
REPORT No. 182

AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III

CONTINUATION OF REPORTS Nos. 93 AND 124

BY
NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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INTRODUCTION.

This collection of data on airfoils has been made from the published reports of a number of the leading aerodynamic laboratories of this country and Europe.¹ The information which was originally expressed according to the different customs of the several laboratories is here presented in a uniform series of charts and tables suitable for the use of designing engineers and for purposes of general reference.

It is a well-known fact that the results obtained in different laboratories, because of their individual methods of testing, are not strictly comparable even if proper scale corrections for size of model and speed of test are supplied. It is, therefore, unwise to compare too closely the coefficients of two wing sections tested in different laboratories. Tests of different wing sections from the same source, however, may be relied on to give true relative values.

The absolute system of coefficients has been used, since it is thought by the National Advisory Committee for Aeronautics that this system is the one most suited for international use and yet is one for which a desired transformation can be easily made. For this purpose a set of transformation constants is included in this report.

Each airfoil section is given a reference number, and the test data are presented in the form of curves from which the coefficients can be read with sufficient accuracy for designing purposes. The dimensions of the profile of each section are given at various stations along the chord in per cent of the chord, the latter also serving as the datum line. When two sets of ordinates are necessary, on account of taper in chord or ordinate, those for the maximum section (at center of span) are given on the individual characteristic sheets, while those for the tip (dotted) section are given in separate tables. Where the ratio of ordinate to chord remains constant the one set of ordinates applies to both center and tip section. The shape of the section is also shown with reasonable accuracy to enable one to more clearly visualize the section under consideration, together with its characteristics.

The authority for the results here presented is given as the name of the laboratory at which the experiments were conducted, with the size of model, wind velocity, and year of test.

TRANSFORMATION CONSTANTS.

For the convenience of those who prefer to use a system of units other than the absolute system, there is given below a table of transformation constants based on the standard condition adopted by the National Advisory Committee for Aeronautics of—

Temperature = 15.6° C.

Pressure = 760 mm Hg.

Humidity = 0.

Gravity = 9.806 m/sec² = 32.172 ft/sec.²

thus giving values of specific weight of air

$$W = 1.223 \text{ kg/m}^3 = 0.07635 \text{ lb/ft.}^3$$

and of density

$$\rho = 0.1247 \text{ in the French engineering or kilogram, meter, second system.}$$

Or

$$= 0.00237 \text{ in the English or pound, foot, second system.}$$

¹ A previous collection of airfoil sections 1 to 375 and charts 1 to 3 may be found in N. A. C. A. Reports Nos. 93 and 124.

In absolute units.....	$P = CV^2 \rho / 2.$
In kg/m ² (m/sec).....	$P = .0625 CV^2.$
In kg/m ² (km/hr).....	$P = .004822 CV^2.$
In lb/sq ft (ft/sec).....	$P = .001189 CV^2.$
In lb/sq ft (mi/hr).....	$P = .002558 CV^2.$

(Note that these constants are half as large as those used in Reports Nos. 93 and 124 and that the absolute coefficients used in this report are twice as large as the old coefficients. See Report 157 regarding change in absolute coefficients.)

INDEX.

Three separate types of index are given—chart indexes which make it possible for a designer to select the wing section most suitable for the particular design in which he is interested; a group index which is arranged by countries and laboratories at which tests were conducted, each section also being designated by a reference number; and an alphabetical index.

CHART INDEX.

In order that the designer may easily pick out a wing section which is suited to the type of airplane on which he is working, four index charts are given which classify the wings according to their aerodynamic and structural properties. In the charts of this report a lower-case letter is placed adjacent to the reference number giving VL values, so that a comparison can be made without referring to the individual drawings.

In chart No. 9 the minimum drag C_D is plotted against the L/D at one-fourth the maximum lift C_L . This chart should be used in choosing a wing section for a high-speed airplane, the wing sections being more suited for this use the farther they are from the lower left-hand corner.

In chart No. 10 the mean spar depth is plotted against the maximum lift C_L in order to show the possible strength and lightness of the wing structure. The higher the maximum lift coefficient is the smaller will be the wing area and the lighter the structural weight, and in the same way the greater the depth of the spars the lighter will be their weight, so that the sections the greatest distance from the lower left-hand corner will give the lightest and strongest wings. The "mean spar depth" is obtained by assuming the spars to be located respectively at 15 and 60 per cent of the chord, and by dividing the sum of their thicknesses by 2. In the case of sections tapered in ordinate, or chord, or both, the mean spar depth of the maximum section (section at center of span) is taken in per cent of the constant chord for the ordinate taper, and of the mean chord for the chord taper although accompanied, in certain airfoils, with an ordinate taper.

In chart No. 11 the maximum L/D is plotted against the maximum lift C_L , which is of use in choosing the wing section for a slow and efficient airplane. In the same way as before, the sections farthest from the lower left-hand corner are the best for this purpose.

In chart No. 12 the L/D at two-thirds the maximum lift C_L is plotted against the maximum lift C_L . This chart can be used for choosing a section that will give an efficient climb or a long range at cruising speed. The best sections for this purpose will be the farthest from the lower left-hand corner of the chart.

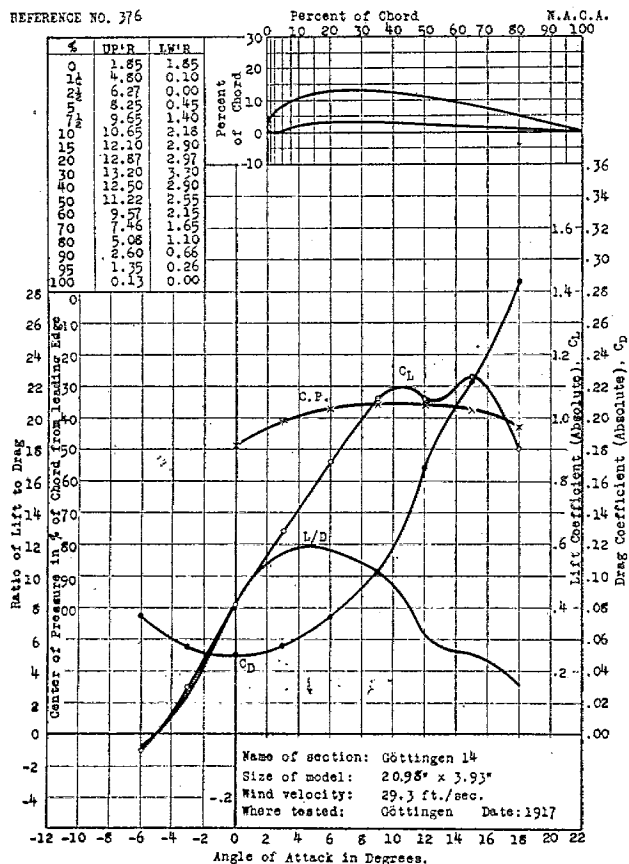
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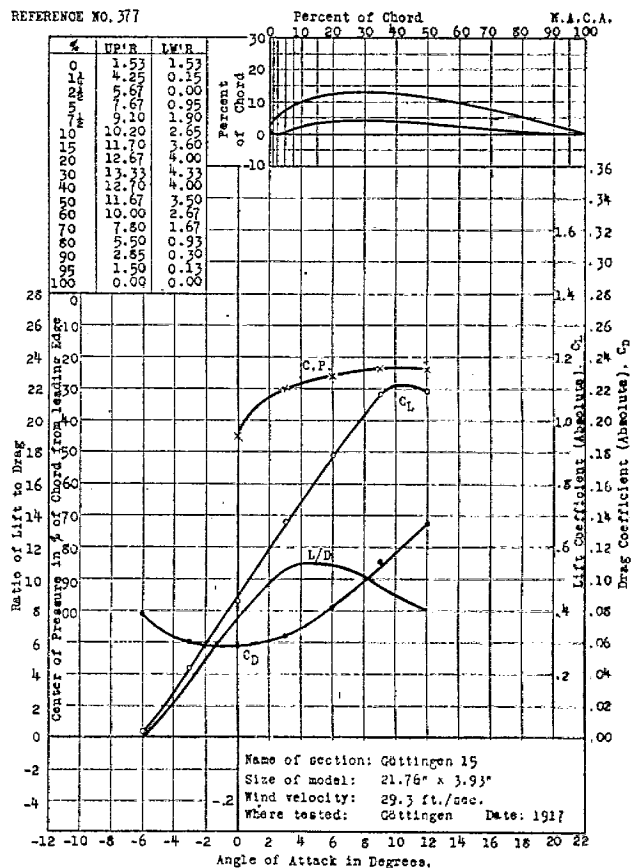
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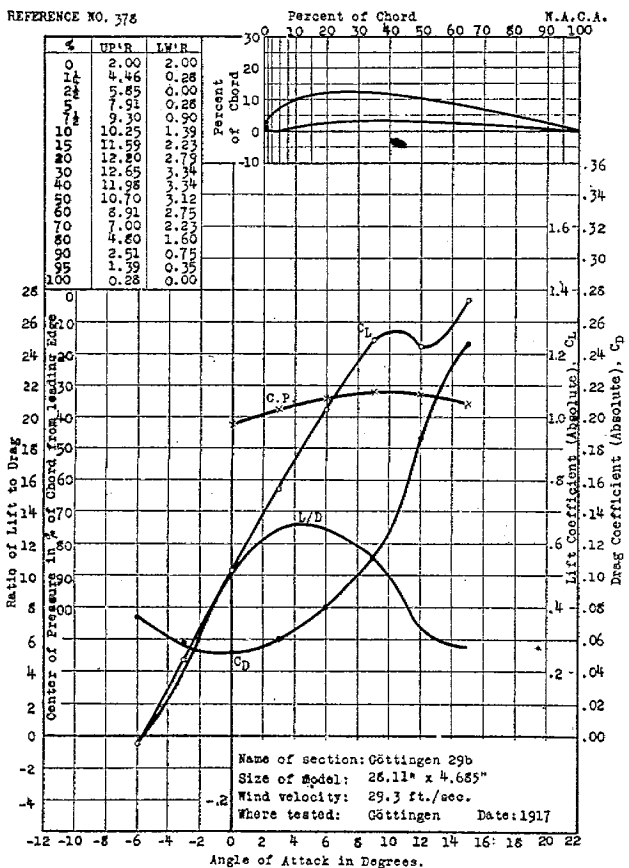
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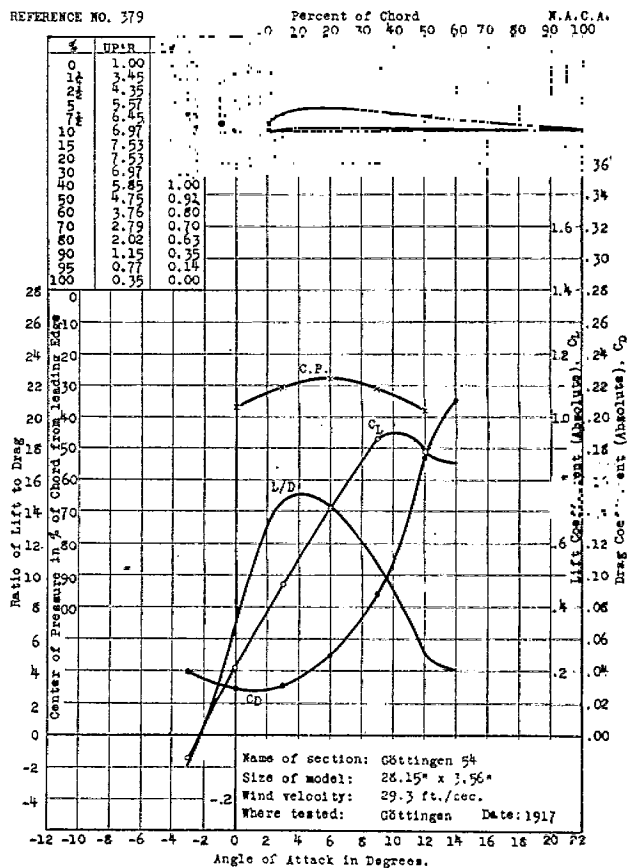
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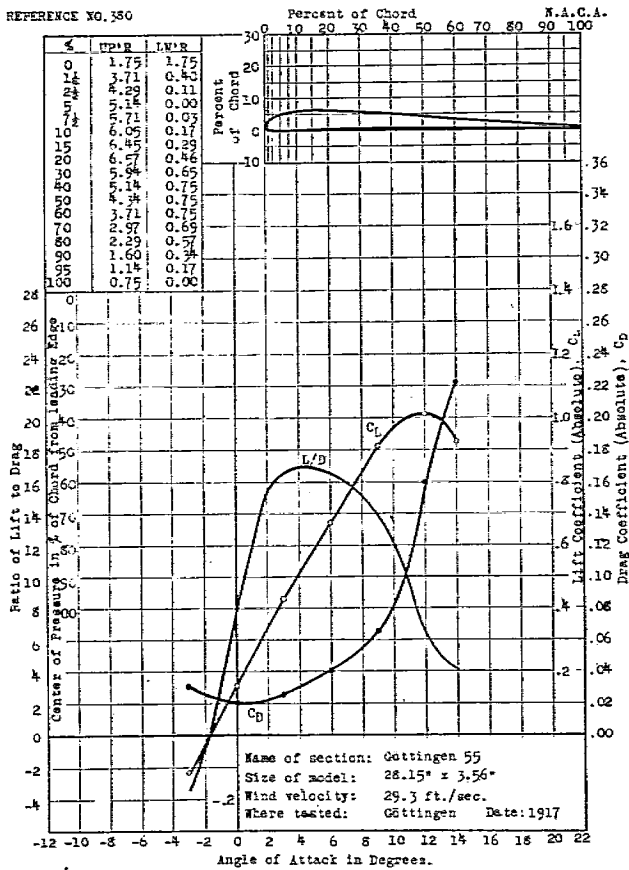
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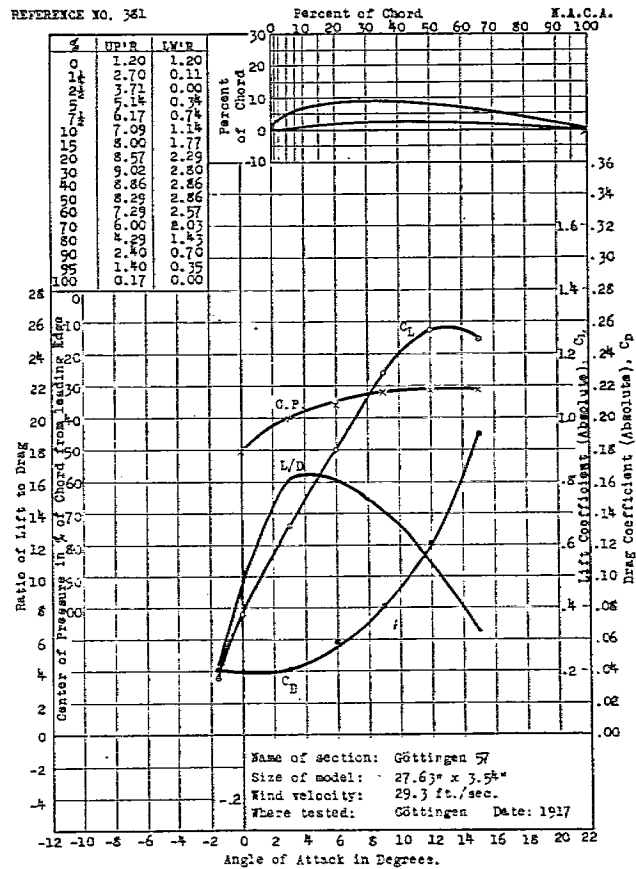
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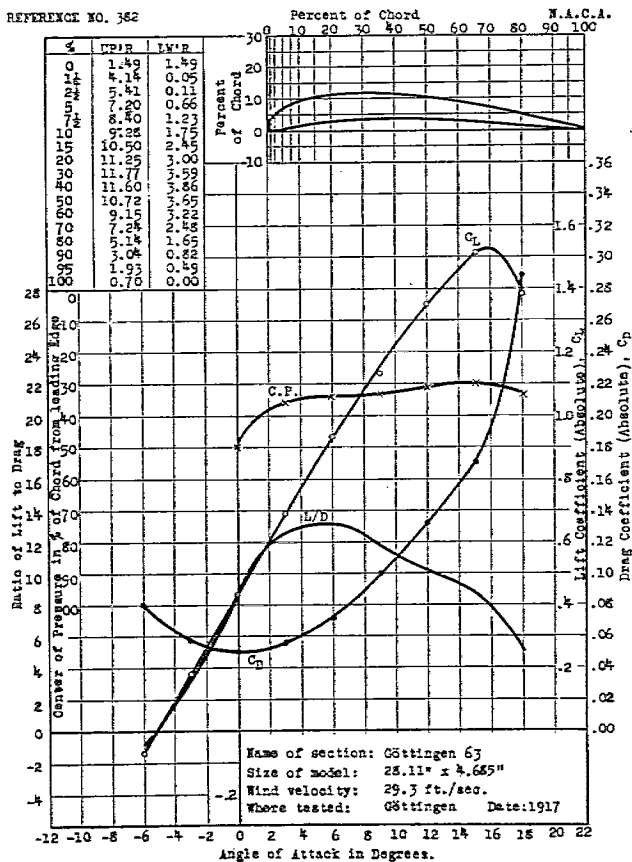
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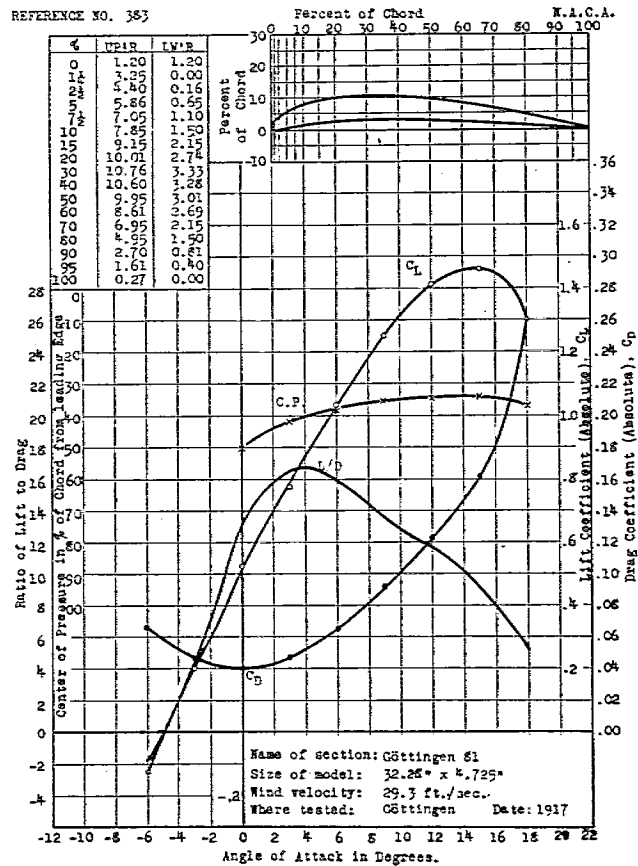
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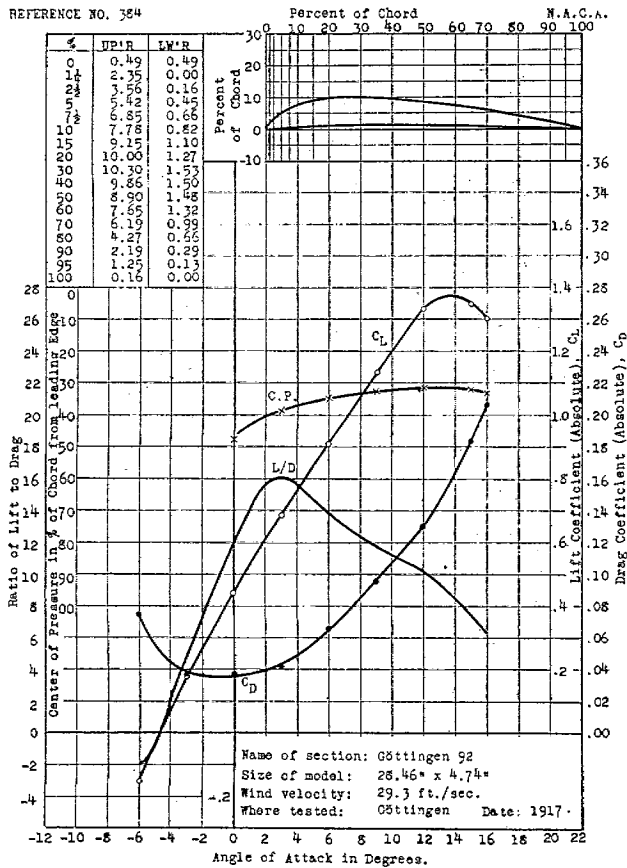
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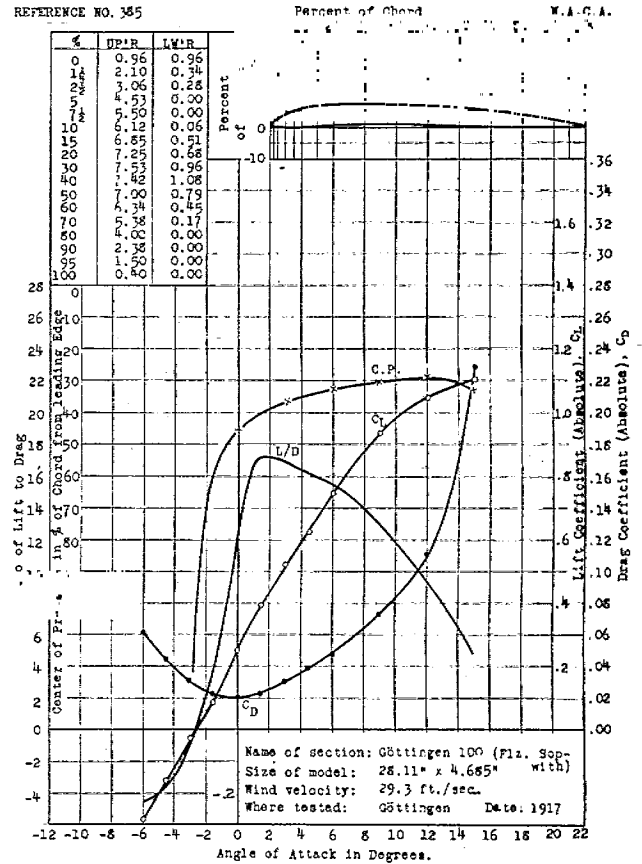
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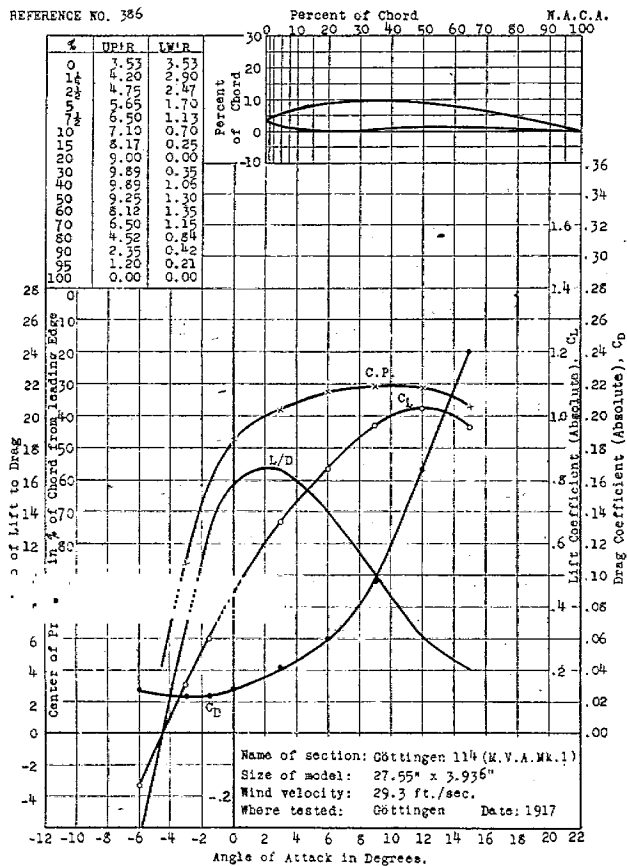
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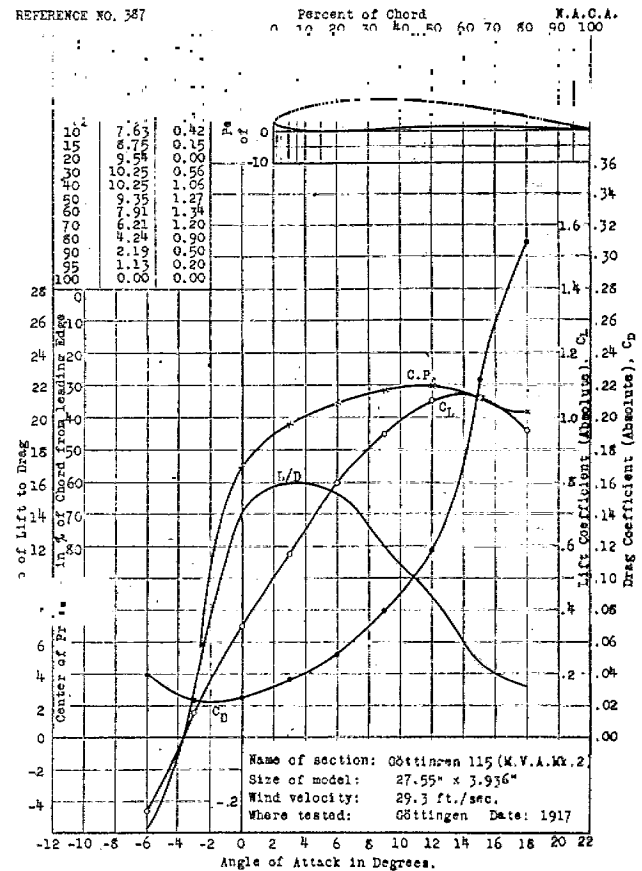
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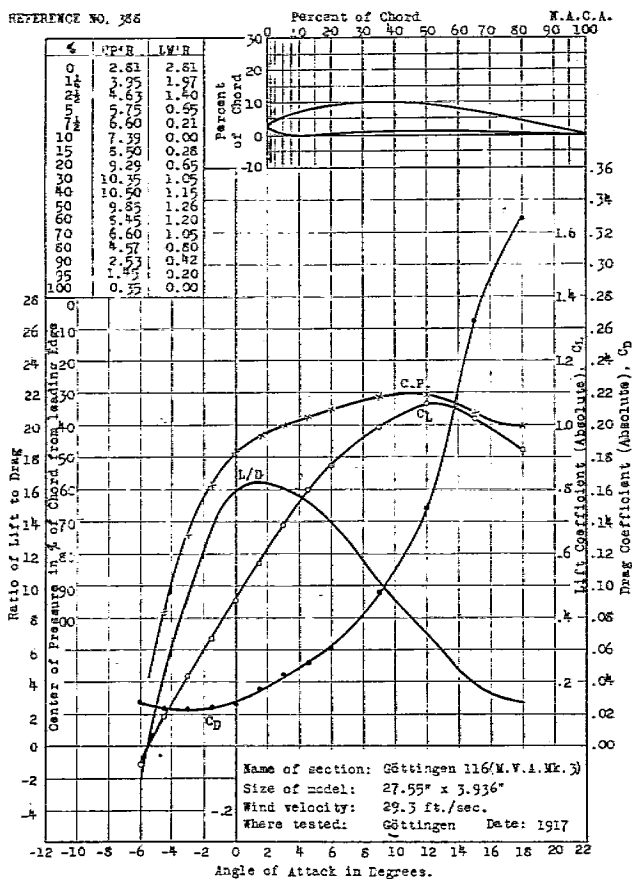
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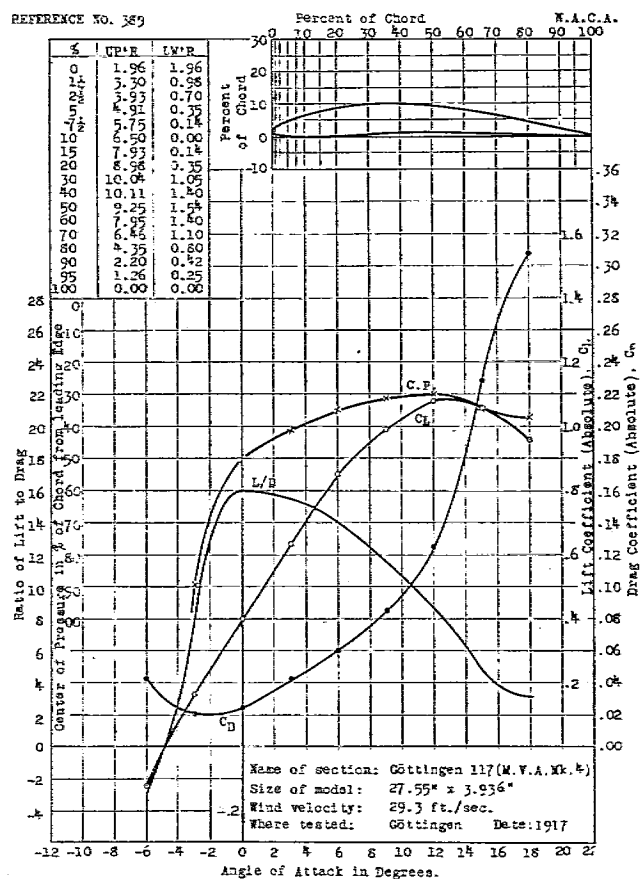
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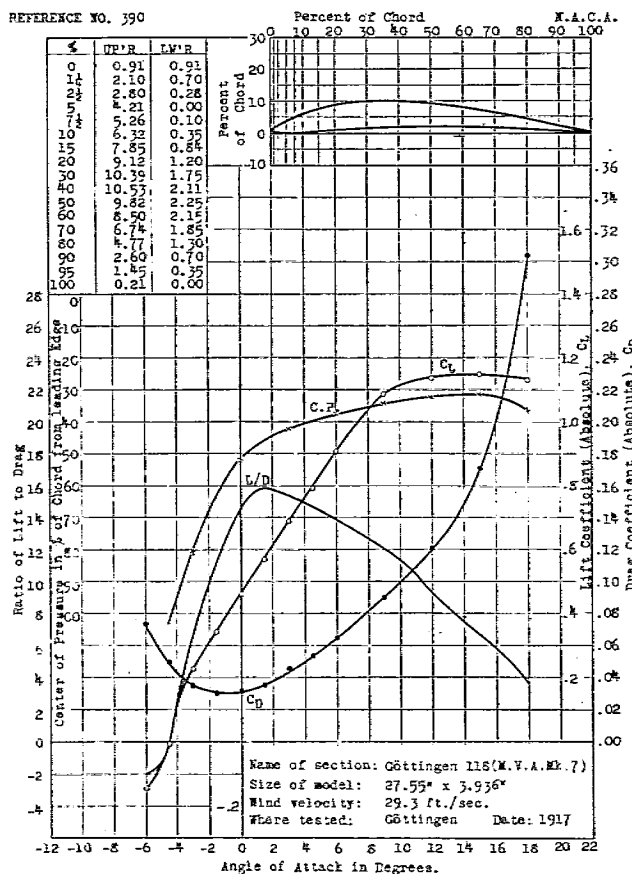
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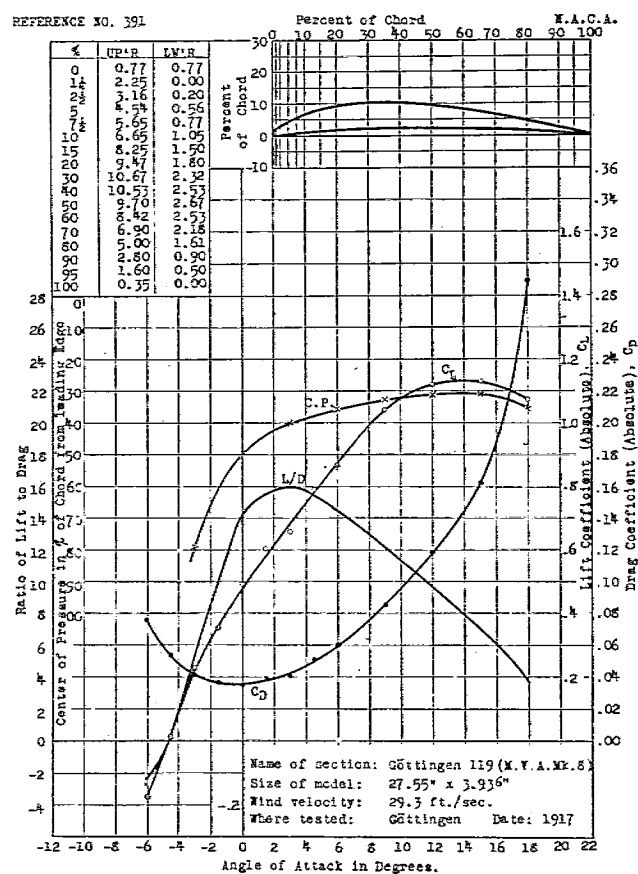
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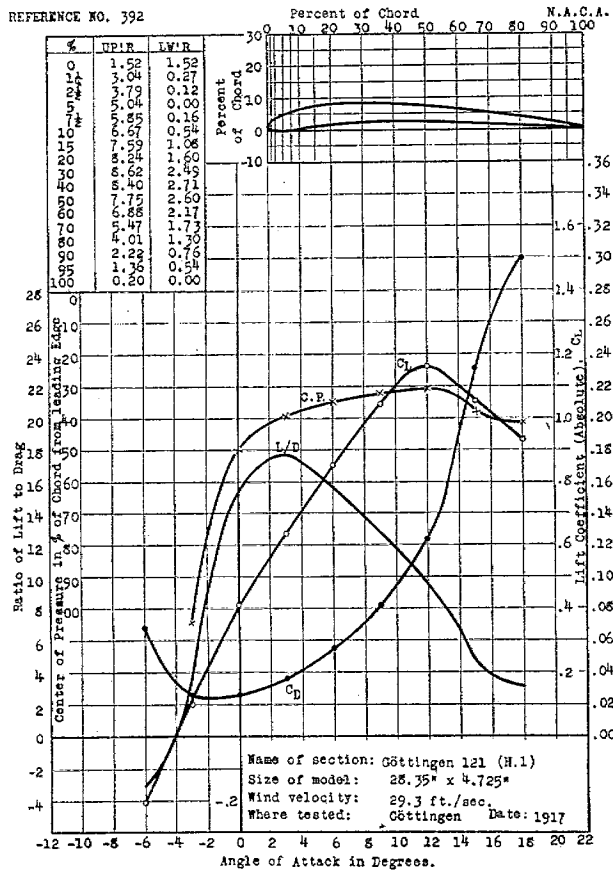
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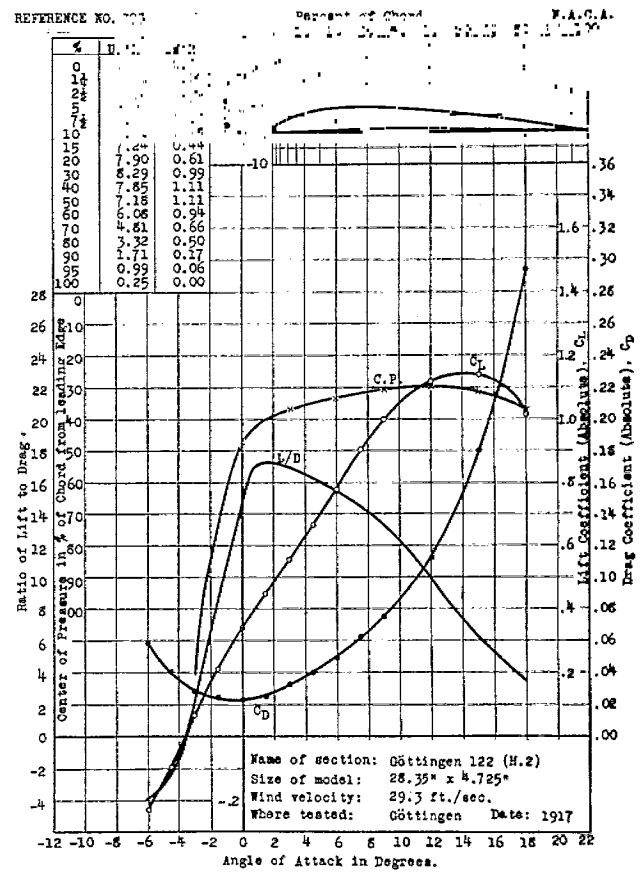
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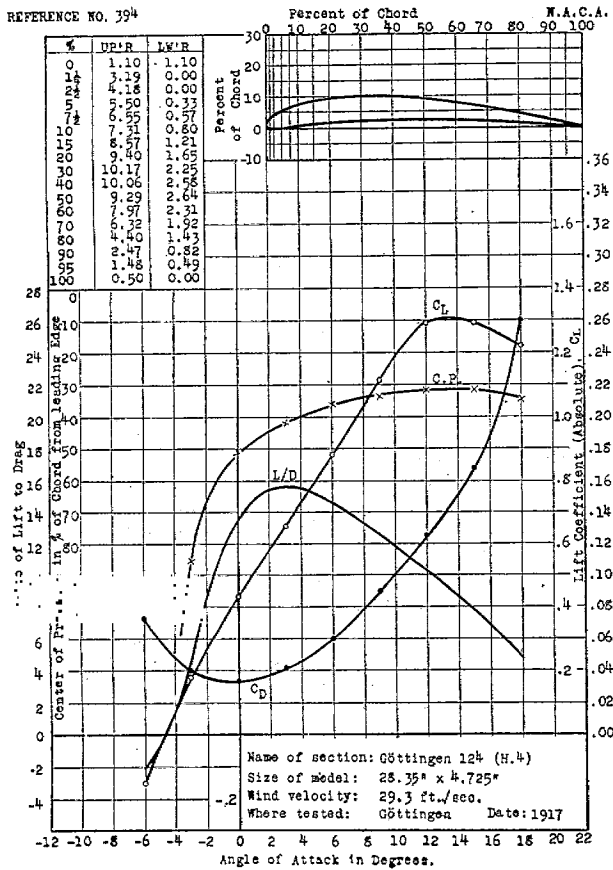
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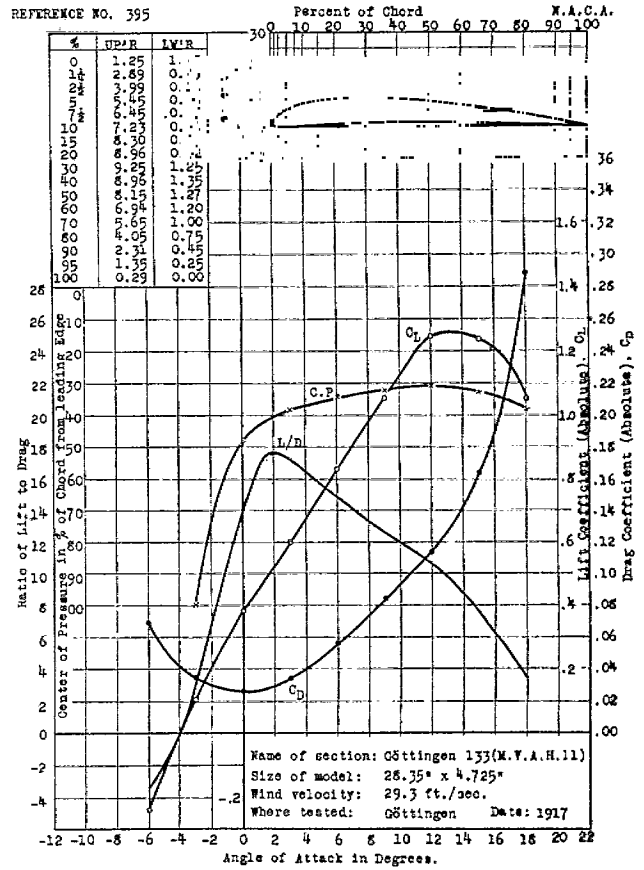
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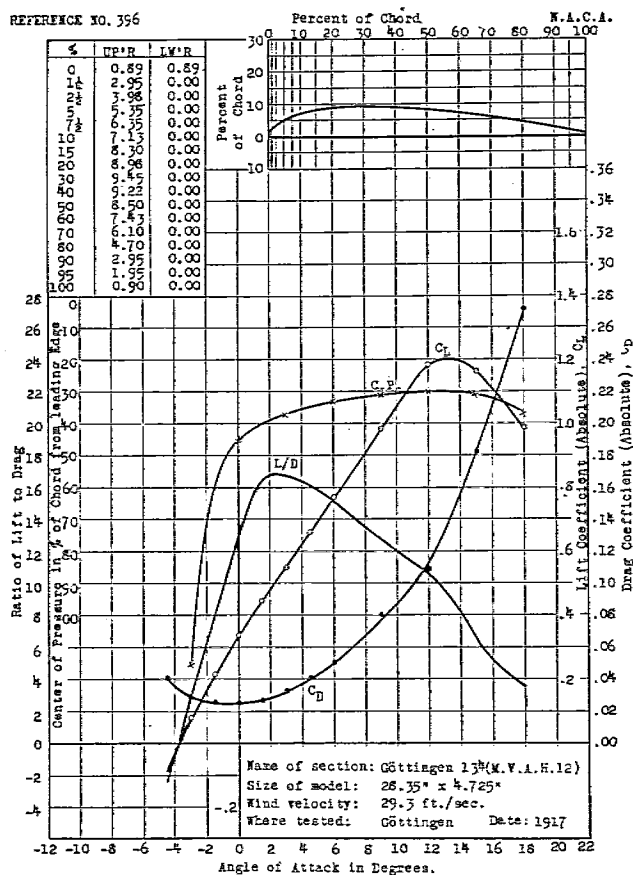
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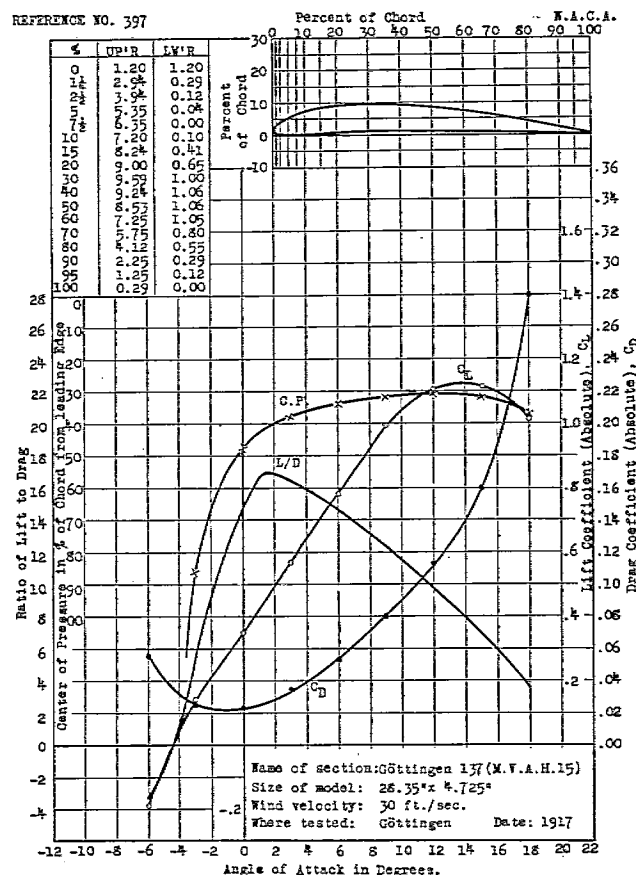
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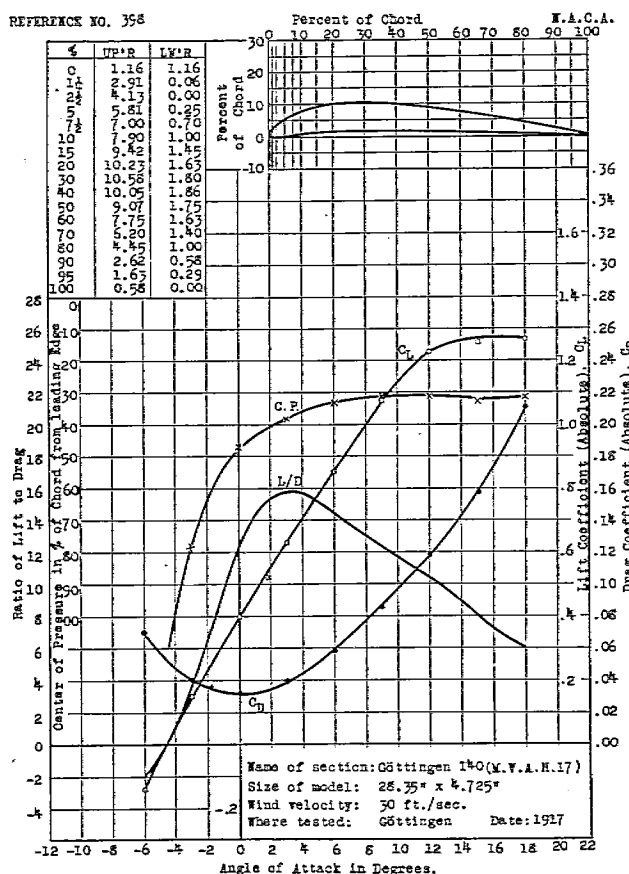
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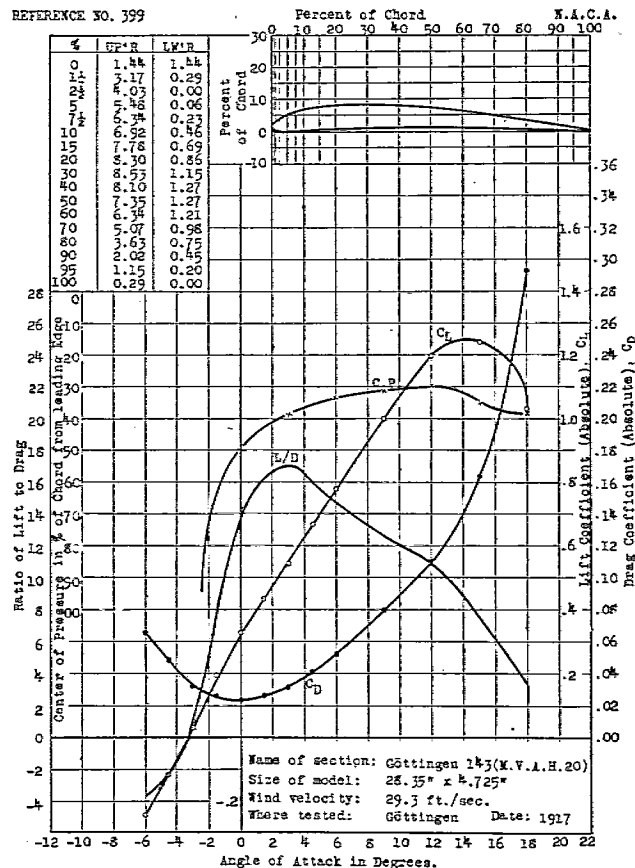
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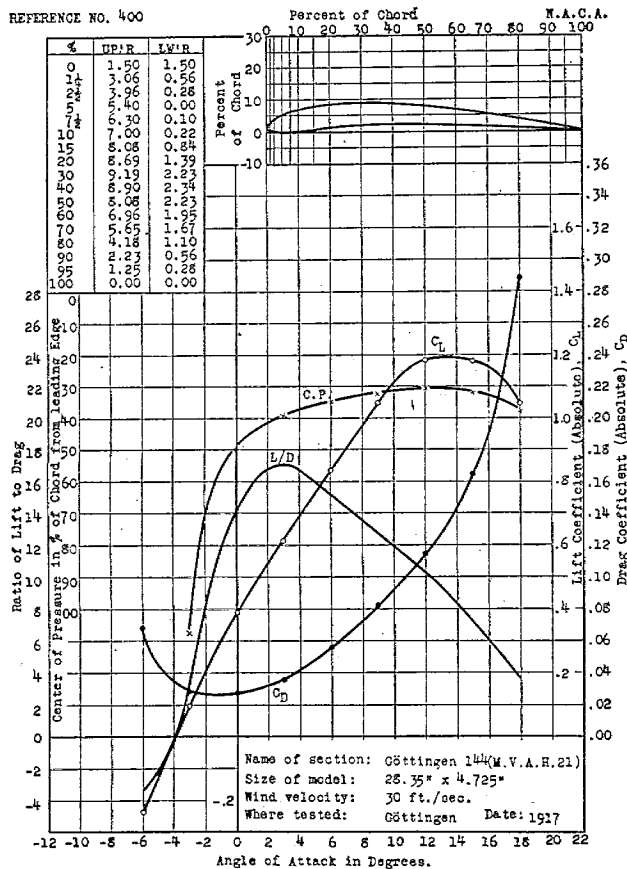
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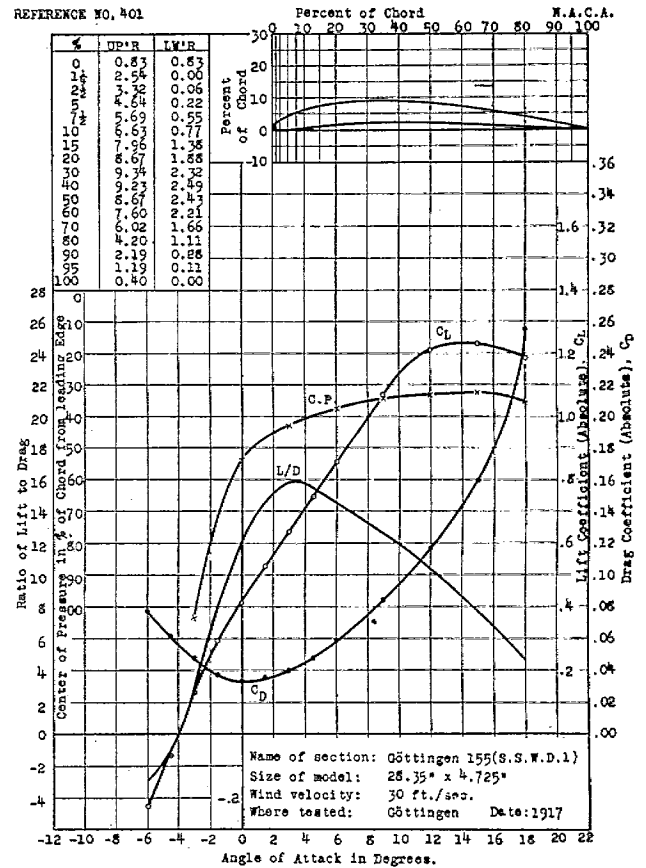
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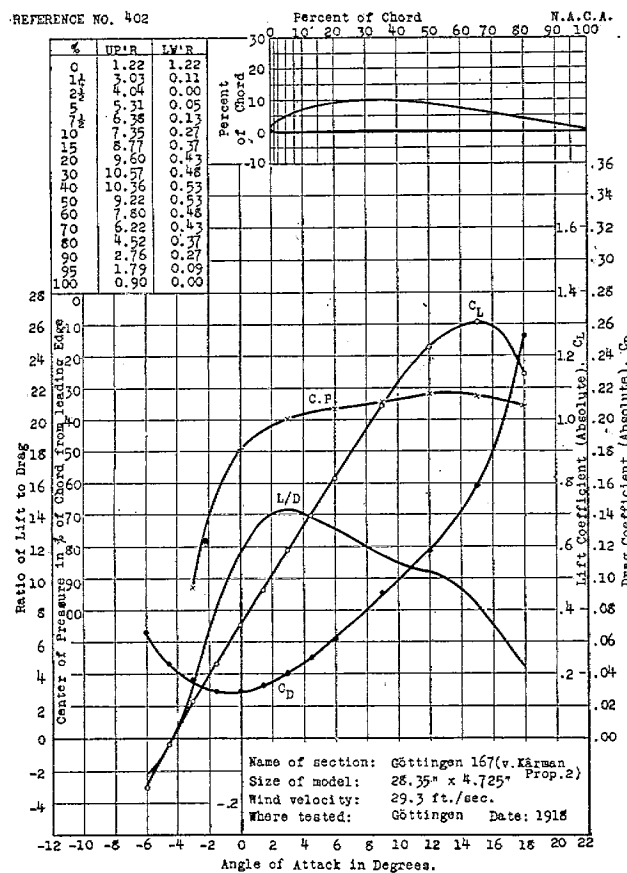
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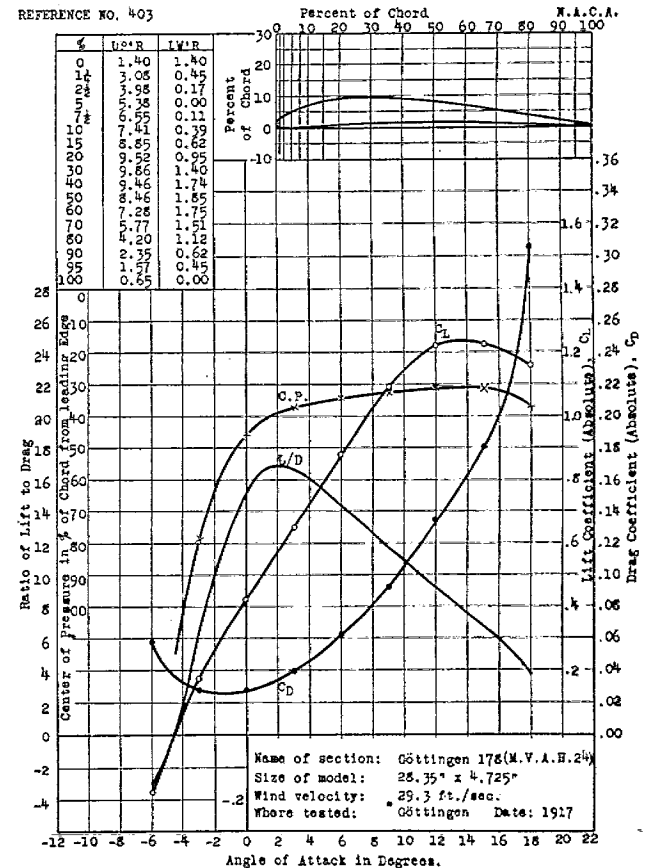
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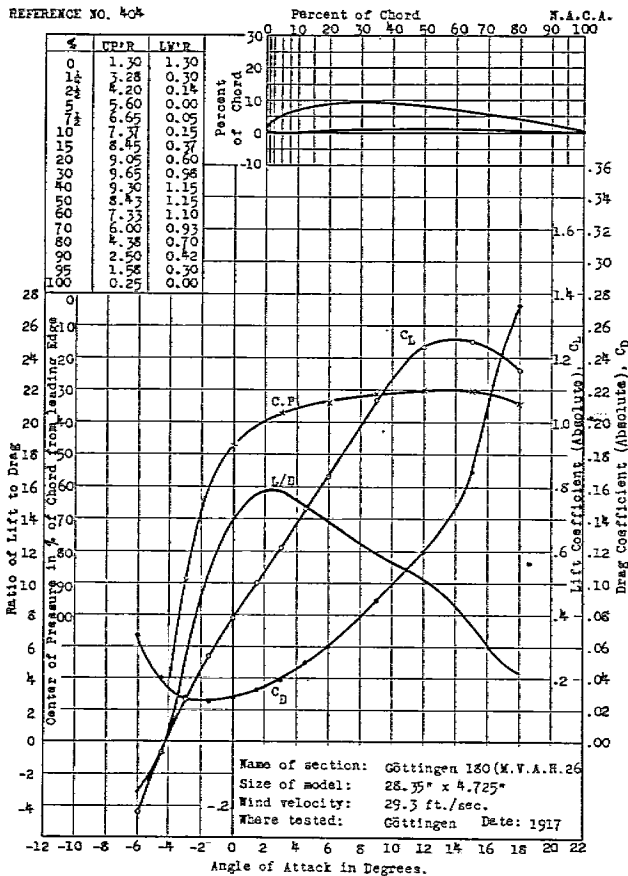
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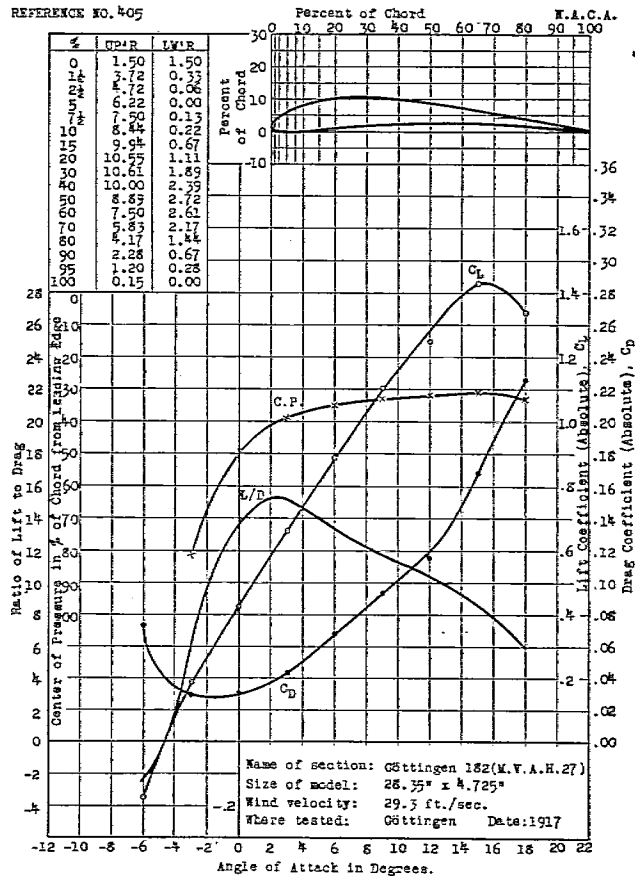
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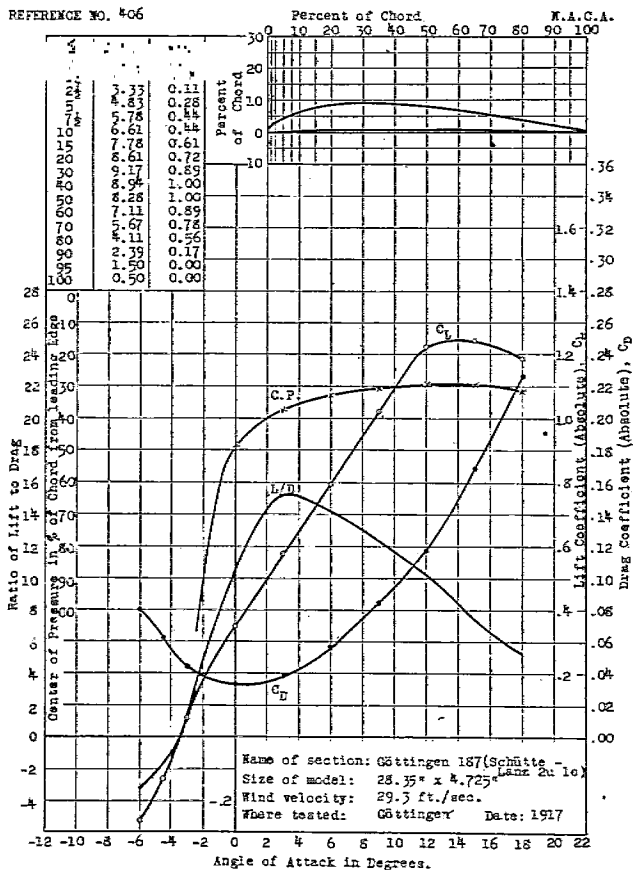
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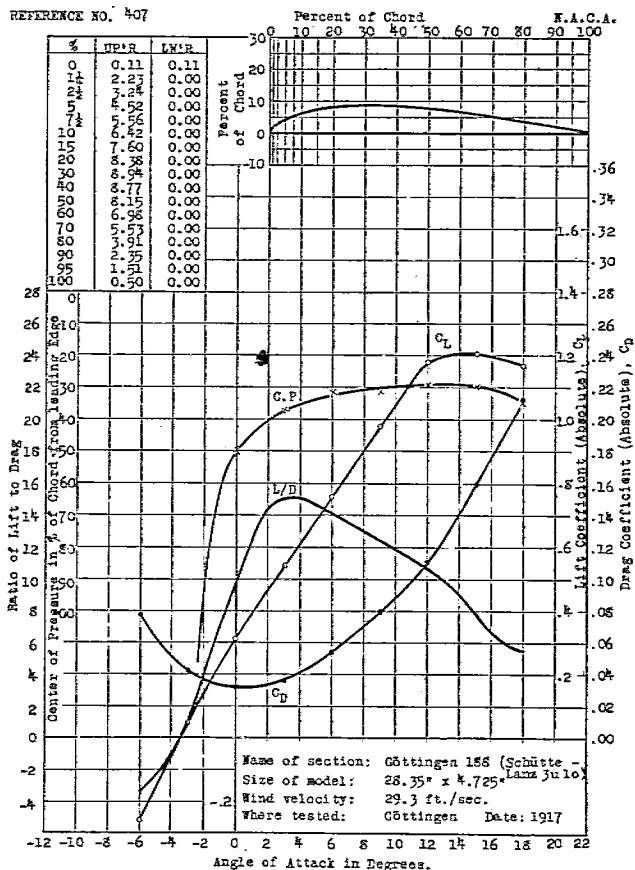
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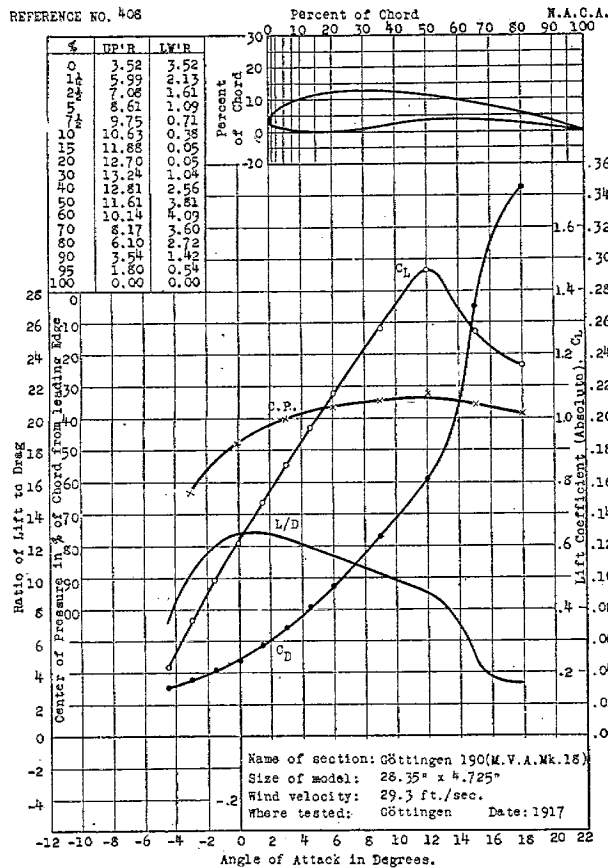
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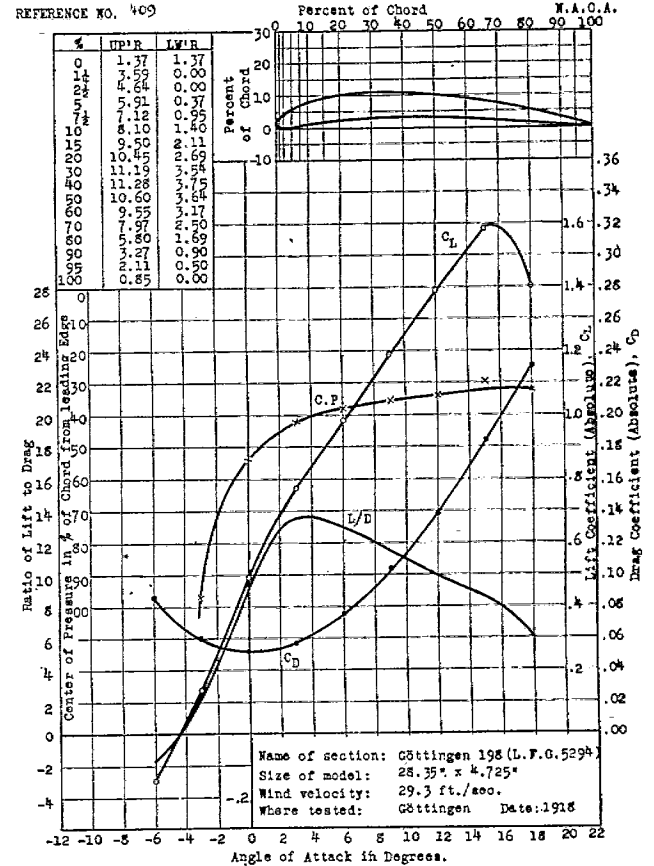
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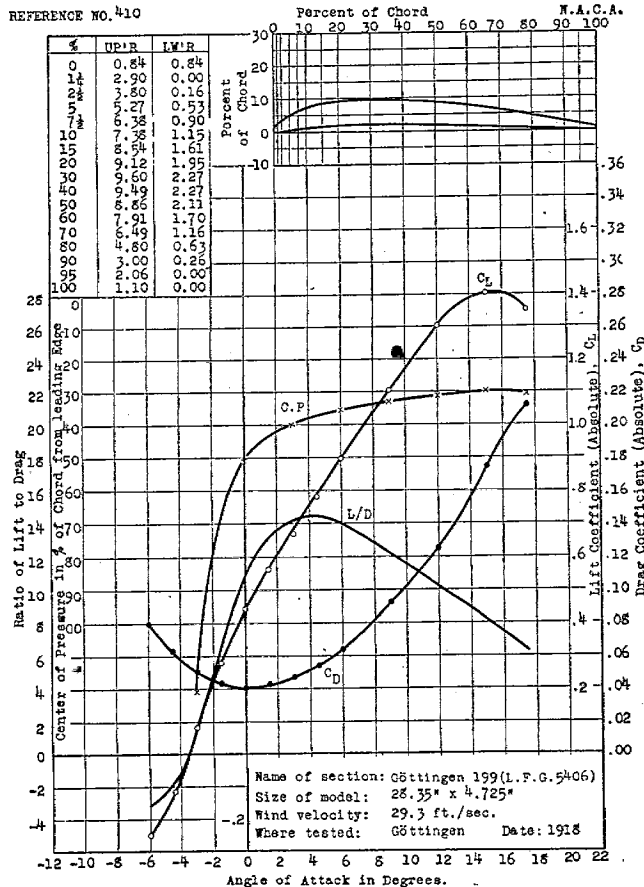
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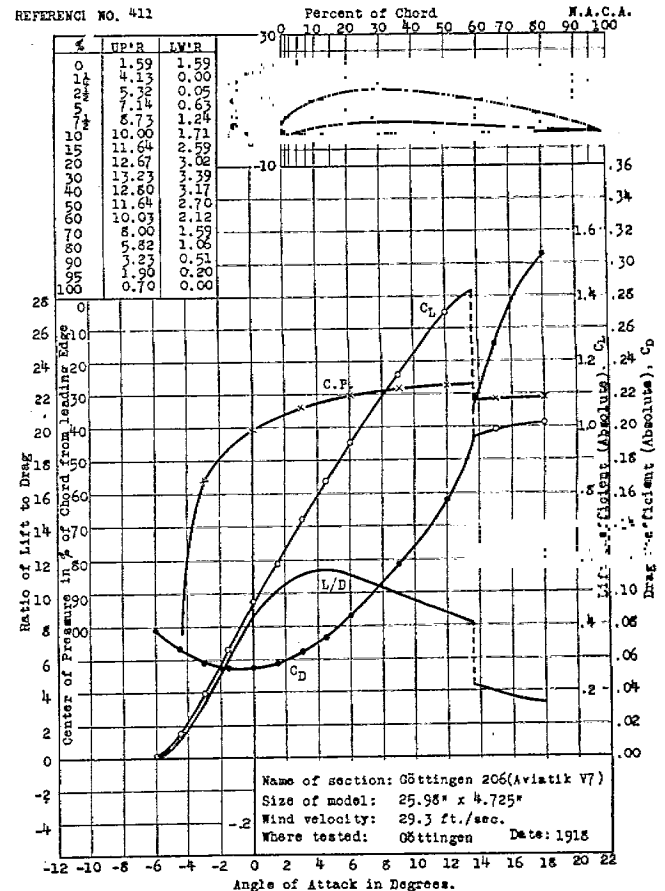
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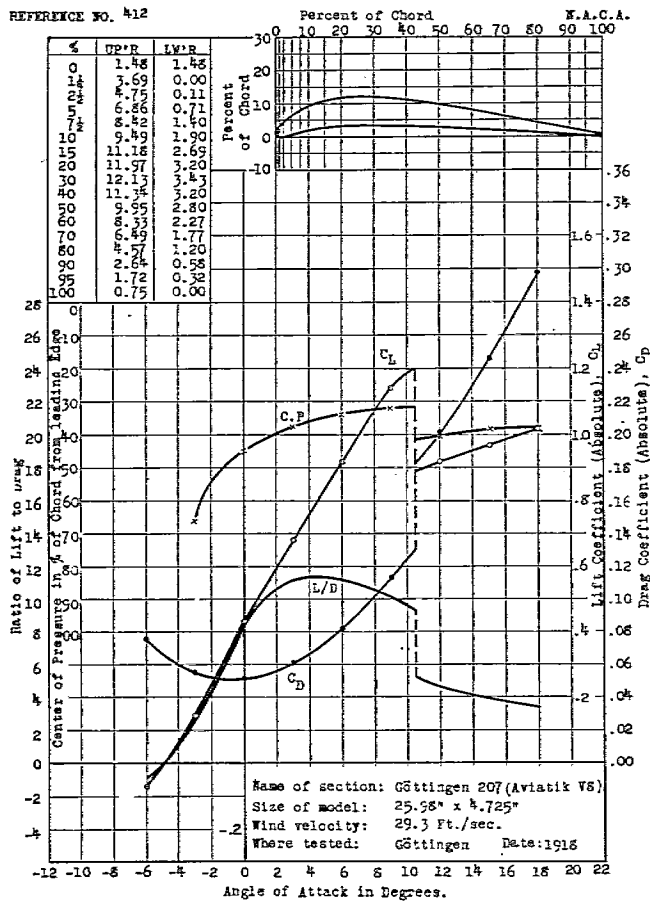
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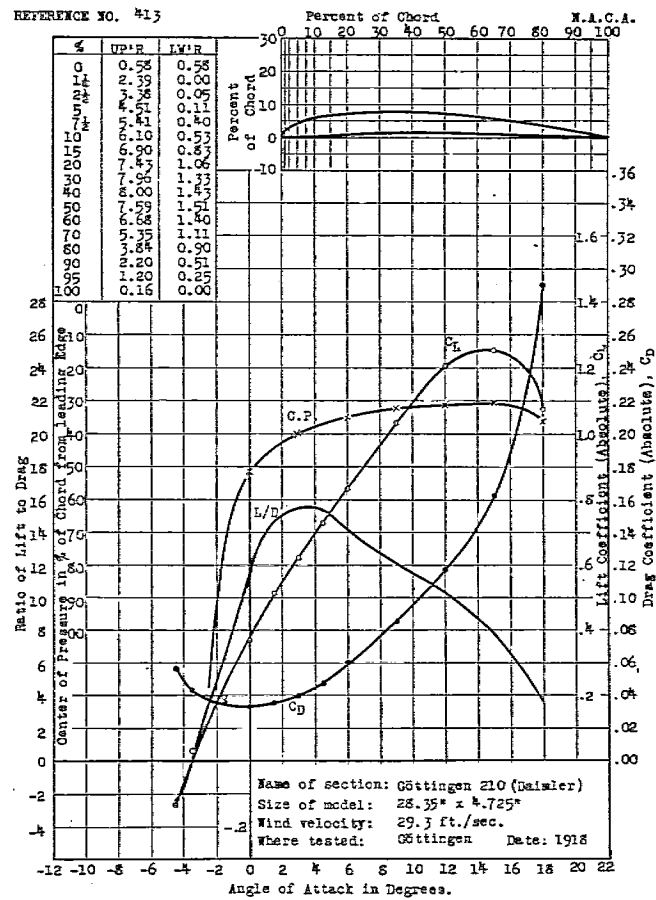
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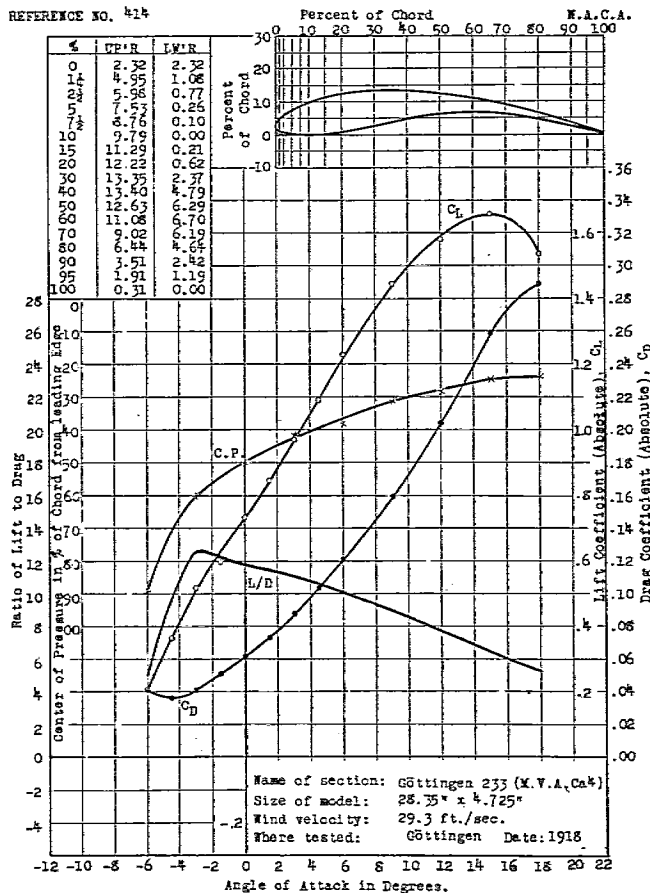
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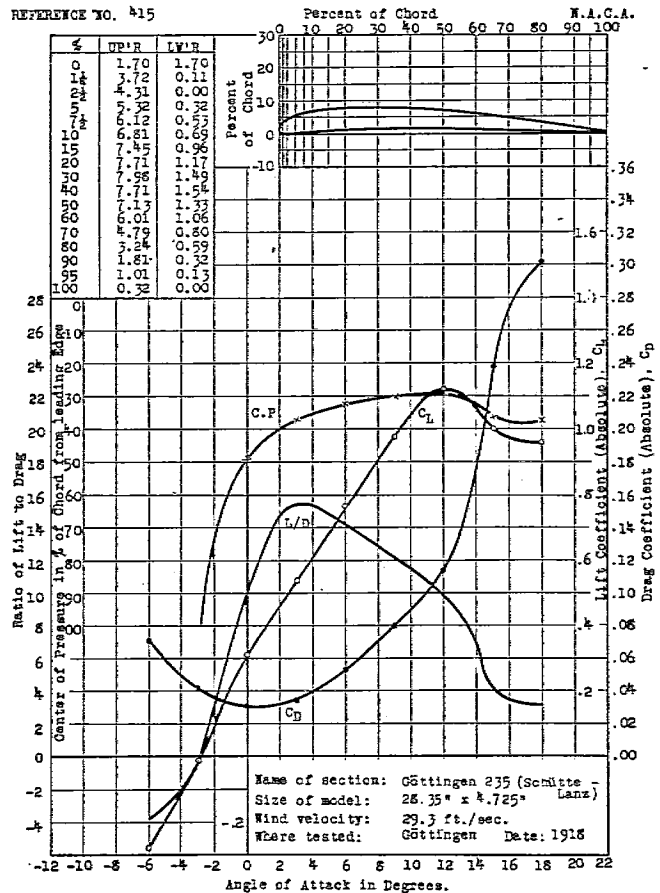
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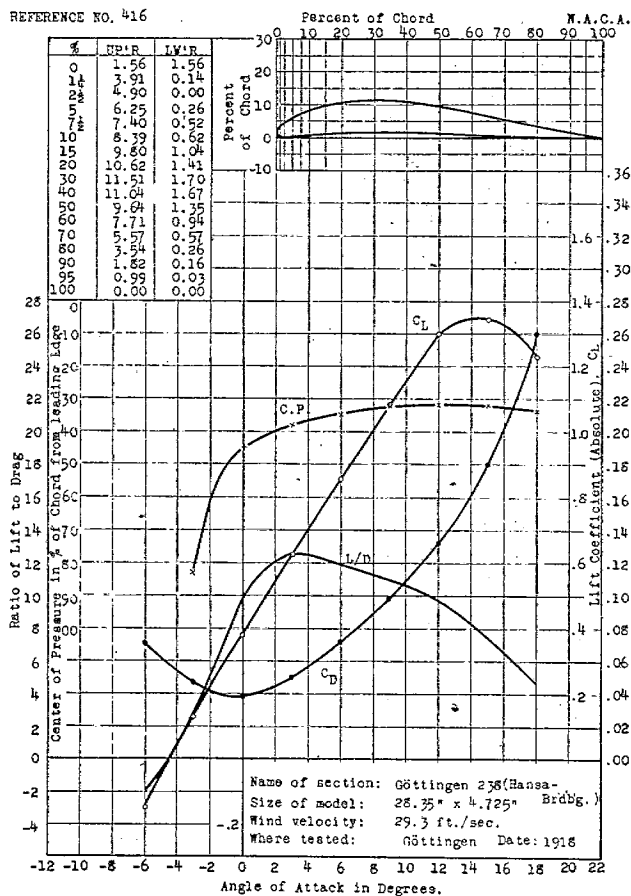
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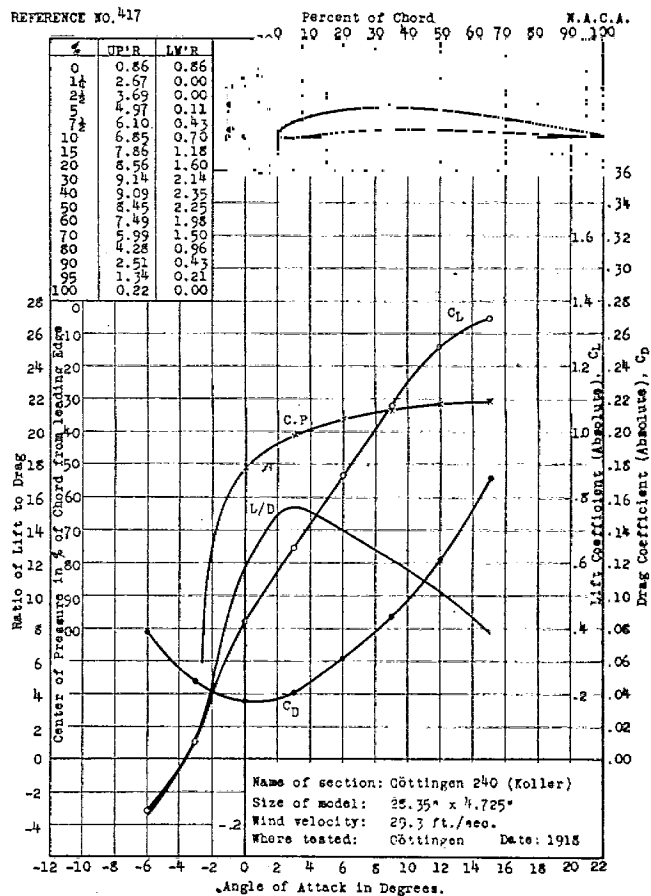
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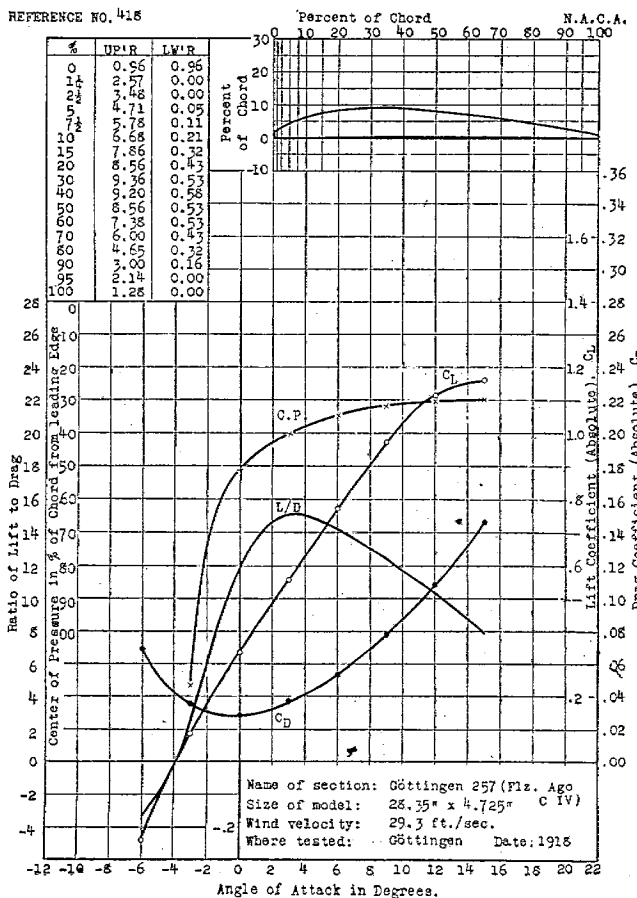
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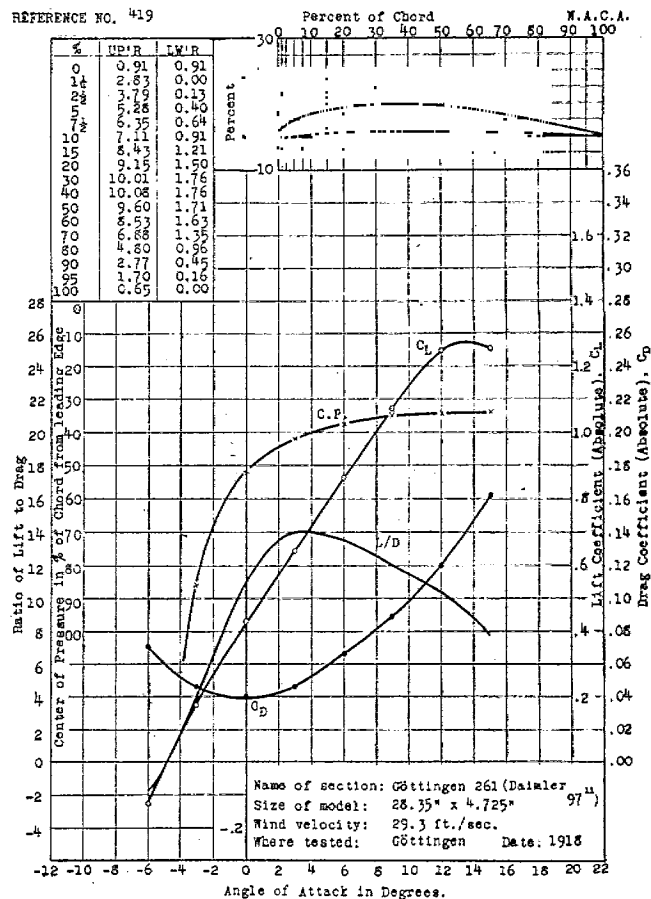
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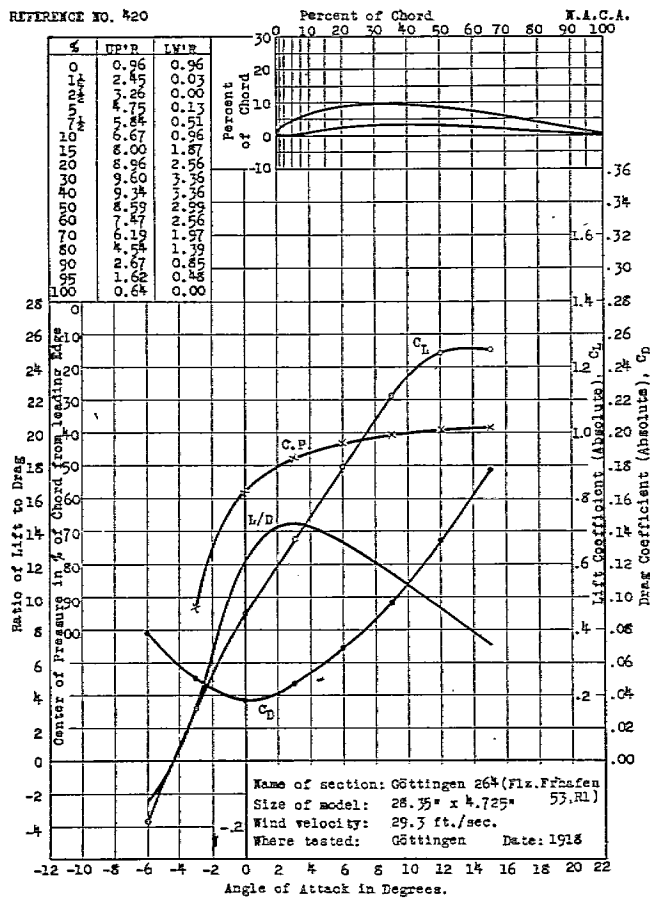
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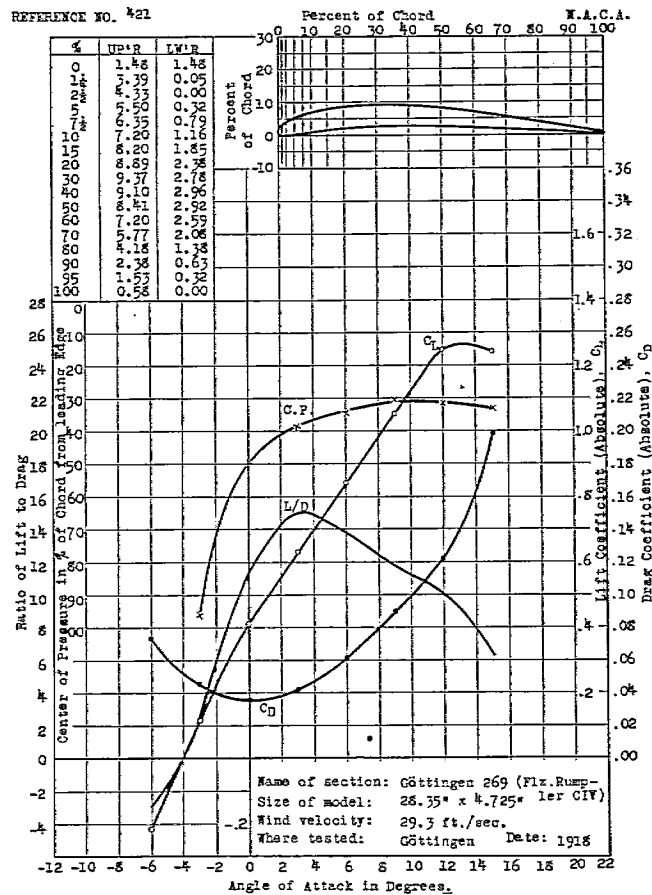
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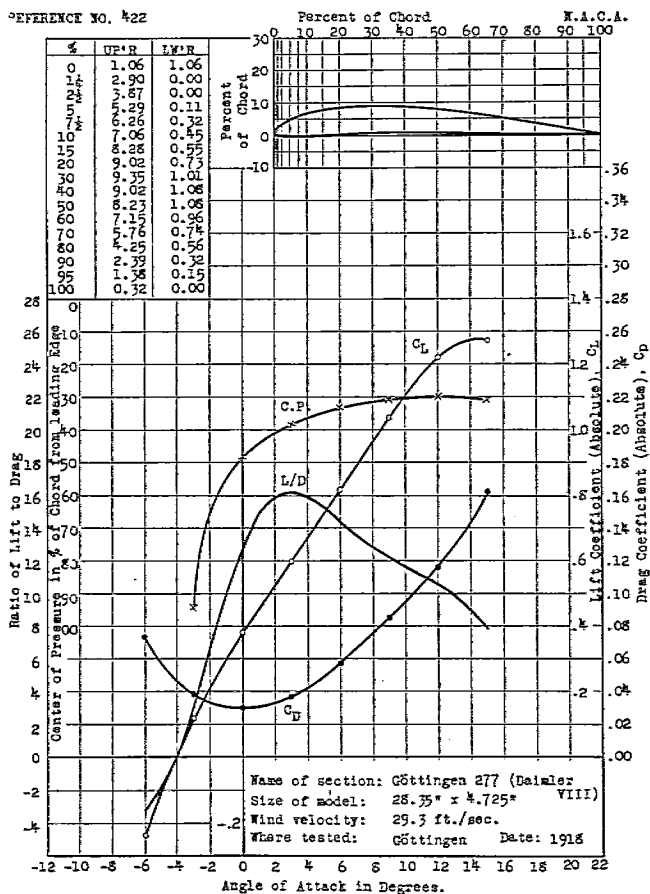
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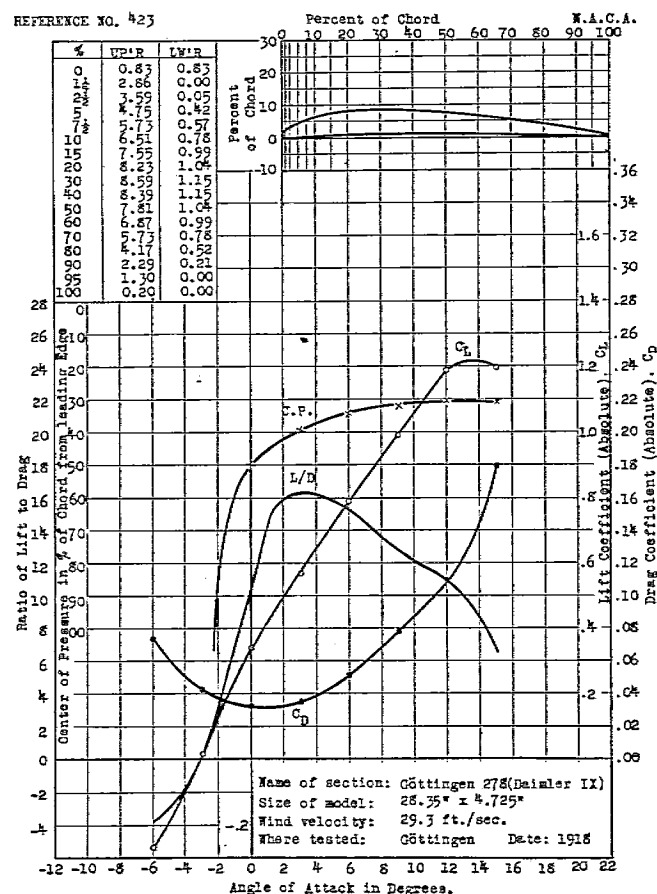
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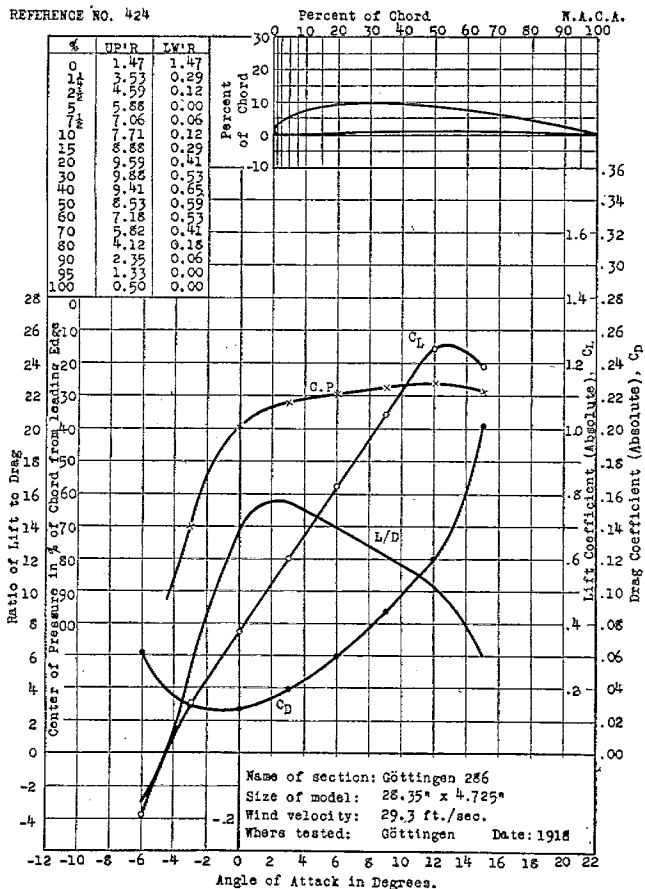
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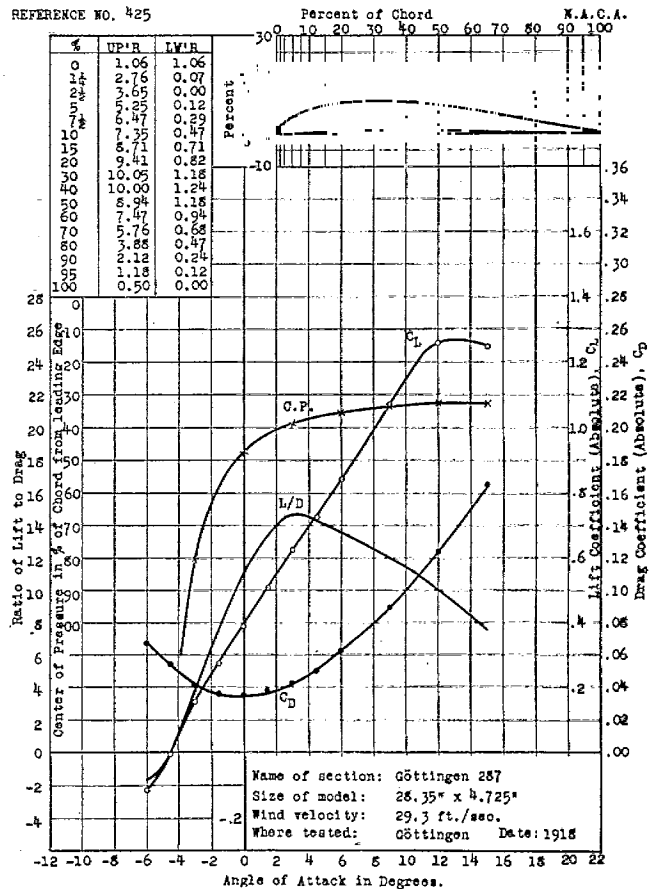
REFERENCE NO. 423



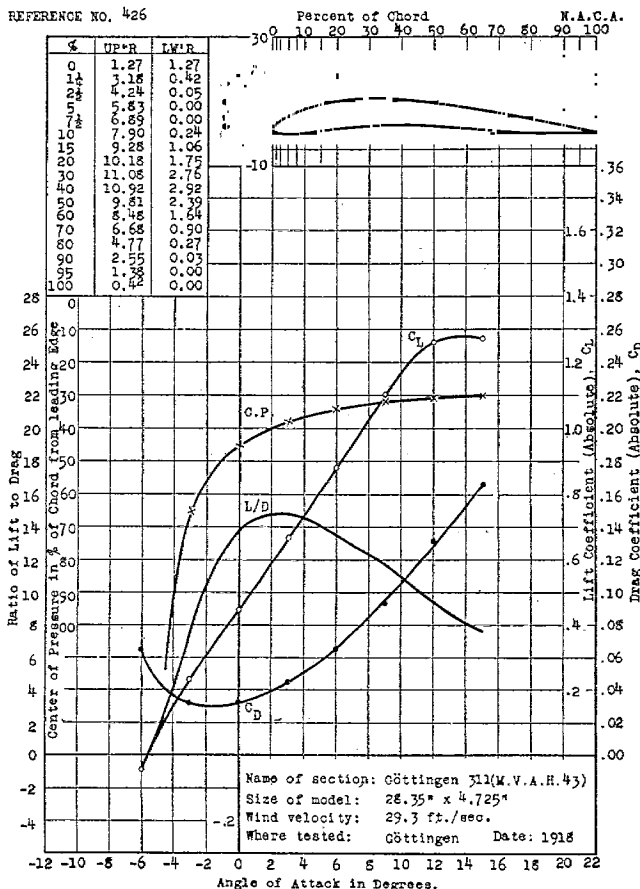
REFERENCE NO. 424



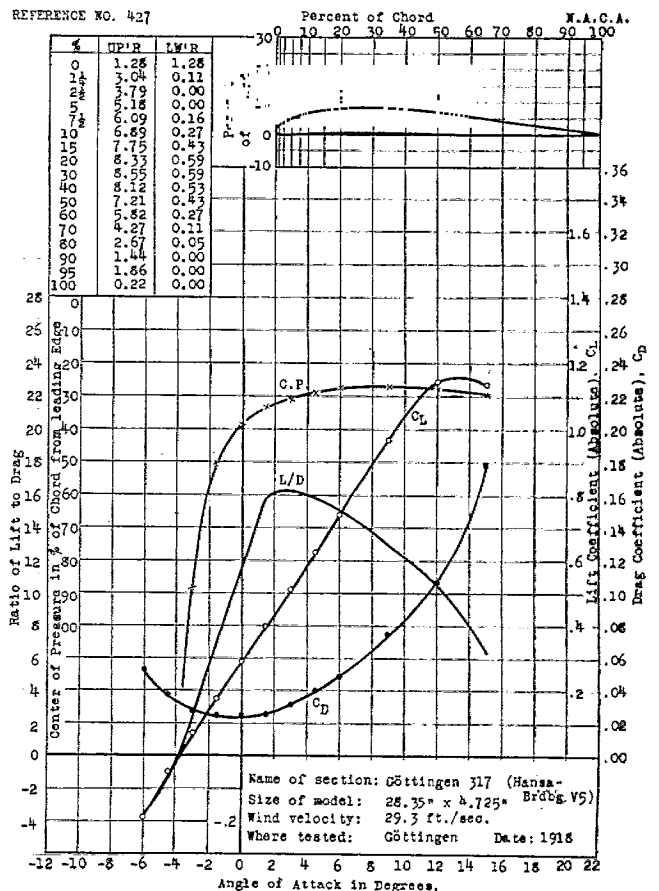
REFERENCE NO. 425



REFERENCE NO. 426



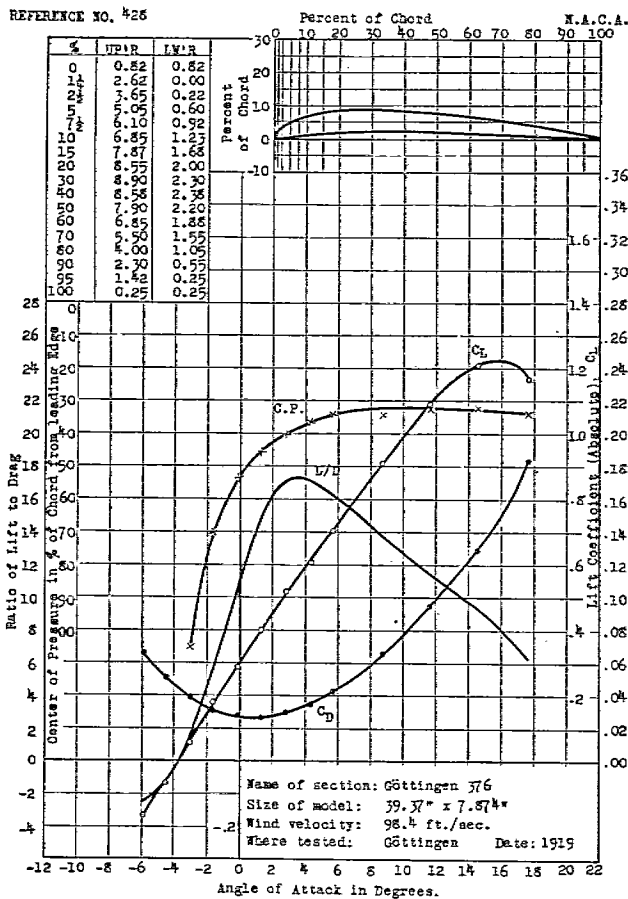
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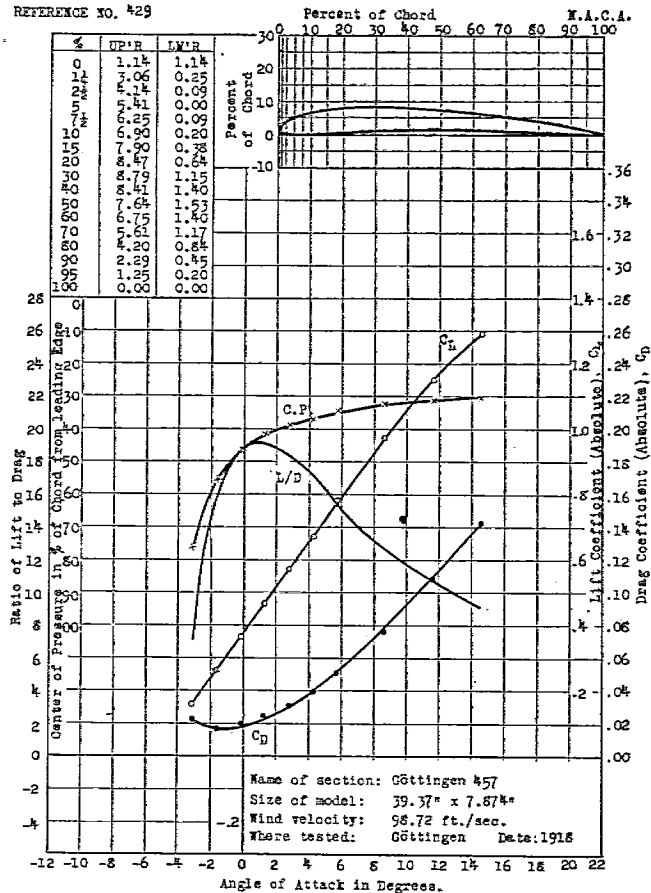
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

415

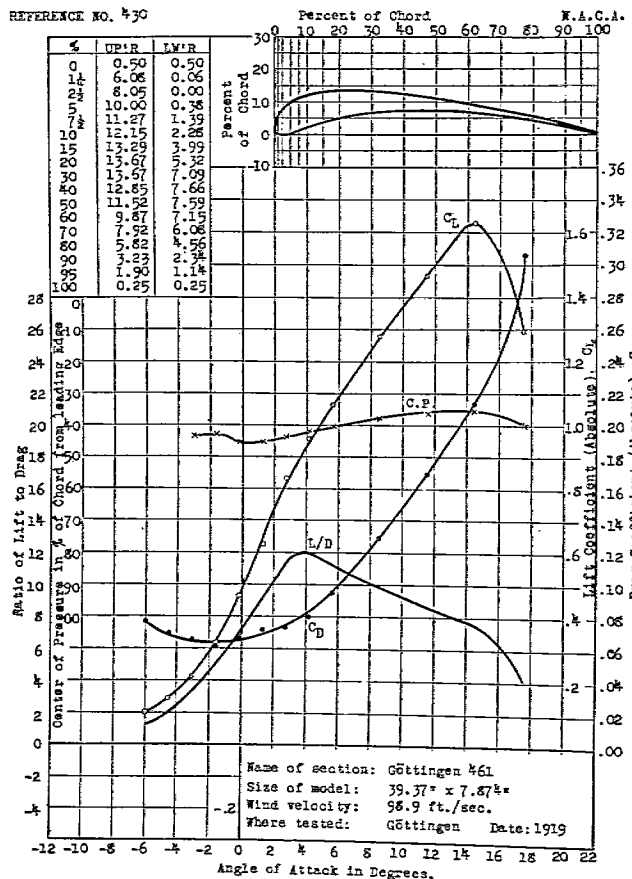
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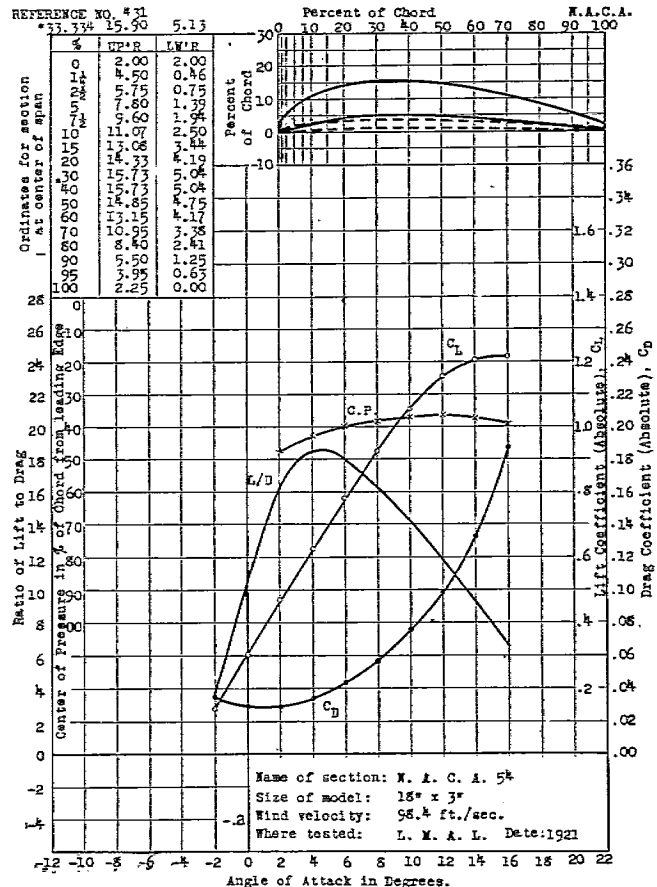
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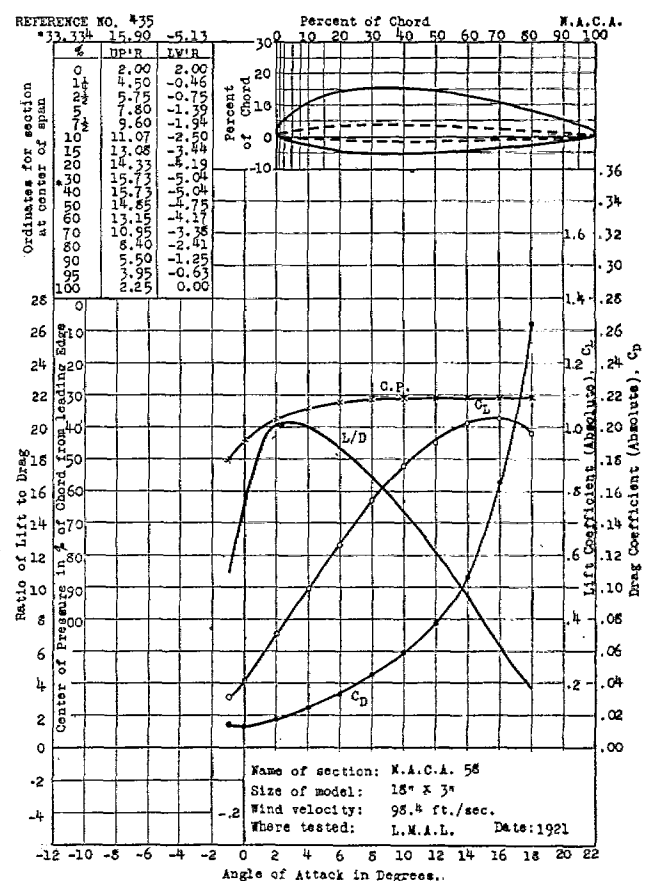
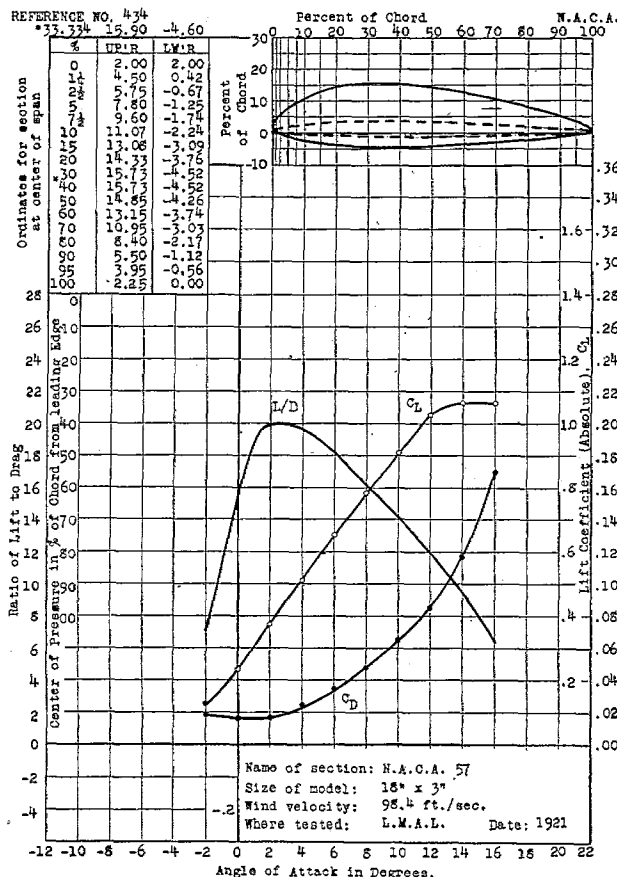
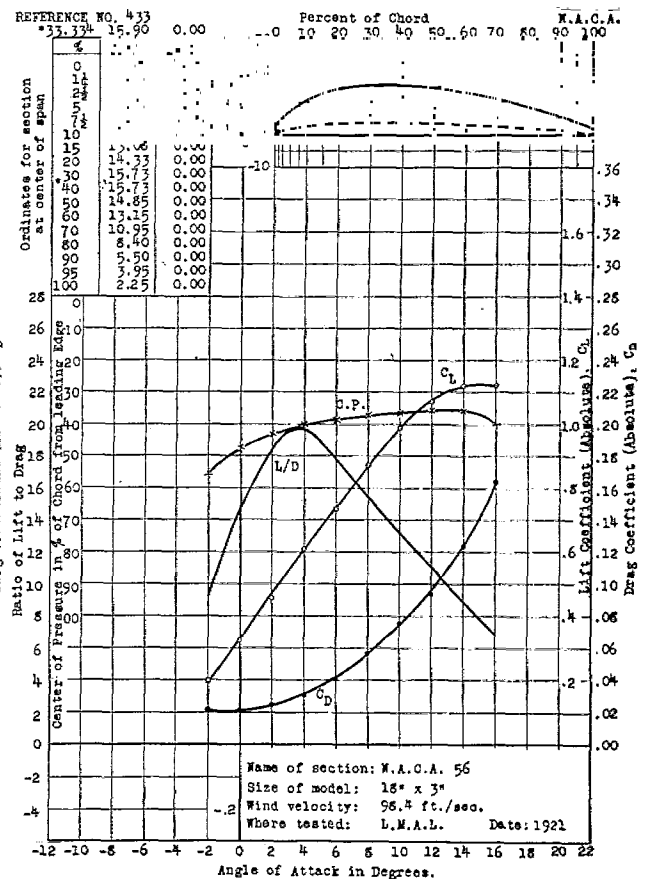
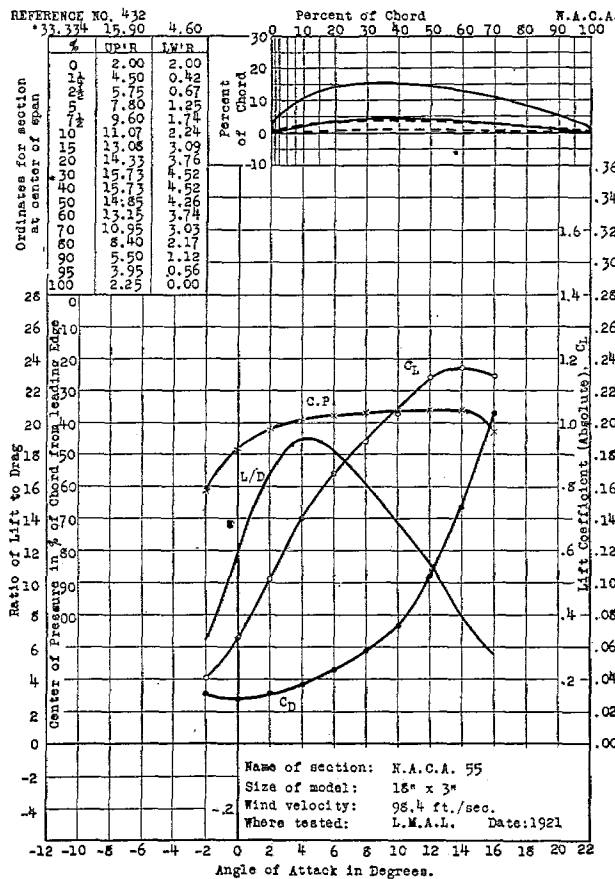


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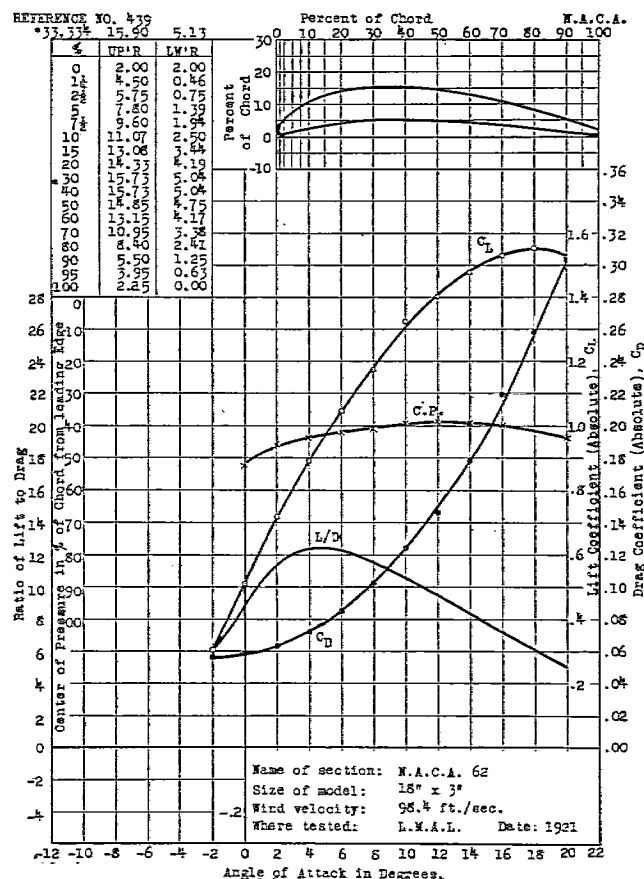
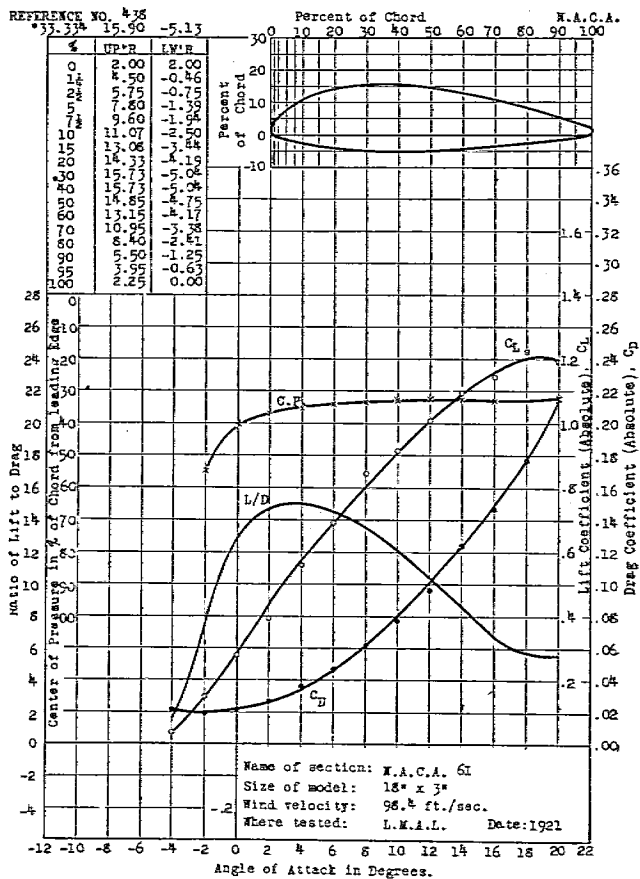
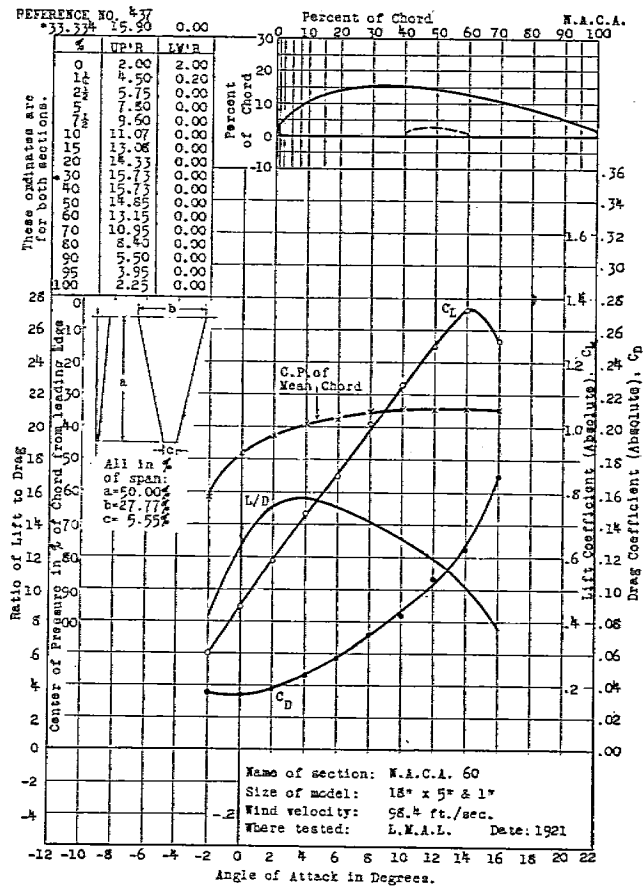
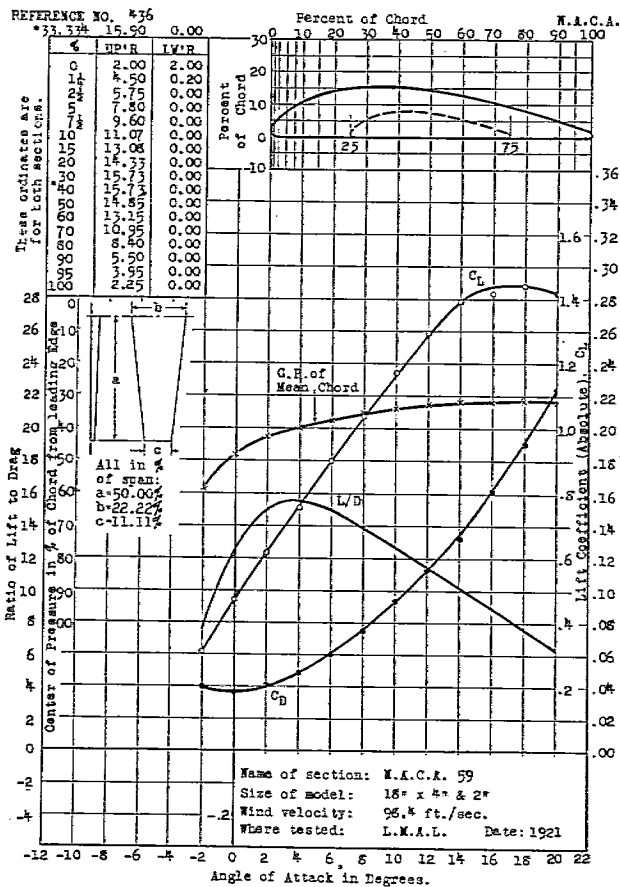
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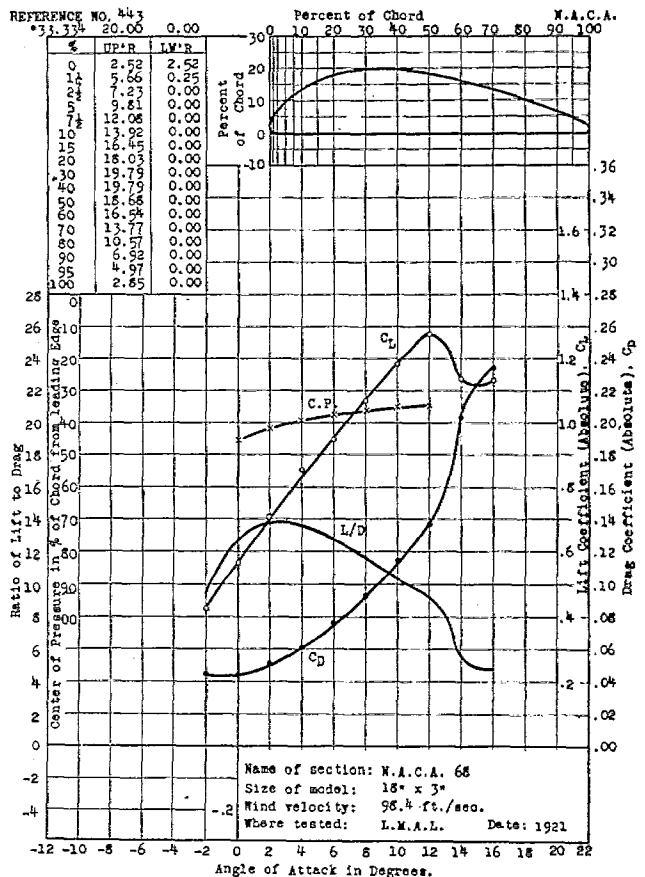
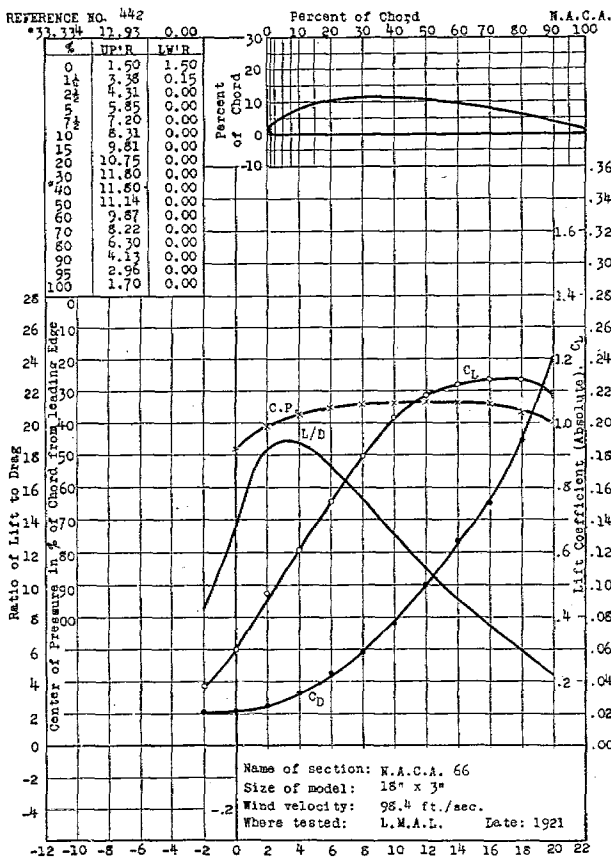
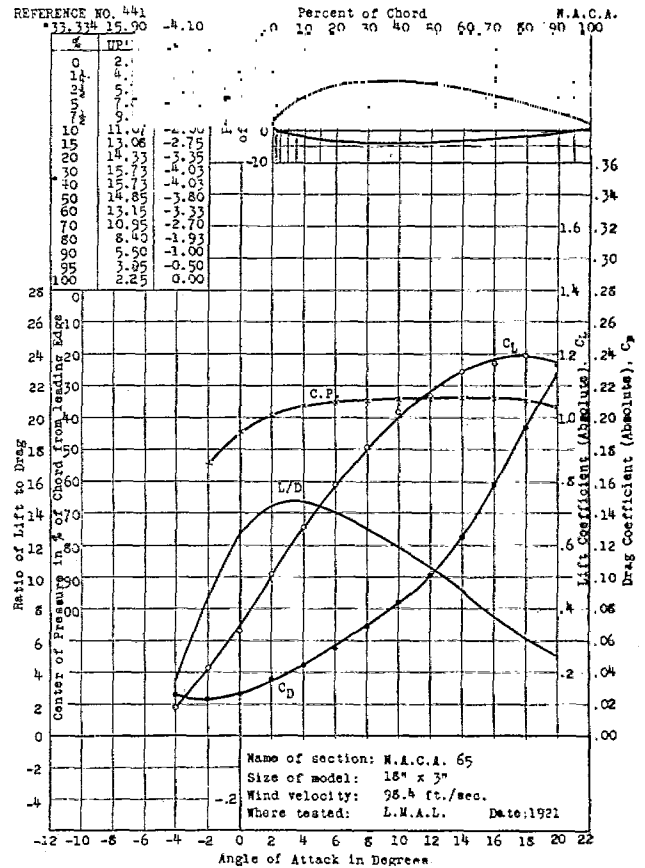
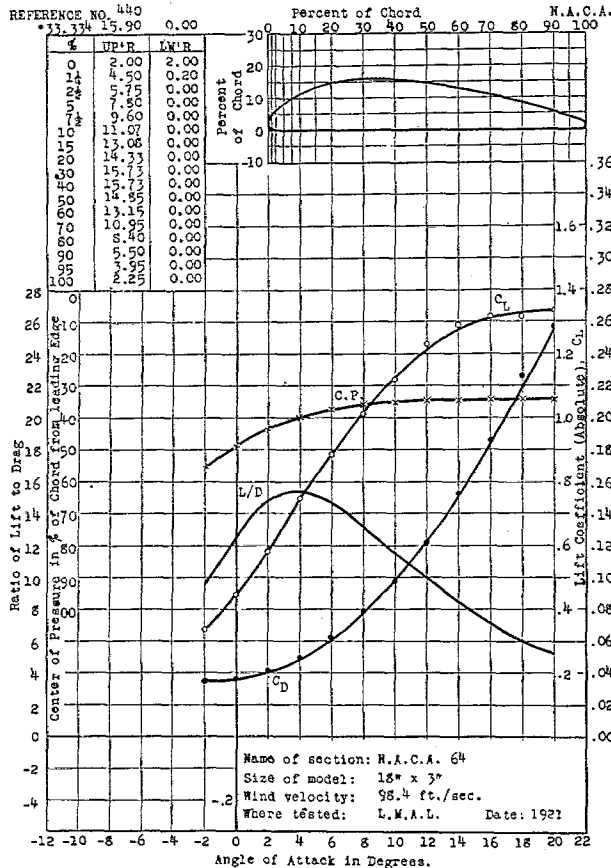




AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

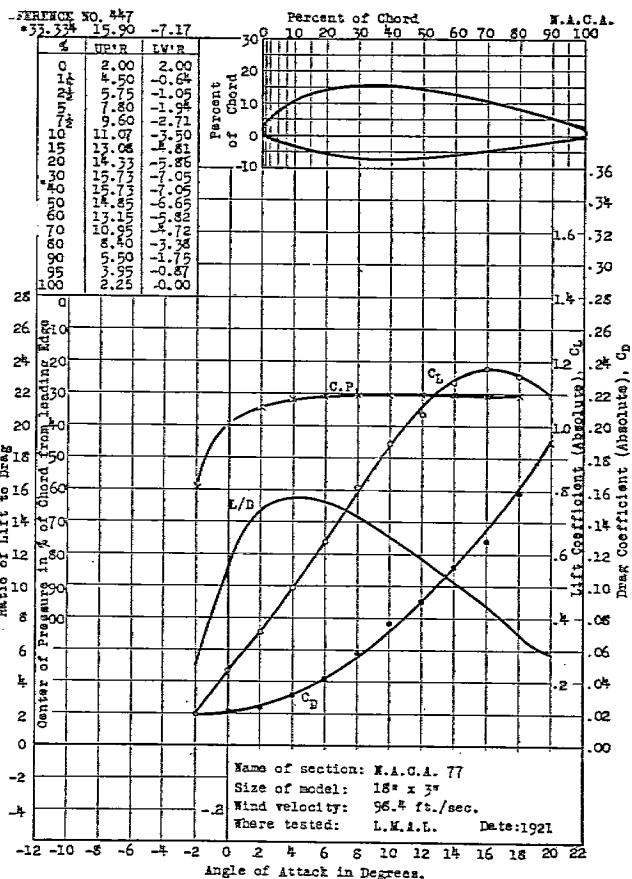
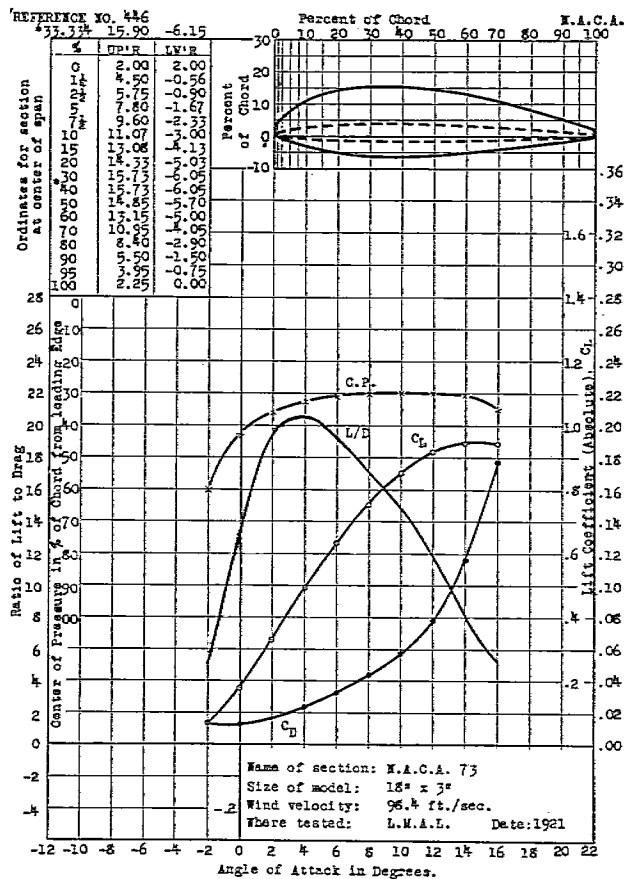
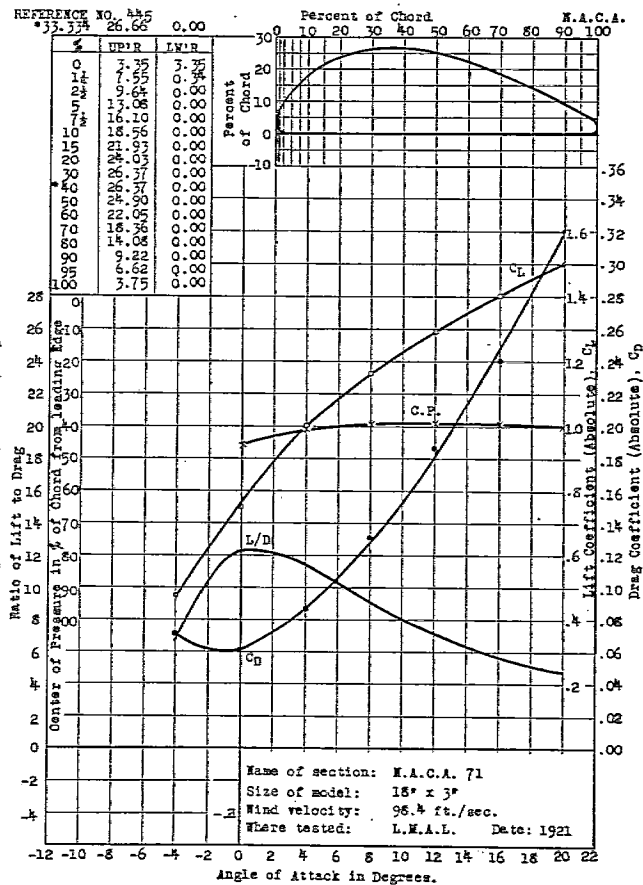
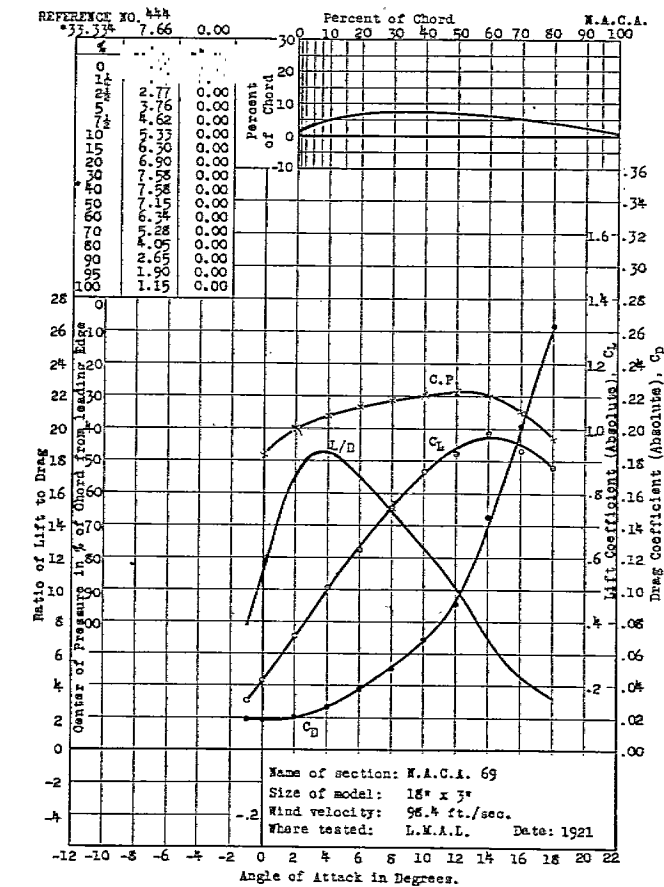
417

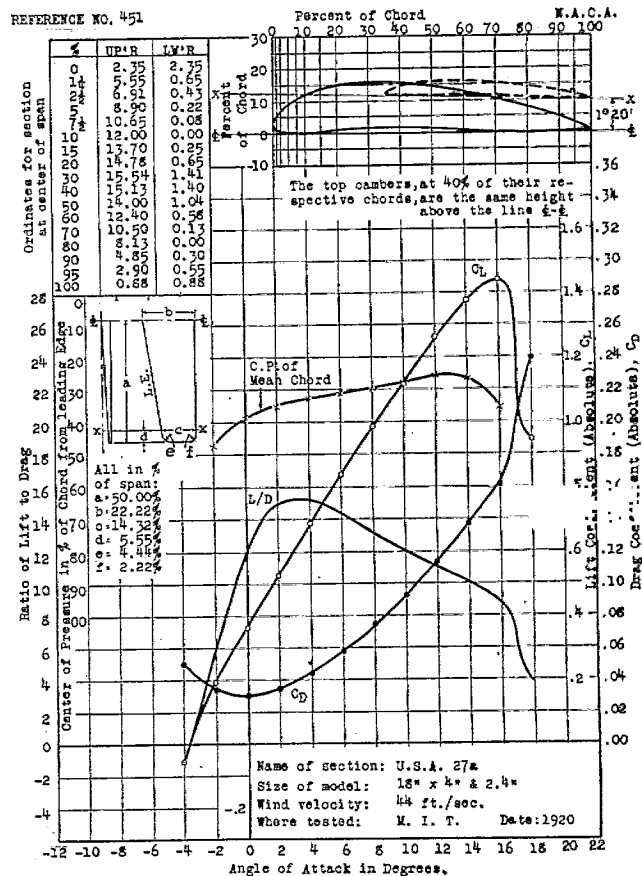
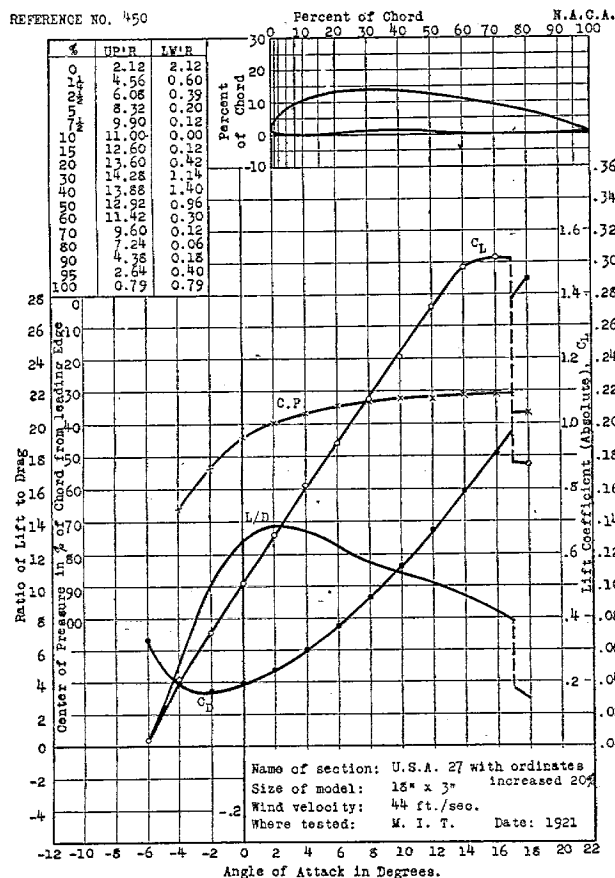
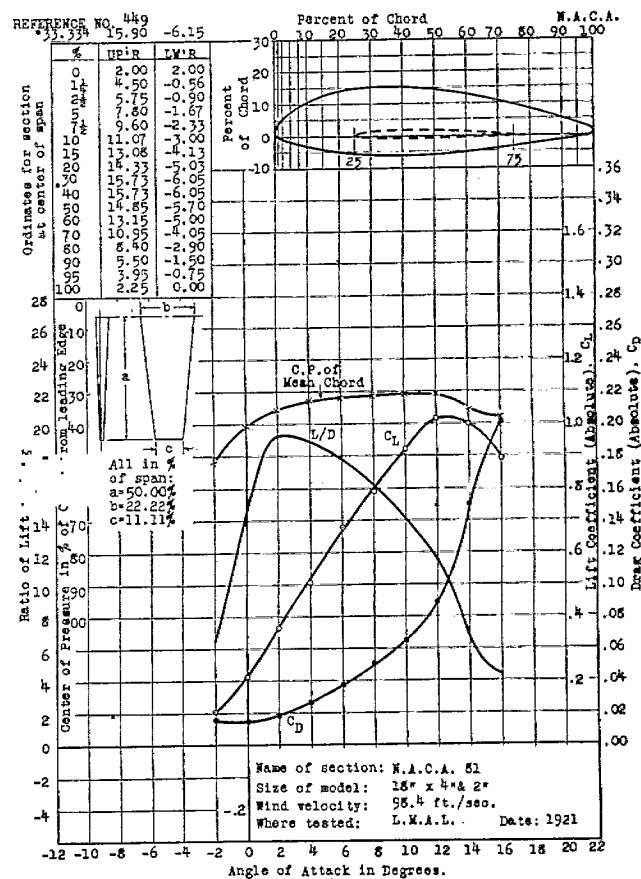
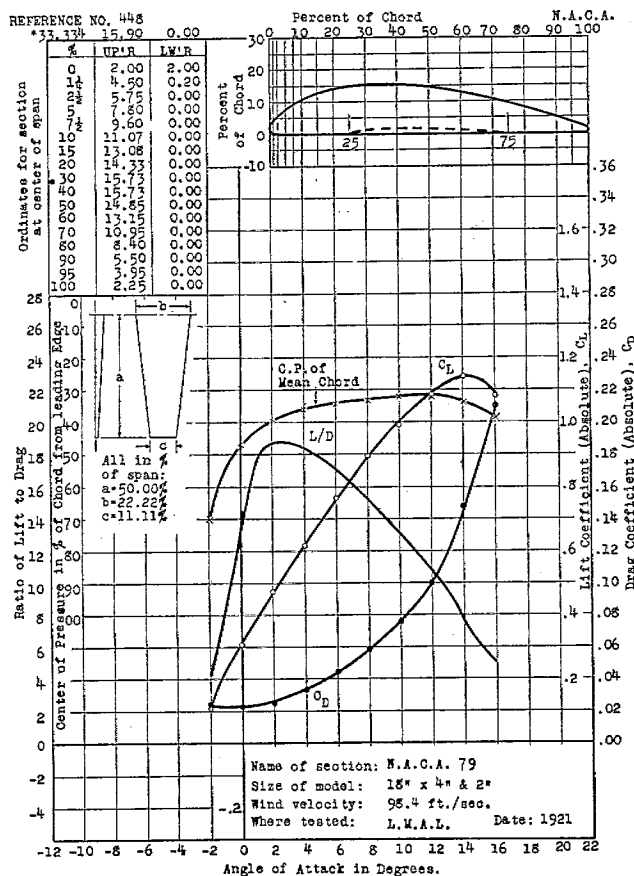




AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

419

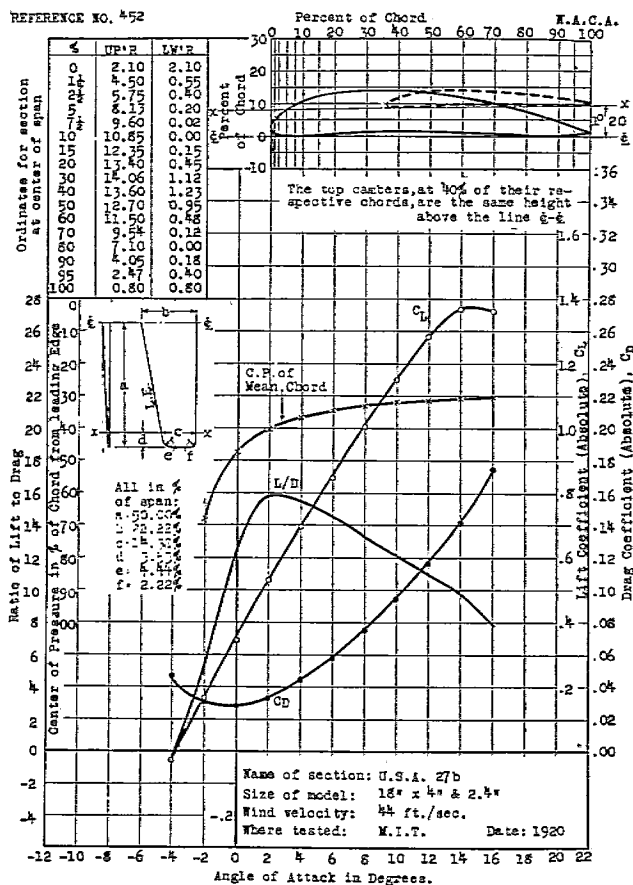




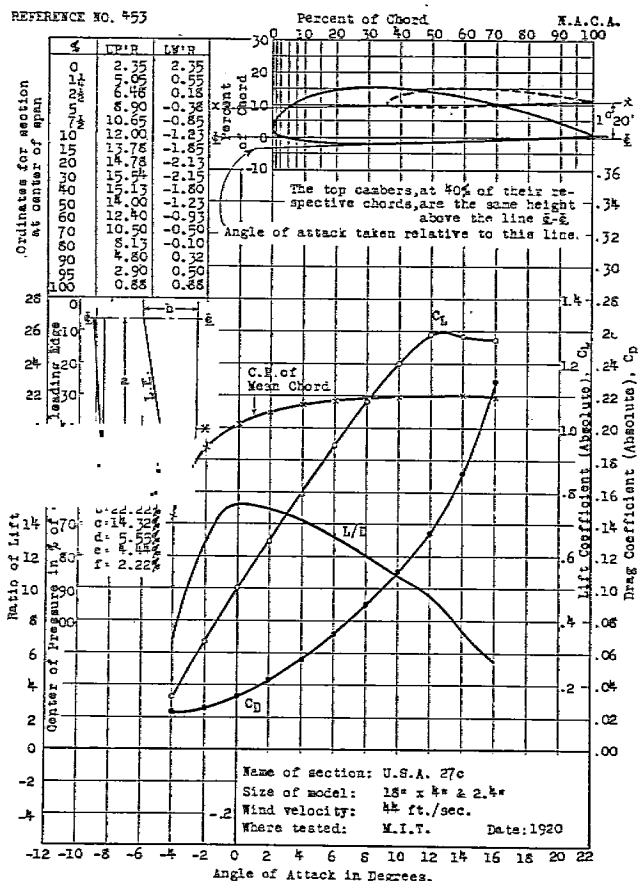
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

421

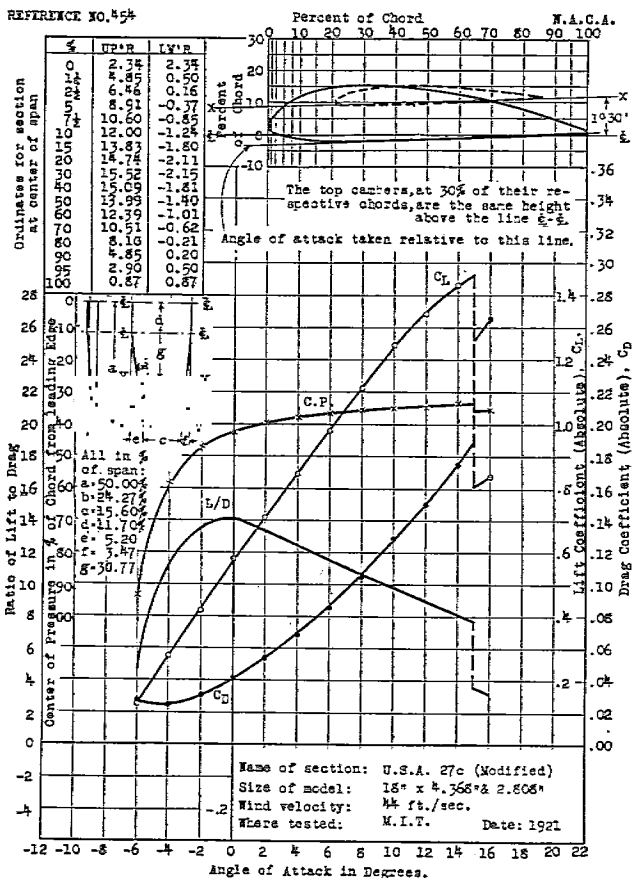
REFERENCE NO. 452



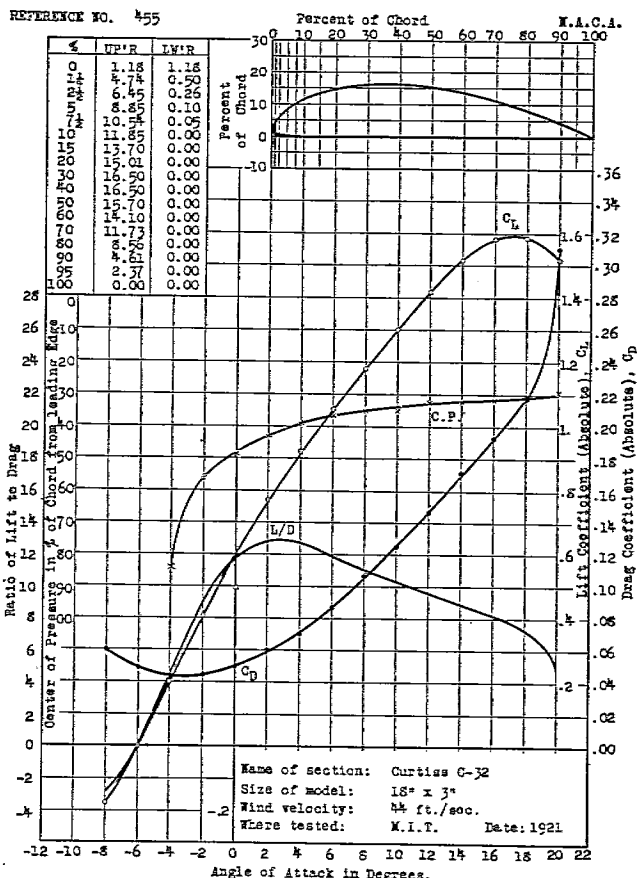
REFERENCE NO. 453

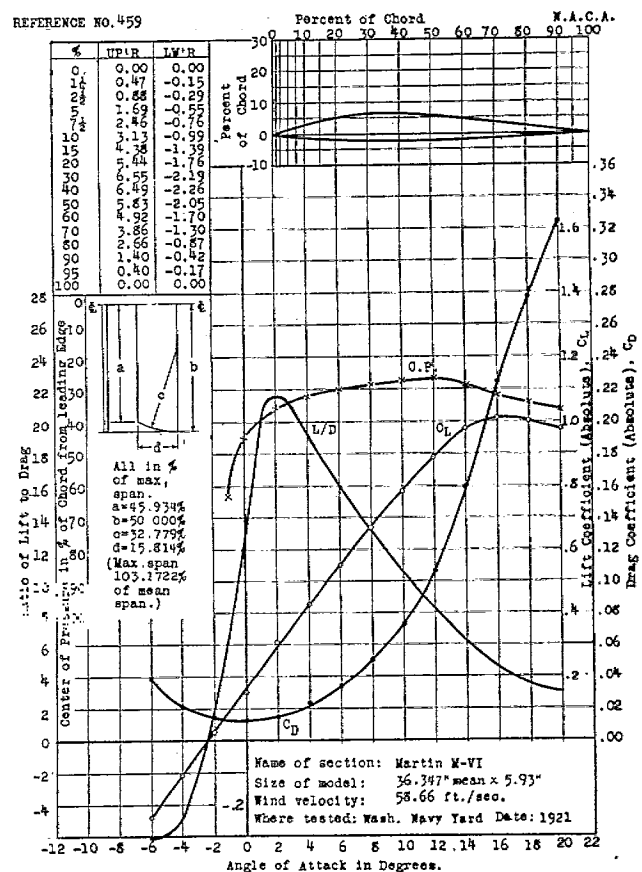
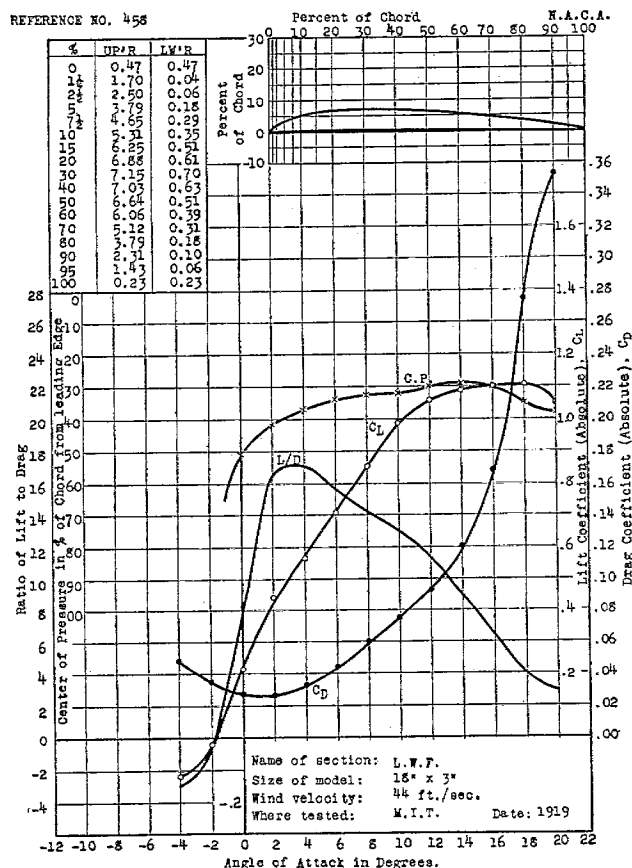
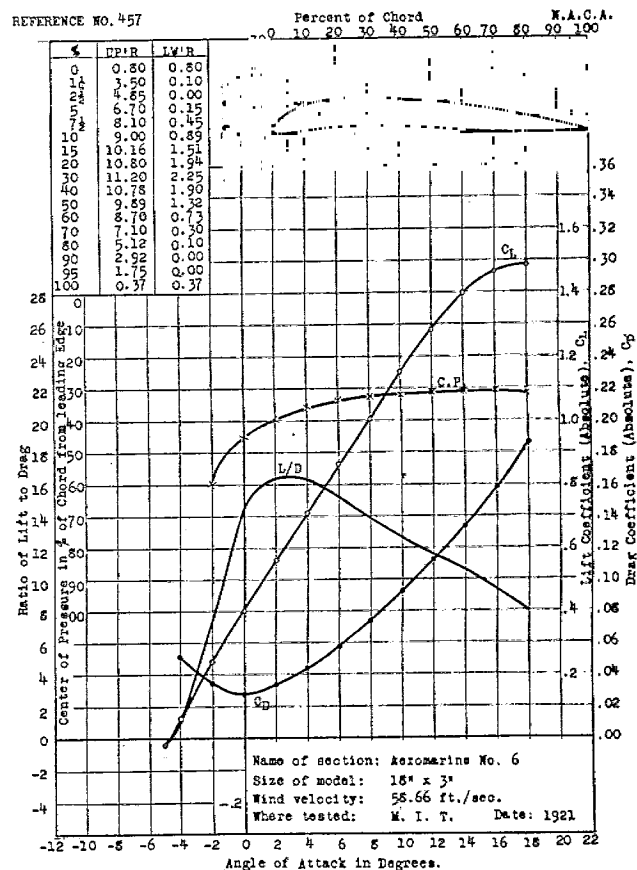
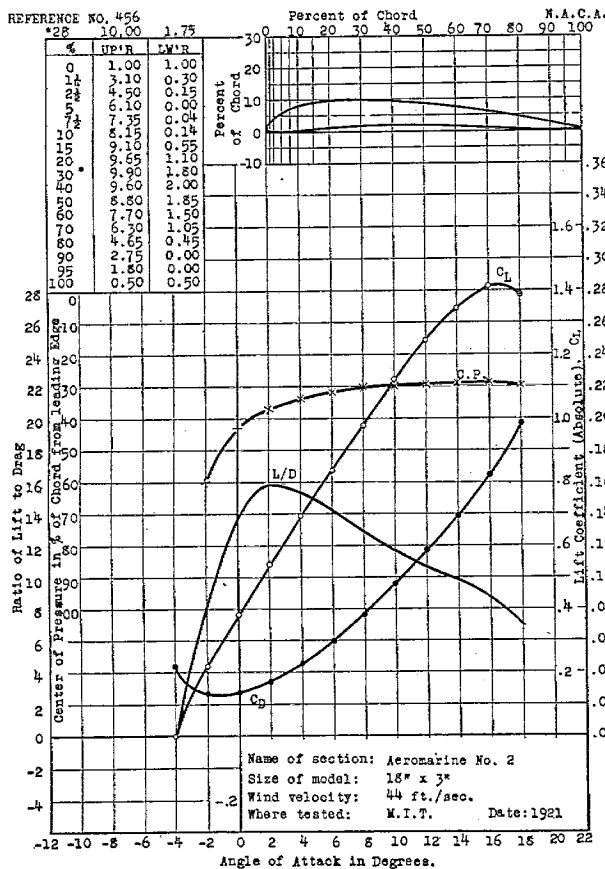


REFERENCE NO. 454



REFERENCE NO. 455

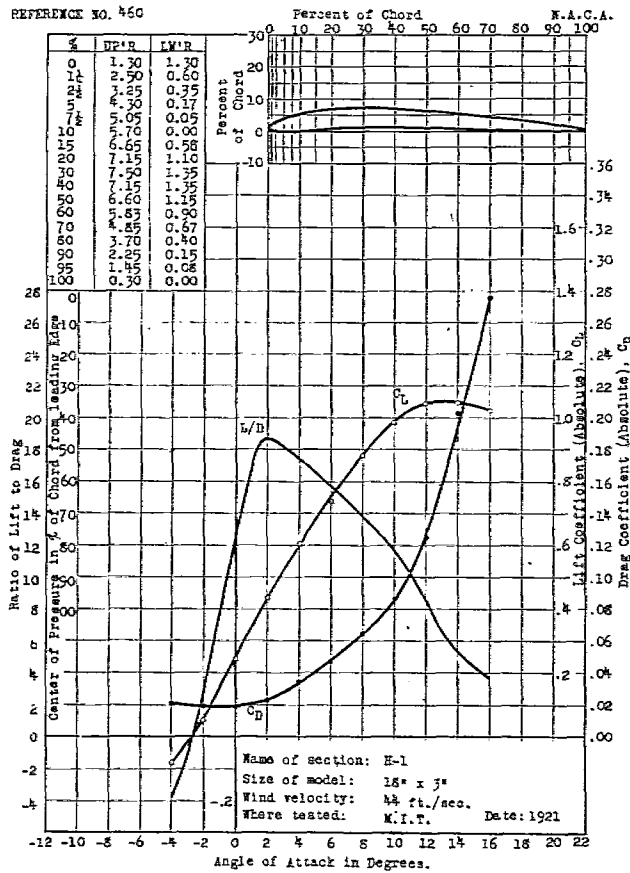




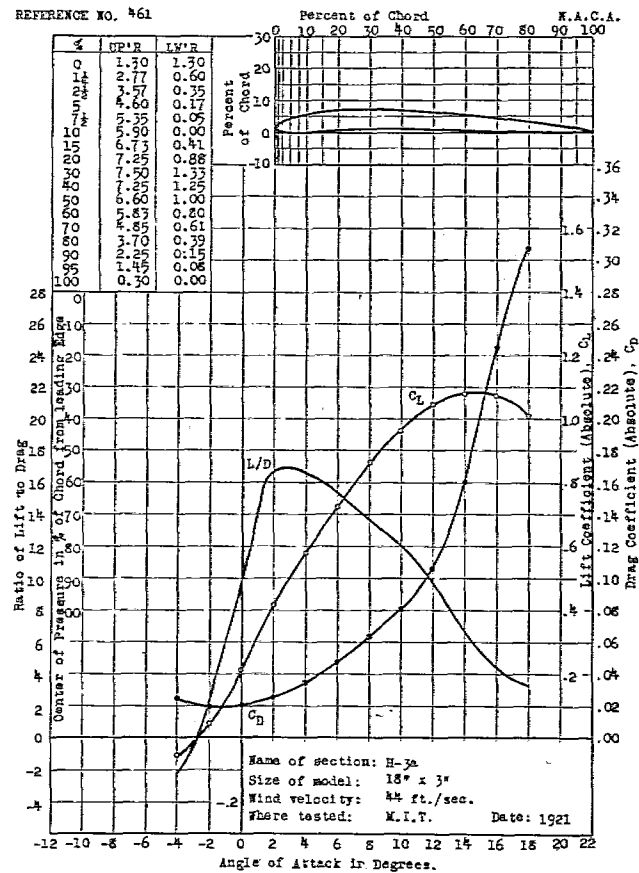
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

423

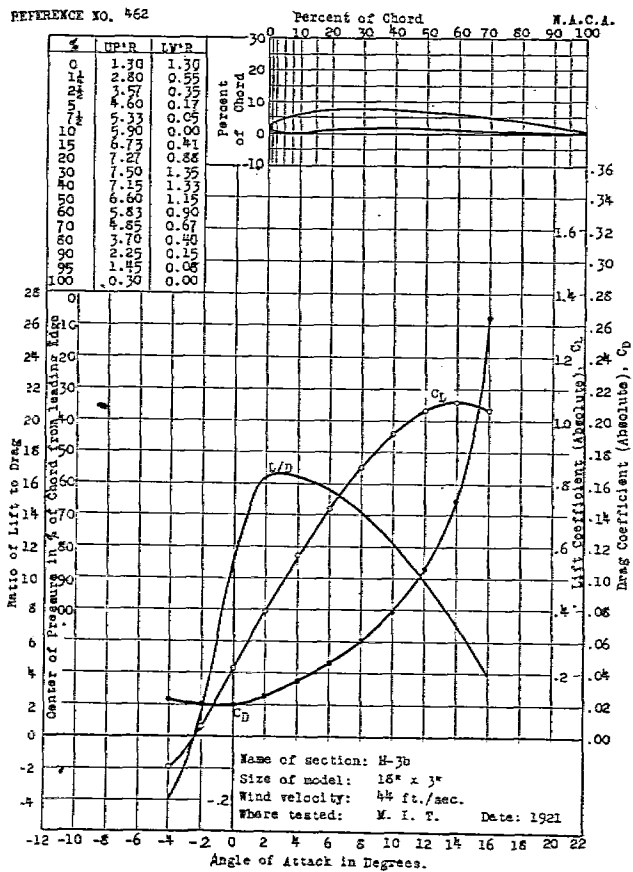
REFERENCE NO. 460



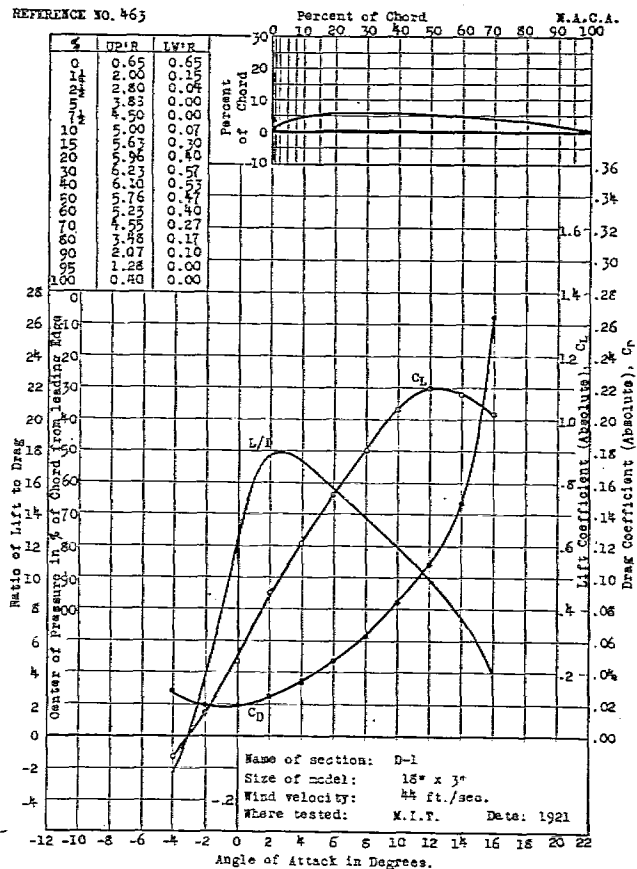
REFERENCE NO. 461

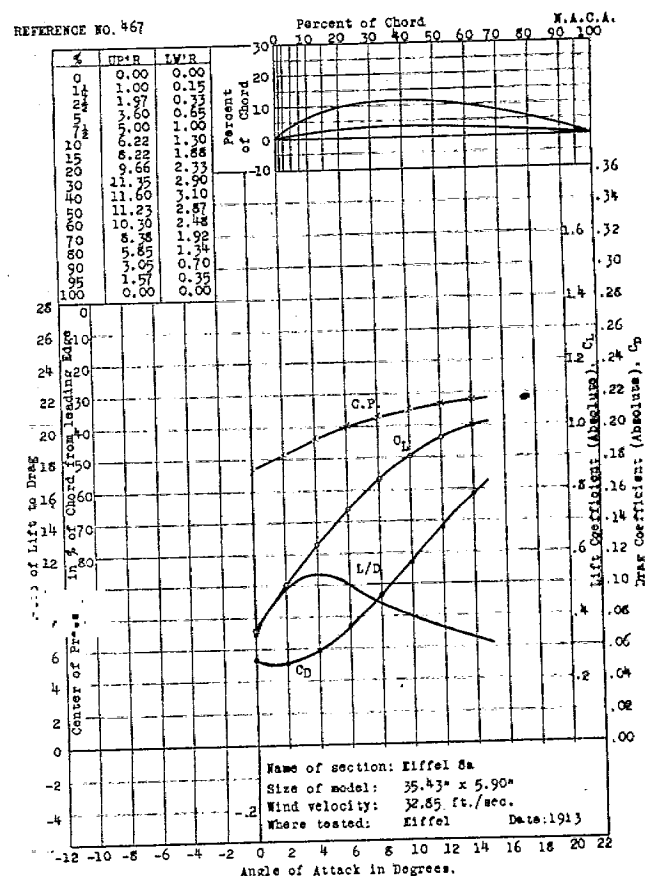
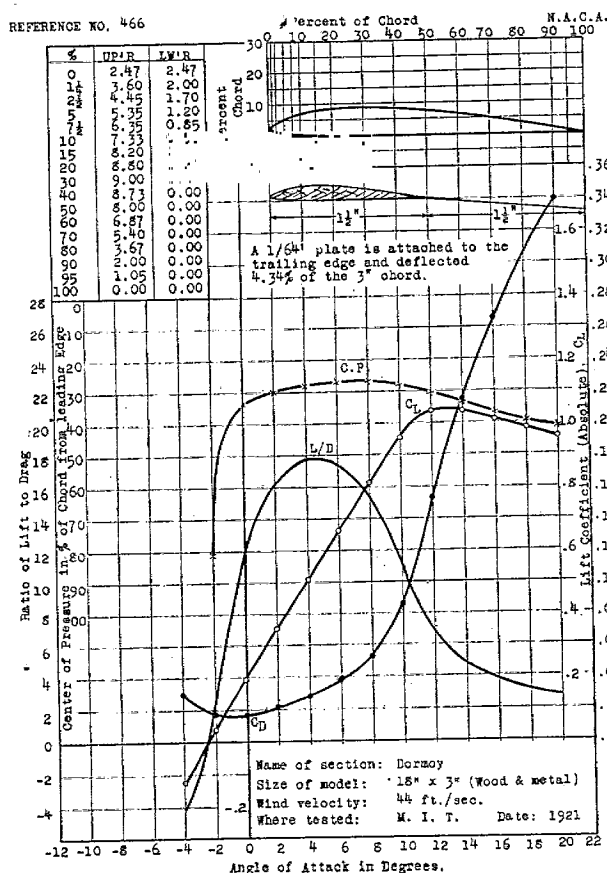
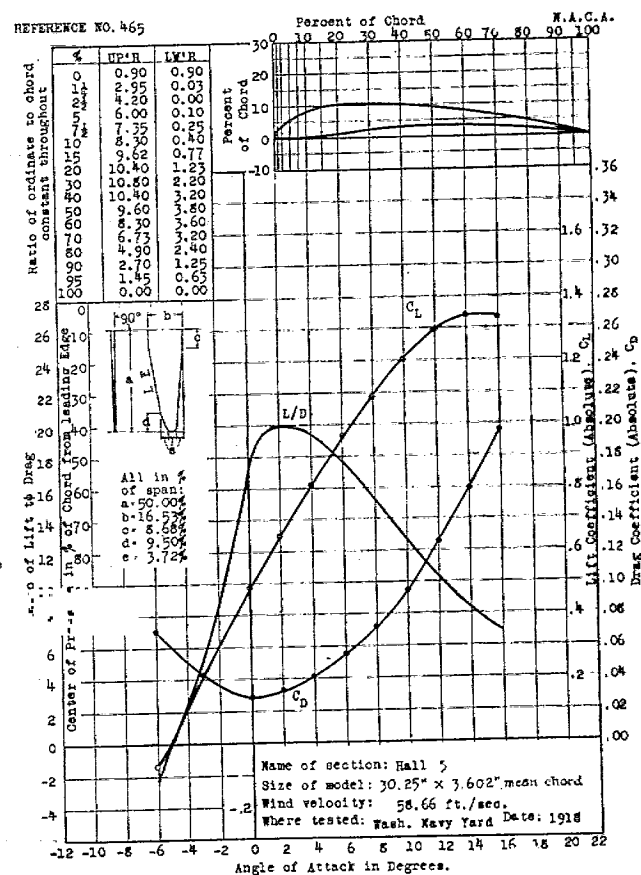
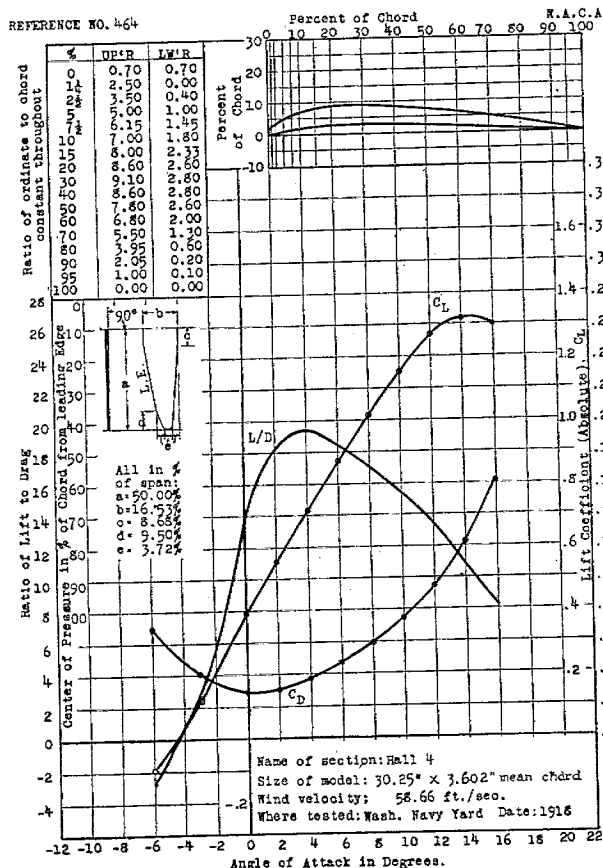


REFERENCE NO. 462



REFERENCE NO. 463

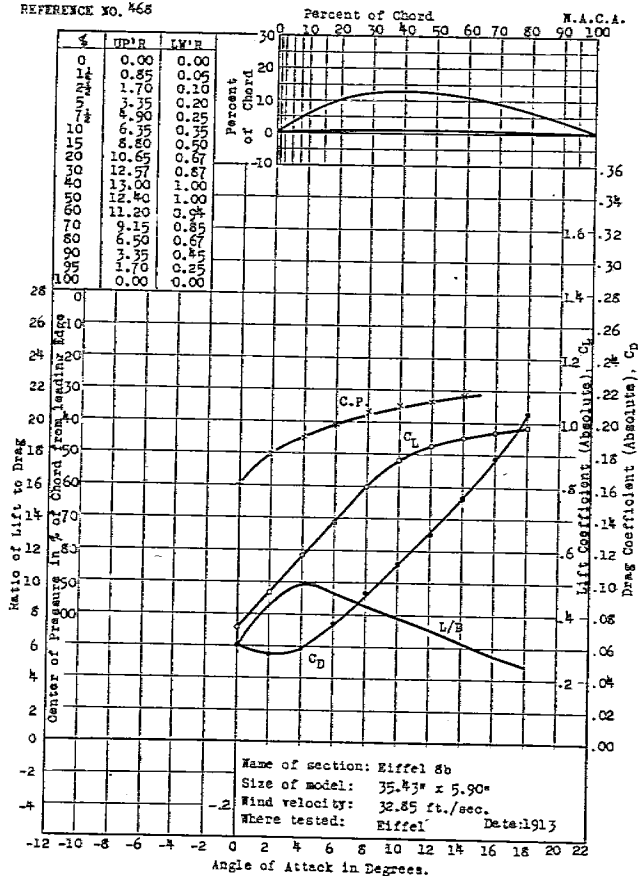




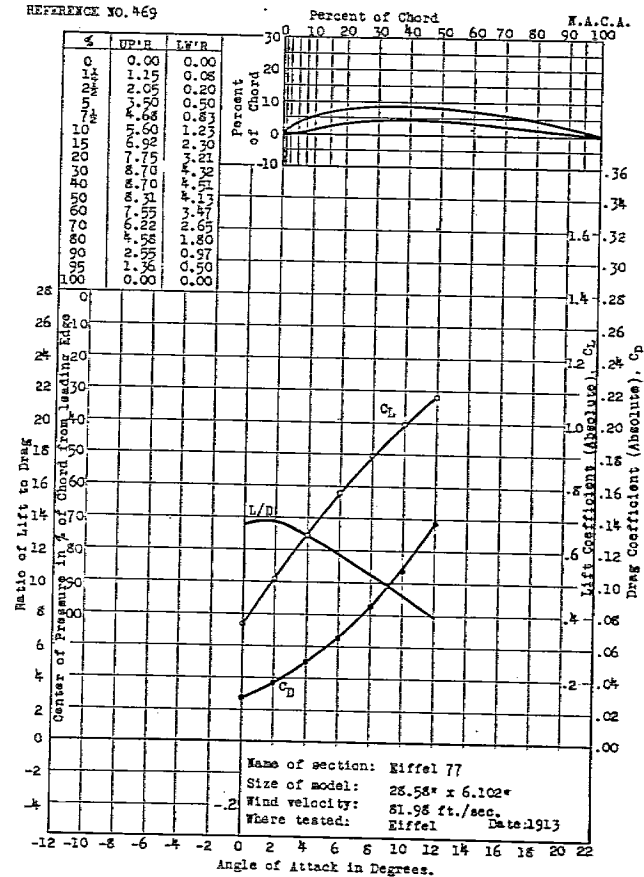
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

425

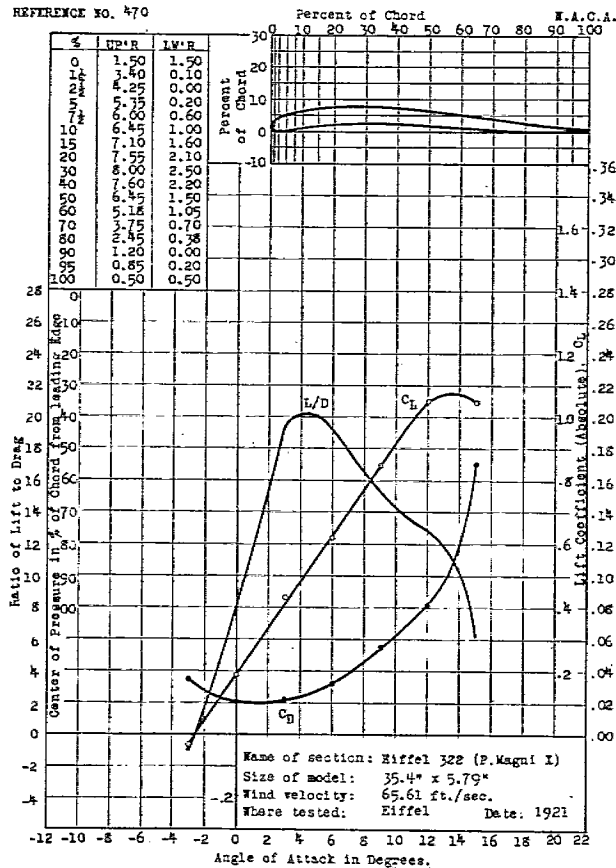
REFERENCE NO. 468



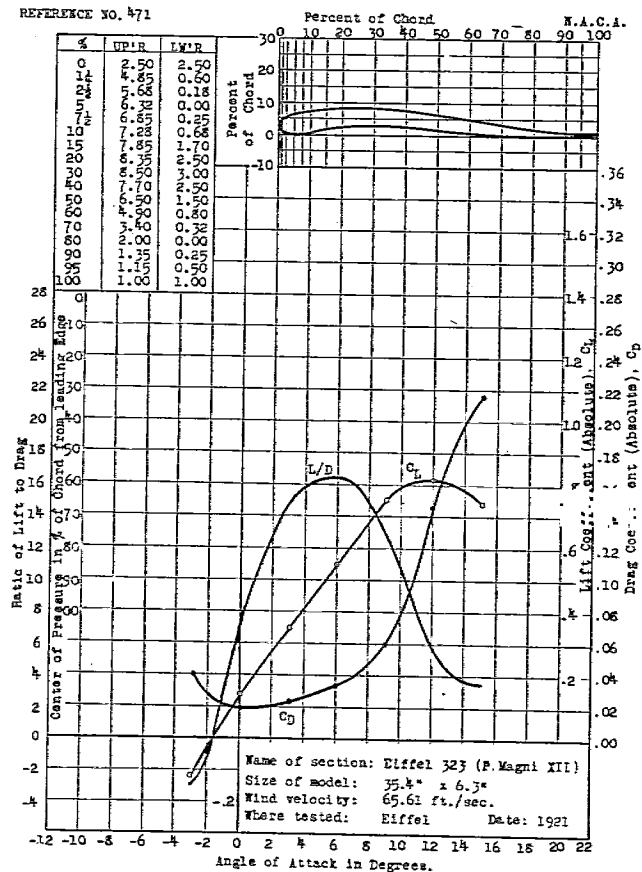
REFERENCE NO. 469

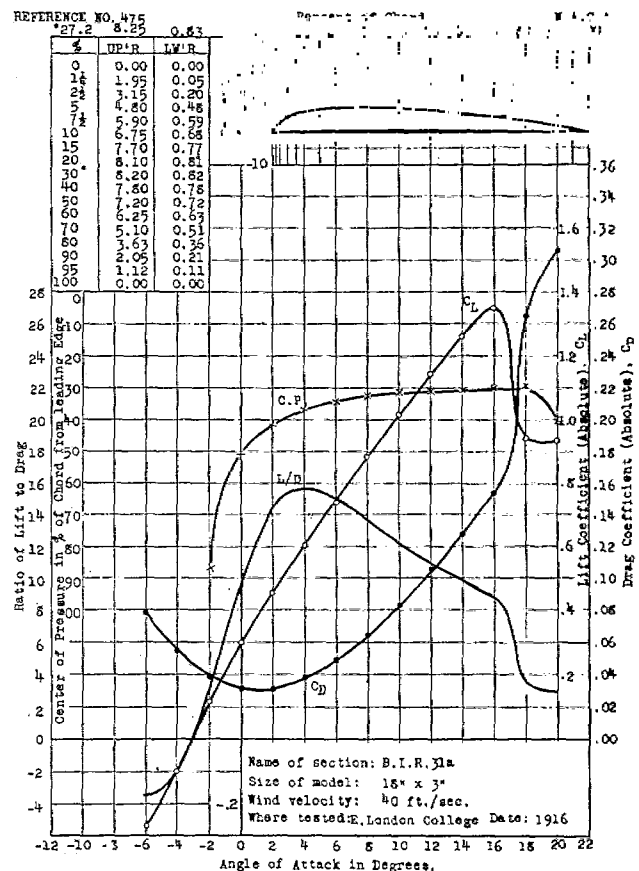
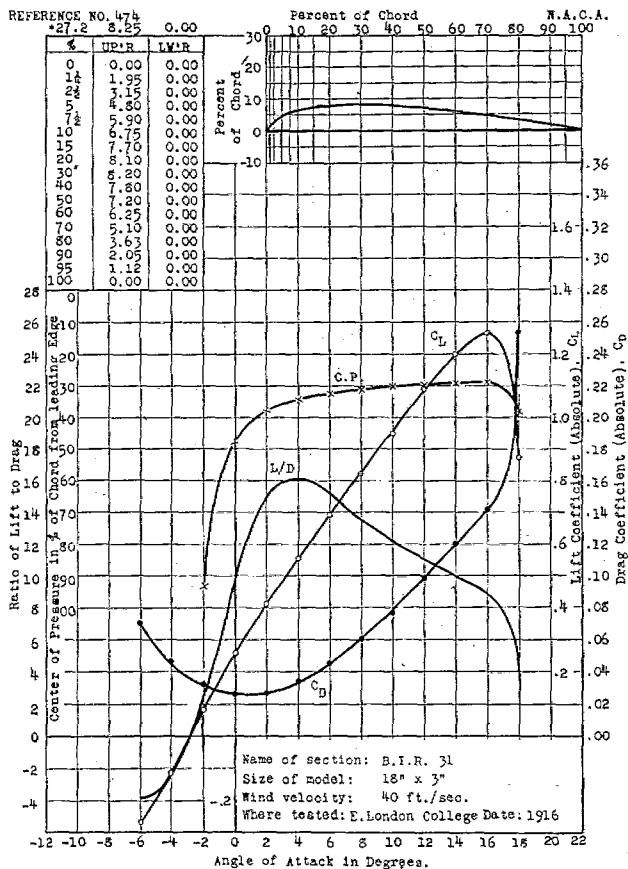
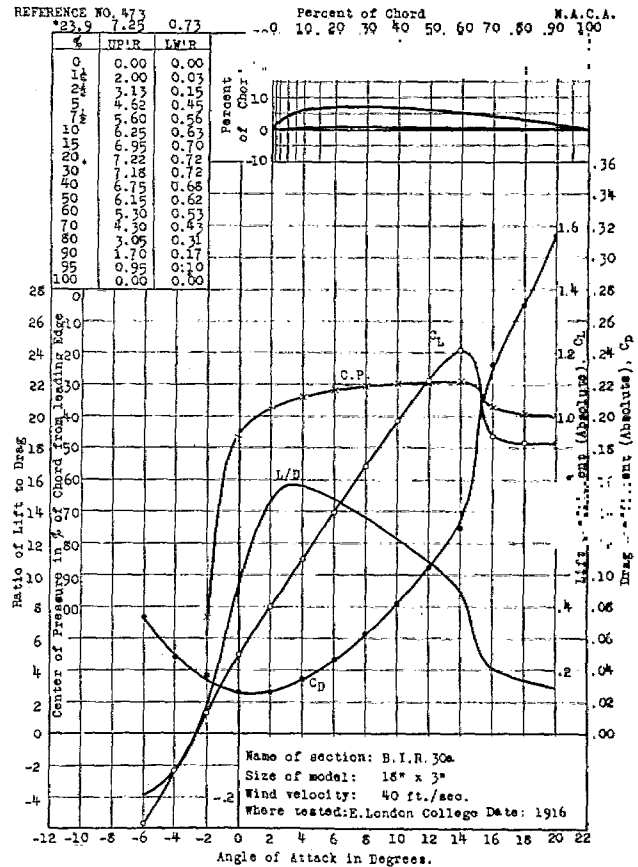
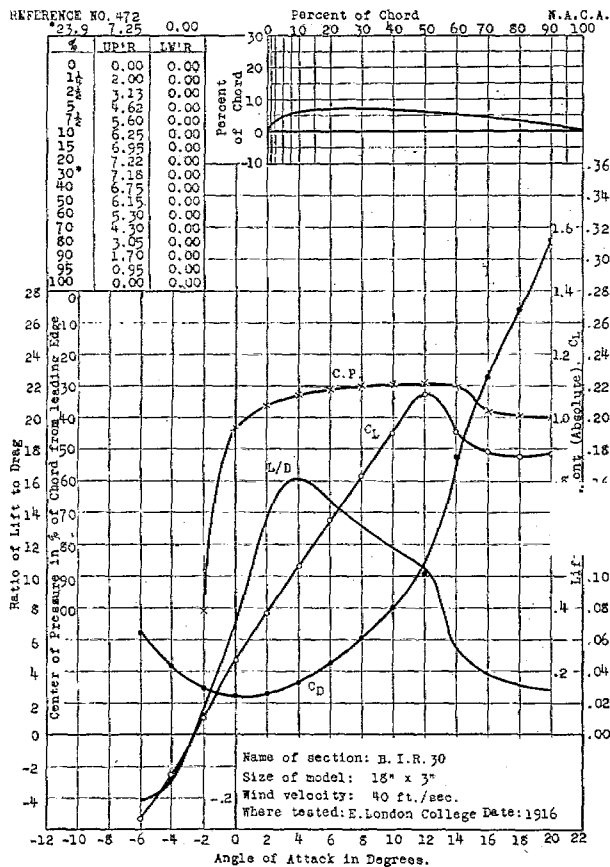


REFERENCE NO. 470



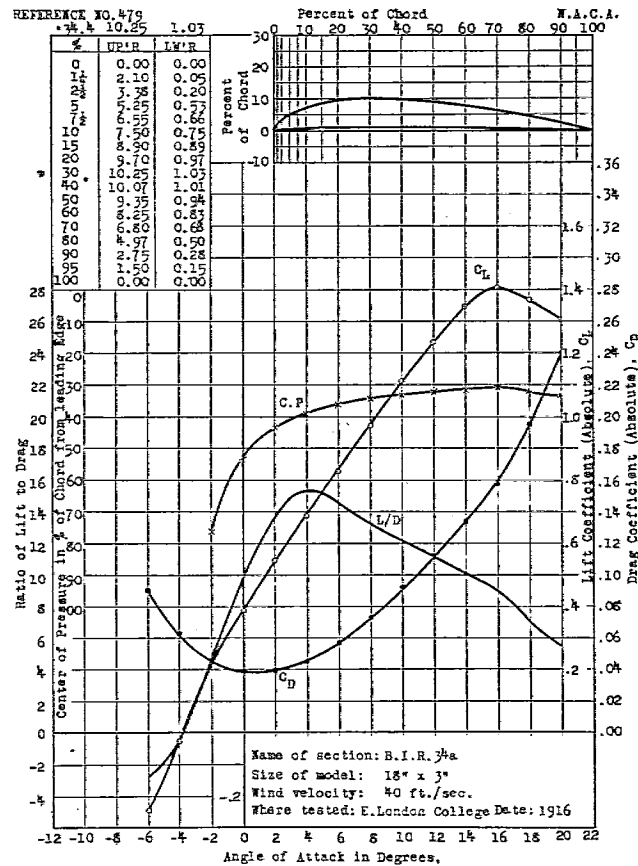
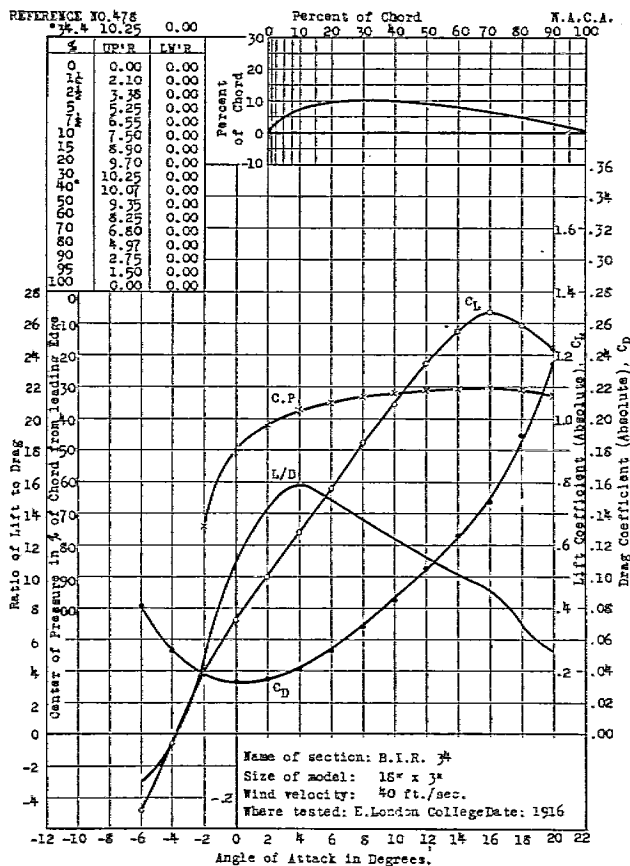
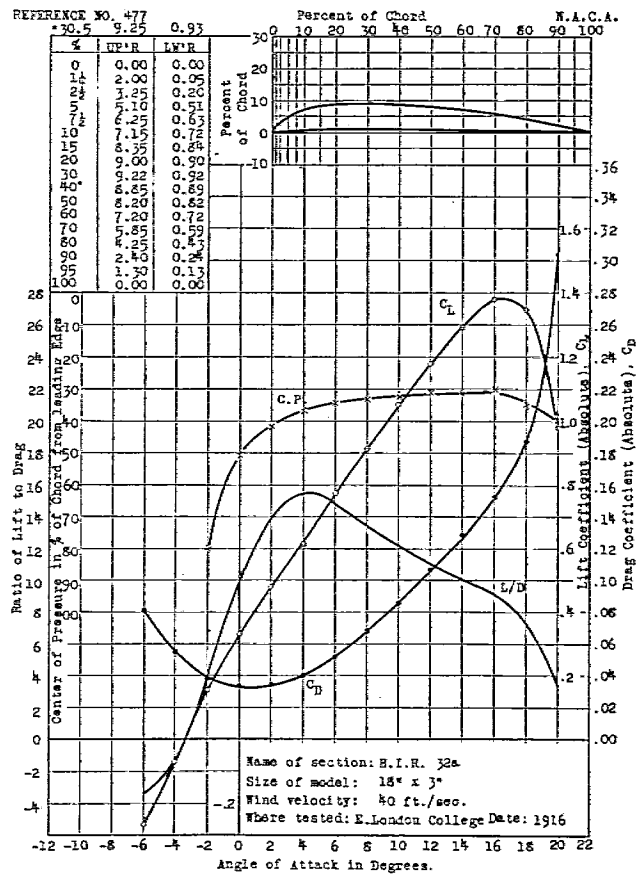
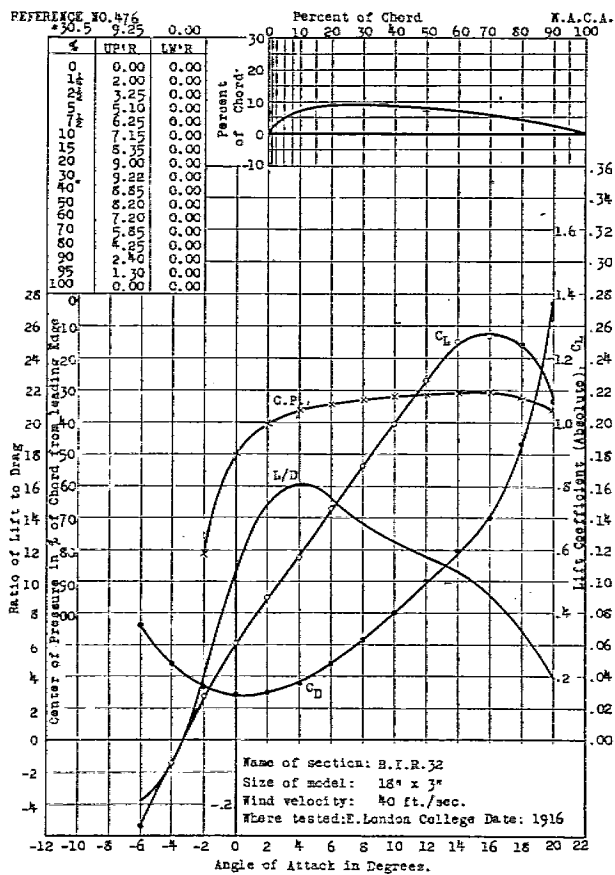
REFERENCE NO. 471



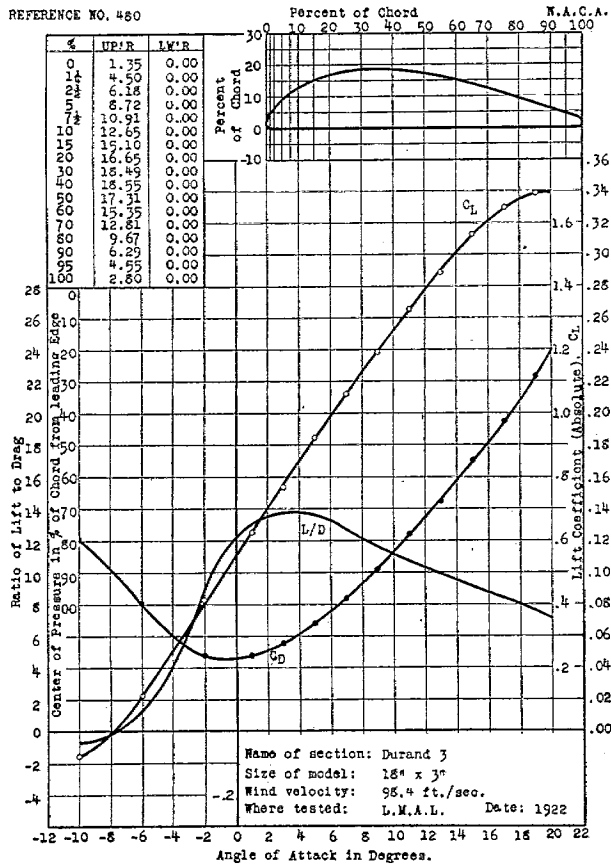


AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

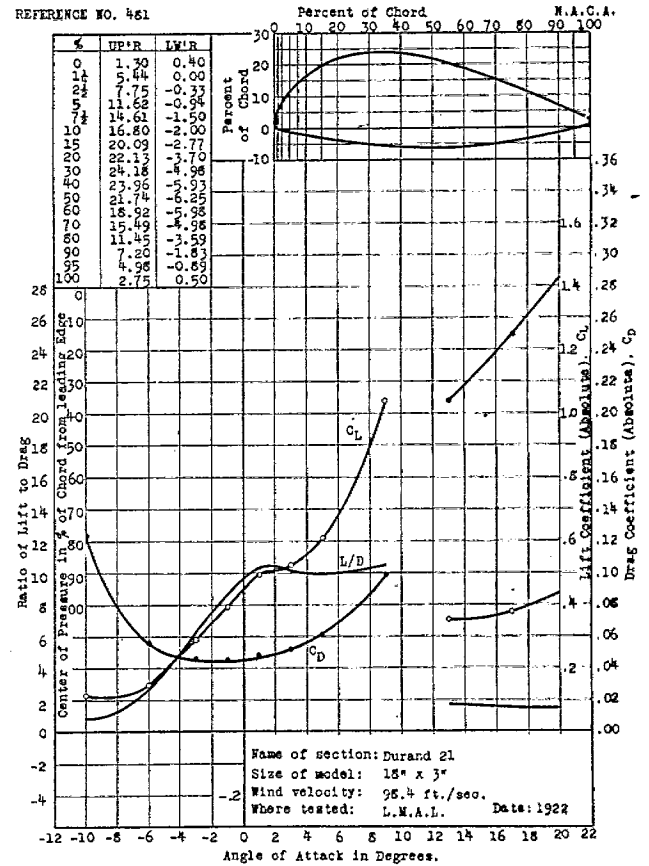
427



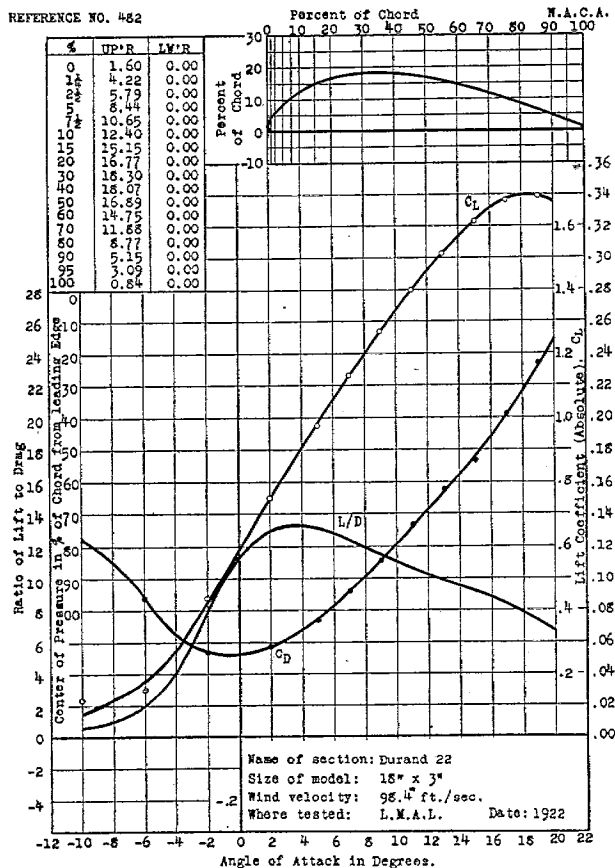
REFERENCE NO. 480



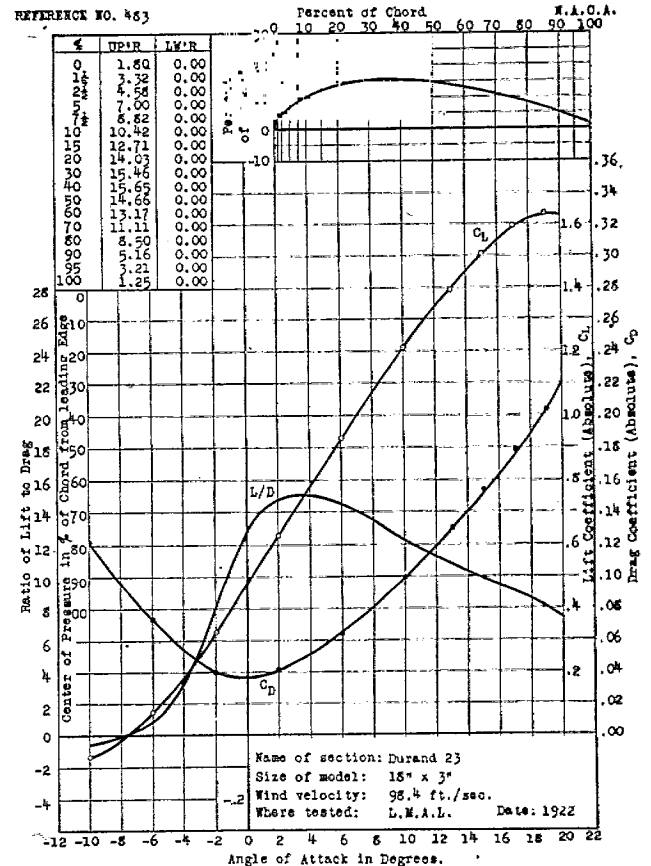
REFERENCE NO. 481



REFERENCE NO. 482



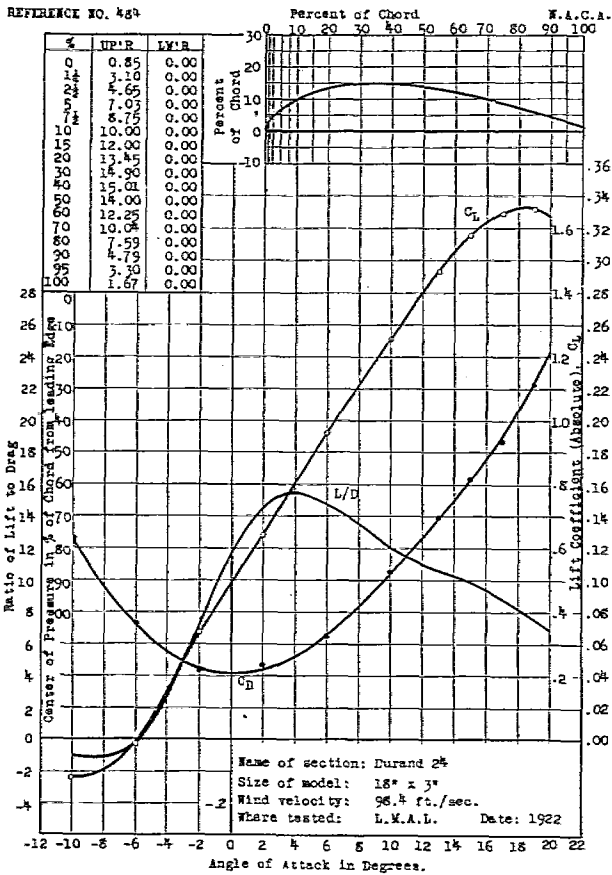
REFERENCE NO. 483



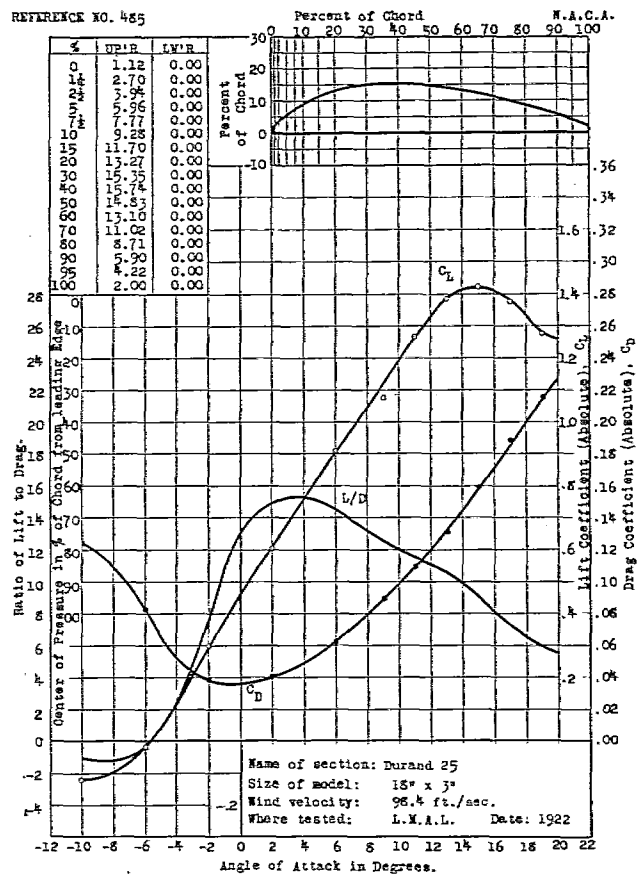
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

429

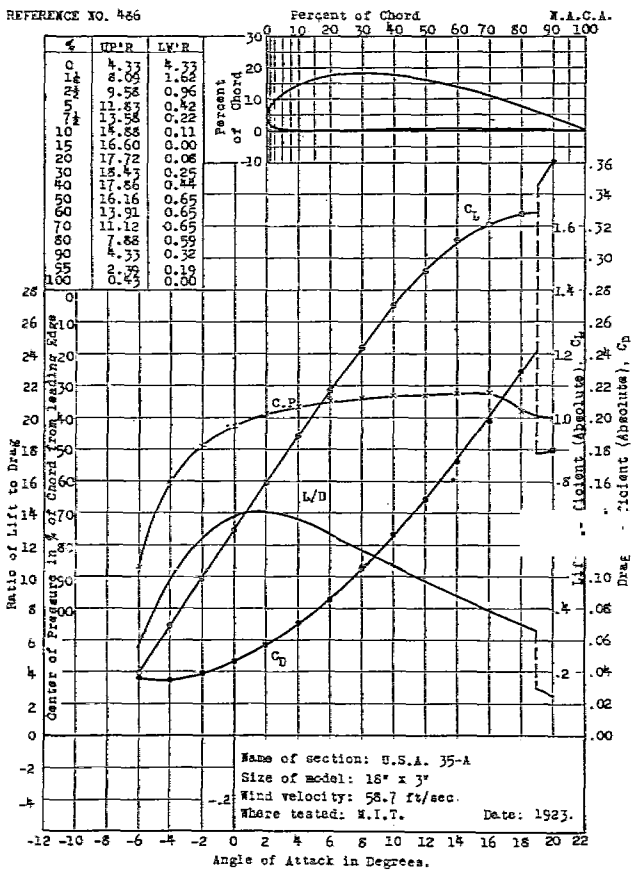
REFERENCE NO. 484



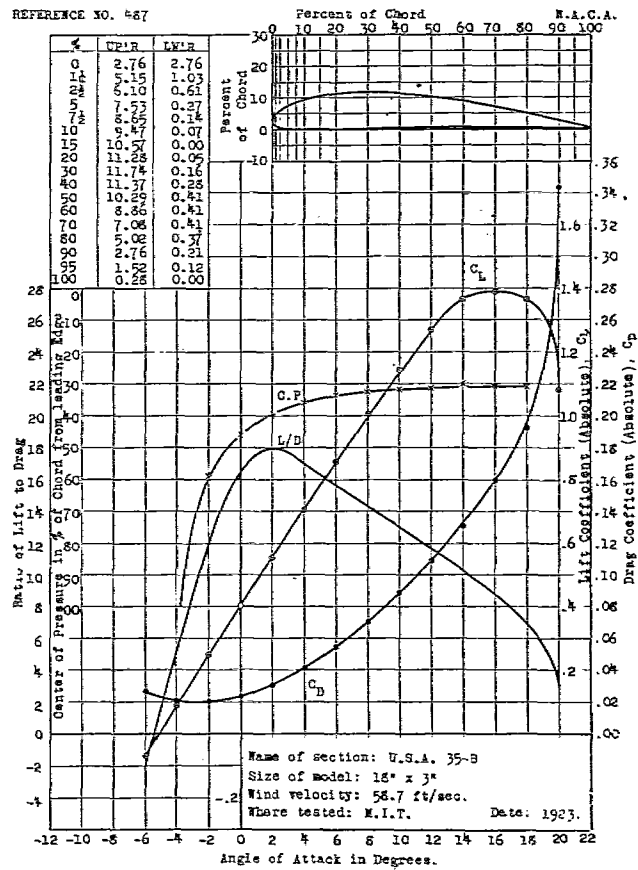
REFERENCE NO. 485



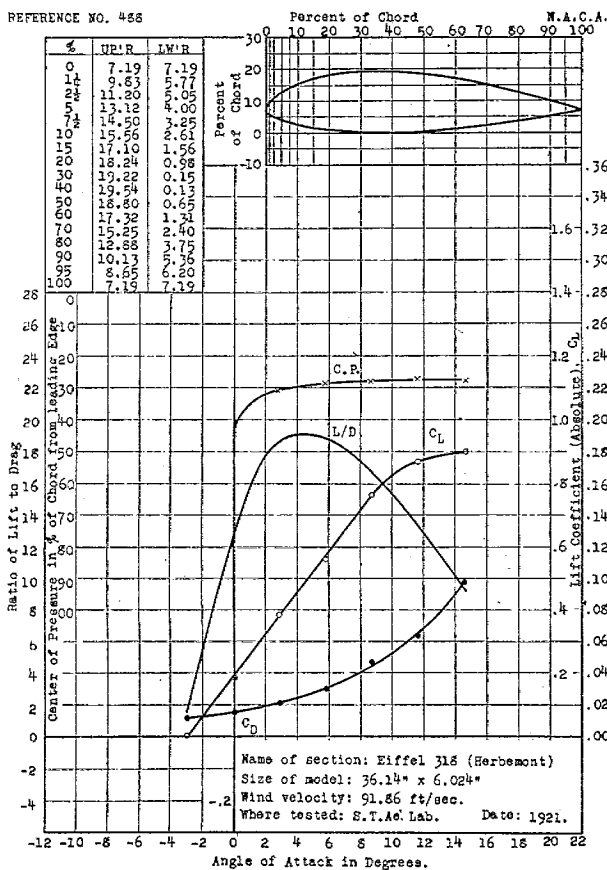
REFERENCE NO. 486



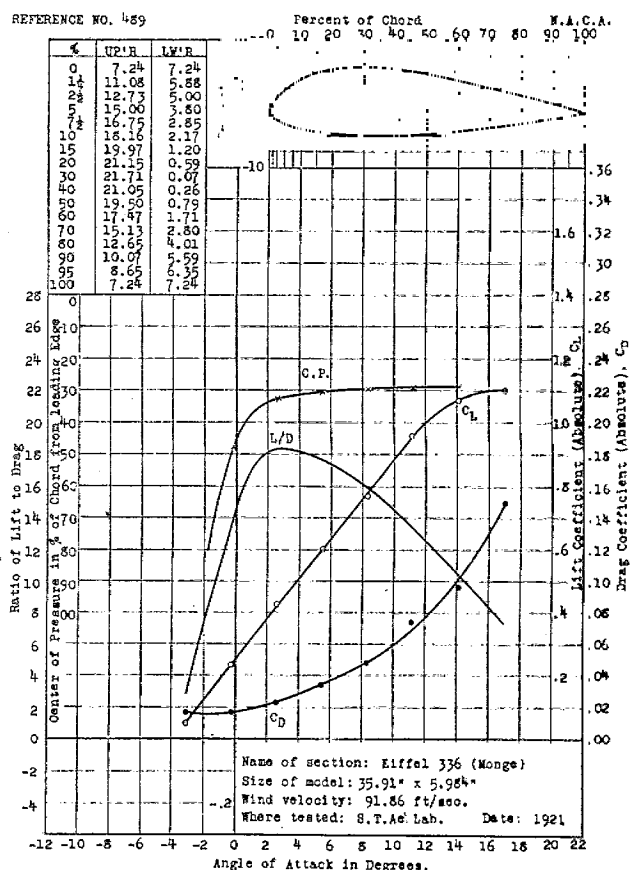
REFERENCE NO. 487



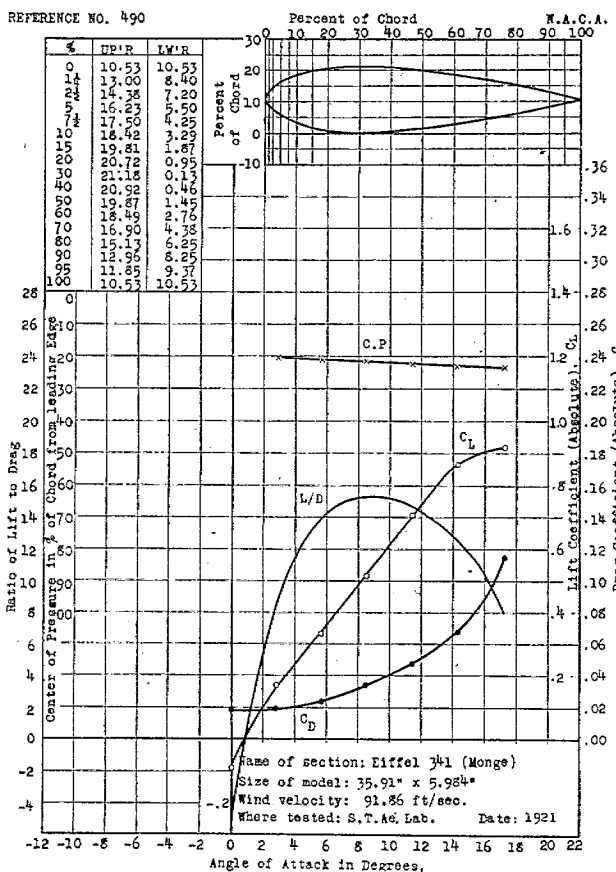
REFERENCE NO. 488



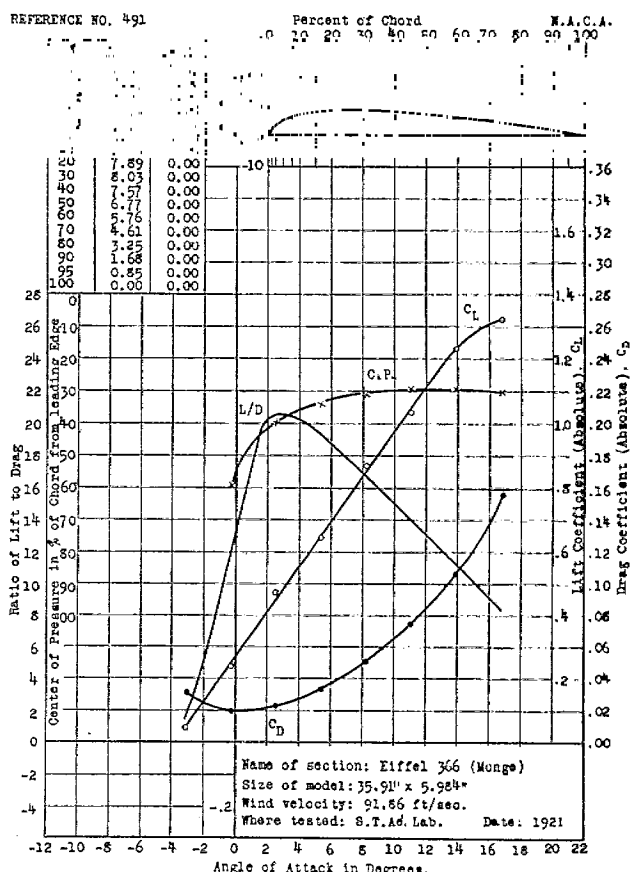
REFERENCE NO. 489



REFERENCE NO. 490



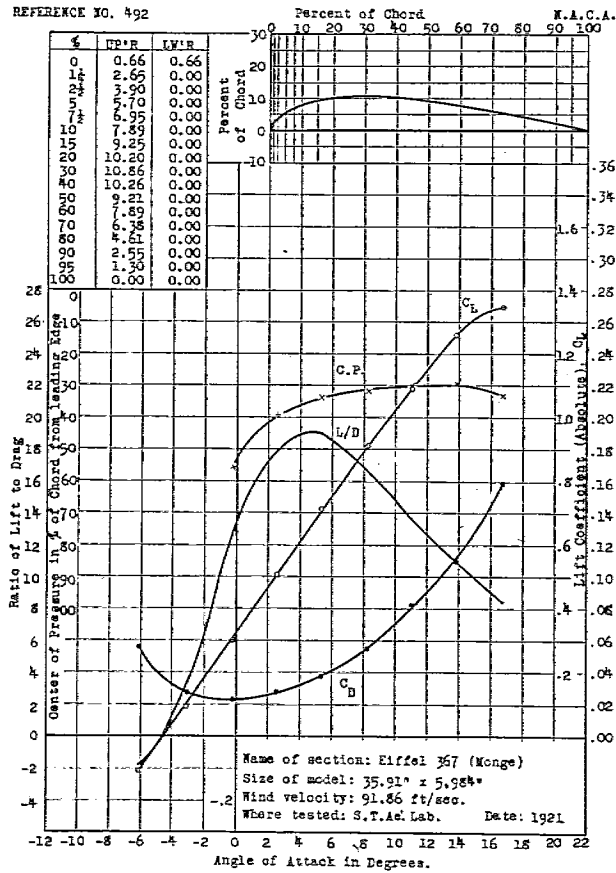
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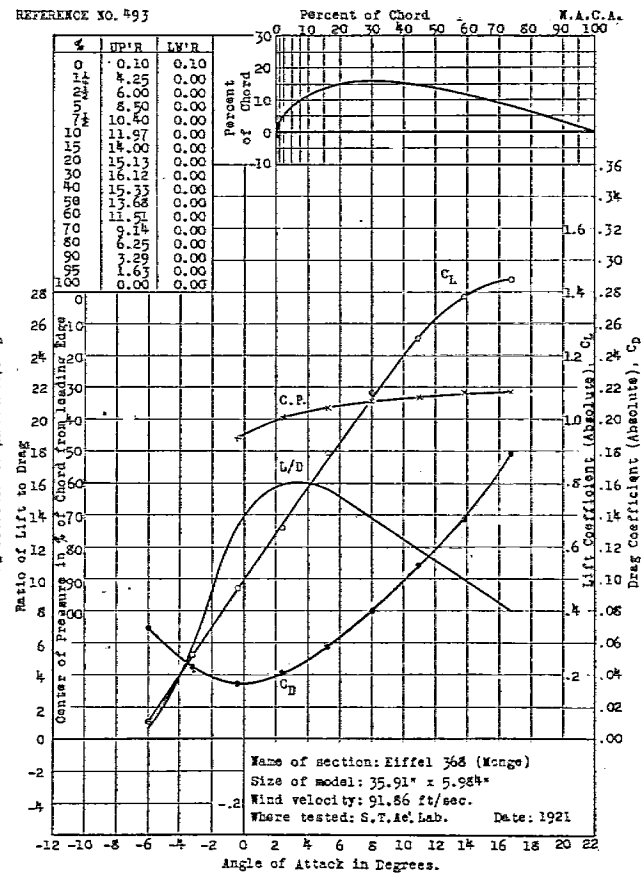
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

431

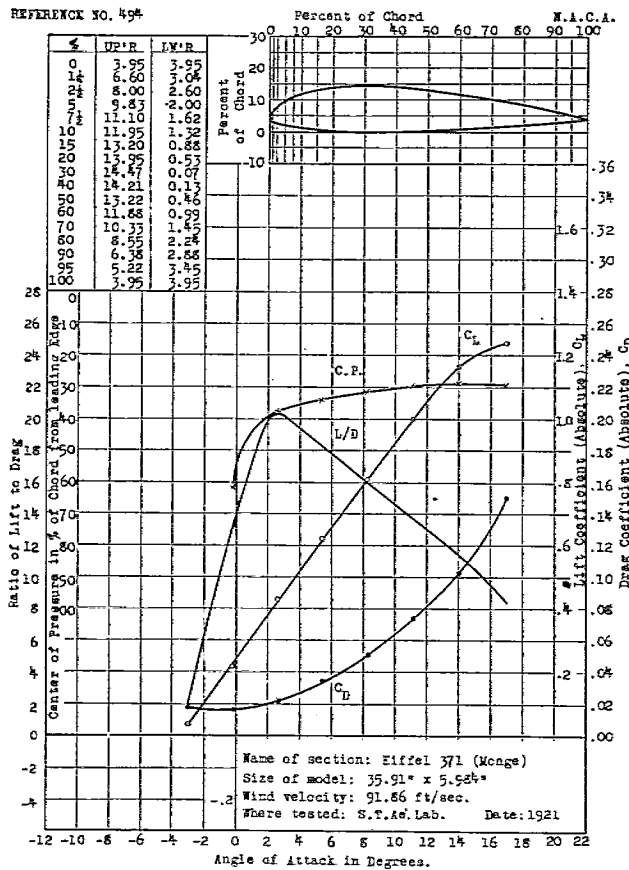
REFERENCE NO. 492



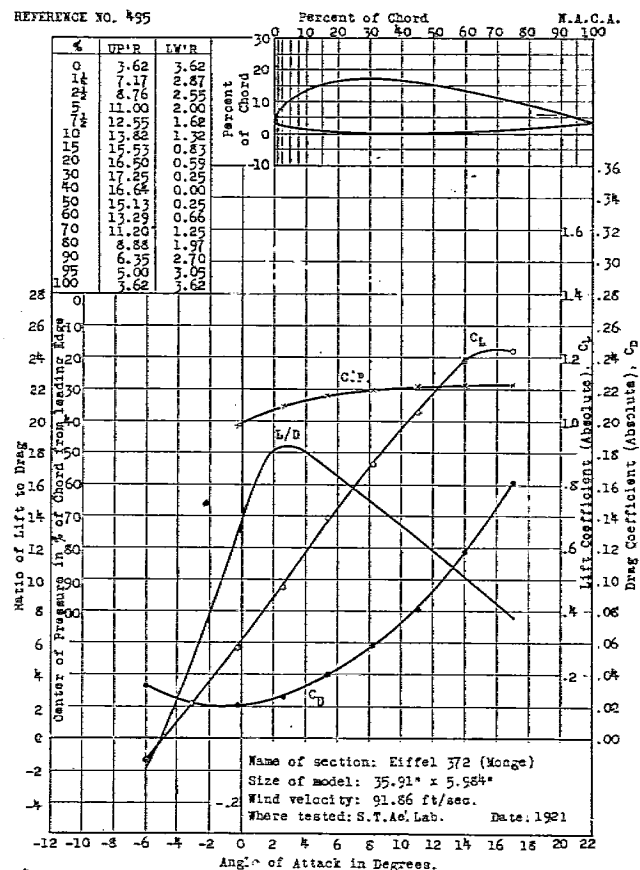
REFERENCE NO. 493



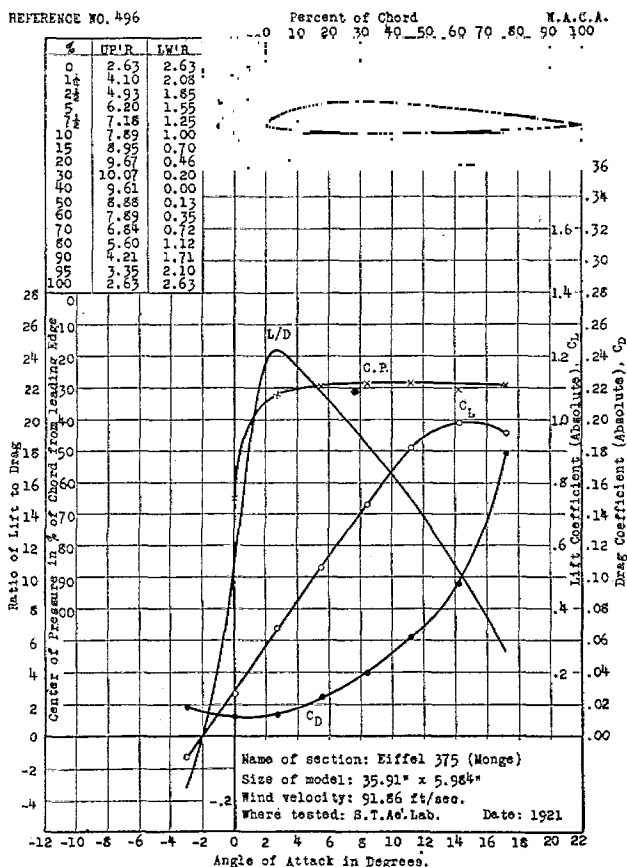
REFERENCE NO. 494



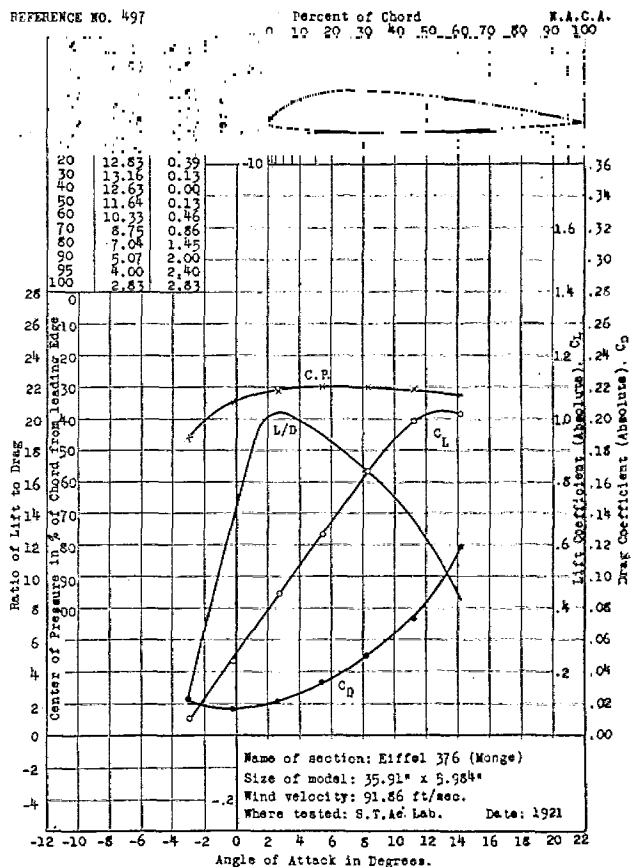
REFERENCE NO. 495



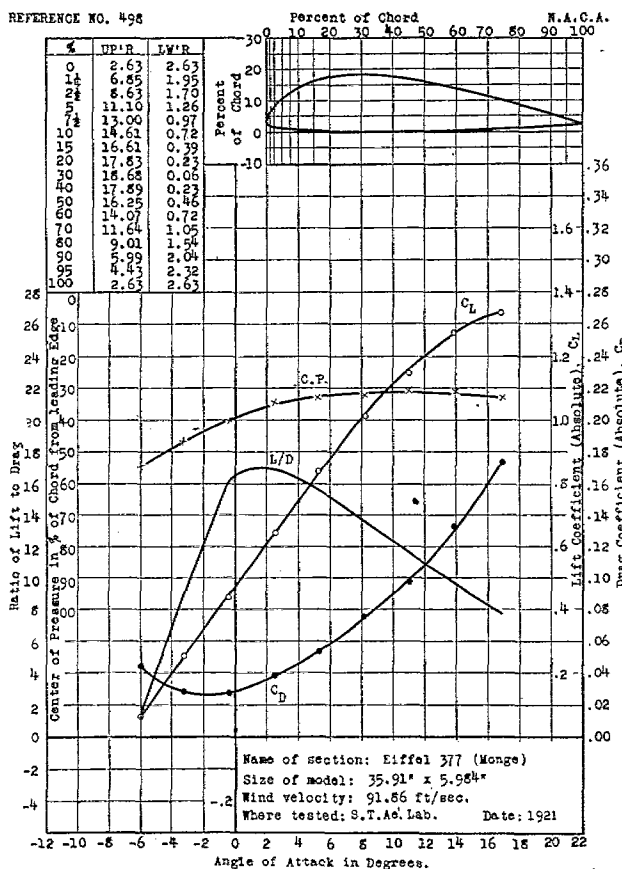
REFERENCE NO. 496



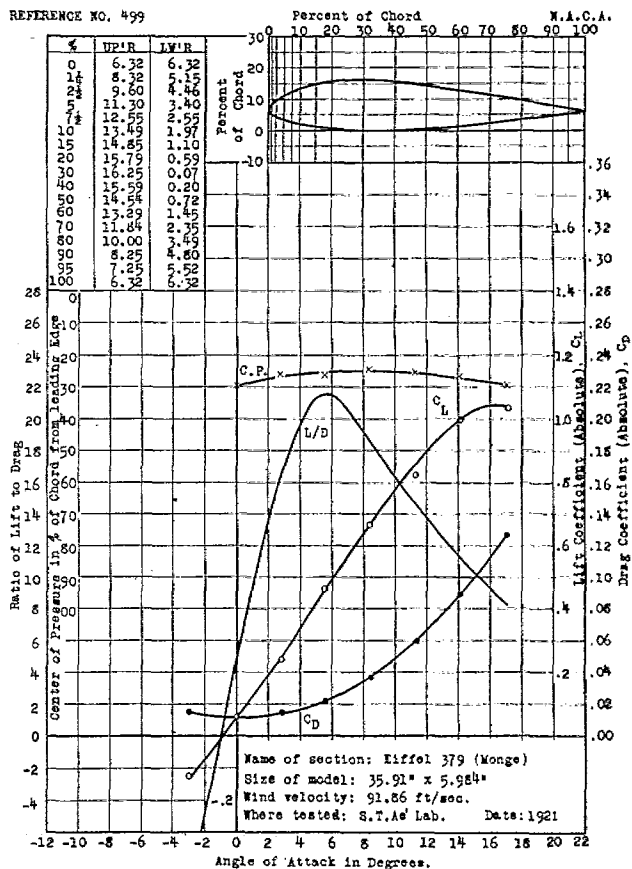
REFERENCE NO. 497



REFERENCE NO. 498



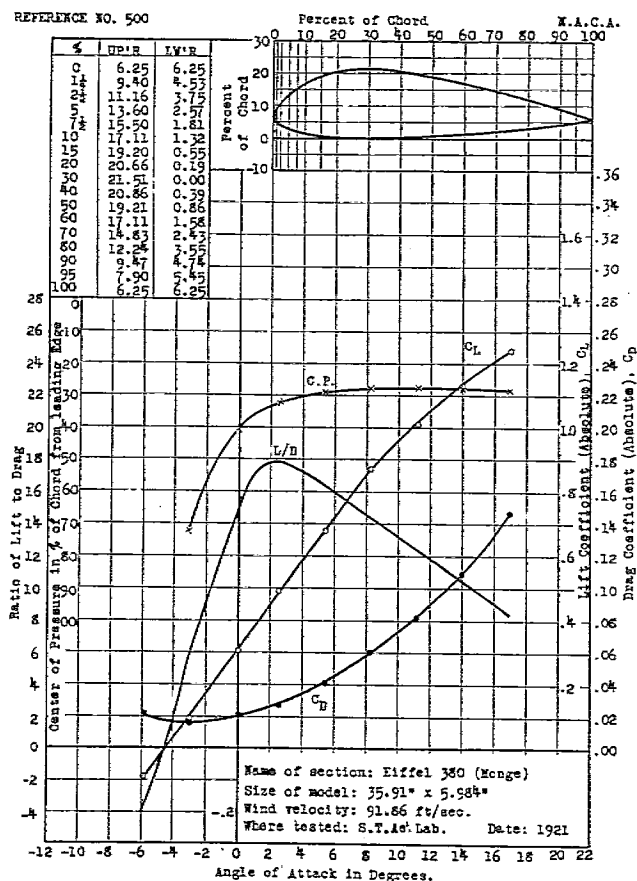
REFERENCE NO. 499



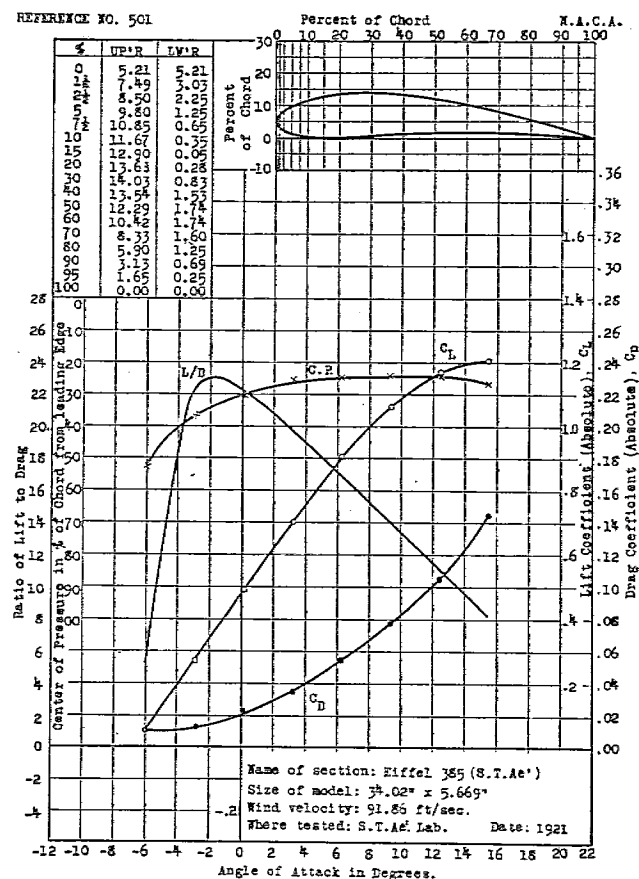
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

433

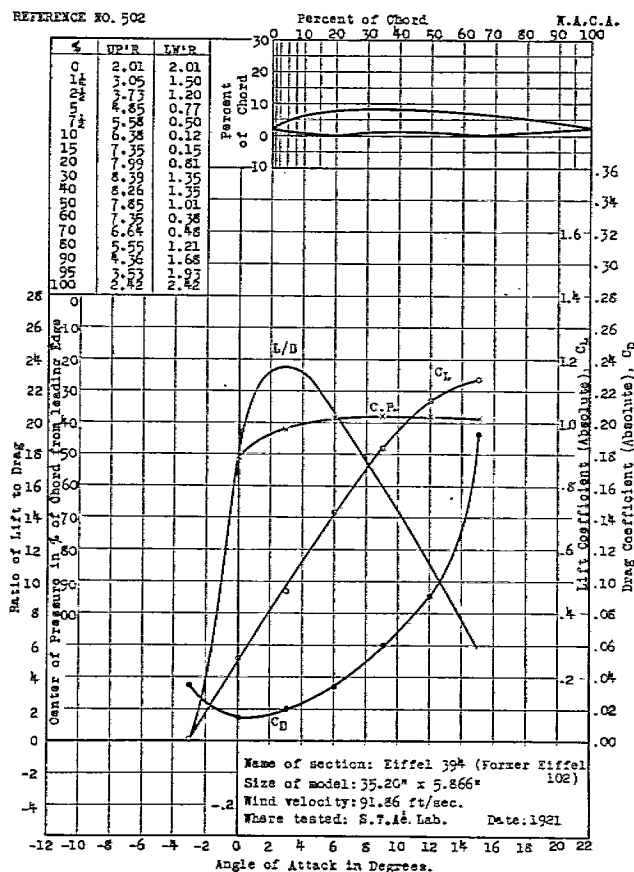
REFERENCE NO. 500



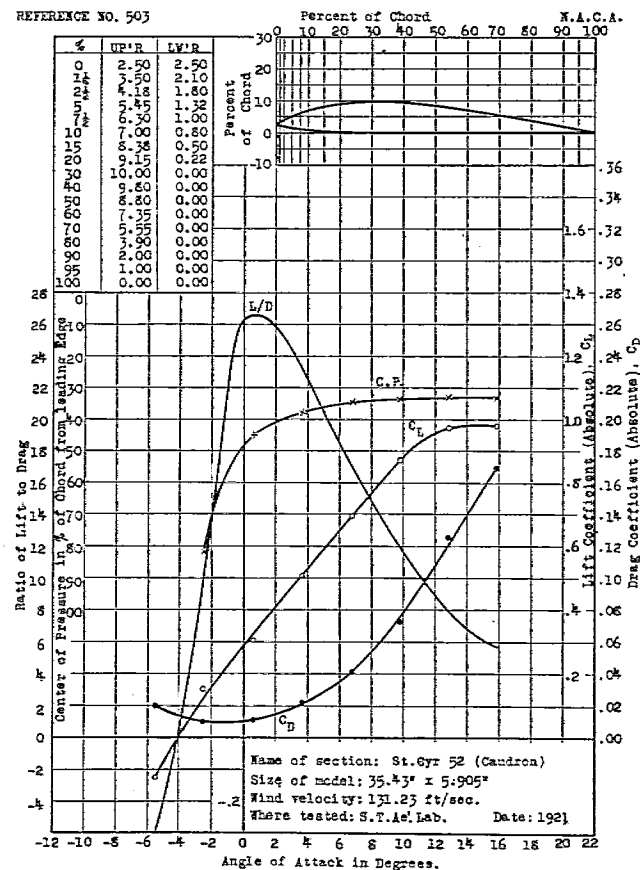
REFERENCE NO. 501



REFERENCE NO. 502



REFERENCE NO. 503



TABLES OF ORDINATES NOT GIVEN ON INDIVIDUAL CHARACTERISTIC SHEETS.

(Airfoils designed by the National Advisory Committee for Aeronautics.)

Ordinates for dotted section at tip where ratio of ordinate to chord differs from that of section at center of span.

Stations, in per cent of chord.	Nos. 54, 55, 56, 57, 58, 73, 79, 81, upper.	Ref. 431, 54.	Ref. 432, 55.	Ref. 433, 56.	Ref. 434, 57.	Ref. 435, 58.	Ref. 446, 73.	Ref. 448, 79.	Ref. 449, 81.
		Lower.	Lower.	Lower.	Lower.	Lower.	Lower.	Lower.	Lower.
0	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
1.25	1.12	0.12	0.10	0.05	-0.10	-0.12	-0.14	0.05	-0.11
2.50	1.44	0.19	0.17	0.00	-0.17	-0.19	-0.22	0.00	-0.22
5	1.95	0.35	0.31	0.00	-0.31	-0.35	-0.42	0.00	-0.42
7.50	2.40	0.53	0.43	0.00	-0.43	-0.45	-0.58	0.00	-0.58
10	2.76	0.62	0.56	0.00	-0.56	-0.62	-0.75	0.00	-0.75
15	3.27	0.86	0.77	0.00	-0.77	-0.85	-1.03	0.00	-1.03
20	3.58	1.05	0.94	0.00	-0.94	-1.05	-1.26	0.00	-1.26
*30	3.93	1.26	1.13	0.00	-1.13	-1.26	-1.51	0.00	-1.51
40	3.93	1.26	1.13	0.00	-1.13	-1.26	-1.51	0.00	-1.51
50	3.71	1.19	1.07	0.00	-1.07	-1.19	-1.43	0.00	-1.43
60	3.28	1.04	0.93	0.00	-0.93	-1.04	-1.25	0.00	-1.25
70	2.73	0.84	0.76	0.00	-0.76	-0.84	-1.01	0.00	-1.01
80	2.10	0.60	0.54	0.00	-0.54	-0.60	-0.72	0.00	-0.72
90	1.37	0.31	0.28	0.00	-0.28	-0.31	-0.38	0.00	-0.38
95	0.99	0.16	0.14	0.00	-0.14	-0.16	-0.19	0.00	-0.19
100	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
*33.3	3.97	1.28	1.15	0.00	-1.15	-1.28	-1.54	0.00	-1.54

Ordinates for dotted section at x-x.

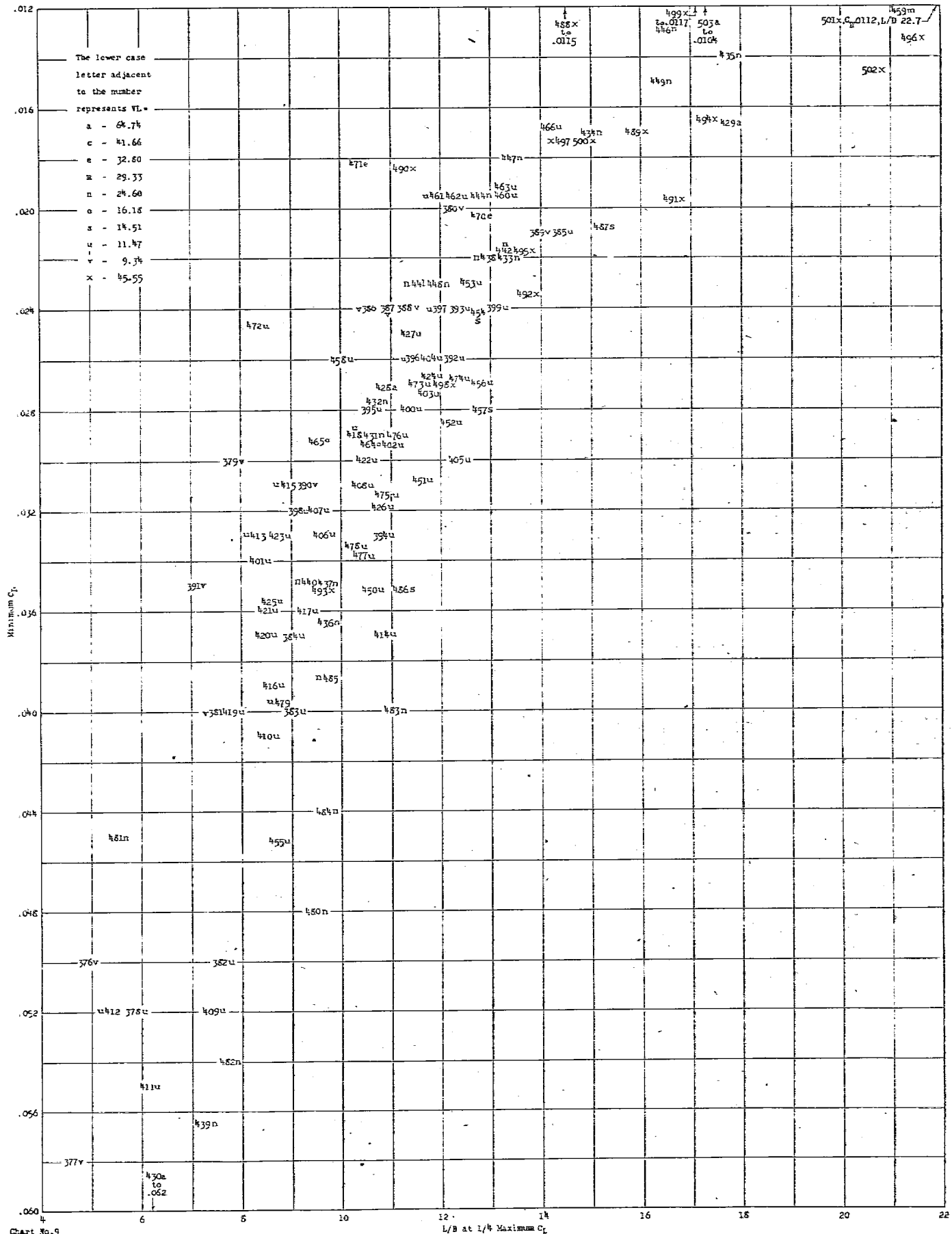
Stations, in per cent of chord.	Ref. No. 451, U. S. A. 27a.		Ref. No. 452, U. S. A. 27b.		Ref. No. 453, U. S. A. 27c.		Ref. No. 454, U. S. A. 27e (mod.).	
	Upper.	Lower.	Upper.	Lower.	Upper.	Lower.	Upper.	Lower.
0	1.16	1.16	1.09	1.09	1.16	1.16	1.18	1.18
1.25	2.42	0.20	2.75	0.35	2.40	0.27	2.30	0.35
2.50	3.14	0.19	3.52	0.21	3.19	0.12	3.06	0.11
5	4.30	0.11	4.29	0.10	4.14	-0.17	4.31	-0.14
7.50	5.10	0.04	5.05	0.07	5.10	-0.40	5.05	-0.38
10	5.78	0.00	5.72	0.00	5.78	-0.58	5.70	-0.57
15	6.68	0.06	6.67	0.10	6.65	-0.80	6.55	-0.82
20	7.18	0.27	7.27	0.23	7.18	-0.93	7.09	-0.96
30	7.55	0.61	7.47	0.60	7.56	-0.85	7.51	-0.85
40	7.33	0.66	7.27	0.66	7.33	-0.70	7.30	-0.68
50	6.75	0.51	6.83	0.50	6.75	-0.58	6.70	-0.57
60	6.01	0.27	5.97	0.19	6.01	-0.39	5.98	-0.39
70	5.11	0.07	5.03	0.06	5.12	-0.36	5.09	-0.28
80	3.88	0.00	3.82	0.00	3.88	-0.16	3.81	-0.11
90	2.40	0.15	2.22	0.10	2.20	0.05	2.25	0.05
95	1.55	0.28	1.40	0.23	1.33	0.20	1.40	0.15
100	0.43	0.43	0.39	0.39	0.43	0.43	0.39	0.39

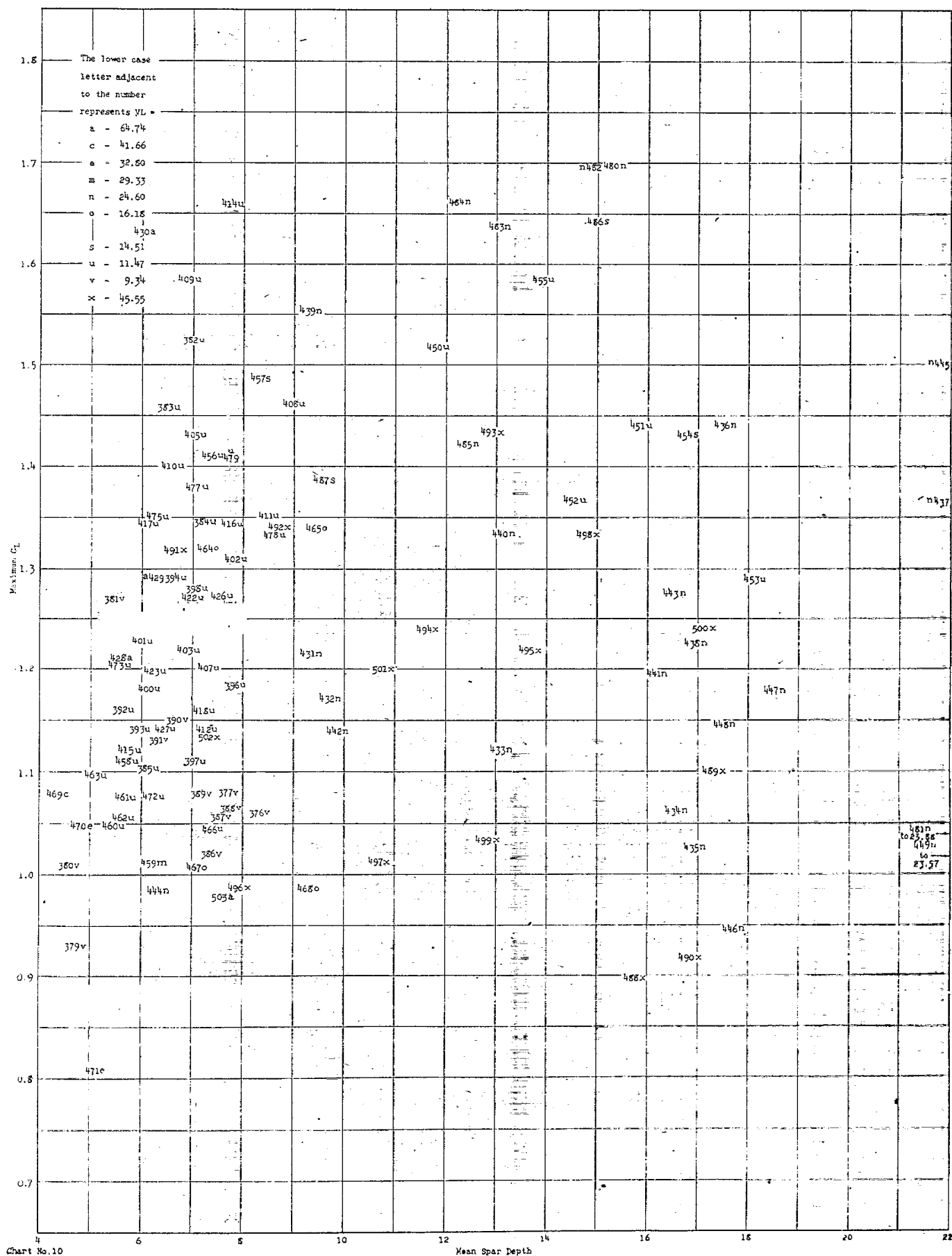
Ordinates for section at y-y.

Stations, in per cent of chord.	Ref. No. 454, U. S. A. 27e (mod.).	
	Upper.	Lower.
0	1.75	1.75
1.25	3.70	0.40
2.50	4.90	0.14
5	6.58	-0.25
7.50	7.88	-0.60
10	8.83	-0.89
15	10.15	-1.24
20	10.92	-1.53
30	11.51	-1.50
40	11.20	-1.25
50	10.34	-1.00
60	9.20	-0.70
70	7.80	-0.44
80	5.94	-0.19
90	3.64	0.15
95	2.36	0.35
100	0.64	0.64

AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

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AERODYNAMIC CHARACTERISTICS OF AIRFOILS—III.

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