves the aerodynamic efficiency of the system. From previous experiments it has been found that these tip vortices can be reduced by the use of shields at the tips. Experiments of this nature have been carried out at

*Based on a Thesis presented by Dronin and Ramsden for the B.S. degree in Engineering at New York University.

Göttingen (Reference 1), Langley Memorial Aeronautical Laboratory (Reference 2), and The Daniel Guggenheim School of Aeronautics, New York University. A theoretical consideration of the drag effect of shielding the tips of wings has been made by Hemke (Reference 3).

This paper describes some recent experiments at The Daniel Guggenheim School of Aeronautics, New York University, to determine the effect of shields on horizontal tail surfaces. The lift and drag forces were measured at various angle settings of a stabilizer and elevator with and without tip shields (vertical).

The Experiments

The horizontal tail surface model used in these tests had a symmetrical cross section slightly over 15 per cent of the chord in thickness (See Figs. 1 and 2). The span was 18 in. and the chord 6 in. It was equipped with an elevator 2-1/8 in. (35.4 per cent chord) wide. The area of the entire model was 0.75 sq.ft., of which the elevator was 35.4 per cent. The tip shields were made of brass of the form and dimensions shown in the above figures. The general shape of the shields used in these tests was adopted because in an earlier series of tests this shape gave the best results. The detailed features shown were necessary to prevent leakage and to allow motion of the elevator.

The tests were made in the wind tunnel of The Daniel Guggenheim School of Aeronautics, New York University, at an air speed of 40 M.P.H. Runs were made at 0°, +6°, and +12° angle of attack with settings of the elevator at 2° intervals from -30° to +30°. The 0° angle of attack represented the condition of level flight; the 6° angle, the condition of climb; and the 12° angle, the condition of the stall.

Results

The data from the tests reduced to the usual coefficients of lift and drag are given in Tables I, II, and III. For convenience of study charts have been prepared for comparison of the results of the different conditions with and without shields (See Figs. 3 to 9, inclusive).

Discussion

An airfoil of finite span in a moving air stream experiences a vortex formation at its tips, causing a loss in lift and an increase in resistance. The direction of rotation of these vortices is such that there is an air flow outward on the lower surface of the airfoil at the tip, upward over the end, and inward on the upper surface. It can be imagined that any device which would tend to prevent this rotation of the air would effect a reduction in the tip losses. Work of this nature has been done previously indicating that this can be done.

These tests cover a similar sort of investigation for a horizontal tail surface unit. Vertical surfaces at the tips were employed to obtain a reduction in the tip losses. The tests were made under the conditions of high speed, climb, and of landing speed, at angles of attack of 0°, 6°, and 12°, respectively. Data were taken for elevator settings from -30° to +30° with and without the vertical tip shields. In addition, data was obtained on the plain horizontal surface or stabilizer with elevator at 0° over a full range of angle of attack with and without the vertical shields.

For comparison with the results of these tests, it is convenient to consider also the use of horizontal tip shields. It may be assumed that horizontal shields could be added to the model such that the total area of the shields would be equal to that of the vertical shields and their cross section would be that of the plain or original horizontal surface. For simplicity let the ends be square. (It would be more advantageous to shape these also, so that their tips would be similar to the vertical shields.) The tail unit would then be equivalent to an airfoil of increased aspect ratio (increased from 3.00 to 4.25). For this comparison the data on the plain horizontal surface without shields has been modified to represent the tail unti with horizontal tip shields by correcting for the increased aspect ratio. Figure 3 shows the polar curves for the plain horizontal surface with and without vertical shields based on both the area of the horizontal portion and on total area. The latter basis is considered more fair in that any type of tip shield must carry pressures, must be adequately considered in the strength design calculations, and is an integral part of the horizontal tail unit. However, as most of the previous data on tip shields has been given on the basis of the original area or, in this case, the area of the plain horizontal surface, the data from these tests has been plotted on that basis as well as on the basis of total area. It may be seen that the addition of the vertical shields improves the characteristics of the horizontal tail surface a slight amount from zero lift to a lift coefficient of 0.5. Above the latter point it is decidedly inferior to the plain unit.

Figure 4 shows the same information for horizontal shields as described above. In this case there is a general improvement throughout the entire range. In Figures 5 and 6, the two styles of shields are compared with each other and with the plain surface. The horizontal shields show the best characteristics for the entire lift or angle range.

The effect of the elevator angle is indicated in Figures 7, 8, and 9, for a stabilizer setting of 0°, 6°, and 12°, respectively. Here also the results given are based on total area and the area of the original horizontal surface. From these charts there seems to be a smaller advantage in the use of shields; the horizontal design again being the best.

If it is desired to employ shields at all, the horizontal type would be preferable, being simpler in construction; in fact, a horizontal tail unit thus equipped would be merely a surface of increased area and aspect ratio. However, vertical shields make for a shorter span. It has been said that this would be of an advantage in that it might be possible to have the entire surface in the slip stream, making the control more effective. The part of a system having horizontal shields that would be outside of such a slip stream is approximately 27 per cent. The forces are modified, of course, as the square of the velocity; consequently, a slip stream having an average velocity of 110 per cent of the surrounding air will increase the control some 21 per cent. From this it may be deduced that the horizontal system would be about 10 per cent less efficient under these circumstances.

From the direction of rotation of the vortices at the tips, it is evident that with vertical shields there is a positive pressure on the outside of the upper portion, and a negative pressure on the inside; on the bottom, the reverse is true. The suction pressures on the top inner side tend to maintain the low pressure region of the plain horizontal surface at the tips and thus reduce the lift losses. The reduction of the induced drag is due, of course, to the interference to the formation of the vortices caused by the shields.

The horizontal shields have a positive pressure on the lower surface and a negative pressure on the upper. Because of the change in effective span the lift distribution on the span of the original horizontal surface is augmented with a consequent reduction of the original tip lift losses. In addition, these shields have a pressure distribution which contributes directly to the lift of the system, a condition which does not occur with vertical shields. This is believed to be a partial explanation of the reason the horizontal type shields indicate the better characteristics.

Conclusion

Some aerodynamic gain can be obtained by the use of tip shields on horizontal tail surfaces, though it is considered doubtful whether their use would be practical in view of the increased weight and of the structural difficulties.

References

1. Nagel, F. : "Flugel mit seitlichen Scheiben." Vorlaufige Mitteilungen der Aerodynamischen Versuchsanstalt zu Göttingen, No. 2, July, 1924.
2. Reid, E. G. : "The Effects of Shielding the Tips of Airfoils." N.A.C.A. Technical Report No. 201, 1925.
3. Hemke, Paul E, : "Drag of Wings with End Plates." N.A.C.A. Technical Report No. 267, 1927.

TABLE I.

Horizontal Tail Unit
With and Without Vertical Shields
Stabilizer at 0°.

Elevator setting	Without Shields				With Shields			
Degrees	K_y	K_x	C_L	C_D	K_y	K_x	C_L	C_D
-30	-0.00166	0.000390	-0.651	0.1530	-0.00208	0.000408	-0.816	0.1600
-28	-.00172	.000356	-.674	0.1397	-.00203	.000384	-.796	.1506
-26	-.00145	.000308	-.568	0.1208	-.00196	.000350	-.769	.1373
-24	-.00141	.000281	-.553	0.1102	-.00194	--	-.762	--
-22	-.00135	.000261	-.530	0.1023	-.00188	.000305	-.738	.1196
-20	-.00133	.000227	-.522	0.0890	-.00189	.000275	-.741	.1079
-18	-.00118	.000195	-.463	0.0765	-.00177	.000239	-.694	.0938
-16	-.00114	.000173	-.447	0.0678	-.00176	.000207	-.690	.0812
-14	-.00112	.000143	-.439	0.0561	-.00169	.000175	-.663	.0686
-12	-.00111	.000115	-.435	0.0451	-.00157	.000146	-.616	.0573
-10	-.00096	.000093	-.376	.0365	-.00142	.000123	-.557	.0482
- 8	-.00082	.000076	-.322	.0298	-.00113	.000094	-.443	.0369
- 6	-.00063	.000060	-.247	.0235	-.00088	.000078	-.345	.0306
- 4	-.00038	.000035	-.149	.0137	-.00058	.000063	-.228	.0247
- 2	-.00017	.000029	-.065	.0114	-.00040	.000054	-.157	.0212
0	+.00000	--	+.000	--	-.00003	.000050	-.012	.0196
+ 2	.00017	.000029	.065	.0114	+.00040	.000054	+.157	.0212
4	.00038	.000035	.149	.0137	.00058	.000063	.228	.0247
6	.00063	.000060	.247	.0235	.00088	.000078	.345	.0306
8	.00082	.000076	.322	.0298	.00113	.000094	.443	.0369
10	.00096	.000093	.376	.0365	.00142	.000123	.557	.0482
12	.00111	.000115	.435	.0451	.00157	.000146	.616	.0573
14	.00112	.000143	.439	.0561	.00169	.000175	.663	.0686
16	.00114	.000173	.447	.0678	.00176	.000207	.690	.0812
18	.00118	.000195	.463	.0765	.00177	.000239	.694	.0938
20	.00133	.000227	.522	.0890	.00189	.000275	.741	.1079
22	.00135	.000261	.530	.1023	.00188	.000305	.738	.1196
24	.00141	.000281	.553	.1102	.00194	--	.762	--
26	.00145	.000308	.568	.1208	.00196	.000350	.769	.1373
28	.00172	.000356	.674	.1397	.00203	.000384	.796	.1506
30	.00166	.000390	.651	.1530	.00208	.000408	.816	.1600

TABLE II.

Horizontal Tail Unit
With and Without Vertical Shields
Stabilizer at 6°

Elevator setting	Without Shields				With Shields			
Degrees	K_y	K_x	C_L	C_D	K_y	K_x	C_L	C_D
-30	-0.00089	0.000278	-0.349	0.1090	-0.00083	0.000293	-0.326	0.1149
-28	-.00080	.000243	-.314	.0953	-.00078	.000272	-.306	.1066
-26	-.00068	.000219	-.247	.0858	-.00061	.000244	-.239	.0956
-24	-.00053	.000189	-.208	.0742	-.00047	.000218	-.184	.0855
-22	-.00045	.000172	-.177	.0674	-.00038	.000195	-.149	.0765
-20	-.00036	.000149	-.141	.0584	-.00022	.000172	-.086	.0675
-18	-.00027	.000134	-.106	.0525	-.00002	.000155	-.008	.0608
-16	-.00022	.000100	-.086	.0392	-.00008	.000142	-.031	.0557
-14	-.00036	.000080	-.141	.0314	-.00017	.000131	-.067	.0514
-12	-.00025	.000066	-.098	.0259	-.00012	.000108	-.047	.0423
-10	-.00020	.000052	-.078	.0204	+.00002	.000079	+.008	.0310
- 8	+.00002	.000045	+.008	.0177	.00015	.000069	.059	.0271
- 6	.00019	.000045	.075	.0177	.00038	.000069	.149	.0271
- 4	.00036	.000050	.141	.0196	.00059	.000071	.231	.0279
- 2	.00050	.000057	.191	.0224	.00085	.000082	.334	.0322
0	.00084	.000091	.329	.0357	.00103	.000092	.404	.0361
+ 2	.00104	.000097	.408	.0380	.00124	.000102	.486	.0400
4	.00125	.000114	.490	.0447	.00143	.000126	.561	.0494
6	.00145	.000137	.569	.0537	.00165	.000148	.647	.0580
8	.00160	.000166	.628	.0651	.00194	.000184	.761	.0722
10	.00172	.000184	.674	.0722	.00193	.000194	.757	.0761
12	.00182	.000206	.714	.0808	.00209	.000225	.820	.0882
14	.00193	.000243	.757	.0953	.00214	.000244	.840	.0957
16	.00202	.000282	.792	.1105	.00217	.000273	.851	.1070
18	.00212	.000315	.832	.1245	.00212	.000276	.832	.1082
20	.00212	.000336	.832	.1318	.00238	.000339	.934	.1330
22	.00222	.000391	.871	.1534	.00251	.000379	.984	.1486
24	.00227	.000408	.890	.1600	.00256	.000413	1.004	.1620
26	.00239	.000481	.938	.1887	.00267	.000467	1.047	.1831
28	.00255	.000523	1.000	.2051	.00282	.000526	1.106	.2062
30	.00258	.000572	1.012	.2243	.00292	.000562	1.145	.2204

TABLE III.

Horizontal Tail Unit
With and Without Vertical Shields
Stabilizer at 12°

Elevator setting	Without Shields				With Shields			
Degrees	K_y	K_x	C_L	C_D	K_y	K_x	C_L	C_D
-30	-0.00008	0.000230	-0.031	0.0918	+0.00013	0.000264	+0.051	0.1036
-28	+ .00005	.000204	+ .020	0.0814	.00020	.000242	.078	.0949
-26	.00015	.000190	.059	0.0758	.00036	.000229	.141	.0898
-24	.00029	.000175	.114	0.0699	.00049	.000216	.192	.0847
-22	.00037	.000158	.145	0.0631	.00064	.000200	.251	.0784
-20	.00032	.000137	.126	0.0547	.00083	.000188	.326	.0738
-18	.00024	.000103	.094	0.0411	.00088	.000179	.345	.0702
-16	.00030	.000087	.118	0.0347	.00090	.000165	.353	.0647
-14	.00036	.000068	.141	0.0271	.00074	.000130	.290	.0510
-12	.00055	.000072	.216	0.0287	.00087	.000107	.341	.0420
-10	.00072	.000080	.282	0.0319	.00090	.000111	.353	.0436
- 8	.00089	.000090	.349	0.0359	.00116	.000123	.455	.0483
- 6	.00110	.000107	.431	0.0427	.00138	.000136	.541	.0534
- 4	.00134	.000132	.526	0.0527	.00162	.000168	.636	.0659
- 2	.00160	.000166	.628	0.0662	.00187	.000195	.734	.0765
0	.00176	.000189	.690	0.0754	.00198	.000211	.777	.0828
+ 2	.00188	.000223	.738	0.0890	.00203	.000235	.796	.0922
4	.00222	.000253	.870	0.1010	.00231	.000257	.906	.1080
6	.00215	.000287	.843	0.1145	.00242	.000285	.949	.1118
8	.00230	.000322	.902	0.1285	.00258	.000313	1.012	.1228
10	.00244	.000340	.957	0.1357	.00266	.000340	1.043	.1334
12	.00247	.000371	.968	0.1480	.00279	.000376	1.094	.1475
14	.00249	.000379	.977	0.1513	.00289	.000408	1.134	.1600
16	.00268	.000462	1.050	0.1845	.00296	.000448	1.161	.1758
18	.00279	.000499	1.094	0.1991	.00303	.000459	1.189	.1801
20	.00288	.000543	1.129	0.2169	.00308	.000505	1.208	.1981
22	.00299	.000594	1.172	0.2370	.00330	.000552	1.295	.2165
24	.00306	.000646	1.200	0.2580	.00339	.000588	1.330	.2308
26	.00332	.000708	1.326	0.2825	.00347	.000658	1.361	.2580
28	.00334	.000766	1.334	0.3058	.00357	.000703	1.400	.2760
30	.00332	.000732	1.326	0.2920	.00369	.000764	1.448	.2998

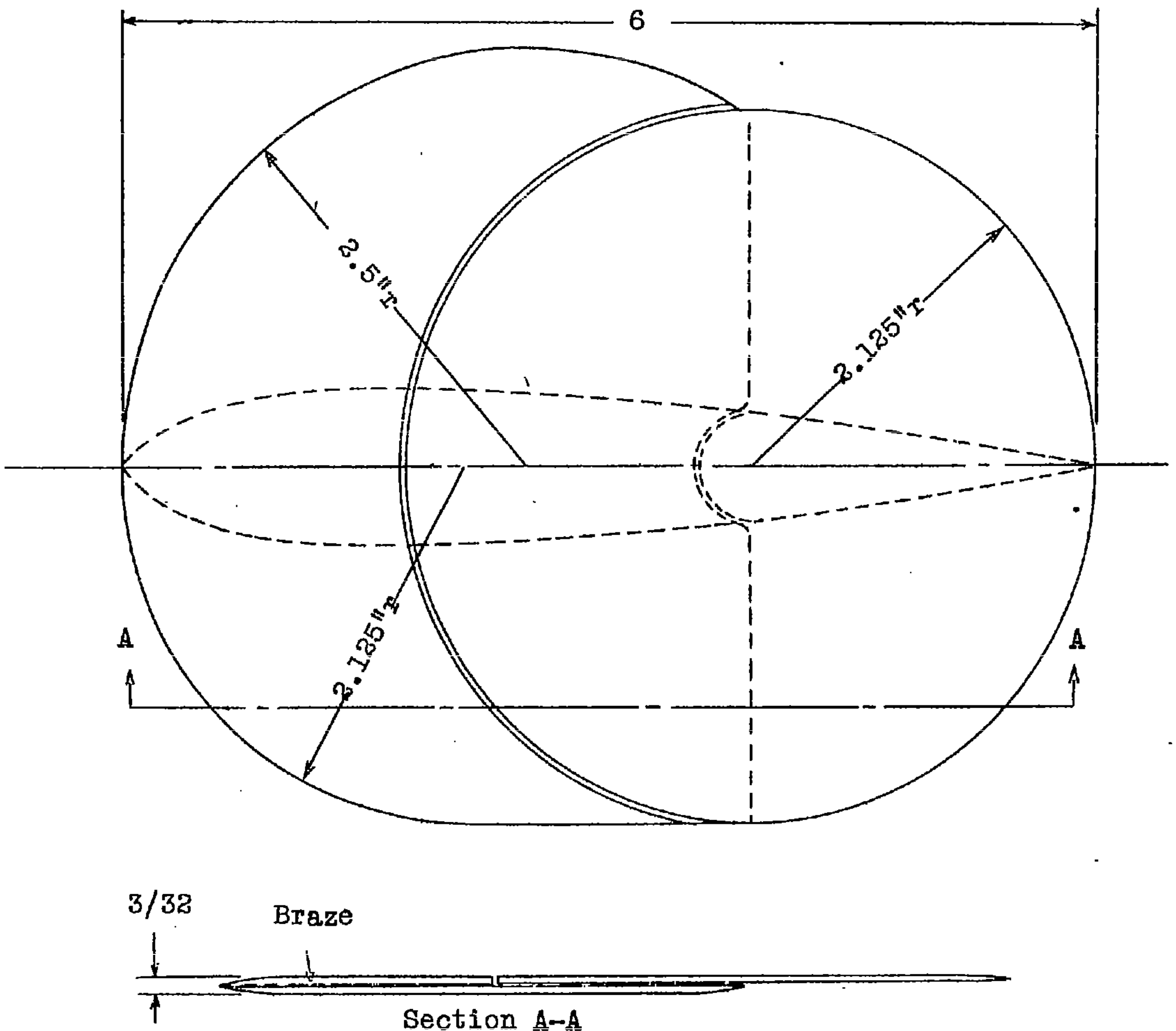

Fig.1 Total area of two sets of shields,45 sq.in.

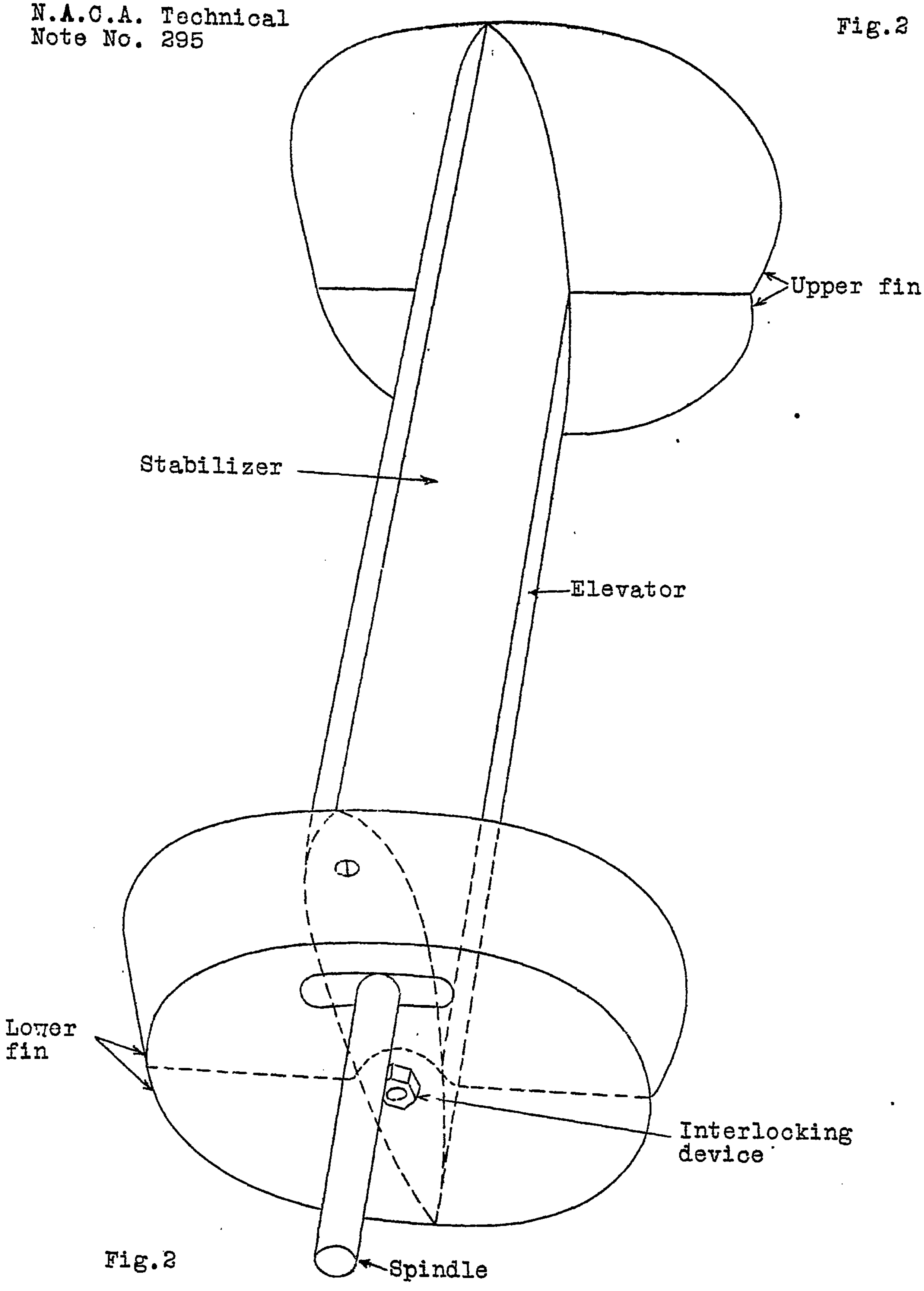
Upper fin
Stabilizer
Elevator
Lower fin
Interlocking device
Spindle

Fig.2

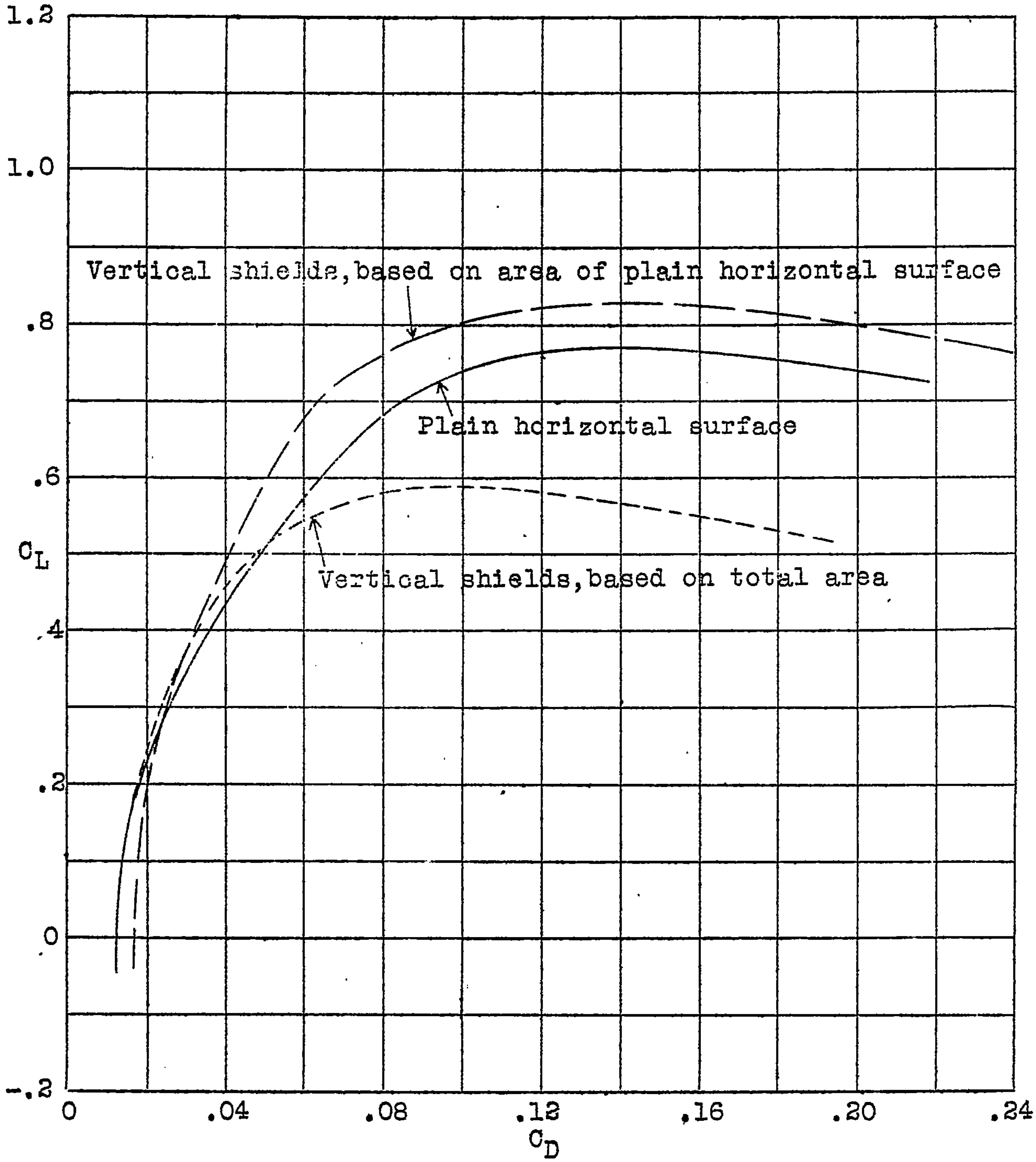

Fig.3 Horizontal tail surface with and without vertical shields.

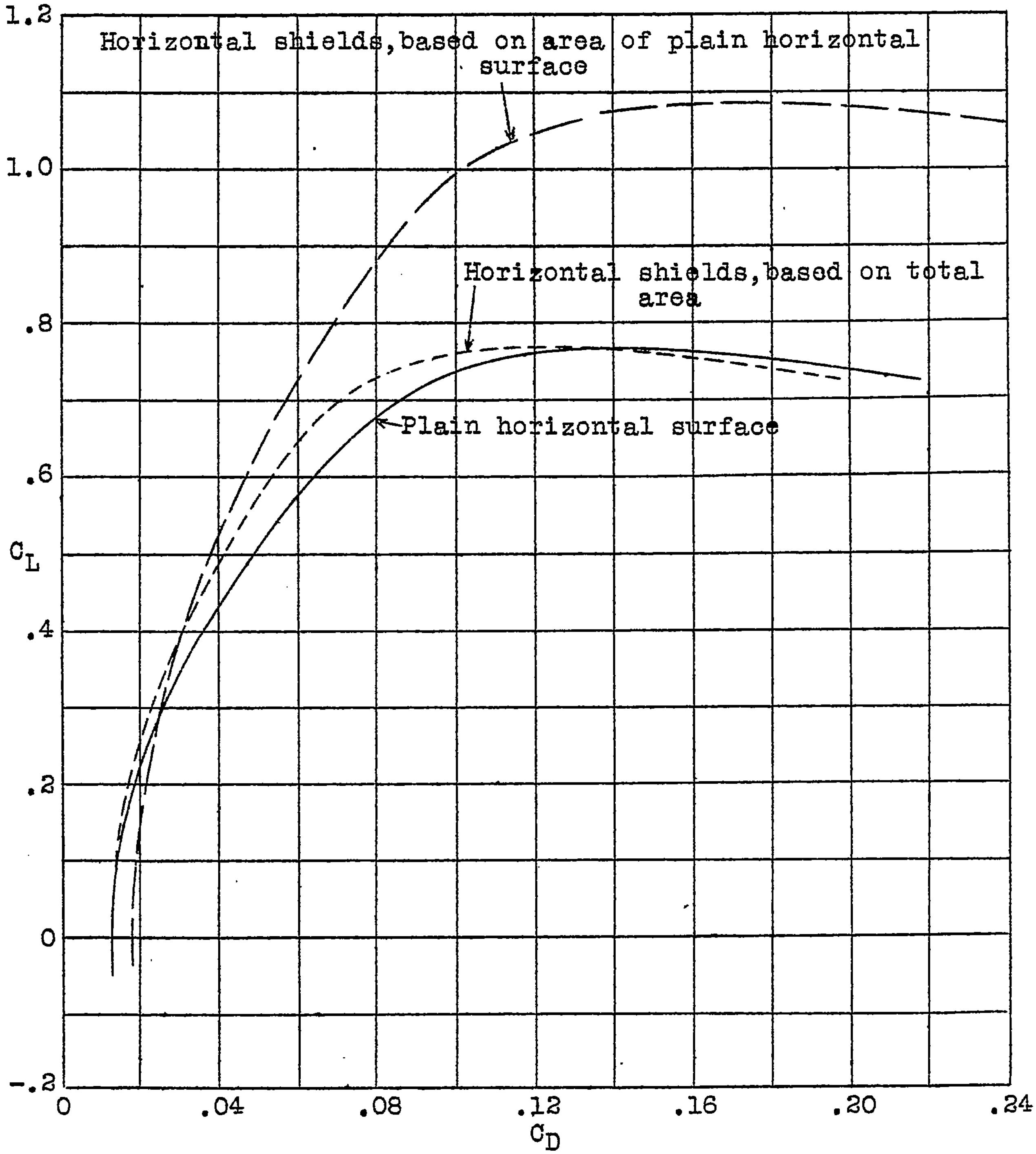

Fig.4 Horizontal tail surface with and without horizontal shields.

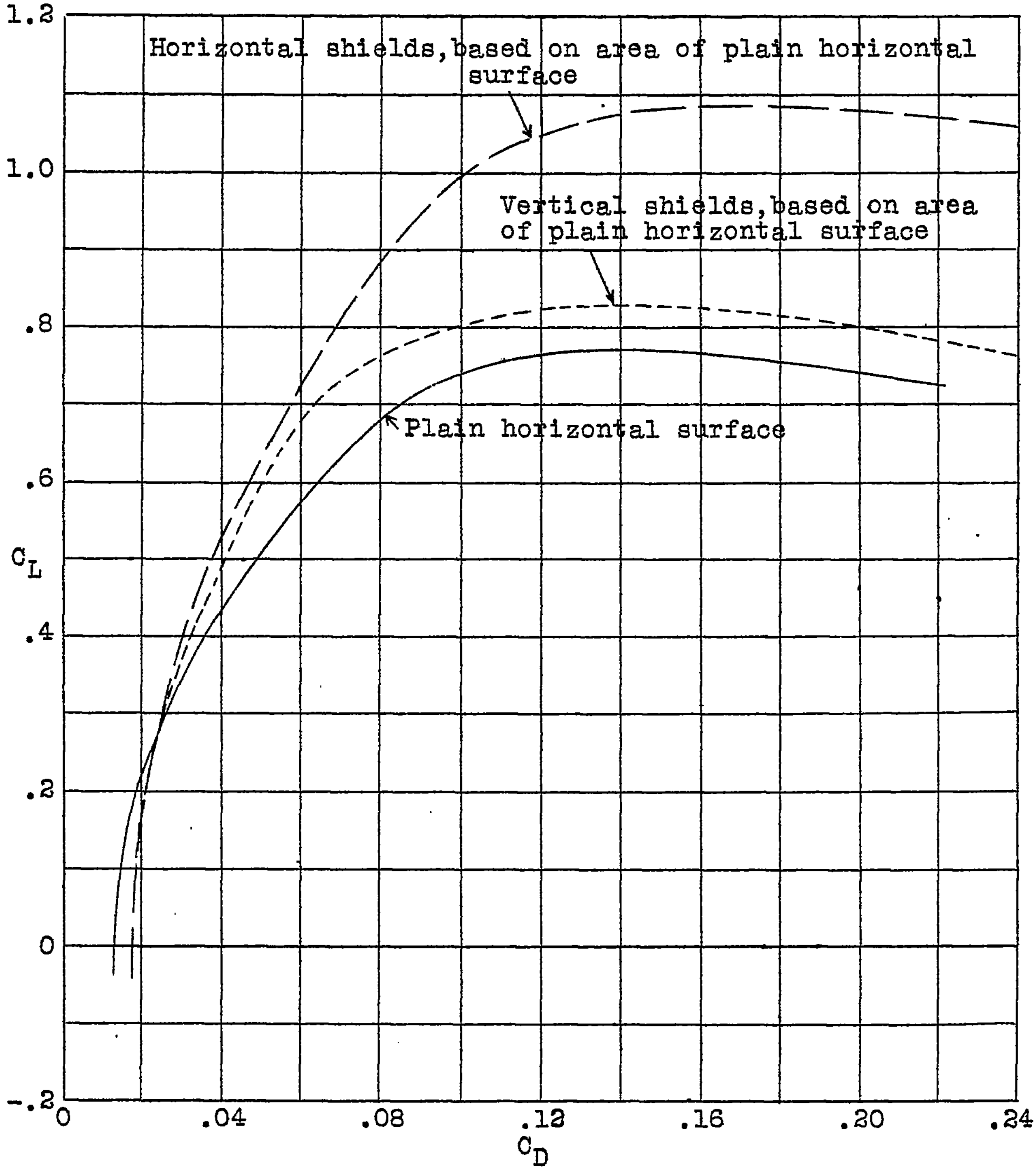

Fig.5 Horizontal tail surfaces plain, with vertical shields, and with horizontal shields, based on area of plain surface.

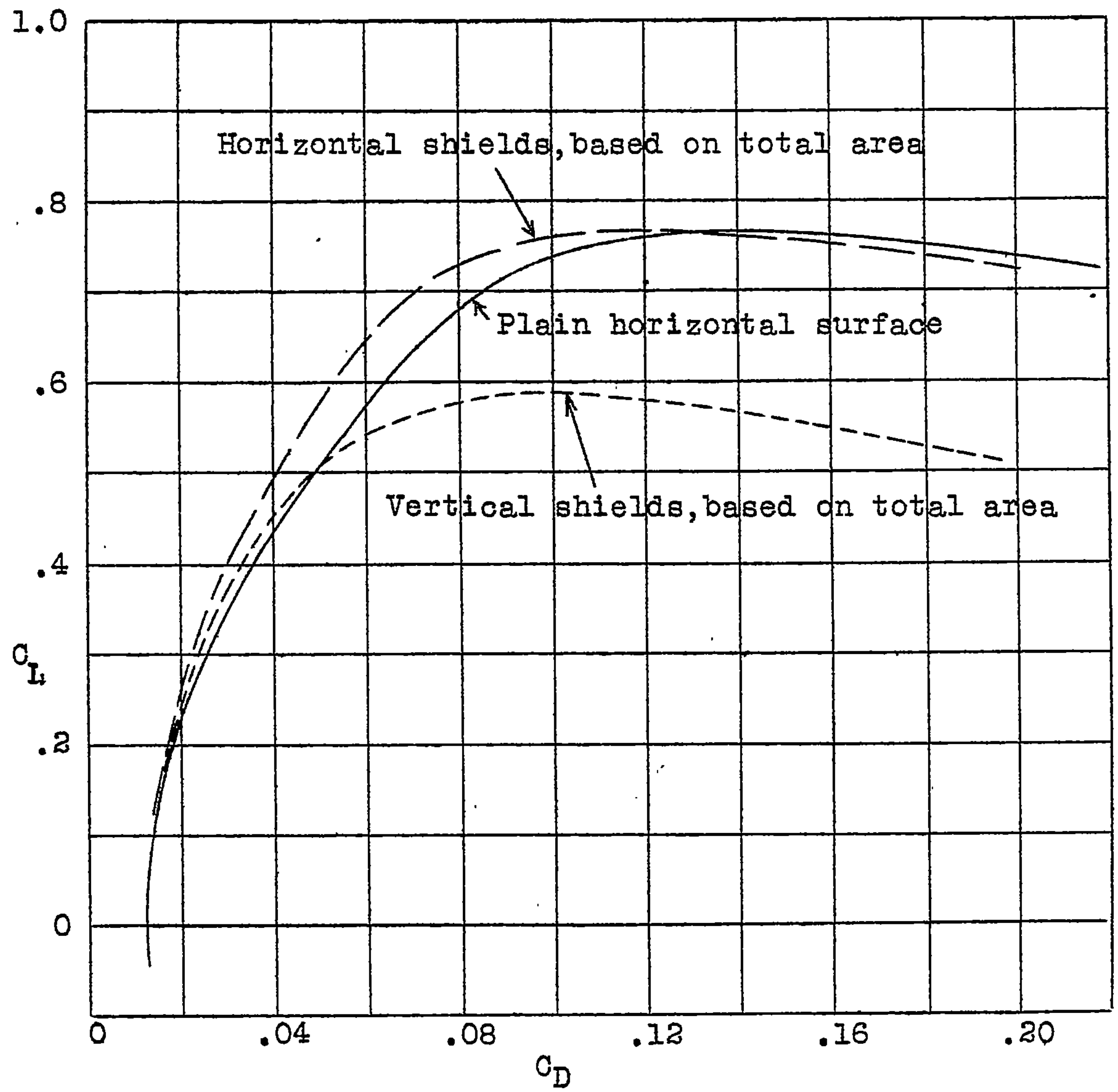

Fig.6 Horizontal tail surfaces plain,with vertical shields, and with horizontal shields,based on total area.

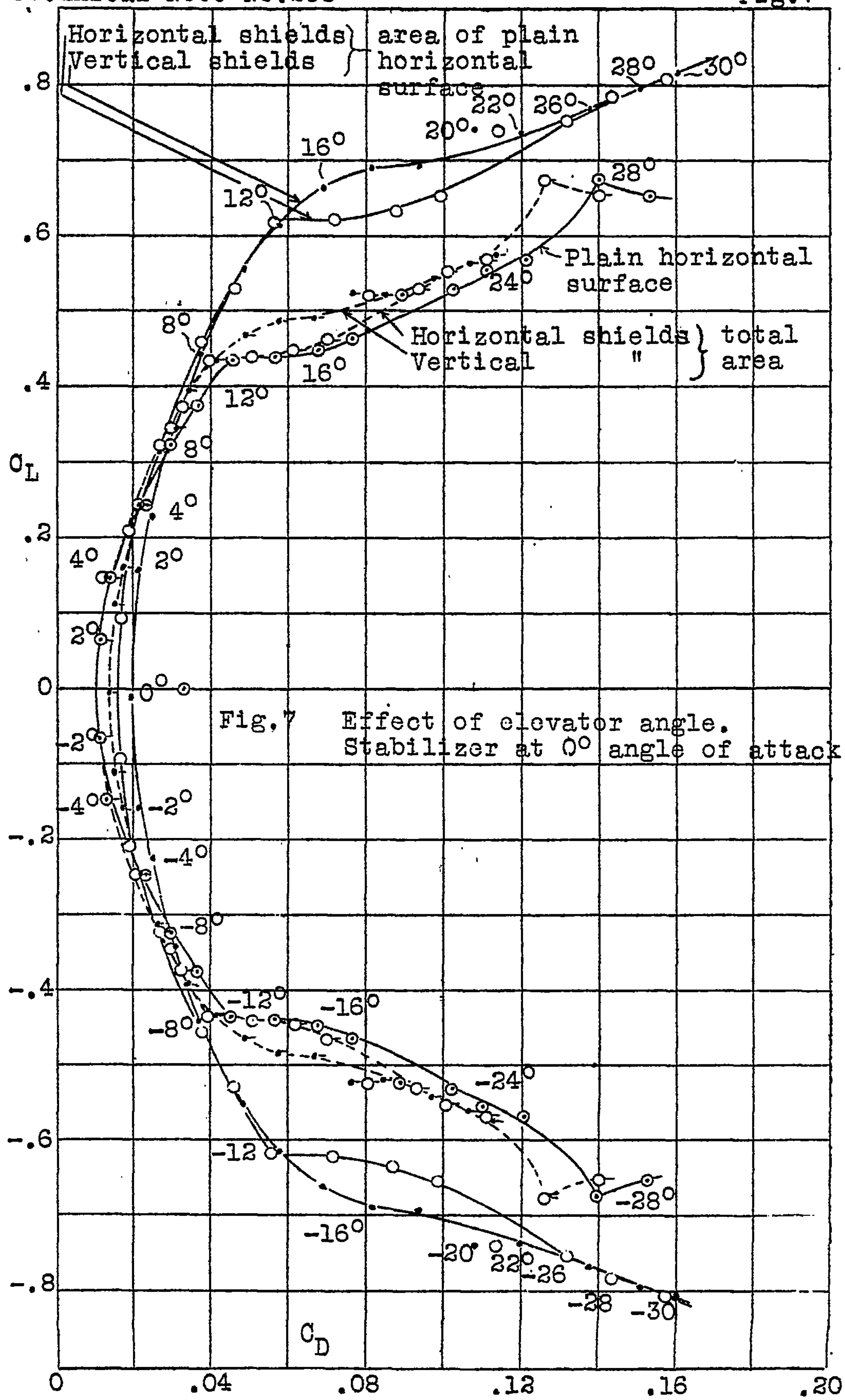

Fig. 7 Effect of elevator angle. Stabilizer at 0° angle of attack

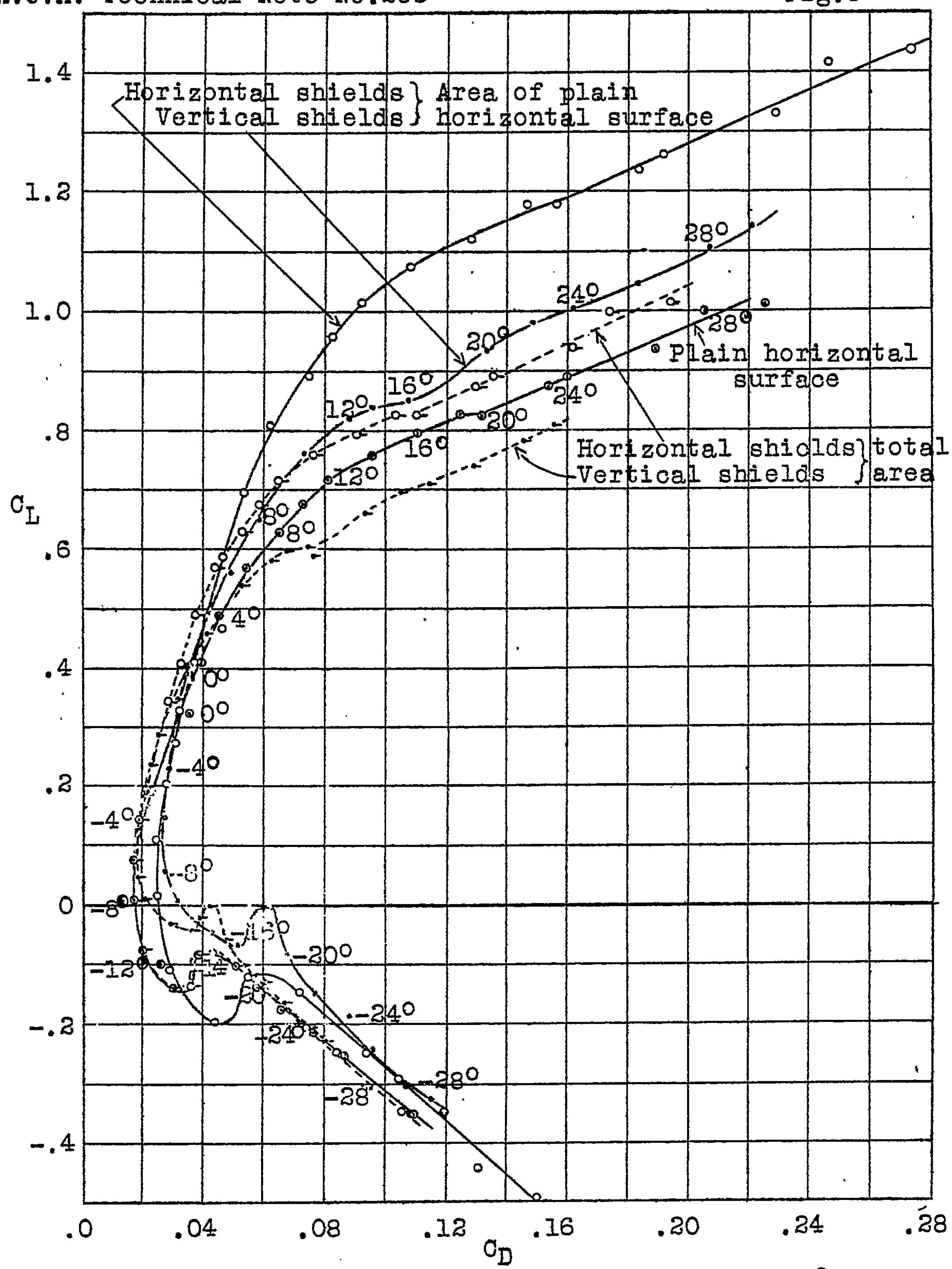

Fig.8 Effect of elevator angle. Stabilizer at 6° angle of attack.

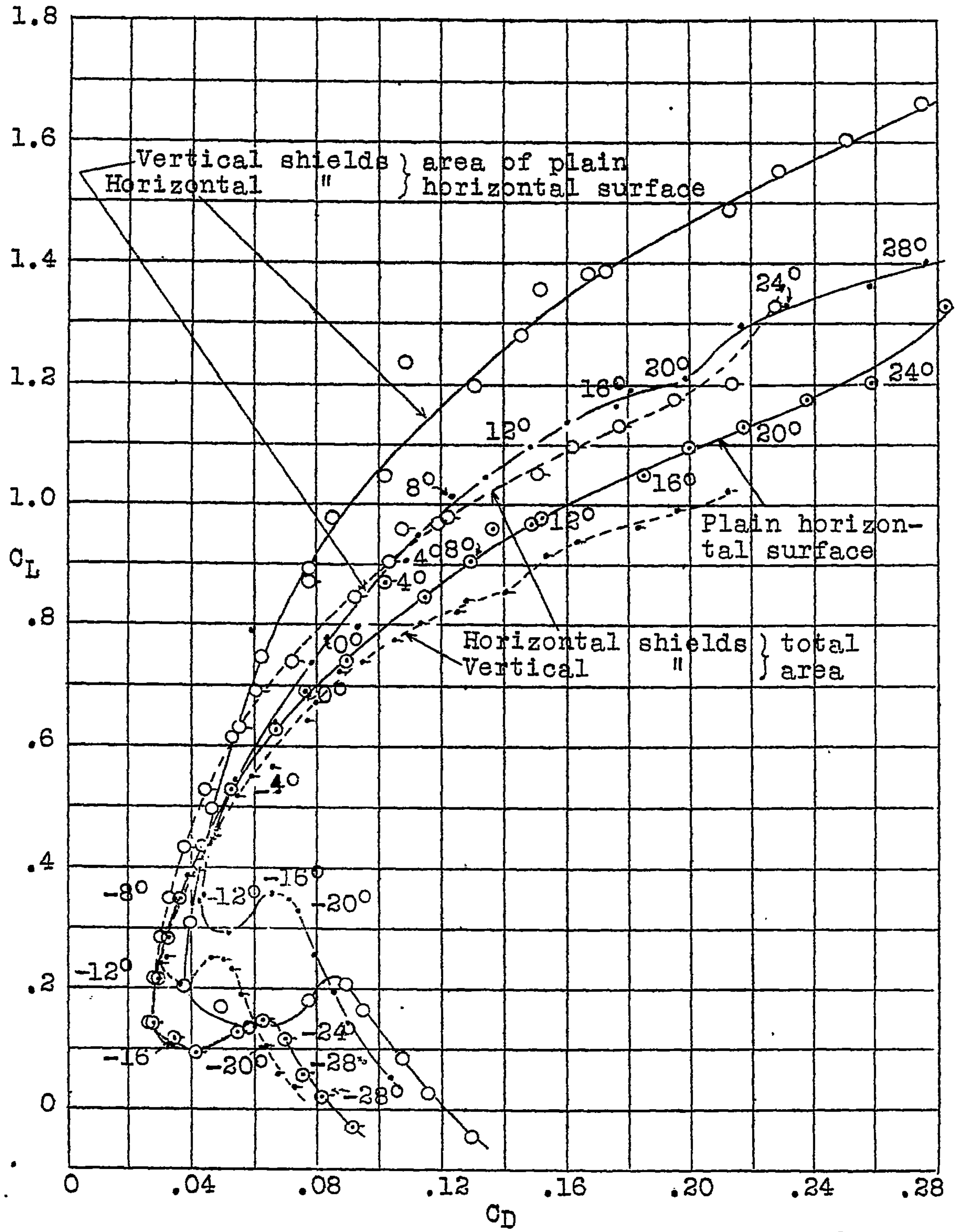

Fig.9 Effect of elevator angle. Stabilizer at 12° angle of attack.