
REPORT No. 286

AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V

CONTINUATION OF REPORTS

Nos. 93, 124, 182, AND 244

By

**NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS**

REPRINT OF REPORT No. 286, ORIGINALLY PUBLISHED APRIL, 1928

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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 it is one from which a desired transformation can be easily made. For this purpose a set of transformation constants is given.

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 length, 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, page 375. The shape of the section is also shown with reasonable accuracy to enable one to more clearly visualize the section under consideration, the outside of the heavy line representing the profile.

The authority for the results here presented is given as the name of the laboratory at which the experiments were conducted, as explained under abbreviations, 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° C.	=59° F.
Pressure	=760 mm Hg.	=29.92 in. Hg.
Humidity	=0.	
Gravity	=9.80665 m/s ²	=32.1740 ft./sec. ²

¹ A previous collection of airfoil sections numbered 1 to 623 and Charts 1 to 16 may be found in N. A. C. A. Reports Nos. 93, 124, 182, and 244

thus giving values of specific weight of air

$$W = 1.2255 \text{ kg/m}^3 = 0.07651 \text{ lb./ft.}^3$$

and of density

$$\rho = 0.12497 \text{ in the French engineering or kilogram, meter, second system.}$$

Or $\rho = 0.002378 \text{ in the English or pound, foot, second system.}$

In absolute units.....	$P = CV^2\rho/2$
In kg/m^2 (m/s).....	$P = .0625 CV^2$
In kg/m^2 (km/h).....	$P = .004822 CV^2$
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 No. 240 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 this value V represents the wind velocity in feet per second and l a linear dimension, the chord length in feet.

In chart No. 17 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. 18 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, in per cent of chord length at these points, 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. 19 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. 20 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 farthest from the lower left-hand corner of the chart.

CHART INDEX

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Chart No. 19. Maximum L/D plotted against maximum lift, C_L -----	182
Chart No. 20. L/D at two-thirds the maximum lift, C_L , plotted against the maximum lift, C_L -----	183

INDEX OF ABBREVIATIONS

Name of laboratory at which tests were made	Abbreviations used on figures
Langley Memorial Aeronautical Laboratory (N. A. C. A.), U. S. A.-----	L. M. A. L.
Washington Navy Yard, U. S. A.-----	W. N. Y.
Engineering Division, McCook Field, U. S. A.-----	McC. F.
Royal Aircraft Establishment, Great Britain-----	R. A. E.
Service Technique de l'Aeronautique, France-----	S. T. Aé
Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen, Germany-----	Göttingen.
Instituto Sperimentale Aeronautico, Italy-----	I. S. A.
Laboratorio della Direzione del Genio Aeronautico, Italy-----	D. G. A.
Laboratoire Aerotechnique de Rhode St. Genese-Bruxelles, Belgium-----	Rhode St. Genese.

GROUP INDEX

Airfoil	Wind tunnel where tested	Report reference number	Airfoil	Wind tunnel where tested	Report reference number
UNITED STATES			GERMANY—continued		
N. A. C. A. 81J	L. M. A. L.	624	532	Göttingen	681
N. A. C. A. -CYH	do	625	533	do	682
B-2 (Modified M-80)	W. N. Y.	626	534	do	683
C-2 (Modified M-80)	do	627	535	do	684
Boeing 103	do	628	546	do	685
N-22	do	629	547	do	686
N-23	do	630	548	do	687
N-24	do	631	549	do	688
Clark Y-15	McC. F.	632	559	do	689
Clark Y-18	do	633	561	do	690
Clark Y-21	do	634	562	do	691
GREAT BRITAIN			570	do	692
R. A. F. 25	R. A. E.	635	571	do	693
R. A. F. 26	do	636	572	do	694
R. A. F. 27	do	637	573	do	695
R. A. F. 28	do	638	574	do	696
R. A. F. 34	do	639	575	do	697
GERMANY			587	do	698
Göttingen 417a	Göttingen	640	590	do	699
Göttingen 456	do	641	592	do	700
Göttingen 458	do	642	593	do	701
Göttingen 461	do	643	595	do	702
Göttingen 462	do	644	FRANCE		
Göttingen 464	do	645	Eiffel 400 (Pescara)	S. T. Aé. Lab.	703
Göttingen 481	do	646	Eiffel 401 (Pescara)	do	704
Göttingen 481a	do	647	Eiffel 403 (Pescara)	do	705
Göttingen 482	do	648	Eiffel 428 (Blériot)	do	706
Göttingen 483	do	649	Eiffel 430 (Lachassagne)	do	707
Göttingen 484	do	650	Eiffel 431 (Lachassagne)	do	708
Göttingen 490	do	651	St. Cyr 150 (Royer)	do	709
Göttingen 491	do	652	St. Cyr 151 (Royer)	do	710
Göttingen 492	do	653	St. Cyr 154 (Royer)	do	711
Göttingen 493	do	654	St. Cyr 155 (Royer)	do	712
Göttingen 494	do	655	St. Cyr 158 (Royer)	do	713
Göttingen 495	do	656	St. Cyr 159 (Royer)	do	714
Göttingen 496	do	657	St. Cyr 160 (Royer)	do	715
Göttingen 497	do	658	St. Cyr 161 (Royer)	do	716
Göttingen 498	do	659	St. Cyr 171 (Royer)	do	717
Göttingen 499	do	660	St. Cyr 172 (Royer)	do	718
Göttingen 500	do	661	St. Cyr 173 (Royer)	do	719
Göttingen 501	do	662	St. Cyr 175 (Royer)	do	720
Göttingen 502	do	663	St. Cyr 176 (Royer)	do	721
Göttingen 503	do	664	St. Cyr 177 (Royer)	do	722
Göttingen 504	do	665	St. Cyr 178 (Royer)	do	723
Göttingen 505	do	666	St. Cyr 185 (Monge)	do	724
Göttingen 506	do	667	St. Cyr 234 (Bartel 17-IC)	do	725
Göttingen 509	do	668	St. Cyr 236 (Bartel 26-IC)	do	726
Göttingen 510	do	669	St. Cyr 238 (Bartel 4-IC)	do	727
Göttingen 511	do	670	St. Cyr 241 (Bartel 37-IC)	do	728
Göttingen 512	do	671	St. Cyr 244 (Bartel 35-IIIC)	do	729
Göttingen 513	do	672	BELGIUM		
Göttingen 514	do	673	Rhode St. Genese 28	Rhode St. Genese	730
Göttingen 518	do	674	Rhode St. Genese 30	do	731
Göttingen 522	do	675	Rhode St. Genese 32	do	732
Göttingen 523	do	676	Rhode St. Genese 34	do	733
Göttingen 527	do	677	Rhode St. Genese 36	do	734
Göttingen 528	do	678			
Göttingen 529	do	679			
Göttingen 530	do	680			
Göttingen 531	do				

¹ Göttingen 461 of this series published in Report No. 182.

AERODYNAMIC CHARACTERISTICS OF AIR FOILS—V

Airfoil	Wind tunnel where tested	Report reference number	Airfoil	Wind tunnel where tested	Report reference number
ITALY			ITALY—continued		
I. S. A. 571	I. S. A.	735	I. S. A. 923b	I. S. A.	748
I. S. A. 573	do.	736	I. S. A. 960	do.	749
I. S. A. 607	do.	737	I. S. A. 961	do.	750
I. S. A. 608	do.	738	I. S. A. 962	do.	751
I. S. A. 666	do.	739	I. S. A. 993	do.	752
I. S. A. 691	do.	740	I. S. A. 994a	do.	753
I. S. A. 692	do.	741	I. S. A. 994c	do.	754
I. S. A. 802	do.	742	Bambino 5	D. G. A.	755
I. S. A. 808	do.	743	Bambino 6	do.	756
I. S. A. 843	do.	744	Bambino, E: 7	do.	757
I. S. A. 906	do.	745	D. G. A. 1188	do.	758
I. S. A. 909	do.	746	D. G. A. 1182	do.	759
I. S. A. 923a	do.	747			

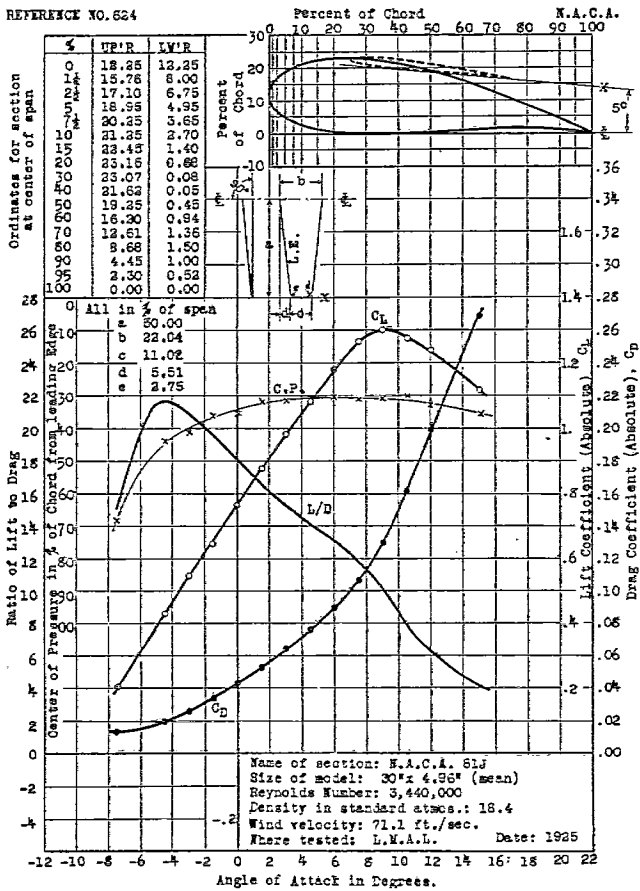
ALPHABETICAL INDEX

Airfoil	Report reference number	Airfoil	Report reference number
B-2 (Modified M-80)	626	562	691
Bambino 5	755	570	692
Bambino 6	756	571	693
Bambino, E: 7	757	572	694
Boeing 103	628	573	695
C-2 (Modified M-80)	627	574	696
Clark Y-15	632	575	697
Clark Y-18	633	587	698
Clark Y-21	634	590	699
D. G. A. 1138	758	592	700
D. G. A. 1182	759	593	701
Eiffel 400 (Pescara)	703	595	702
Eiffel 401 (Pescara)	704	I. S. A. 571	735
Eiffel 403 (Pescara)	705	I. S. A. 573	736
Eiffel 428 (Blériot)	706	I. S. A. 607	737
Eiffel 430 (Lachassagne)	707	I. S. A. 608	738
Eiffel 431 (Lachassagne)	708	I. S. A. 666	739
417a	640	I. S. A. 691	740
456	641	I. S. A. 692	741
Göttingen 458	642	I. S. A. 802	742
Göttingen 461	430	I. S. A. 805	743
Göttingen 462	643	I. S. A. 843	744
Göttingen 464	644	I. S. A. 906	745
Göttingen 481	645	I. S. A. 909	746
Göttingen 481a	646	I. S. A. 923a	747
Göttingen 482	647	I. S. A. 923b	748
483	648	I. S. A. 960	749
484	649	I. S. A. 961	750
490	650	I. S. A. 962	751
Göttingen 491	651	I. S. A. 993	752
Göttingen 492	652	I. S. A. 994a	753
Göttingen 493	653	I. S. A. 994c	754
Göttingen 494	654	N-22	629
Göttingen 495	655	N-23	630
496	656	N-24	631
497	657	N. A. C. A. 81J	624
498	658	N. A. C. A. -CYH	625
499	659	R. A. F. 25	635
500	660	R. A. F. 26	636
Göttingen 501	661	R. A. F. 27	637
502	662	R. A. F. 28	638
503	663	R. A. F. 34	639
504	664	Rhode St. Genese 28	730
Göttingen 505	665	Rhode St. Genese 30	731
Göttingen 506	666	Rhode St. Genese 32	732
Göttingen 509	667	Rhode St. Genese 34	733
Göttingen 510	668	Rhode St. Genese 36	734
Göttingen 511	669	St. Cyr 150 (Royer)	709
Göttingen 512	670	St. Cyr 151 (Royer)	710
Göttingen 513	671	St. Cyr 154 (Royer)	711
514	672	St. Cyr 155 (Royer)	712
518	673	St. Cyr 158 (Royer)	713
Göttingen 522	674	St. Cyr 159 (Royer)	714
Göttingen 523	675	St. Cyr 160 (Royer)	715
527	676	St. Cyr 161 (Royer)	716
528	677	St. Cyr 171 (Royer)	717
529	678	St. Cyr 172 (Royer)	718
530	679	St. Cyr 173 (Royer)	719
531	680	St. Cyr 175 (Royer)	720
Göttingen 532	681	St. Cyr 176 (Royer)	721
Göttingen 533	682	St. Cyr 177 (Royer)	722
Göttingen 534	683	St. Cyr 178 (Royer)	723
Göttingen 535	684	St. Cyr 185 (Monge)	724
Göttingen 546	685	St. Cyr 234 (Bartel 17-IC)	725
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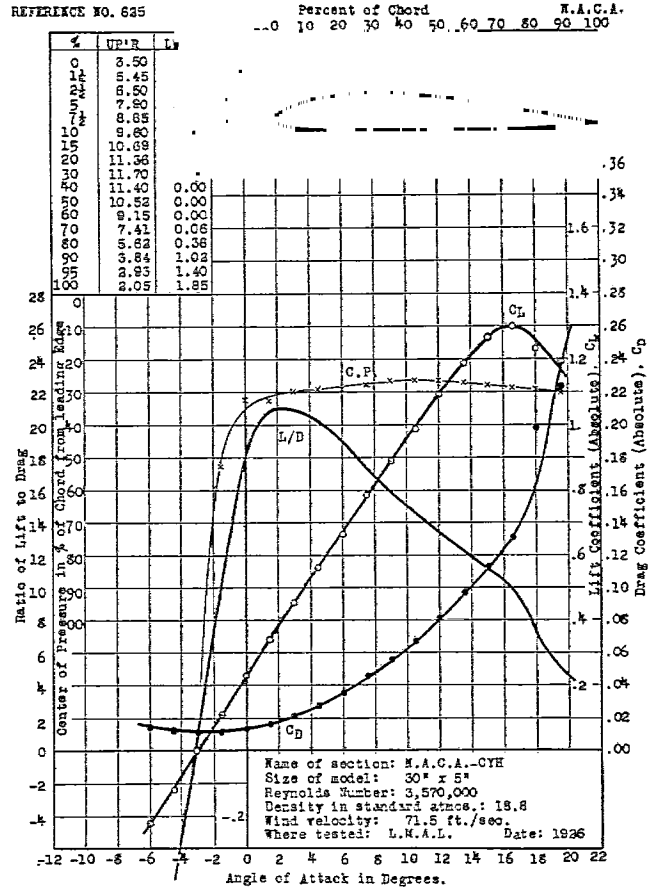
¹ Göttingen 461 of this series published in Report No. 182.

AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V

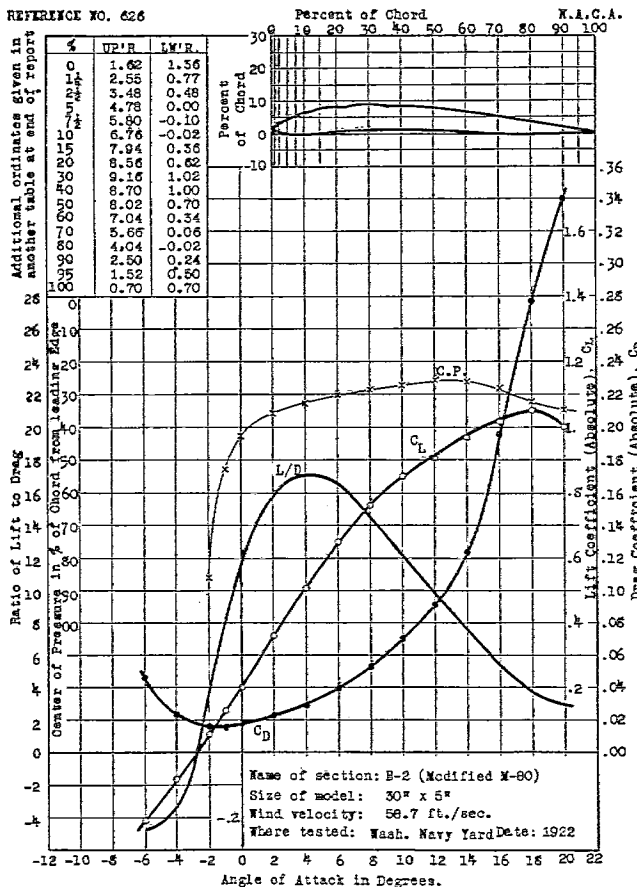
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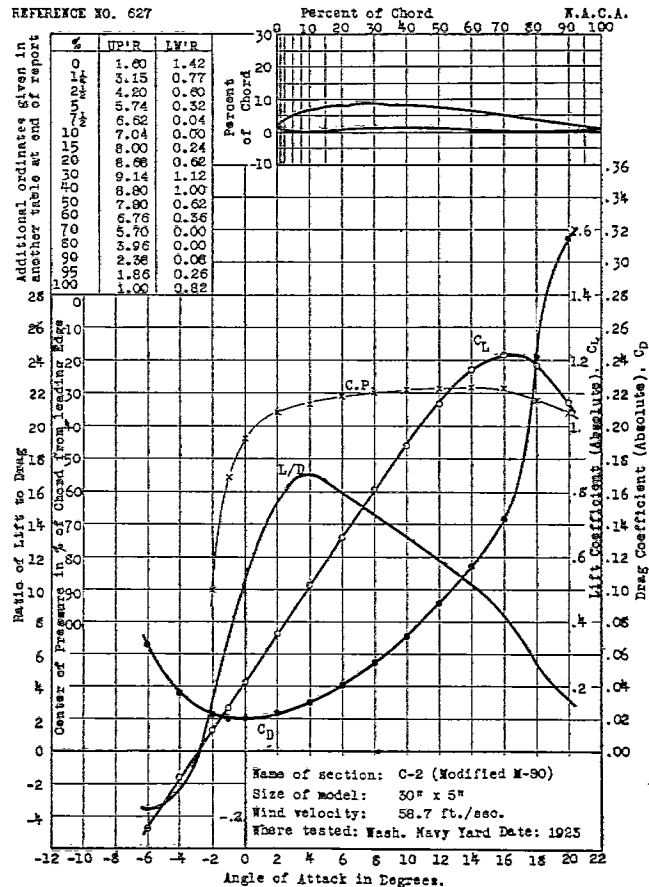
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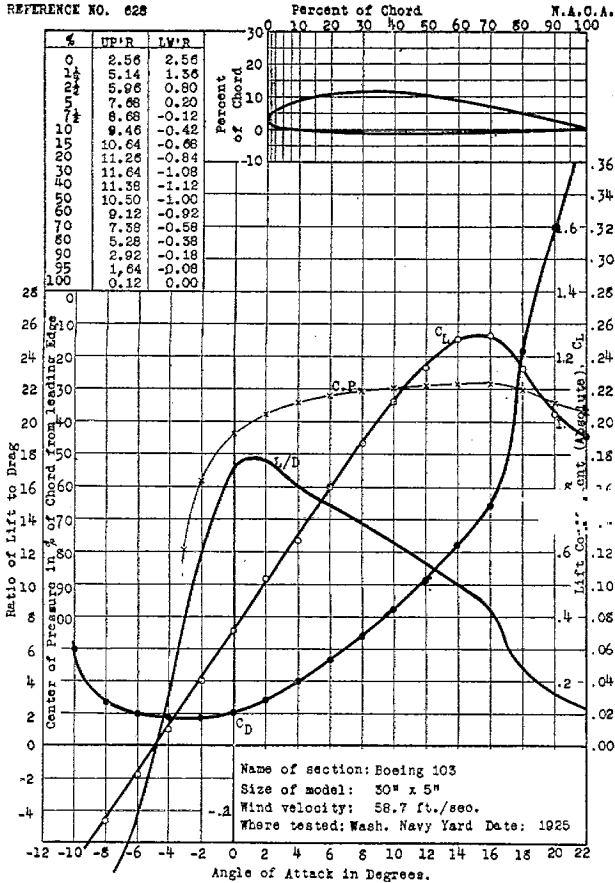
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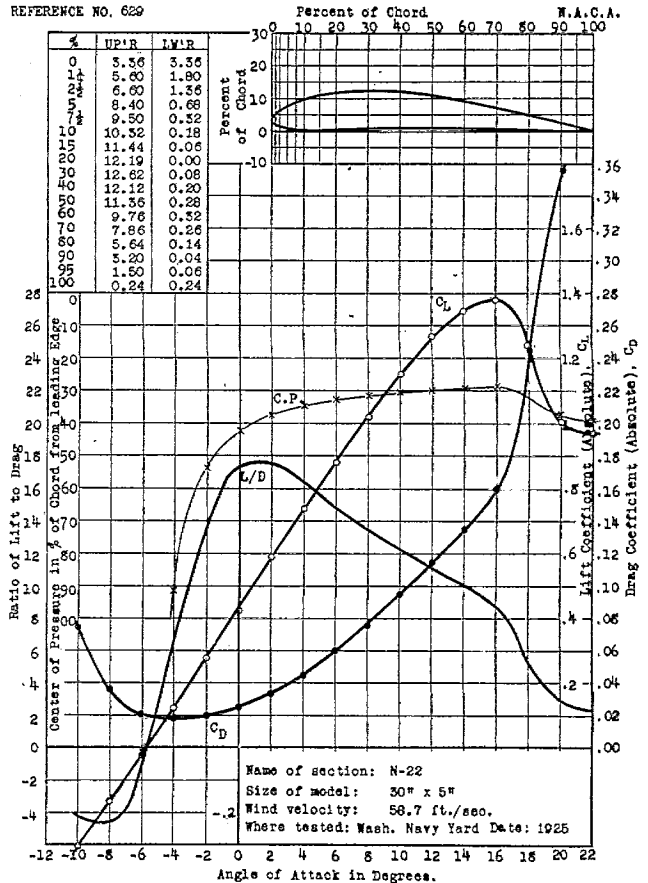
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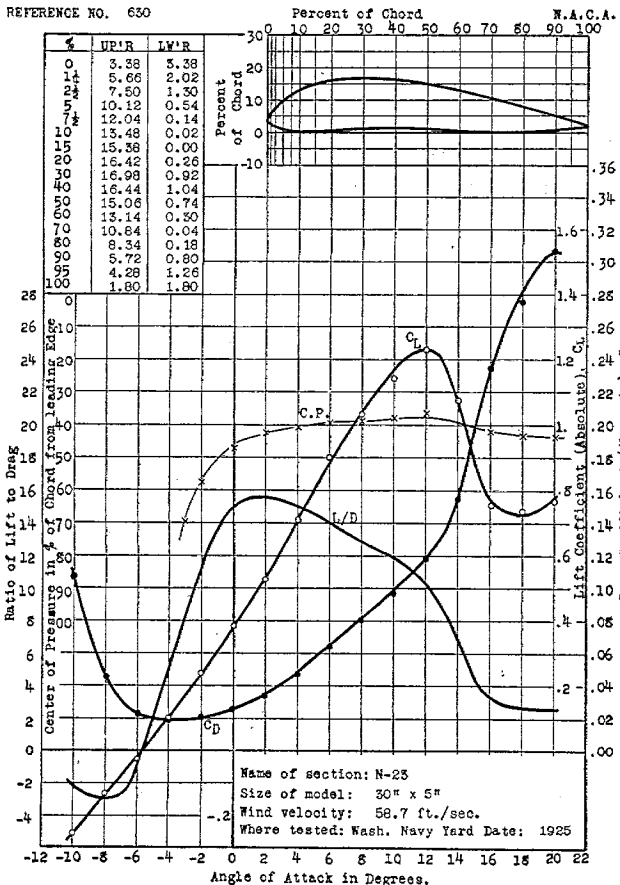
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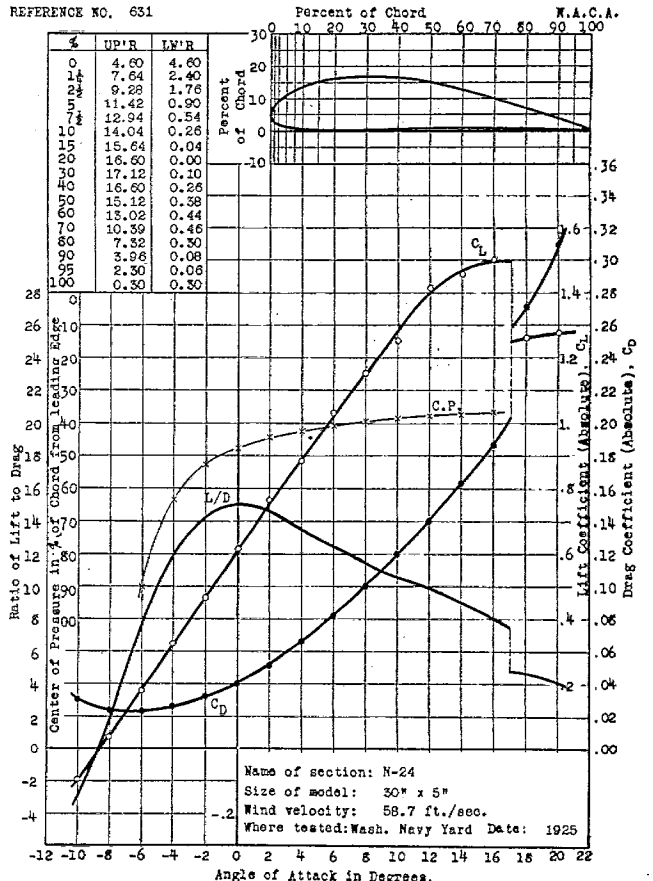
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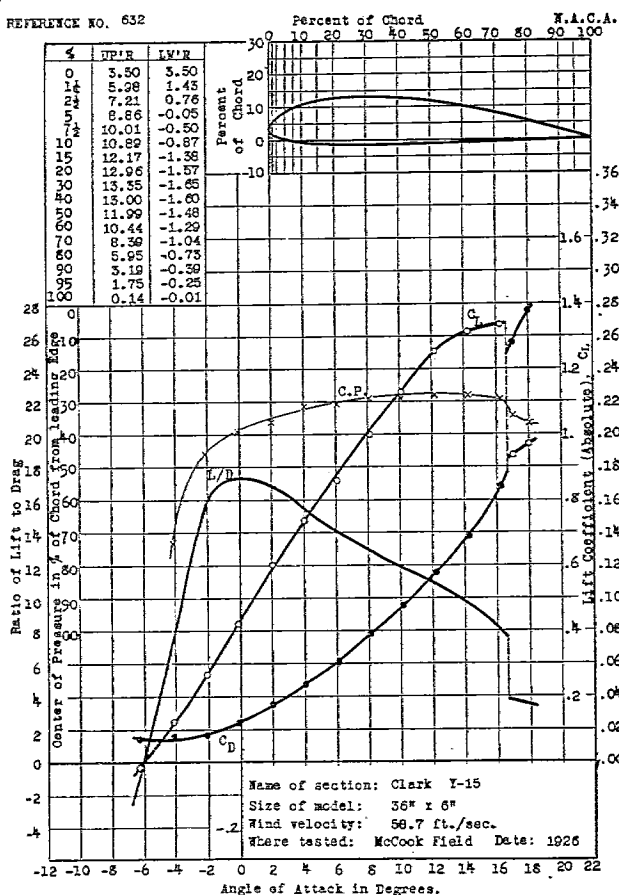


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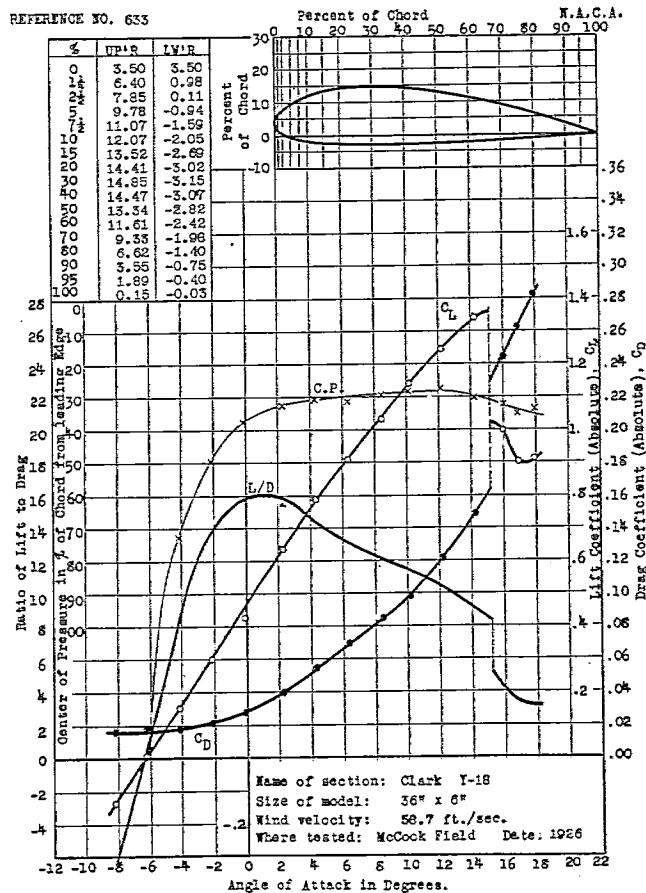


AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V

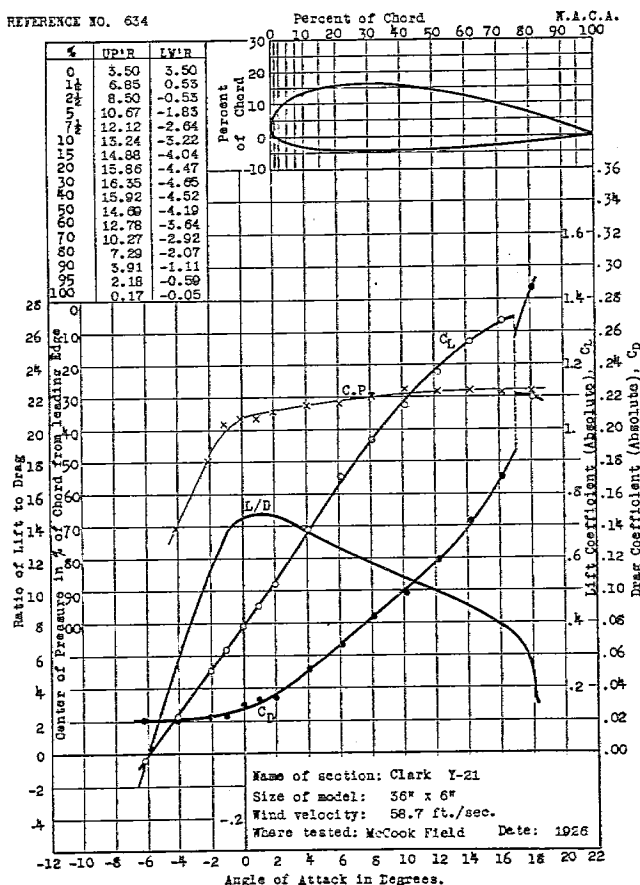
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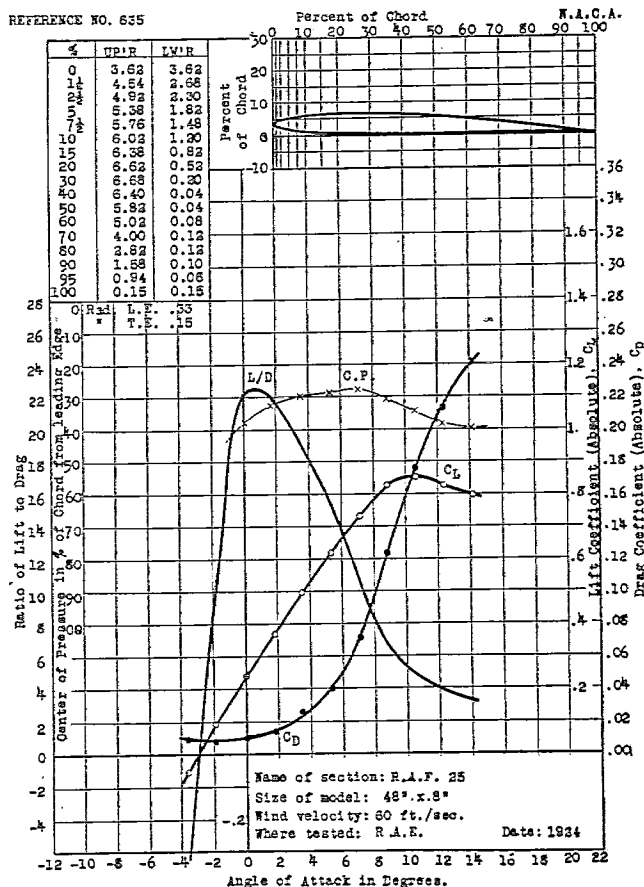
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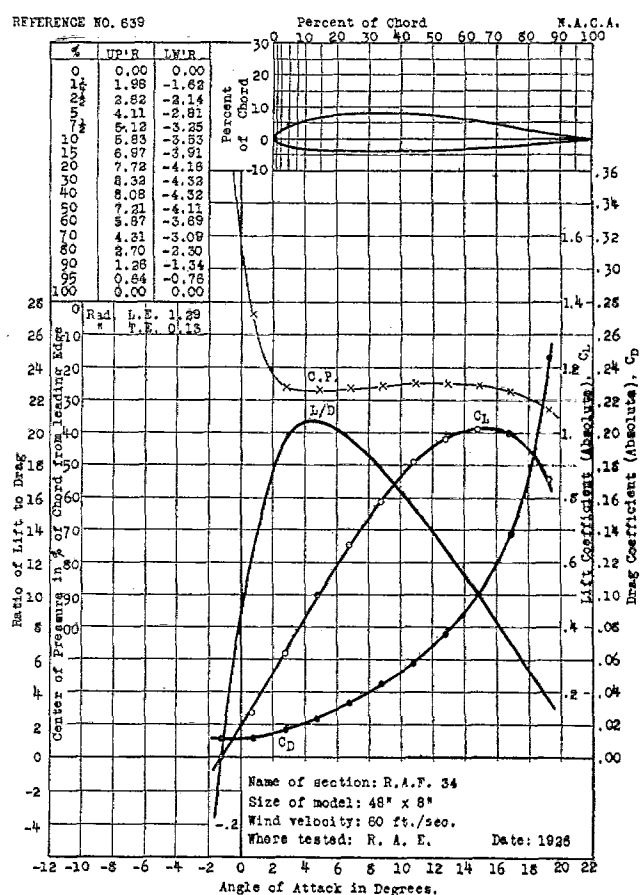
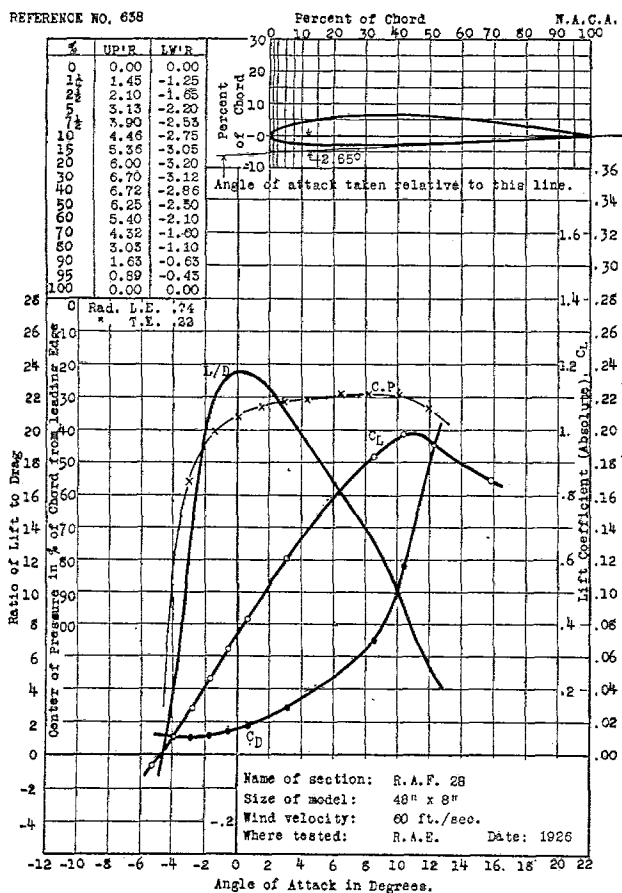
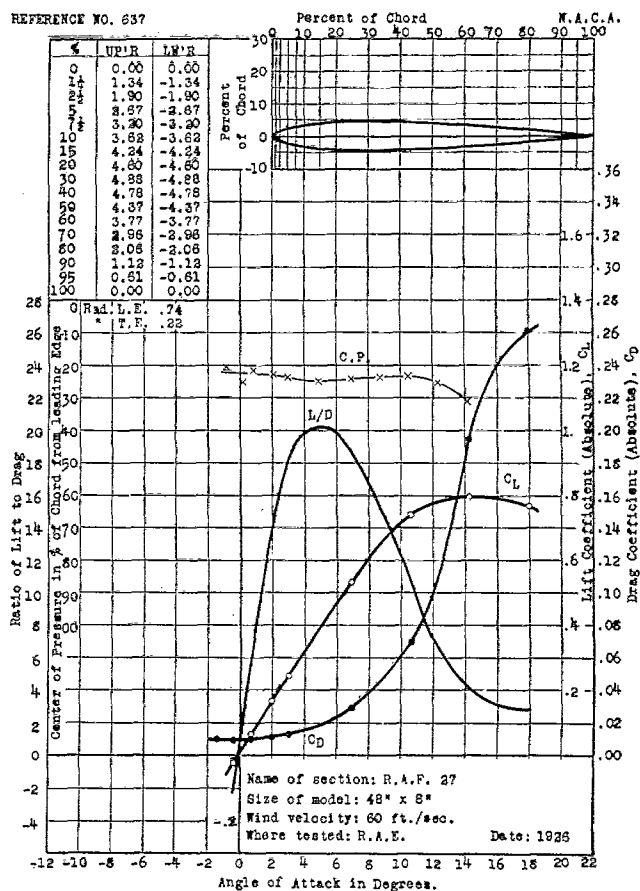
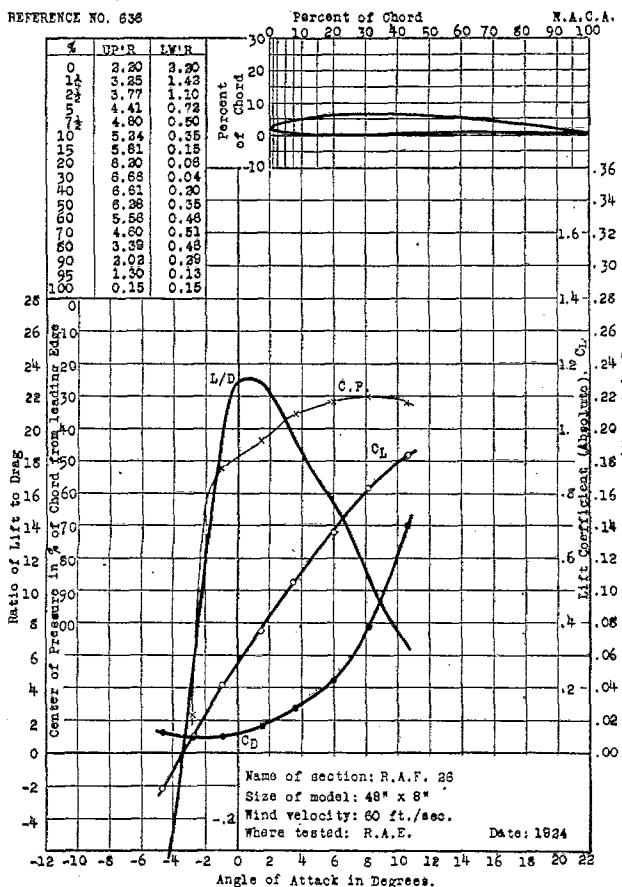


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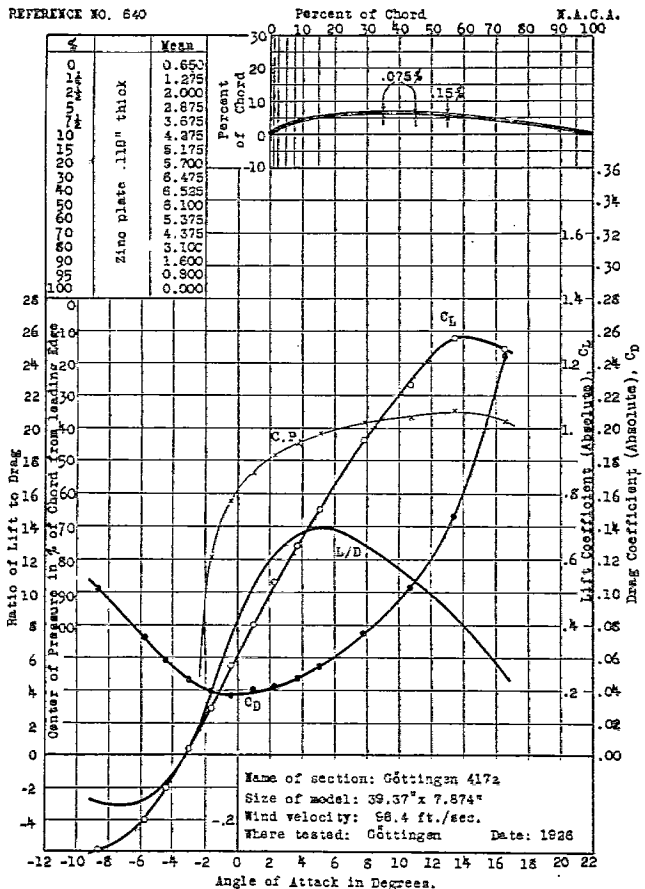
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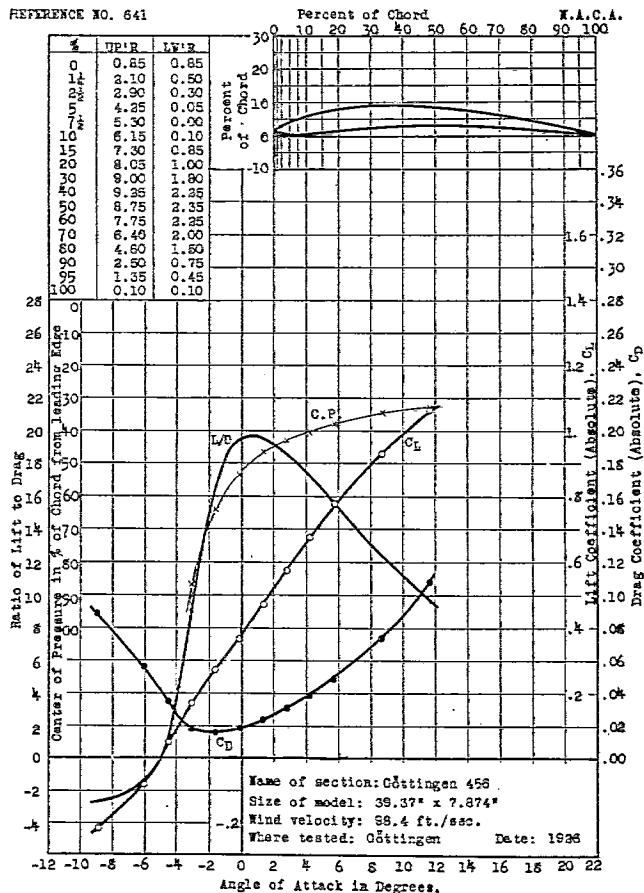


AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V

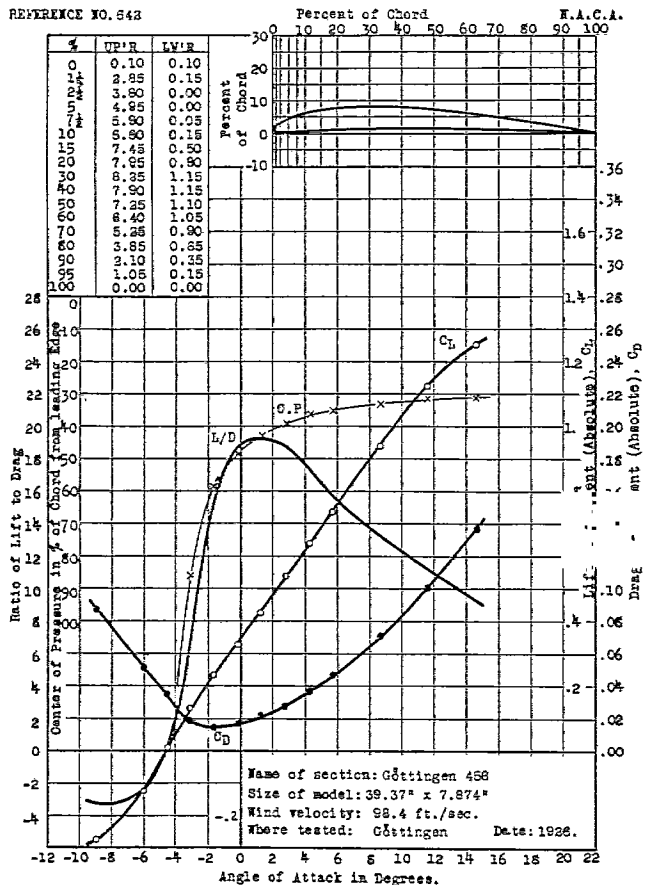
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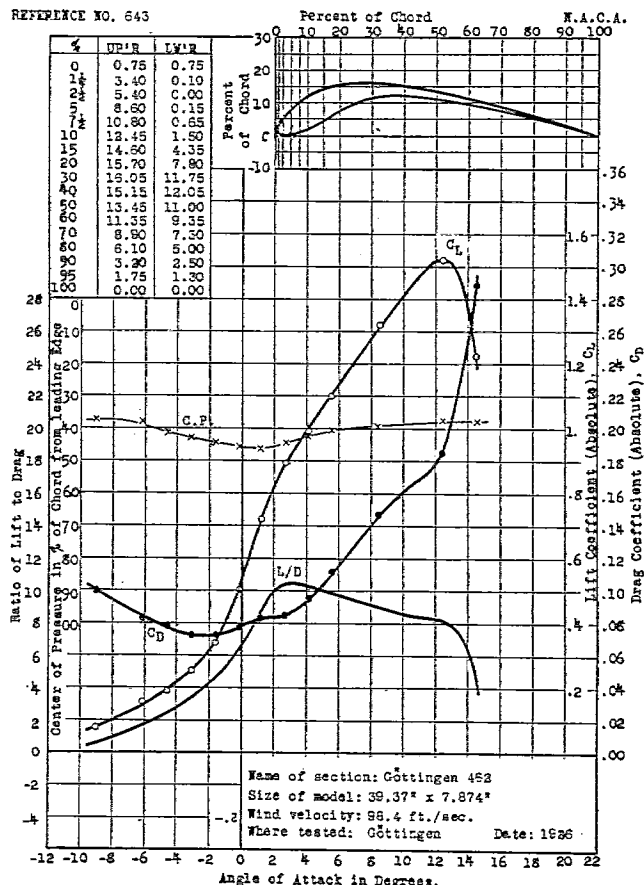
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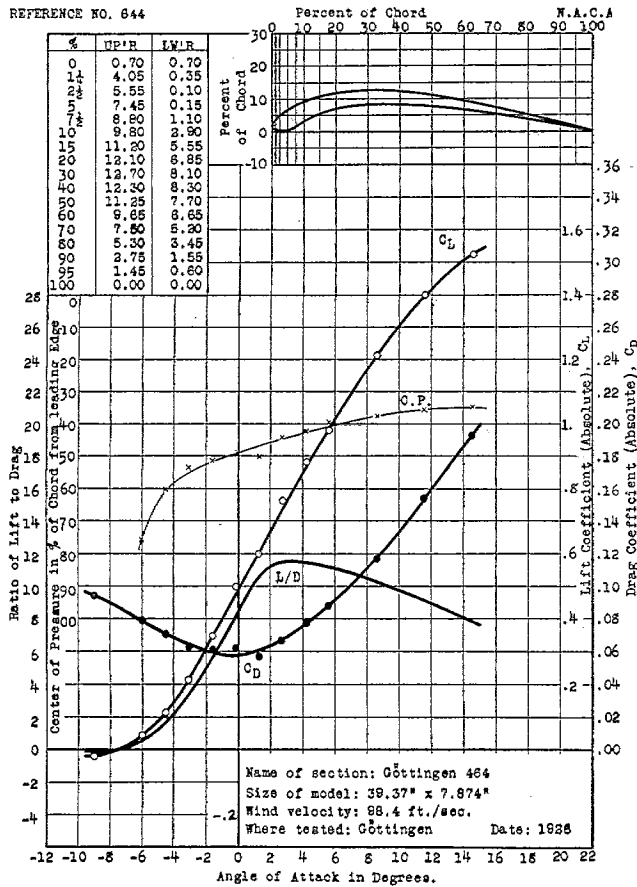
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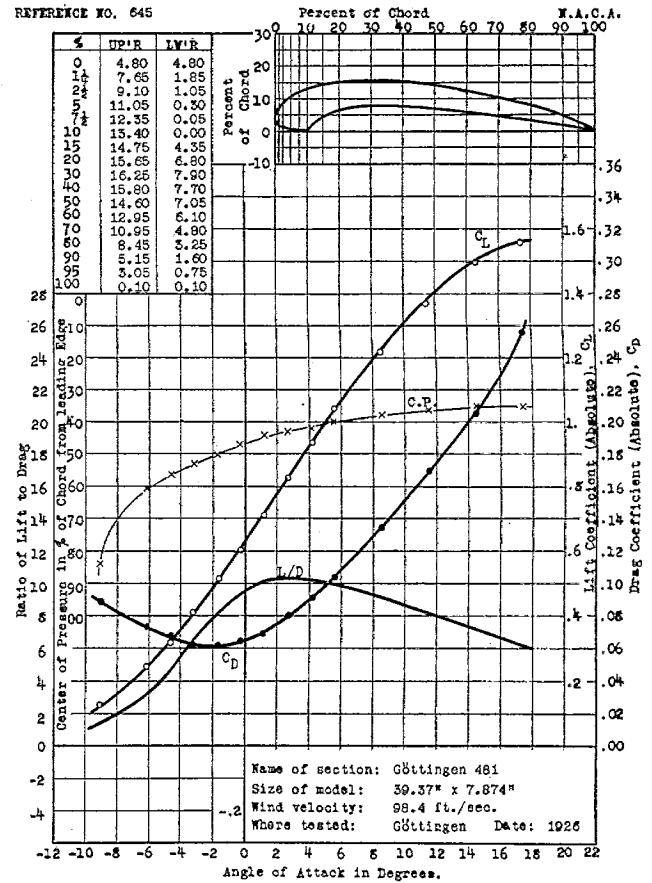
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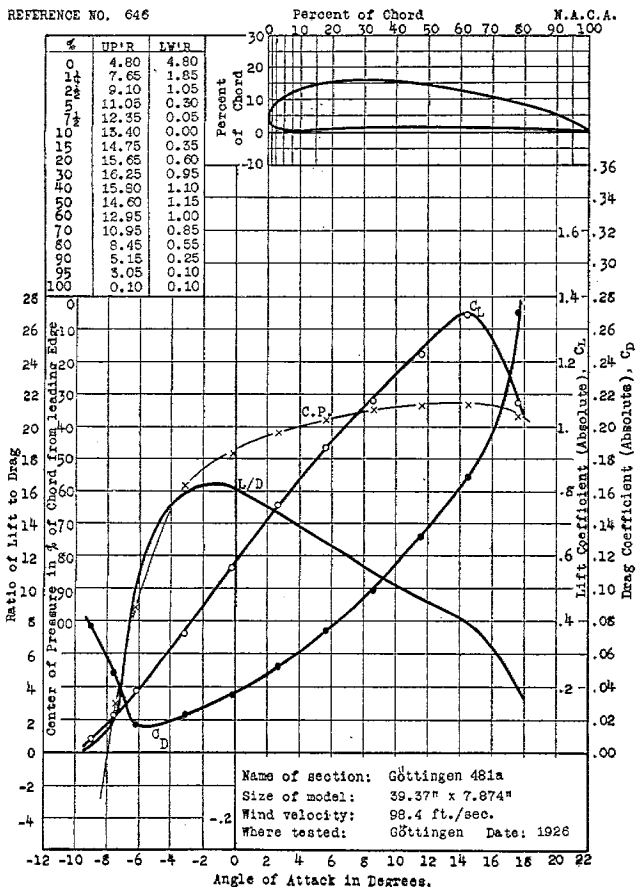
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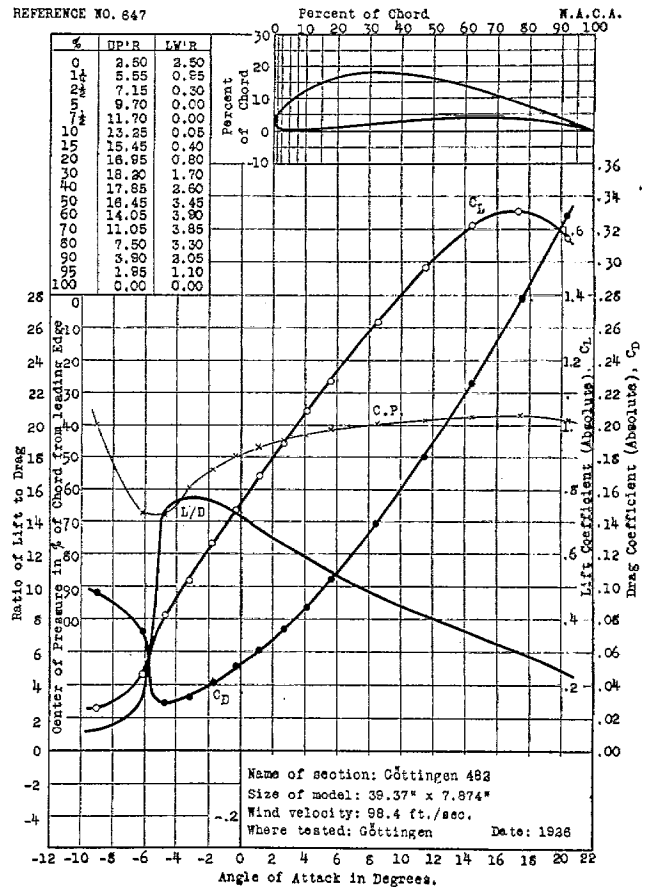
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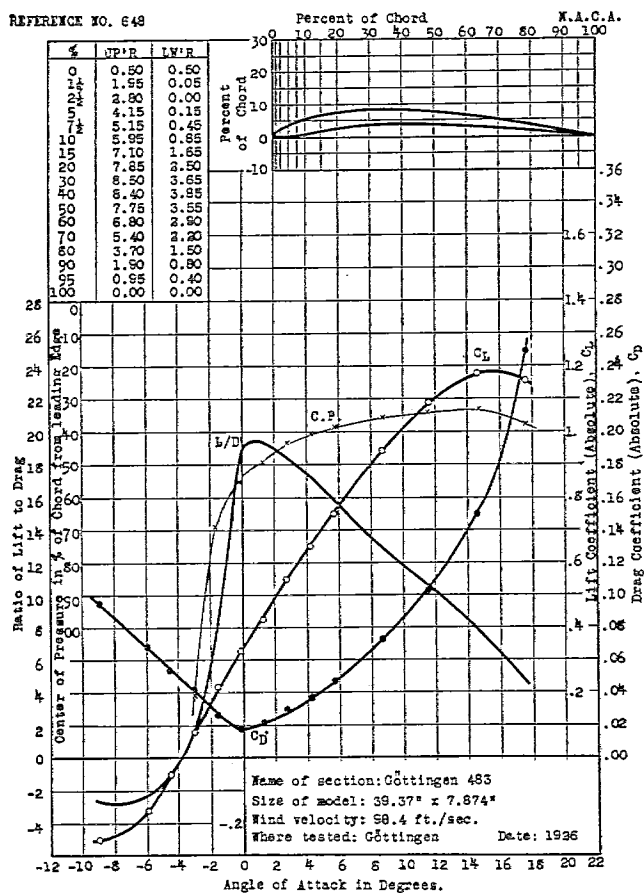


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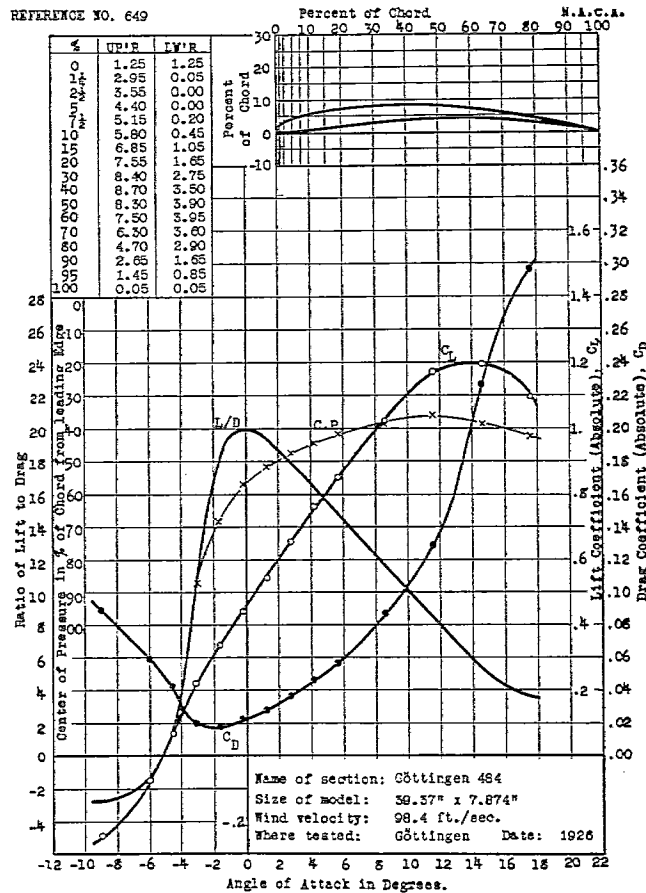


AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V

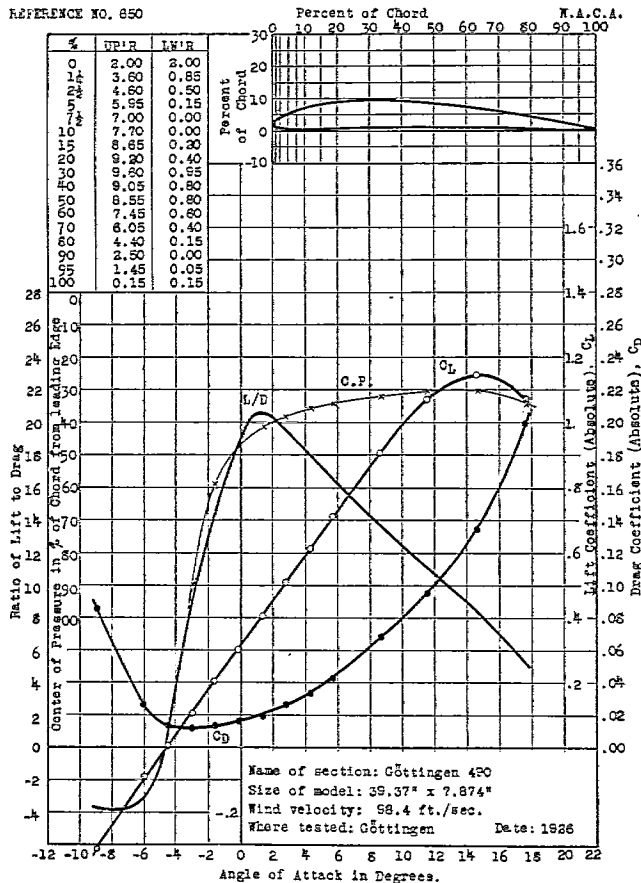
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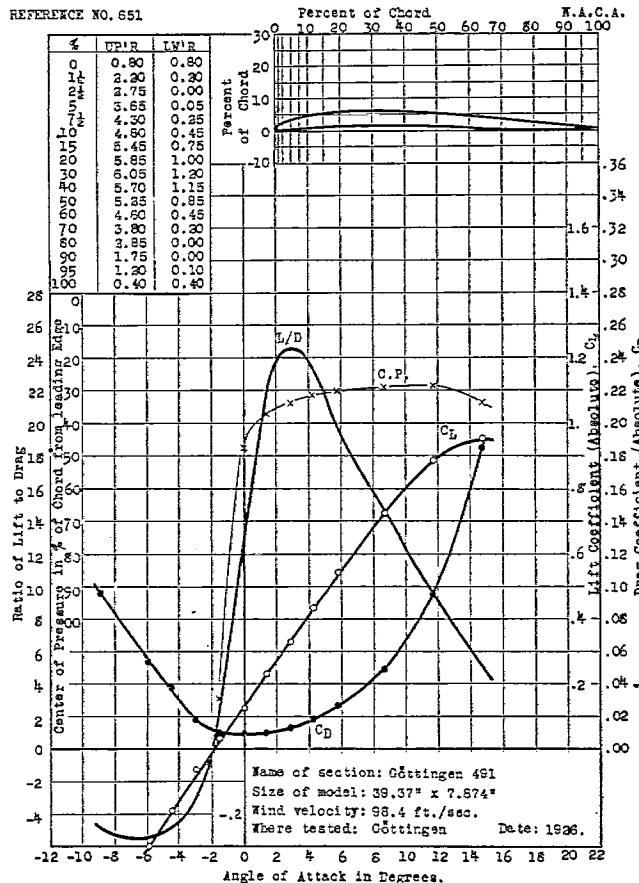
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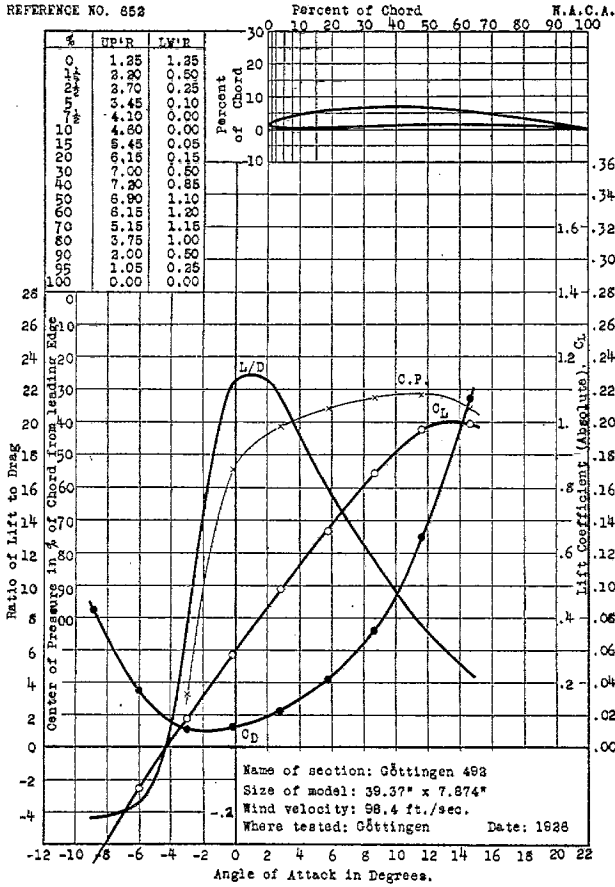
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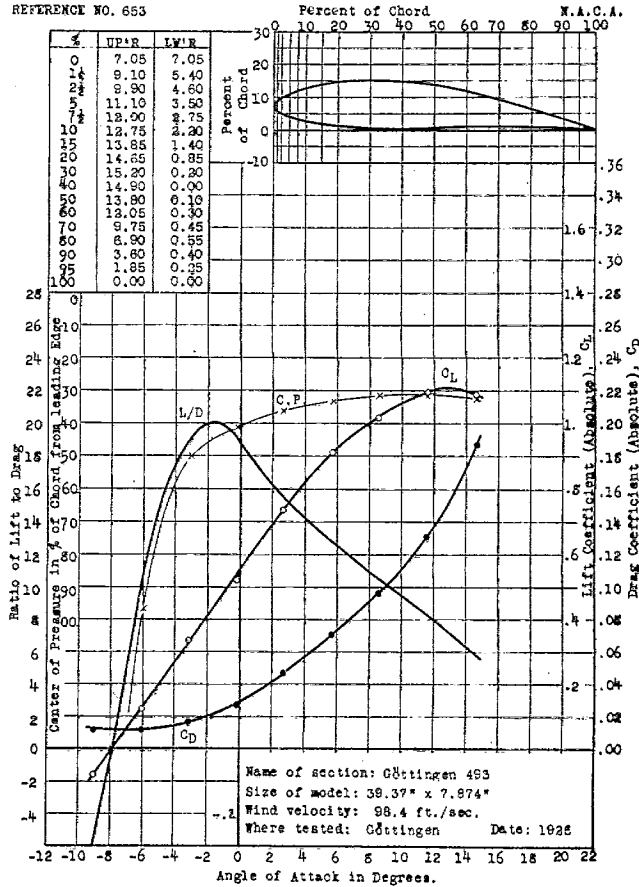
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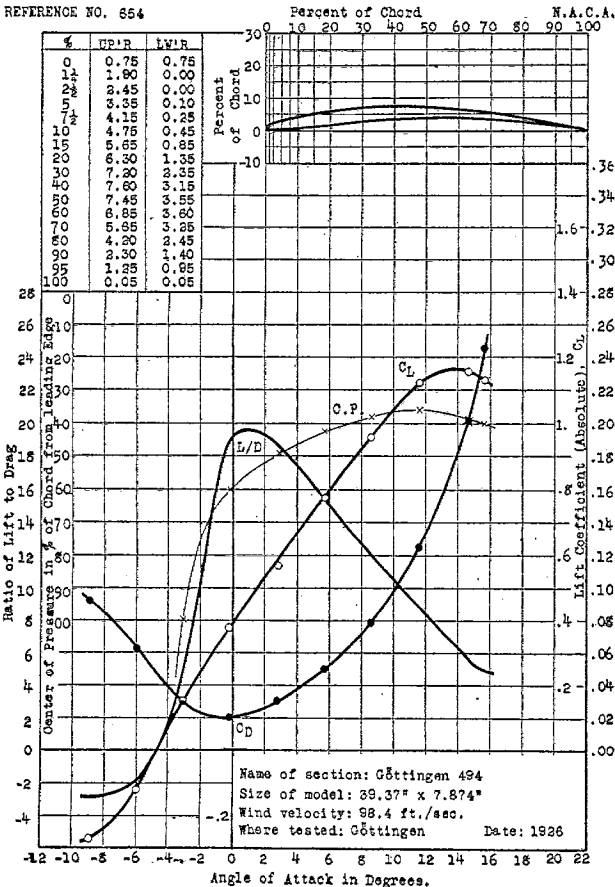
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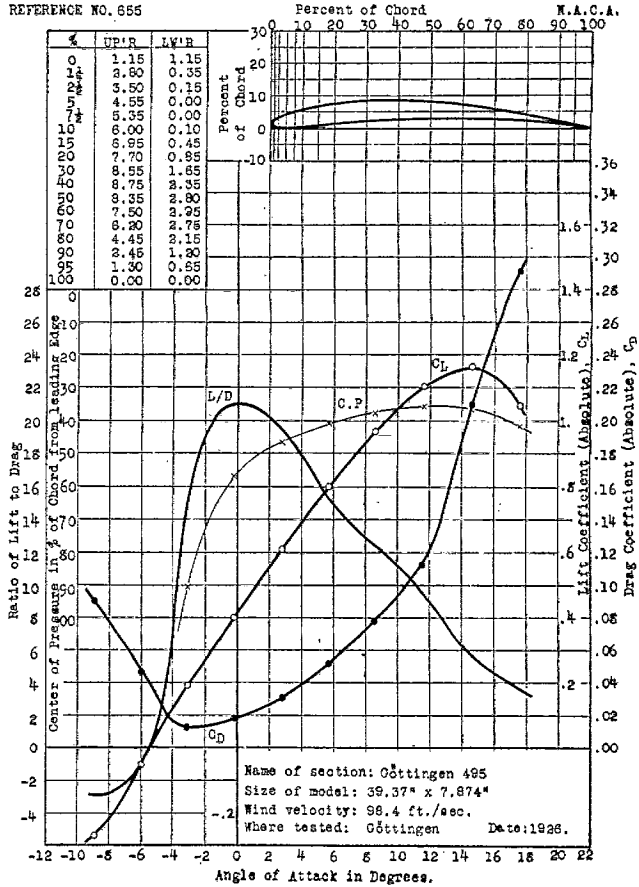
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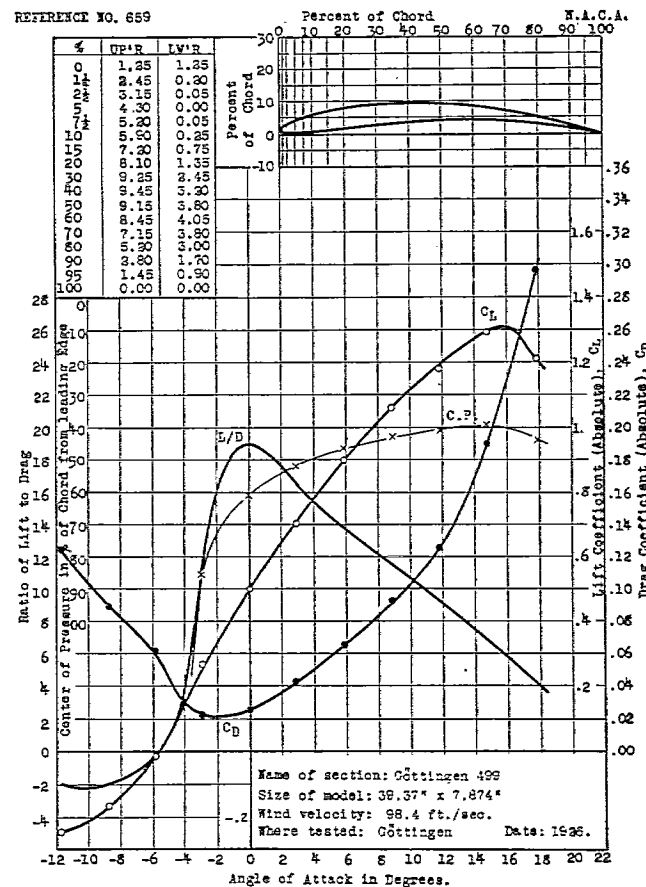
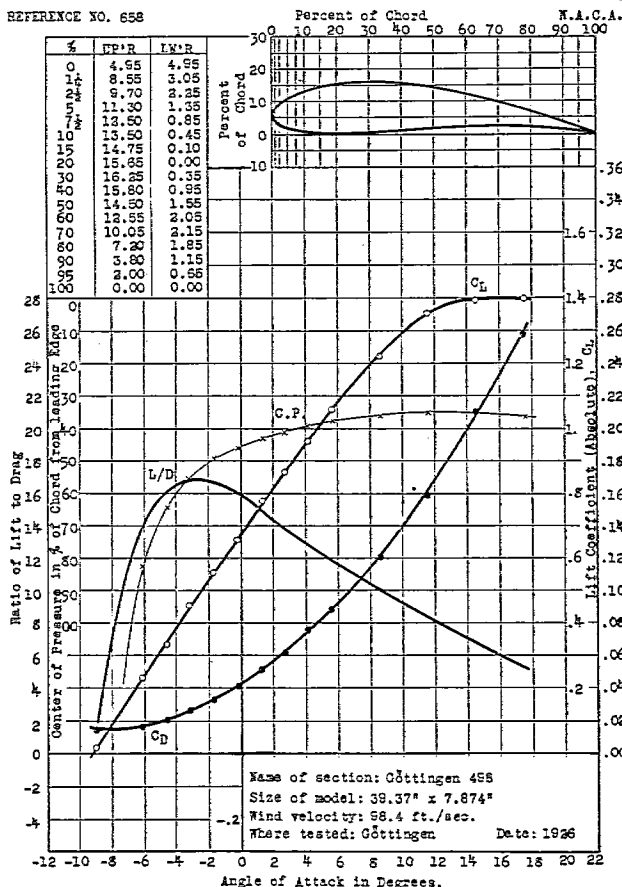
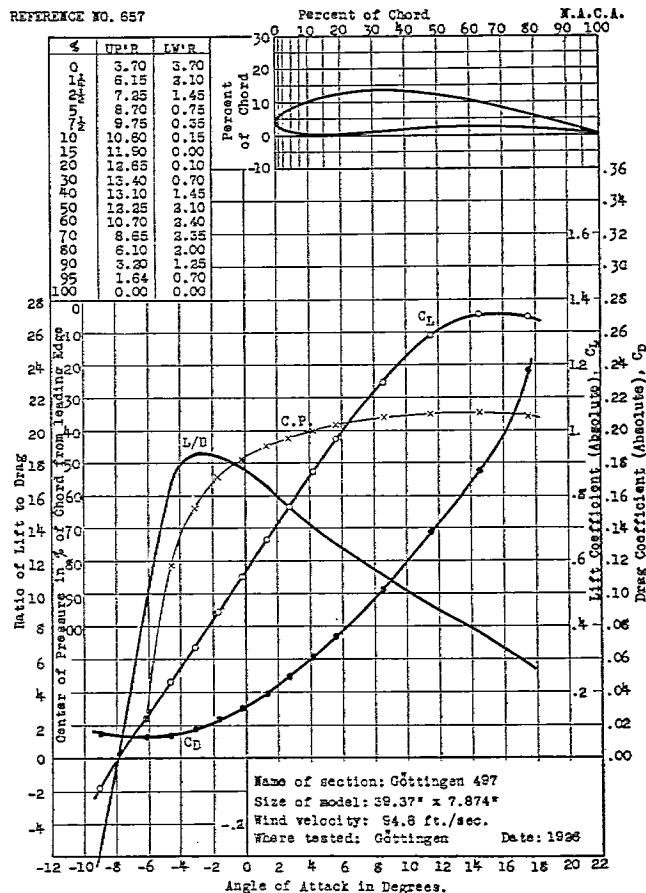
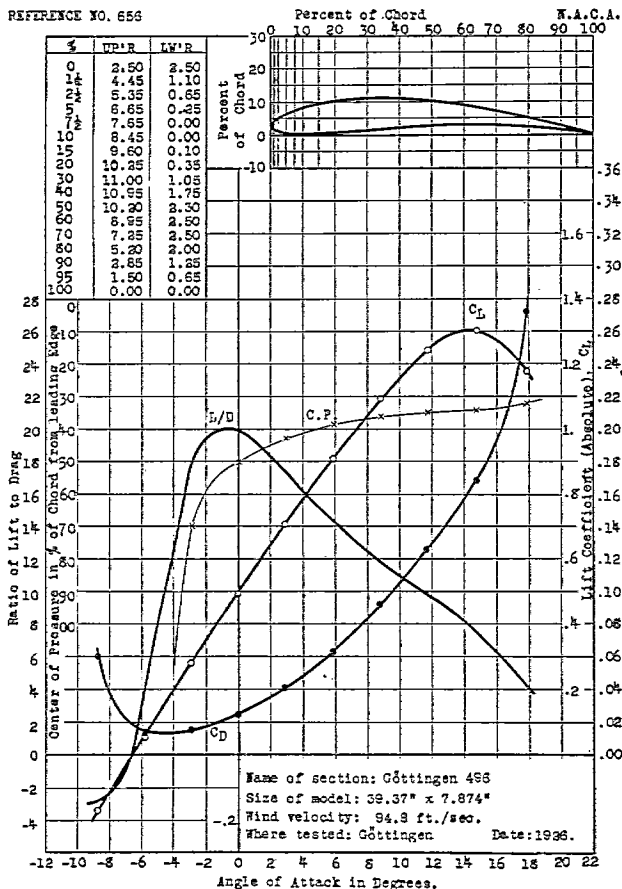
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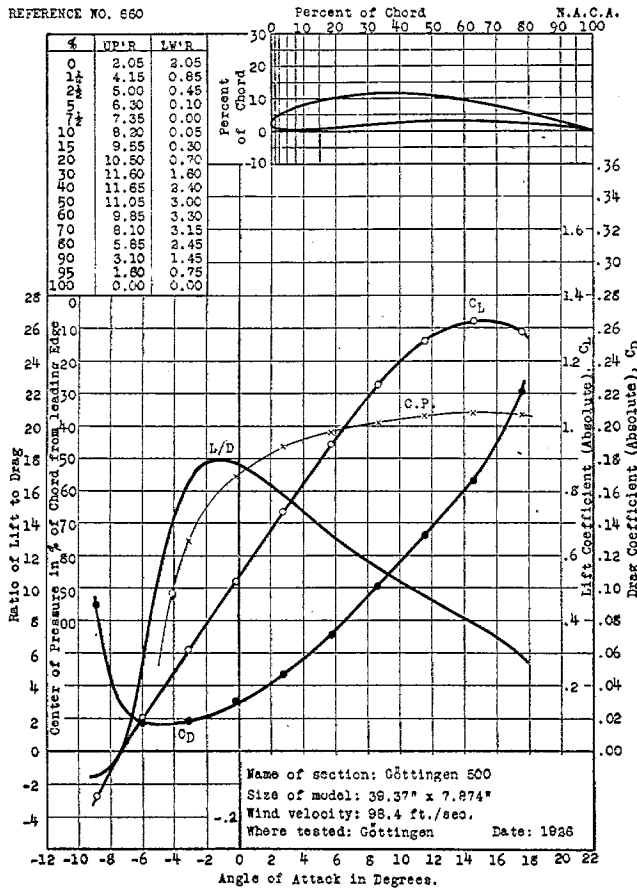
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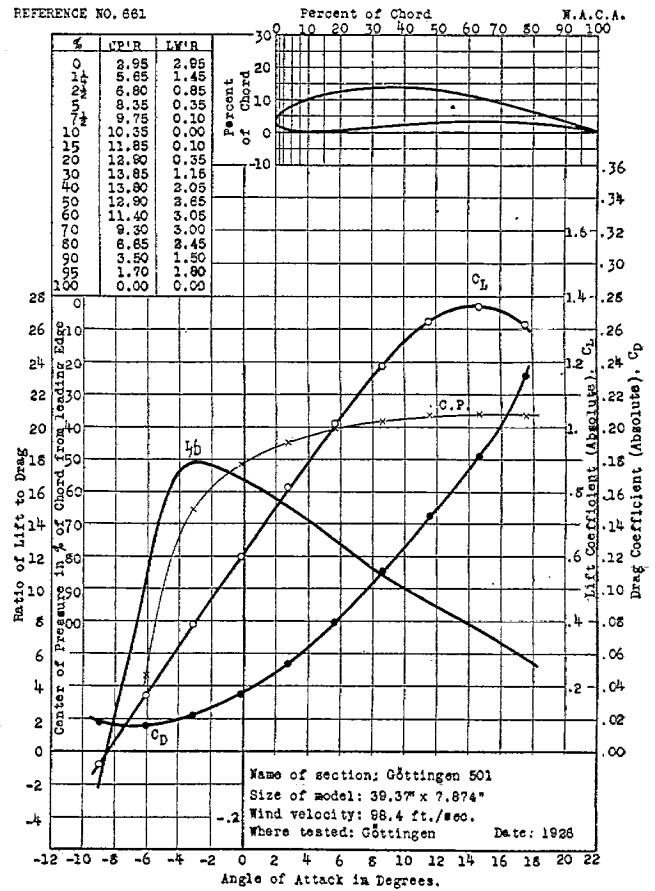
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V



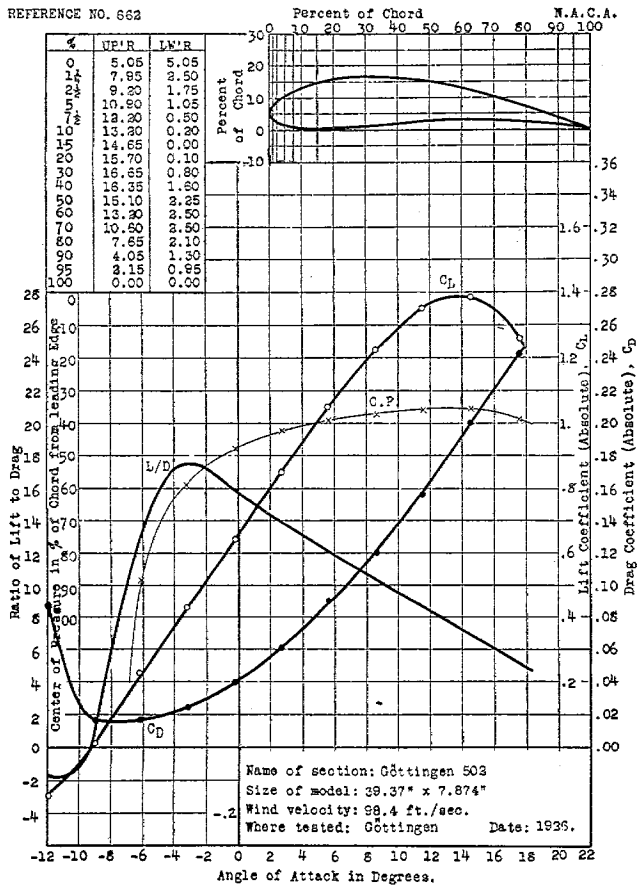
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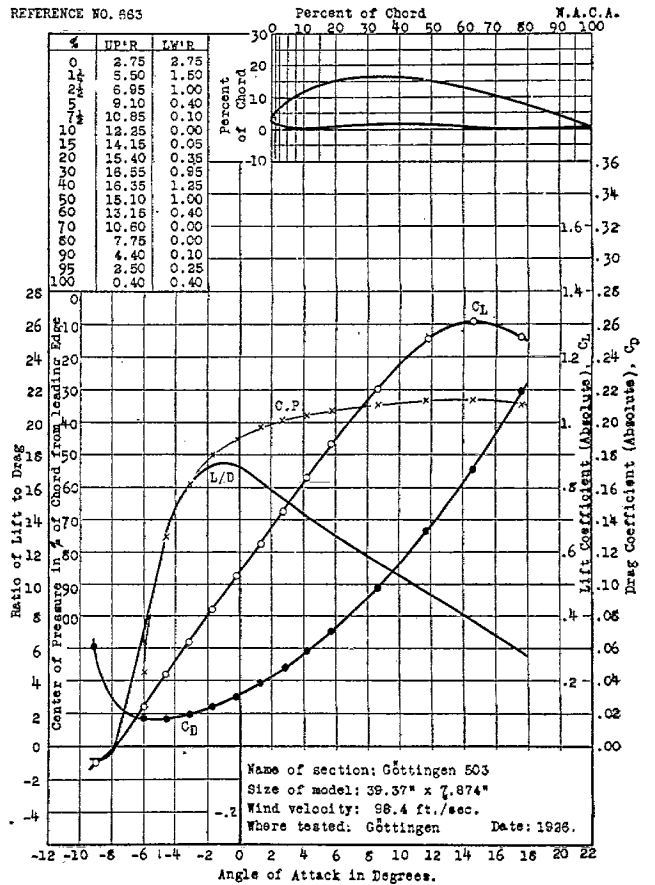
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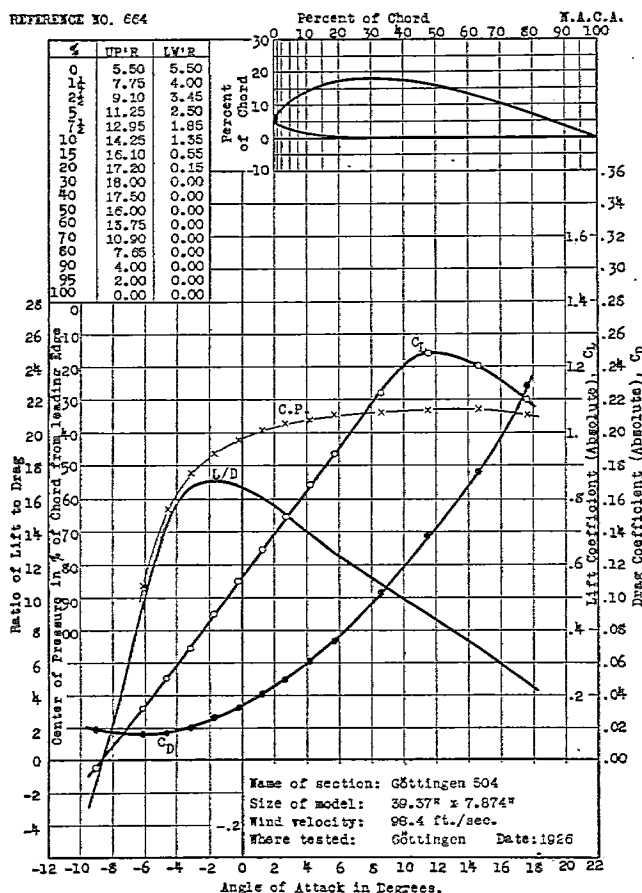
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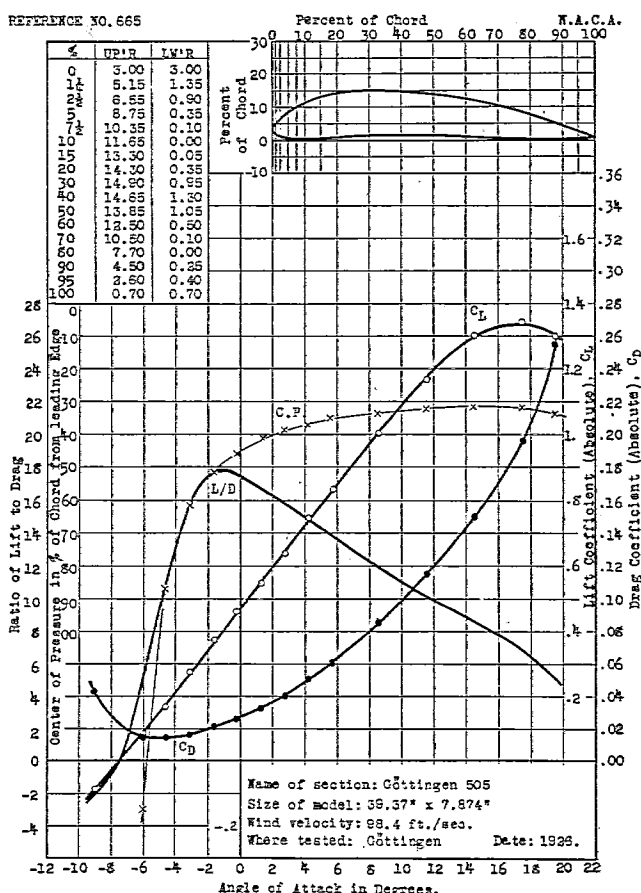
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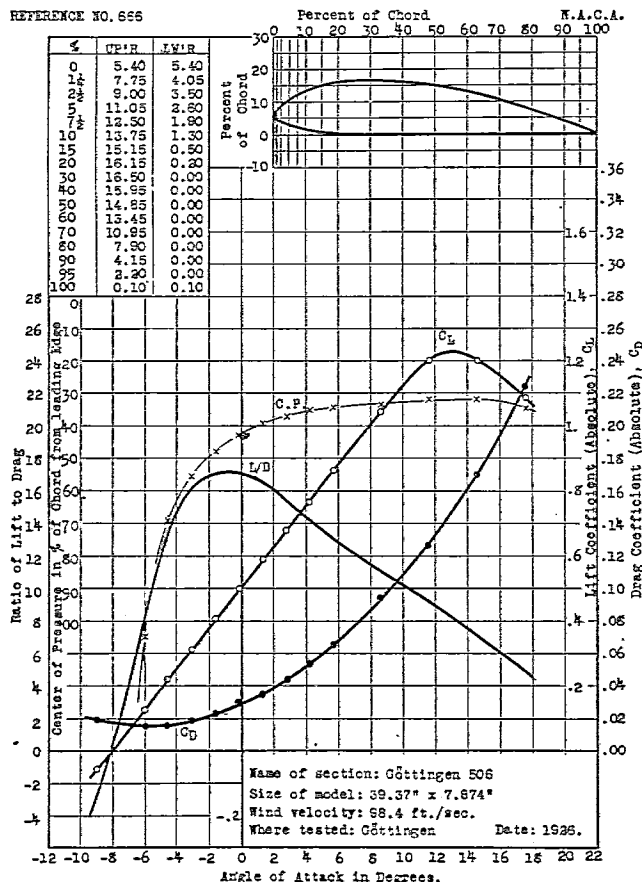
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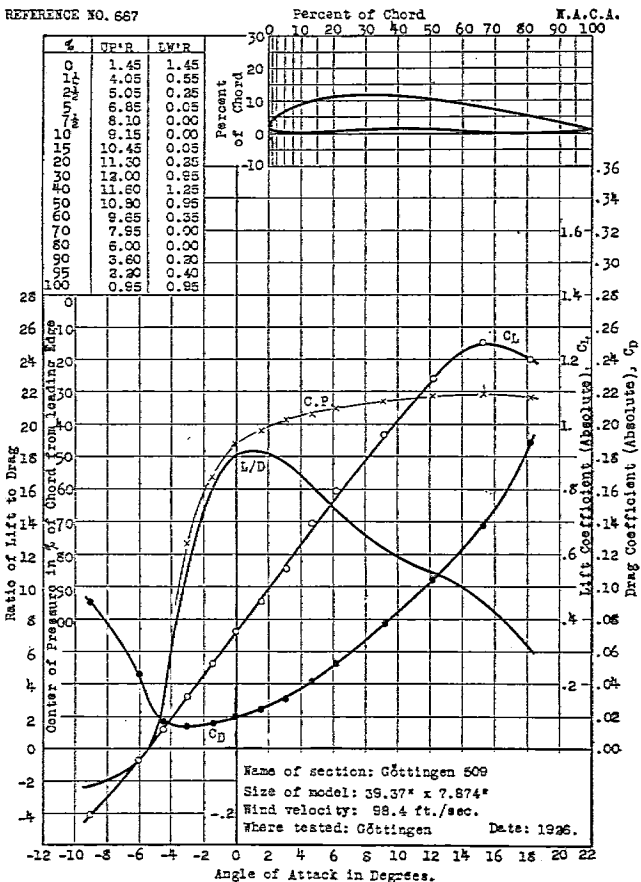
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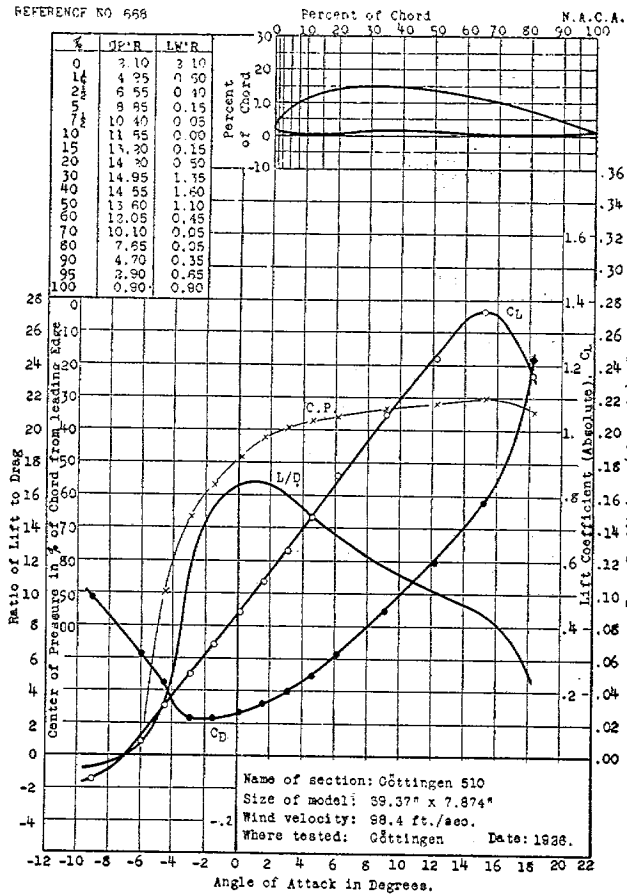
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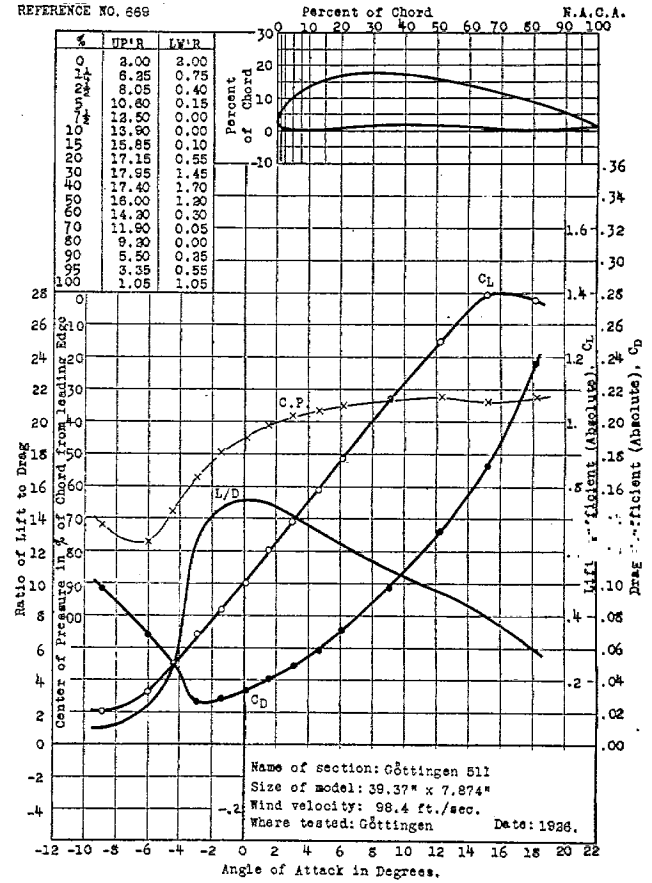
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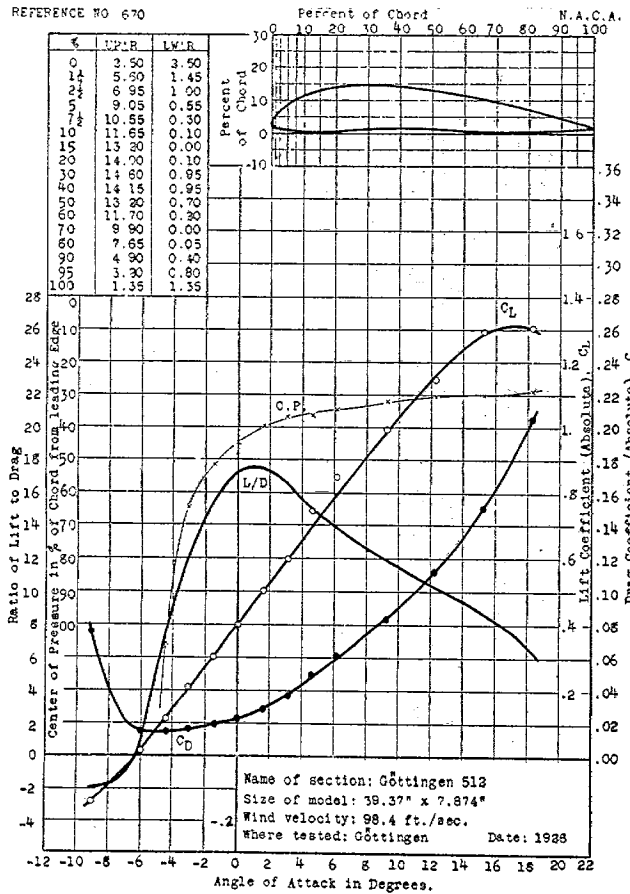
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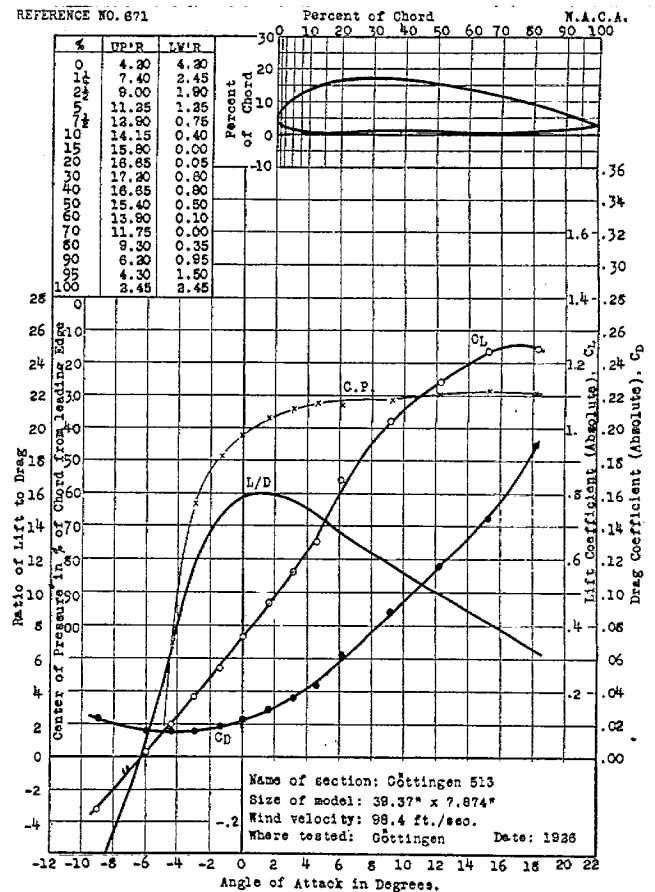
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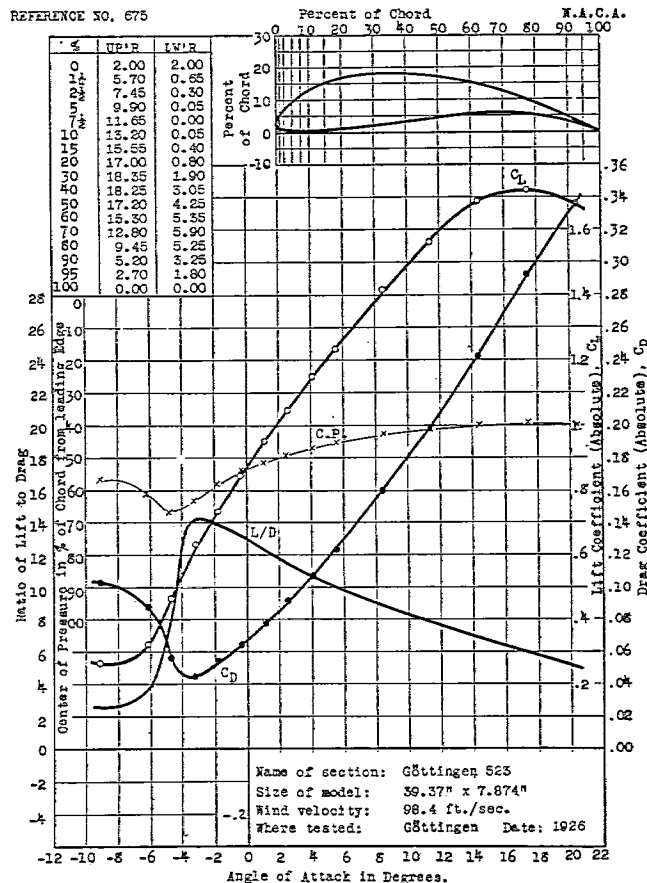
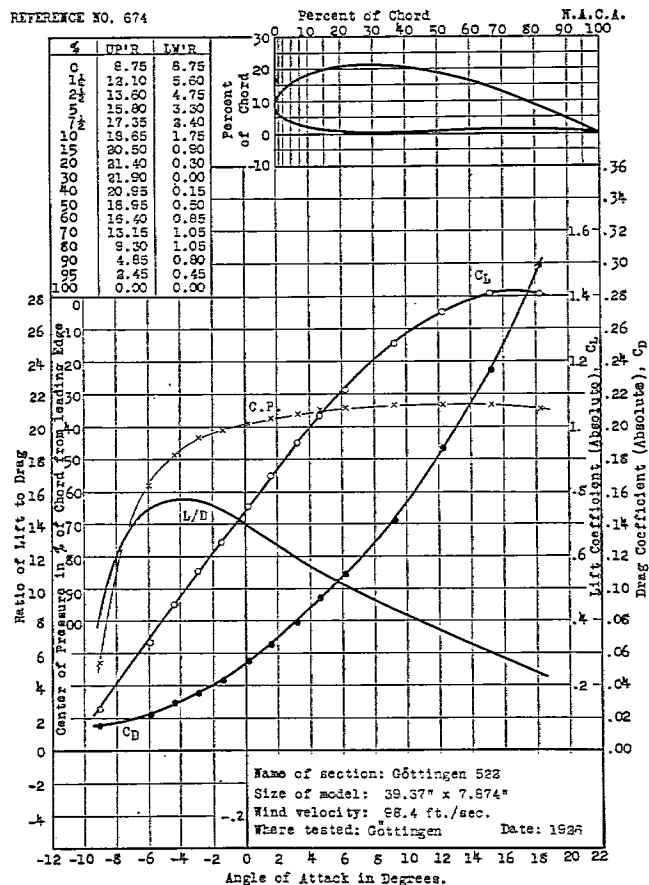
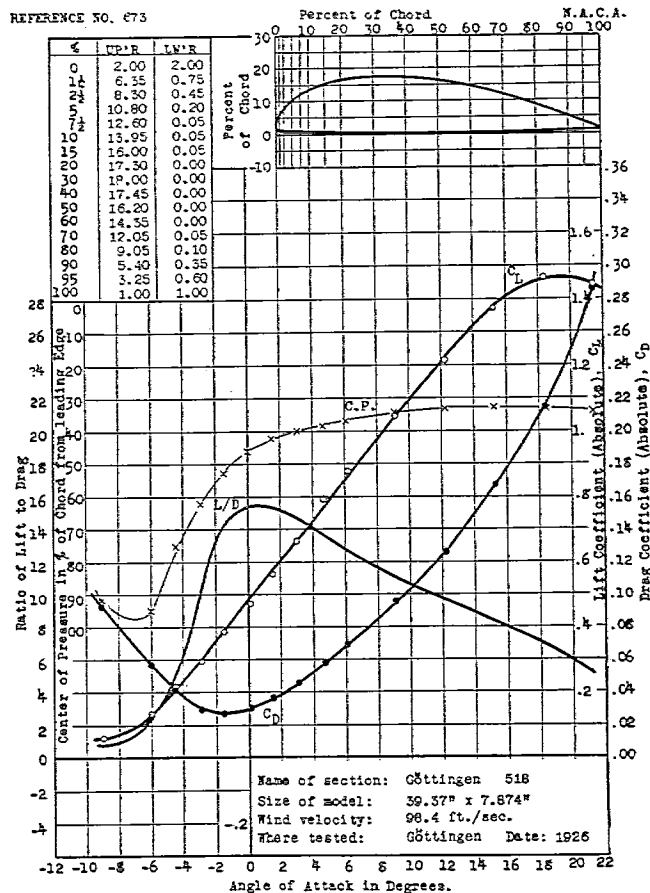
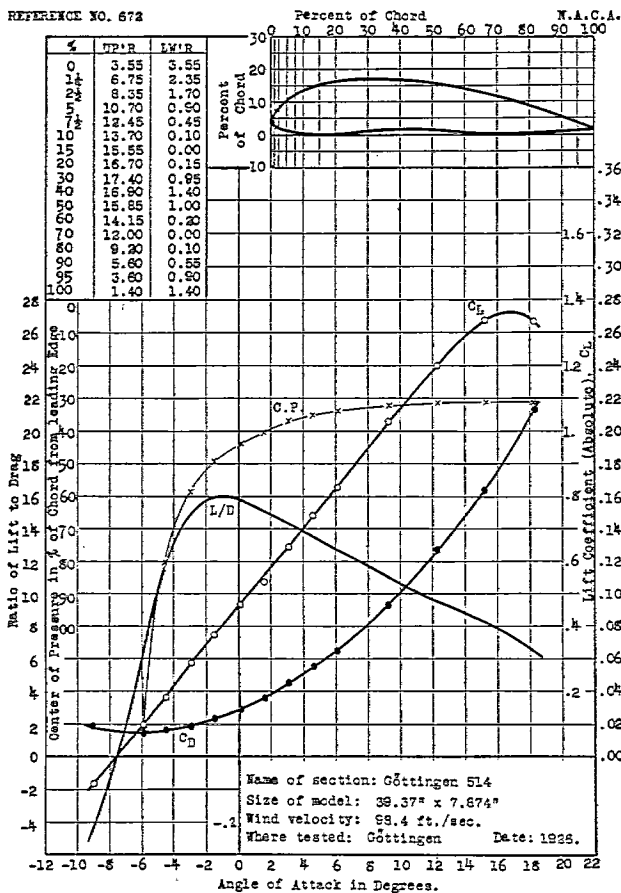
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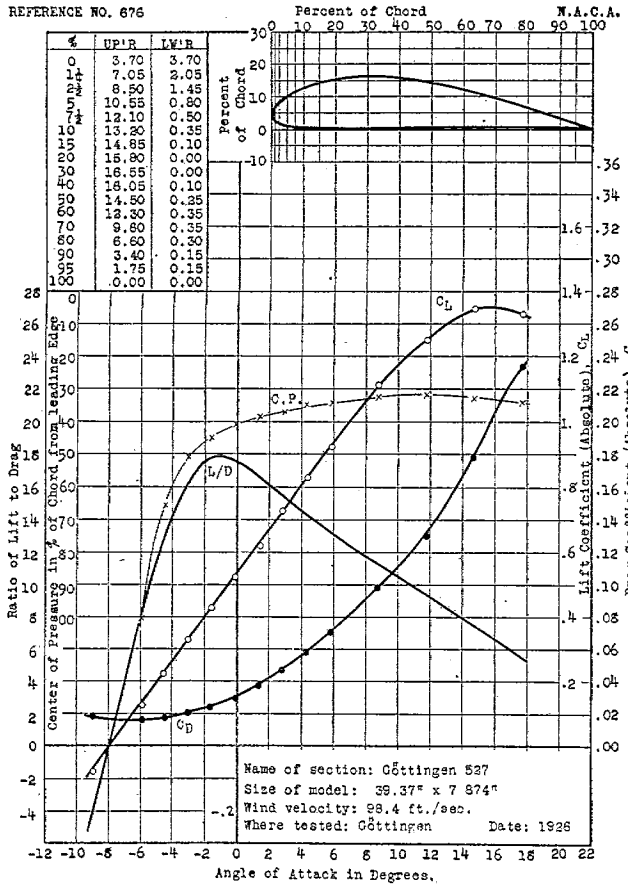
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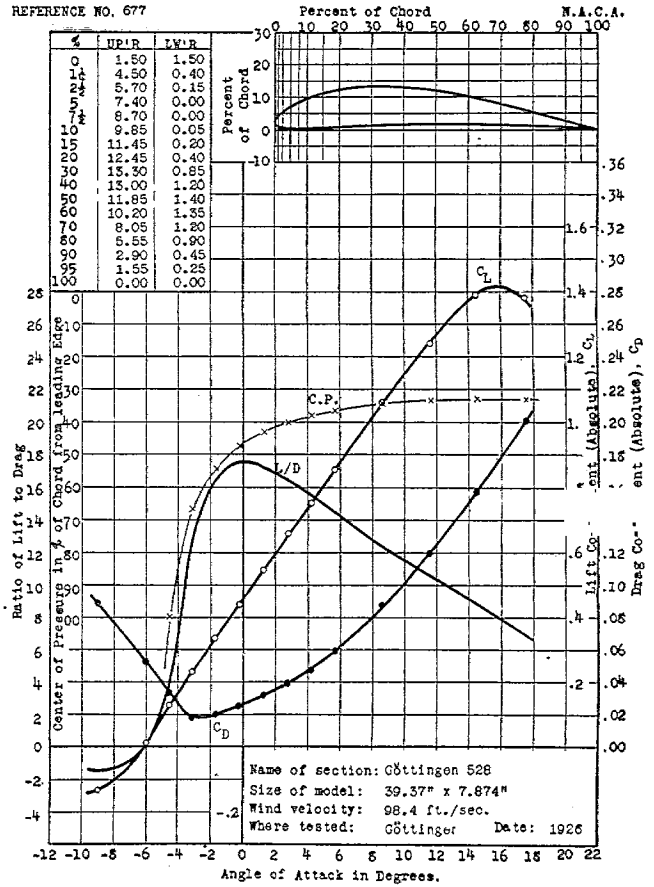
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V



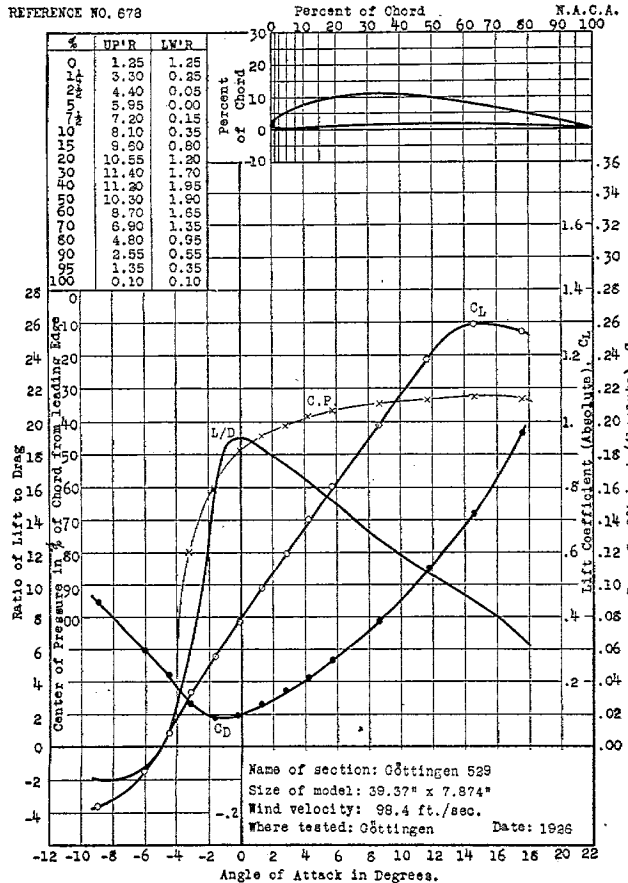
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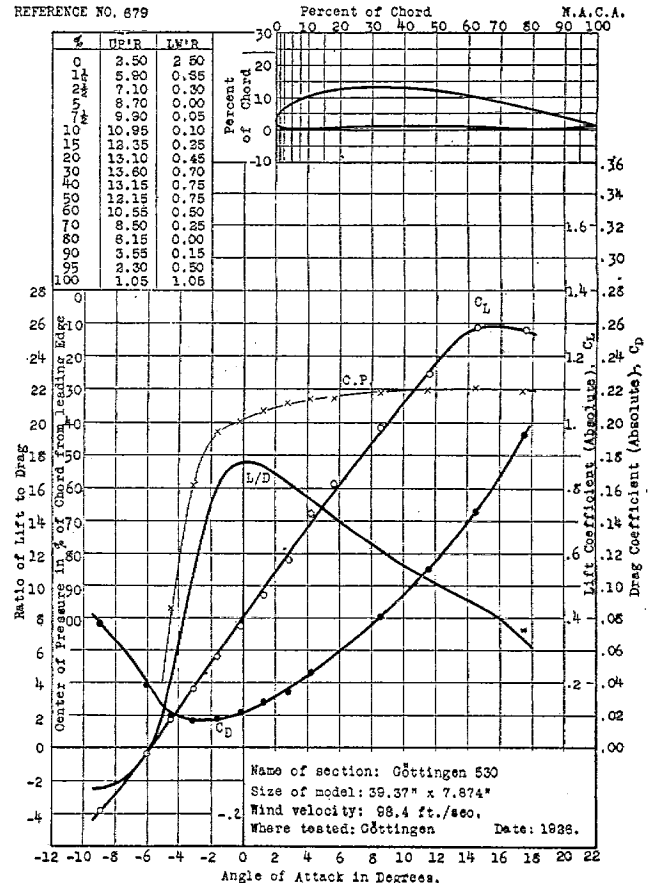
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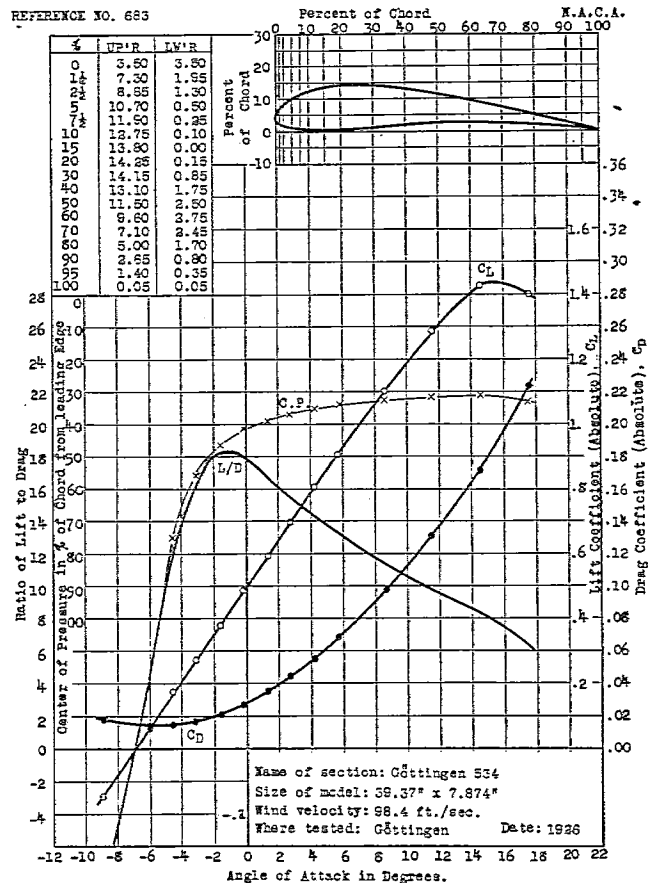
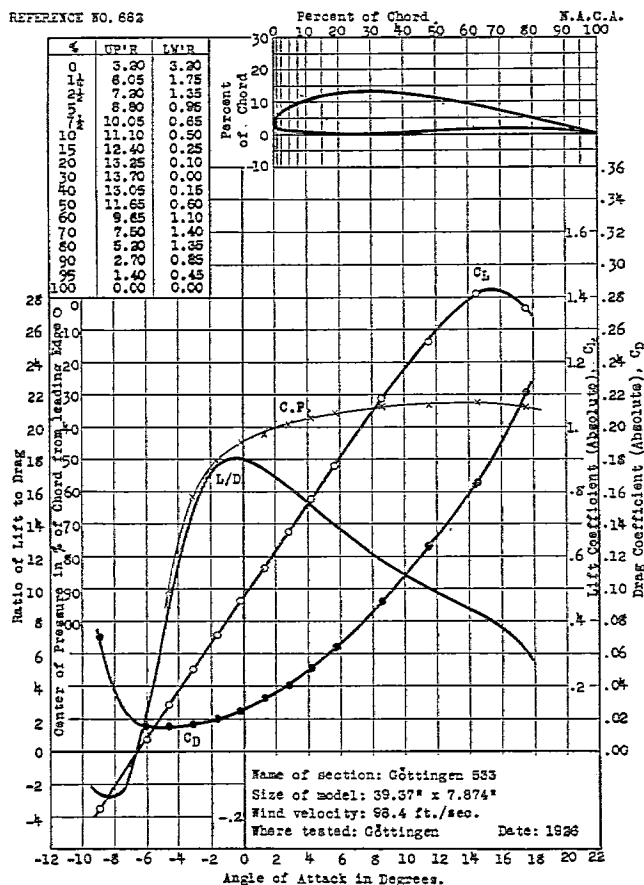
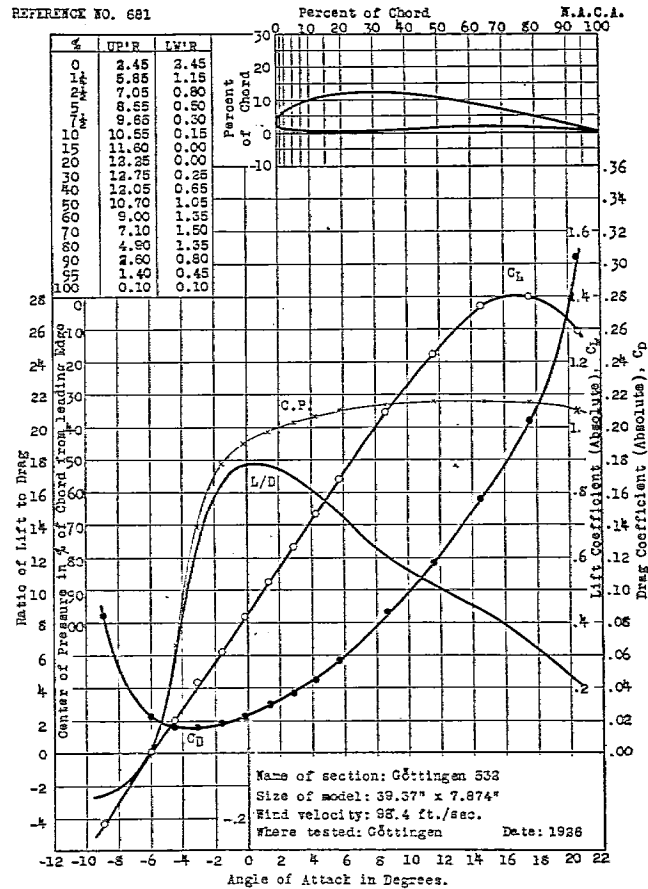
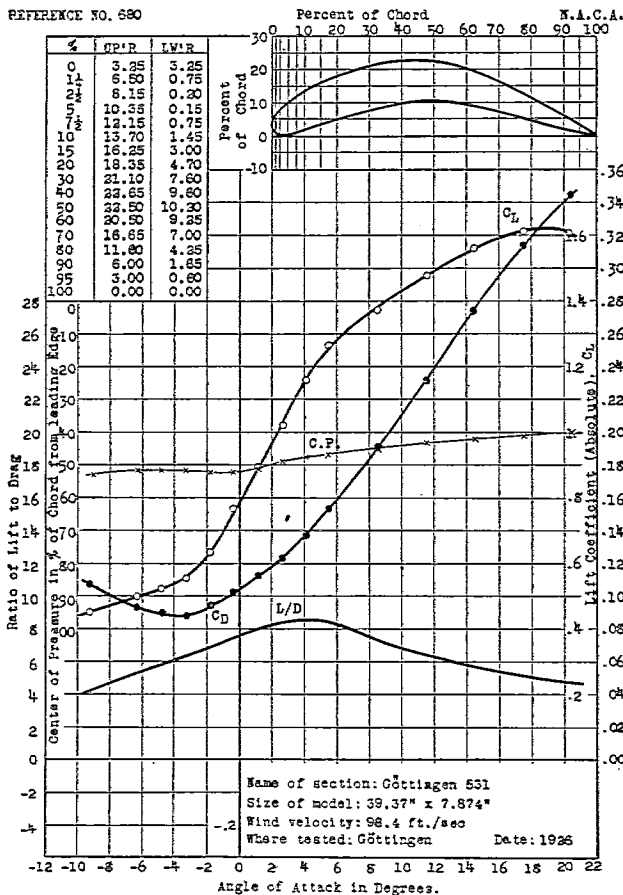
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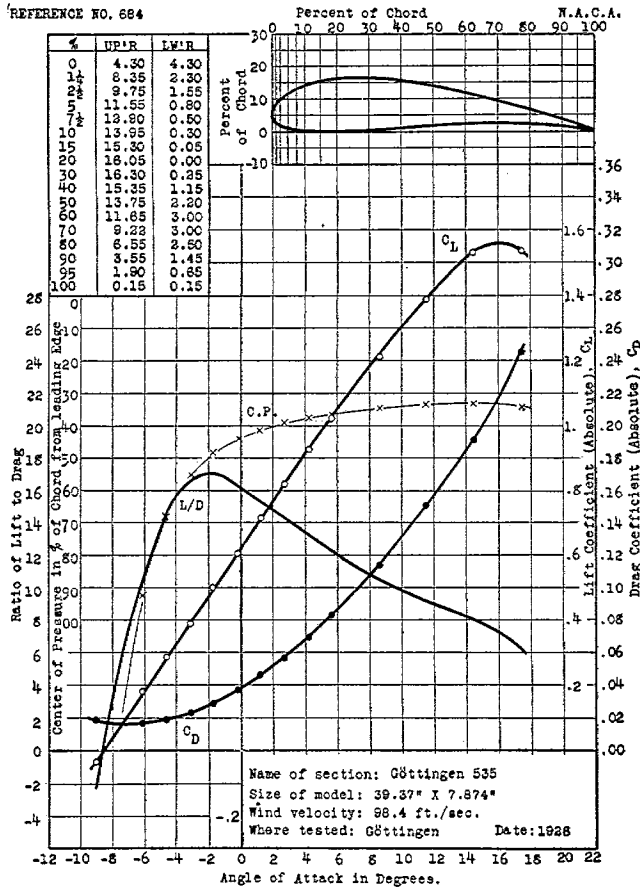
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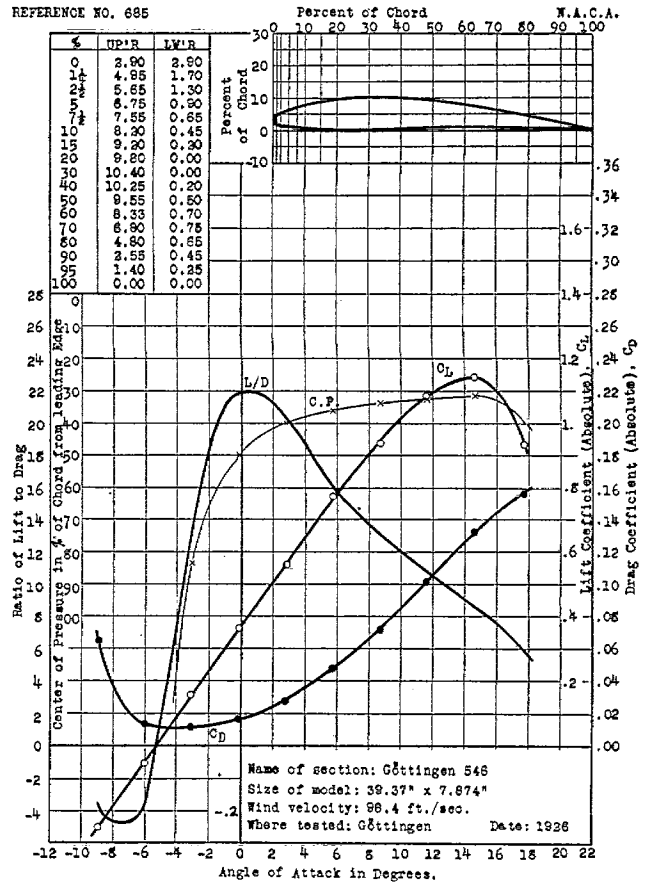
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V



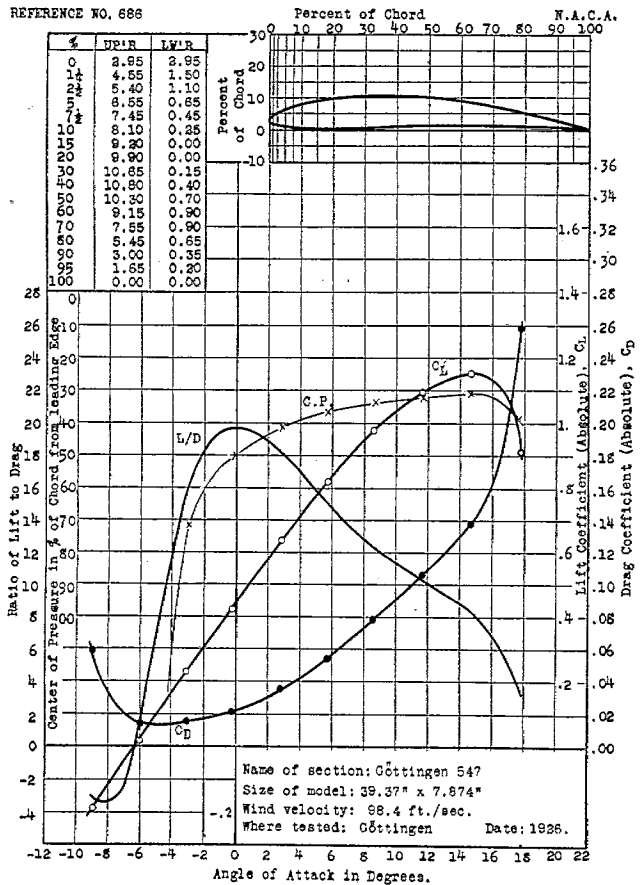
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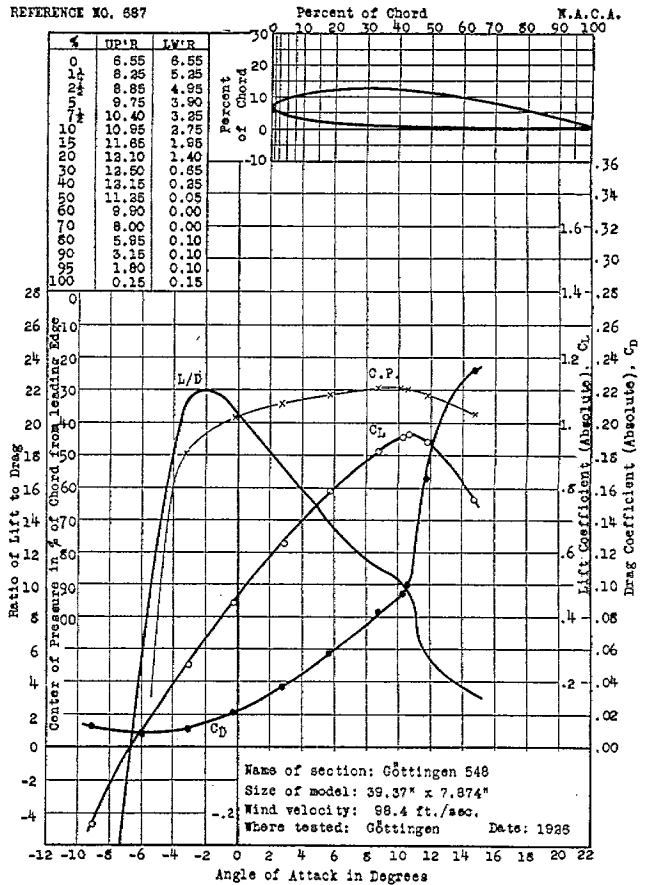
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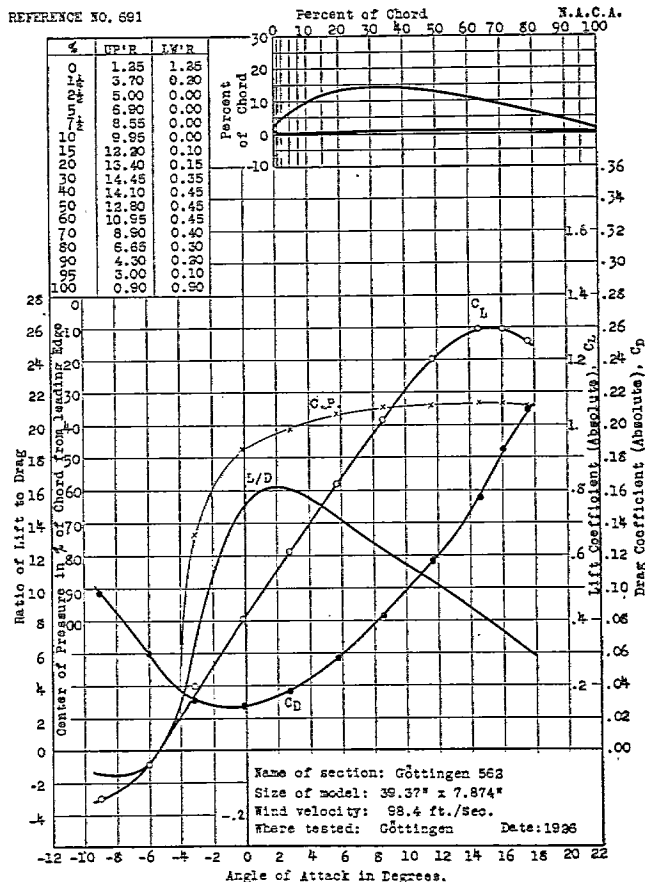
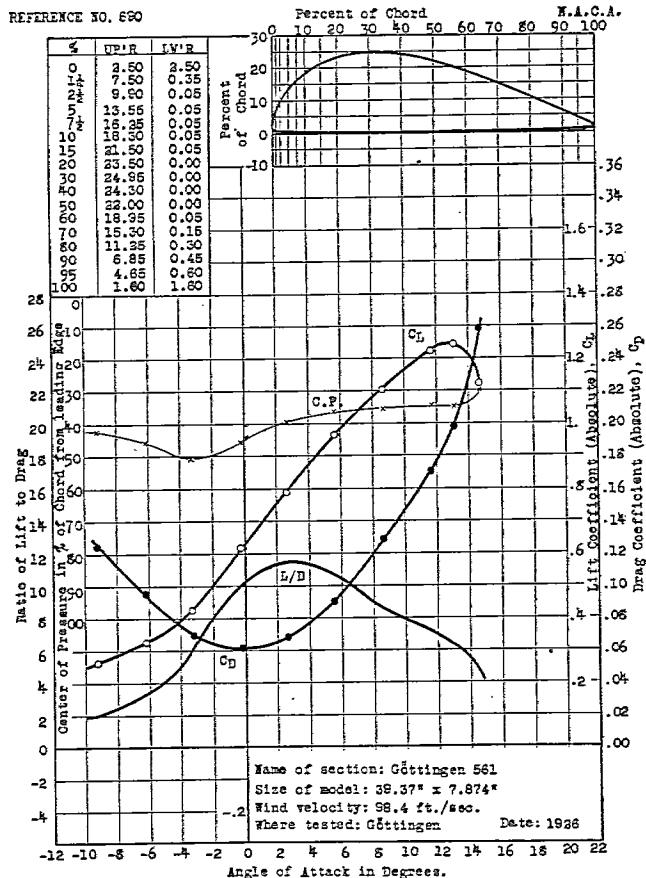
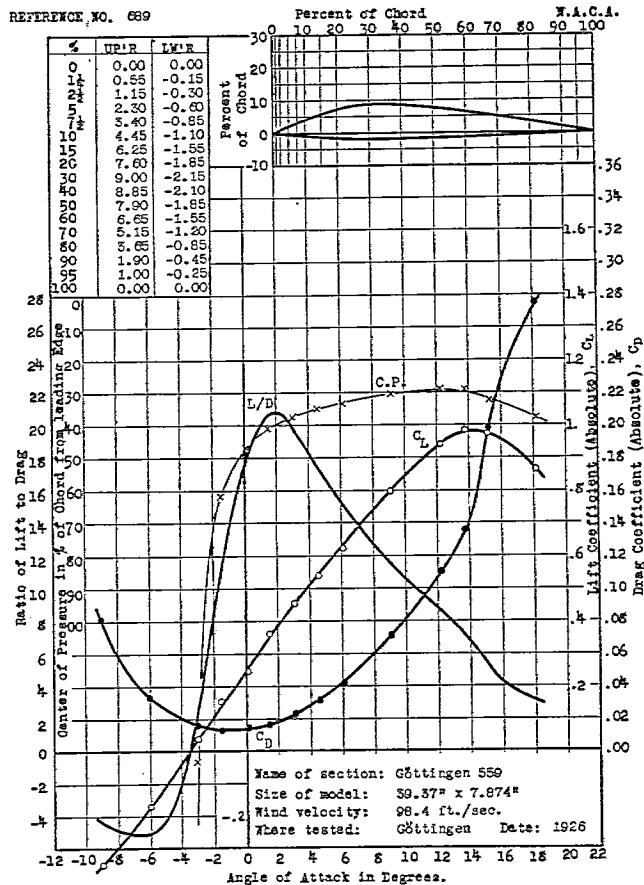
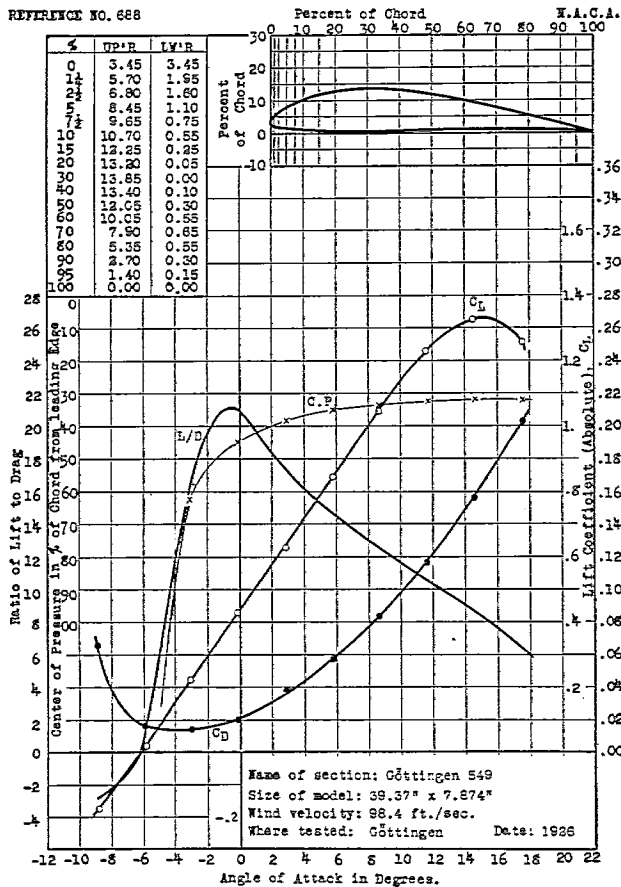
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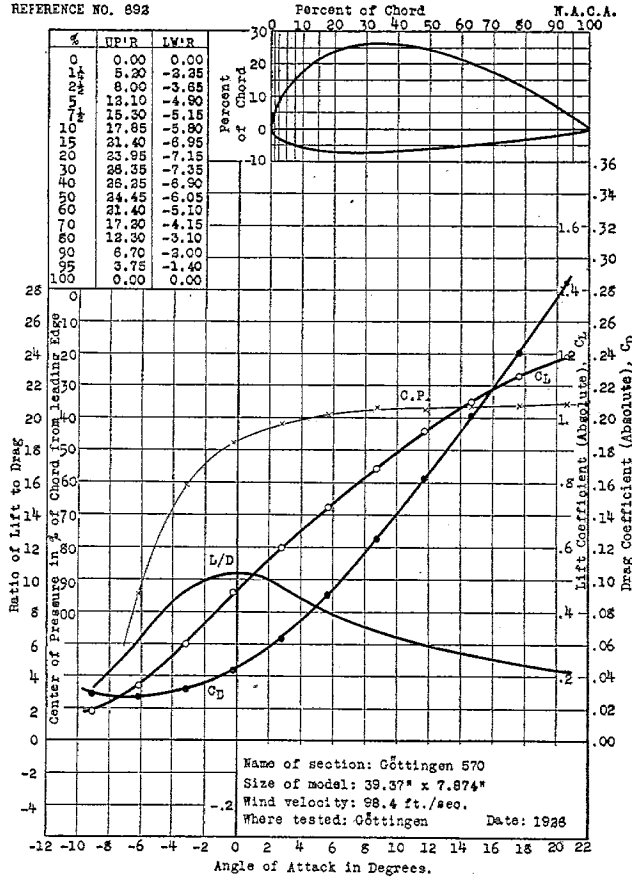
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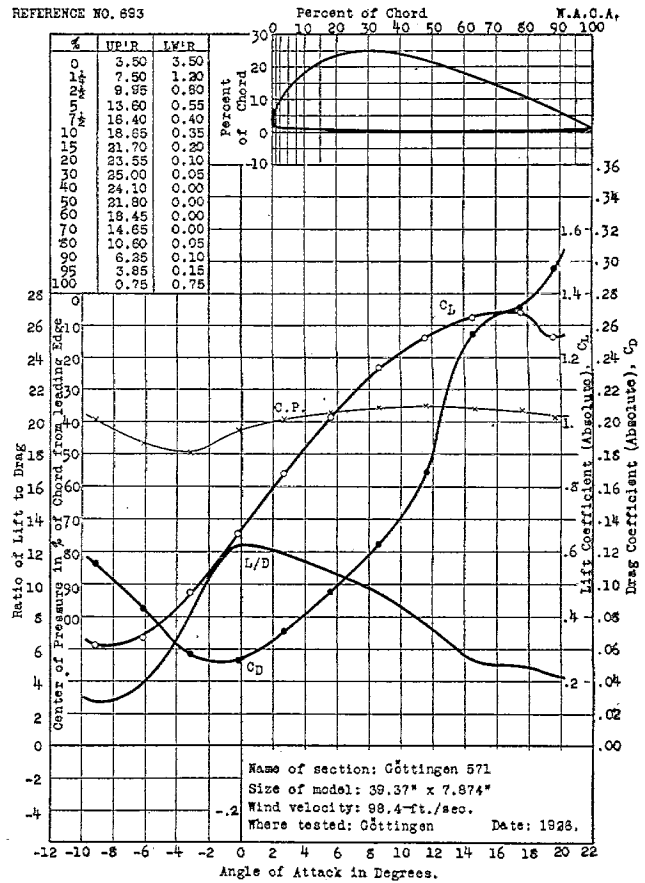
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V



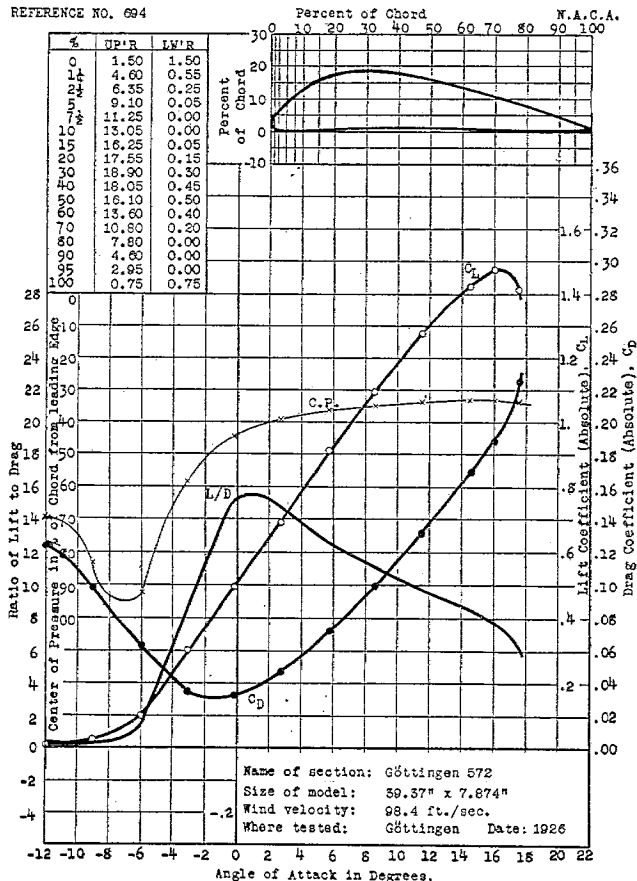
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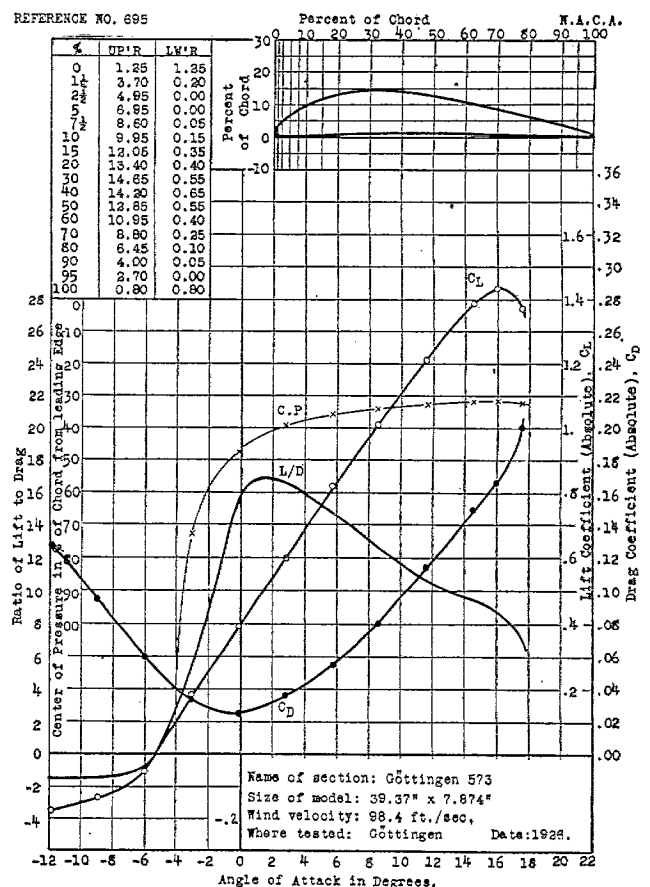
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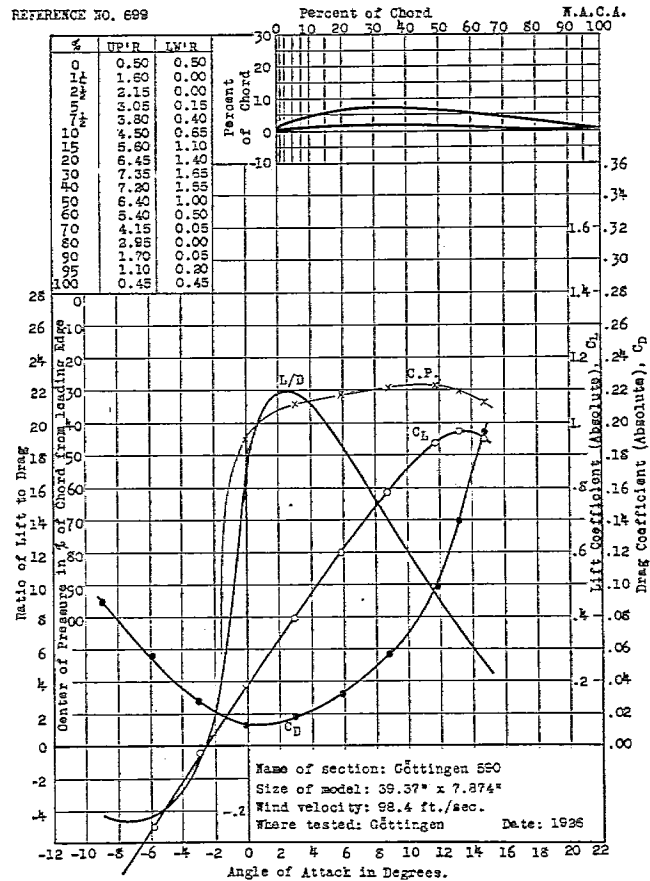
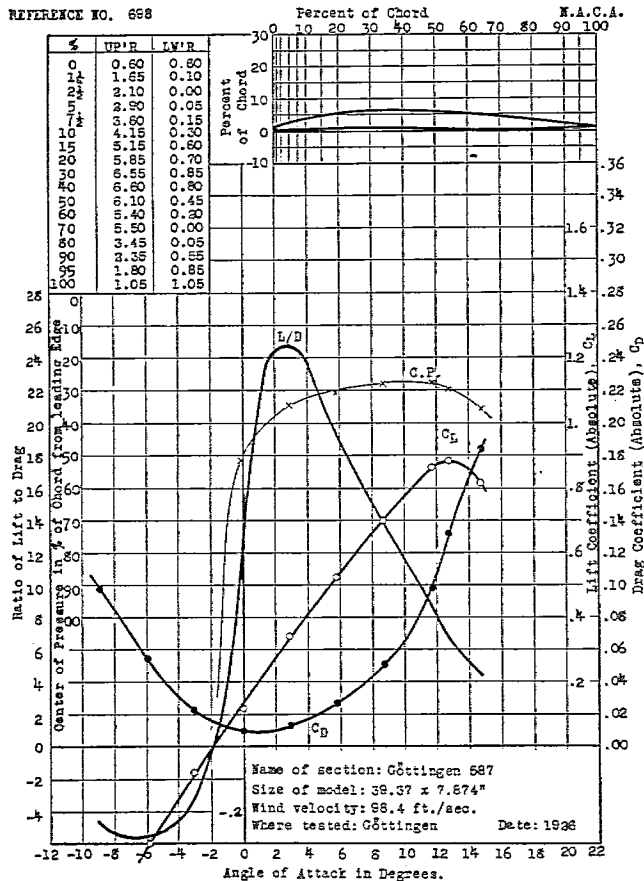
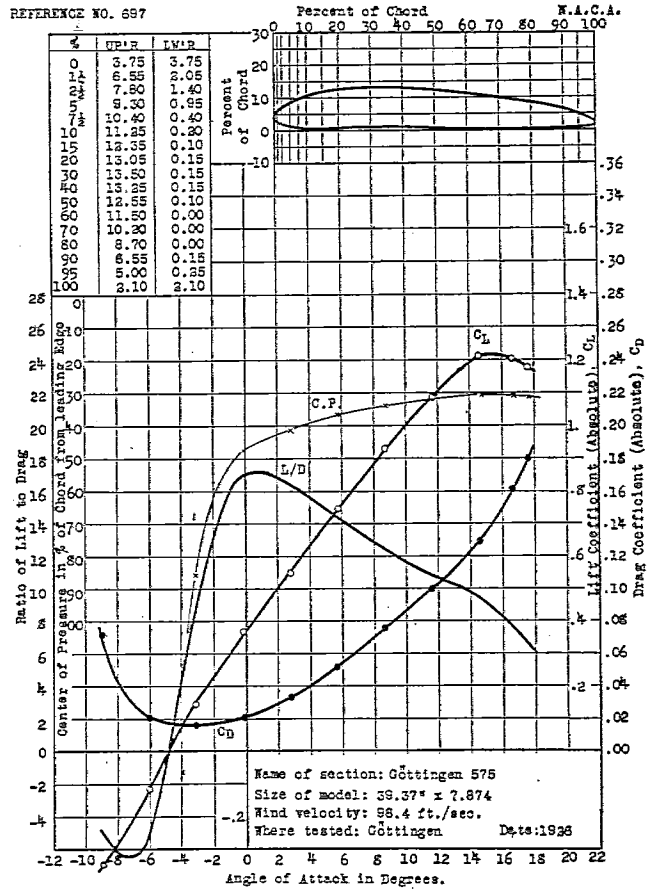
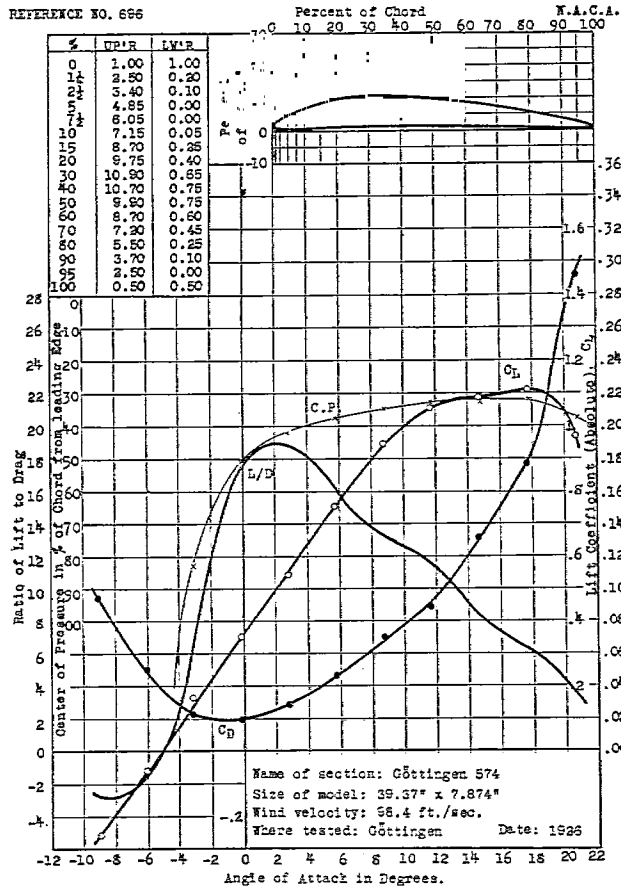
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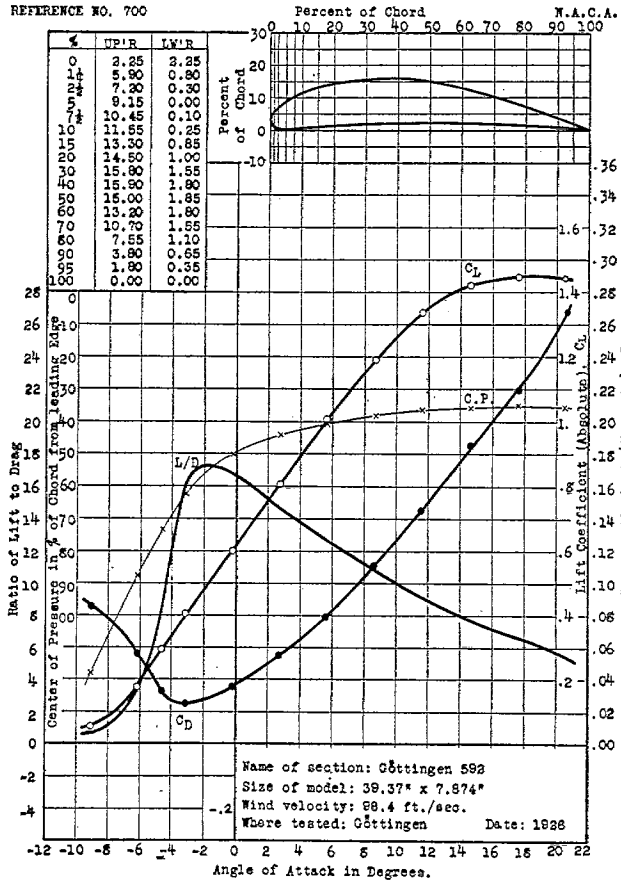
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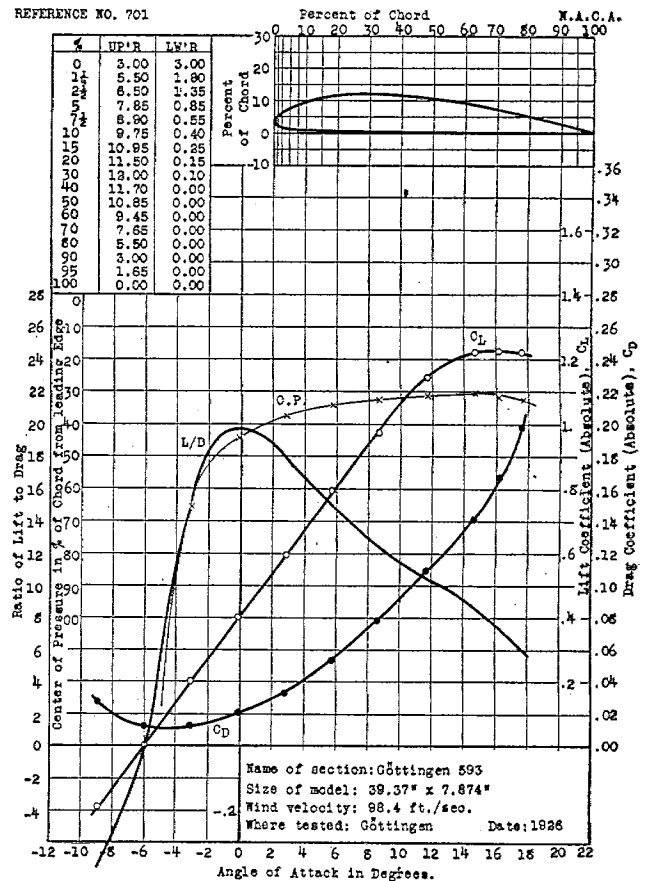
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V



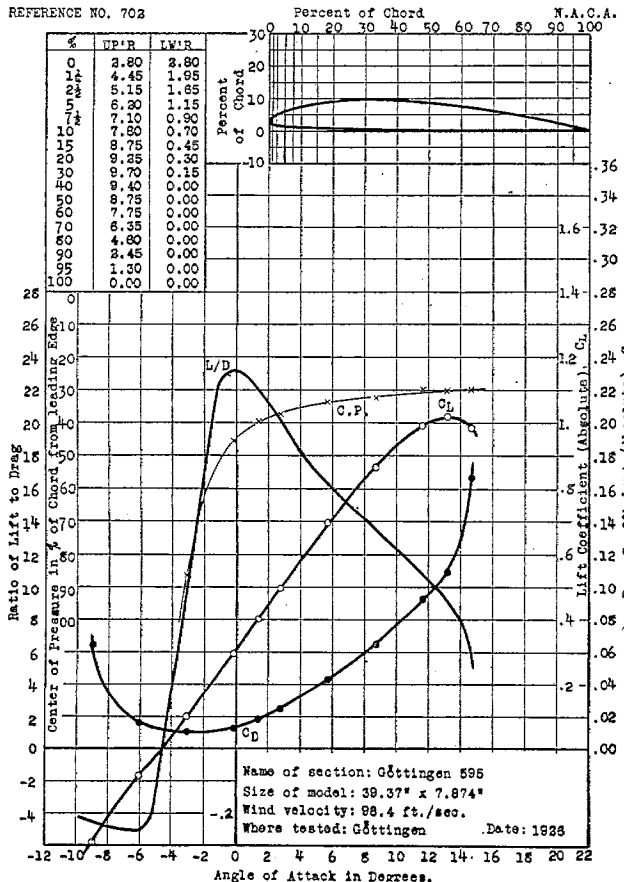
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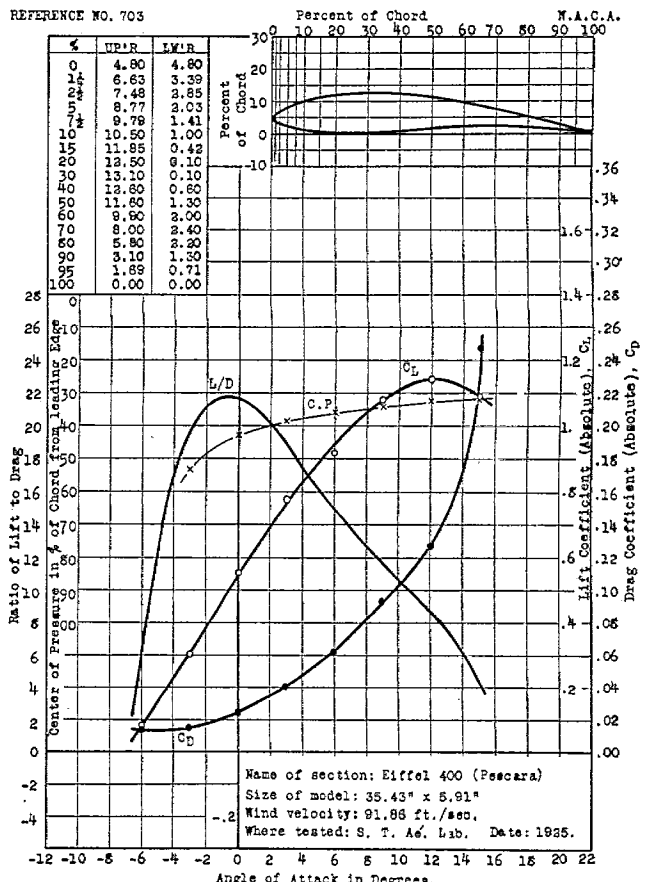
REFERENCE NO. 701



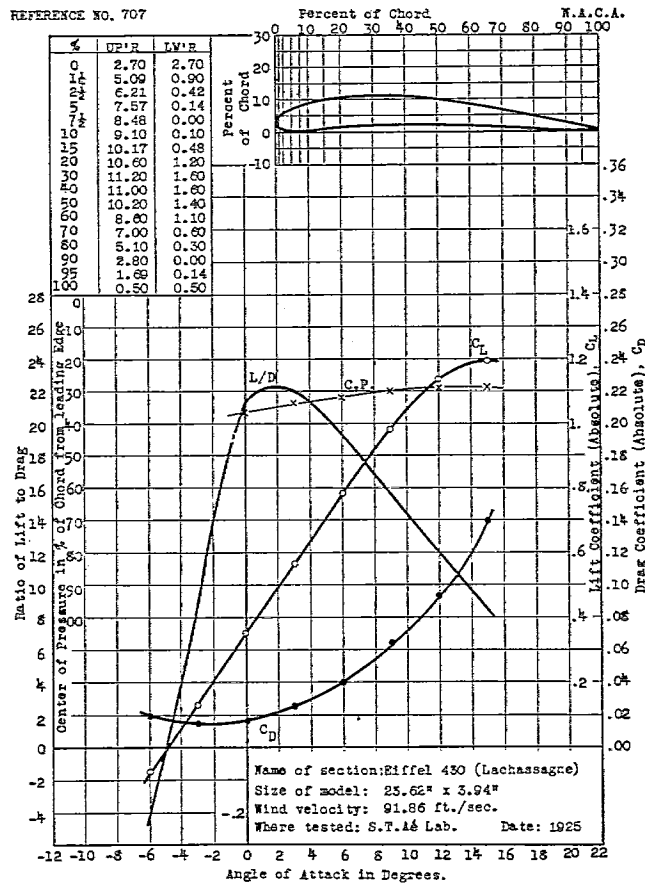
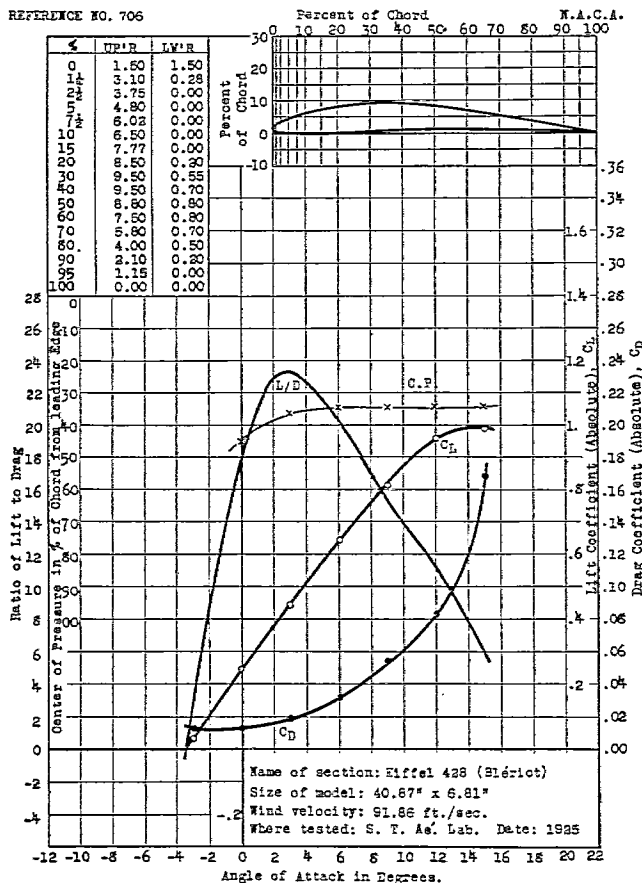
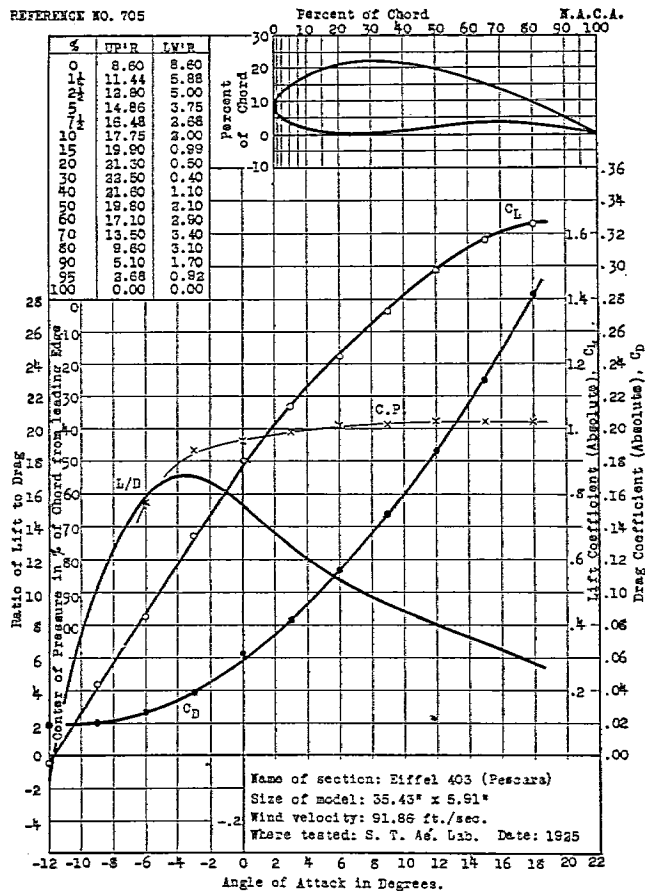
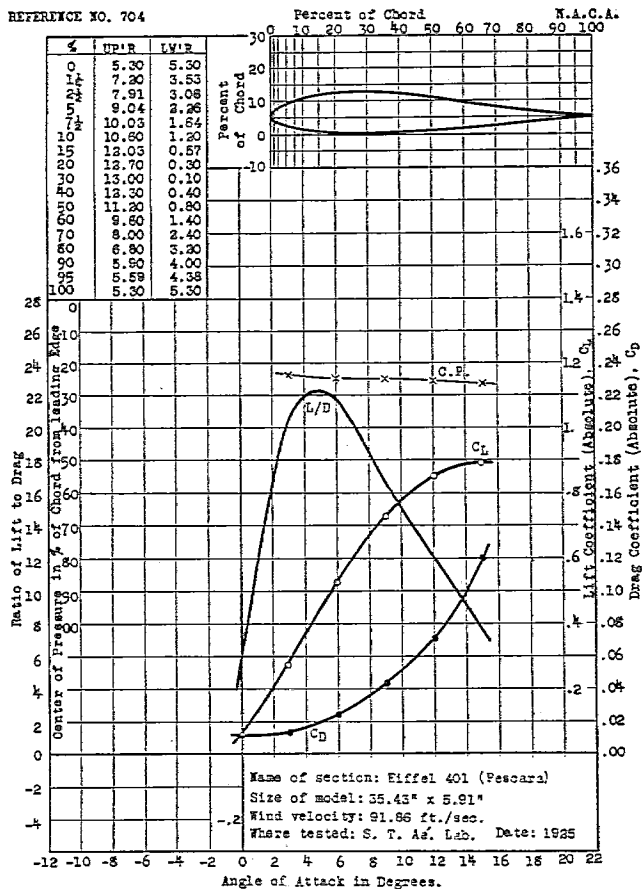
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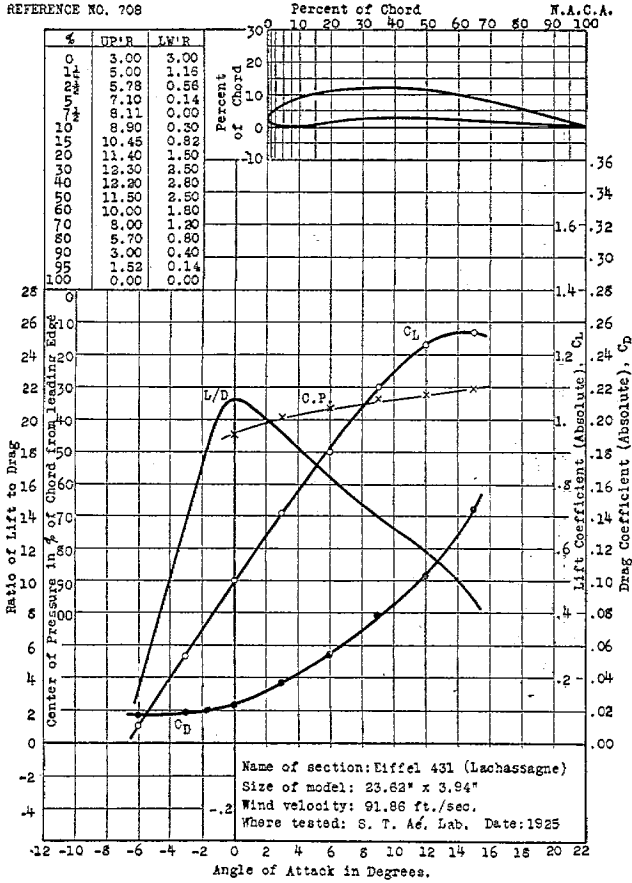
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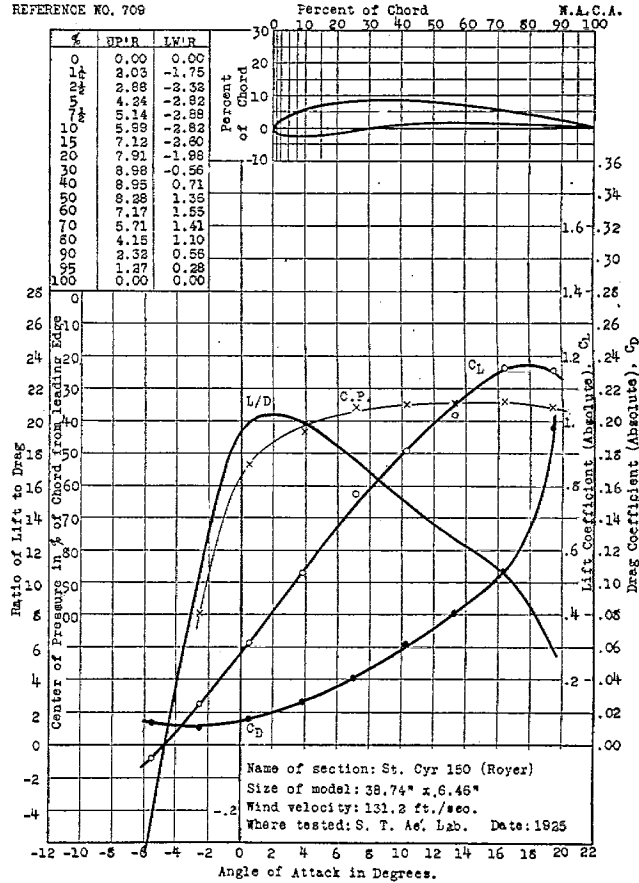
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V



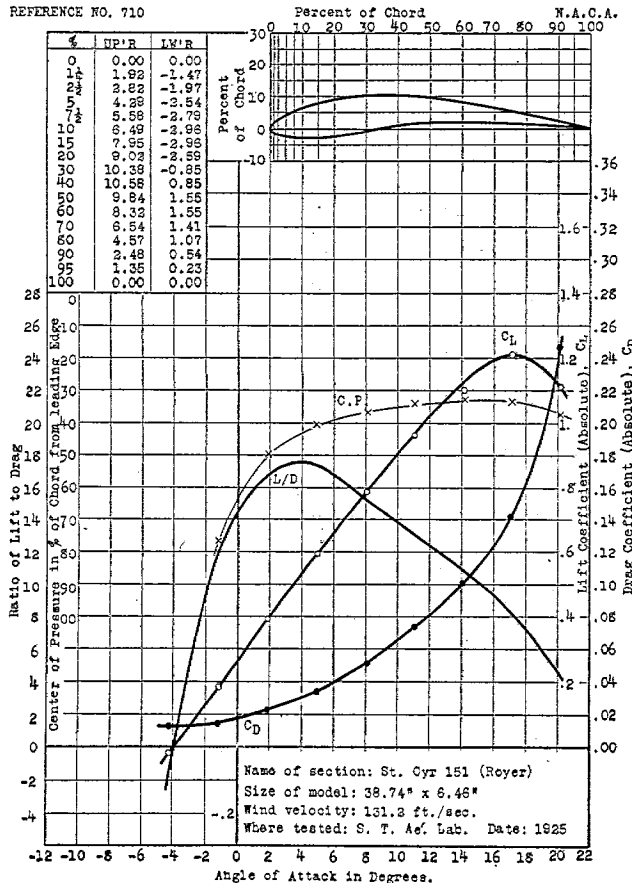
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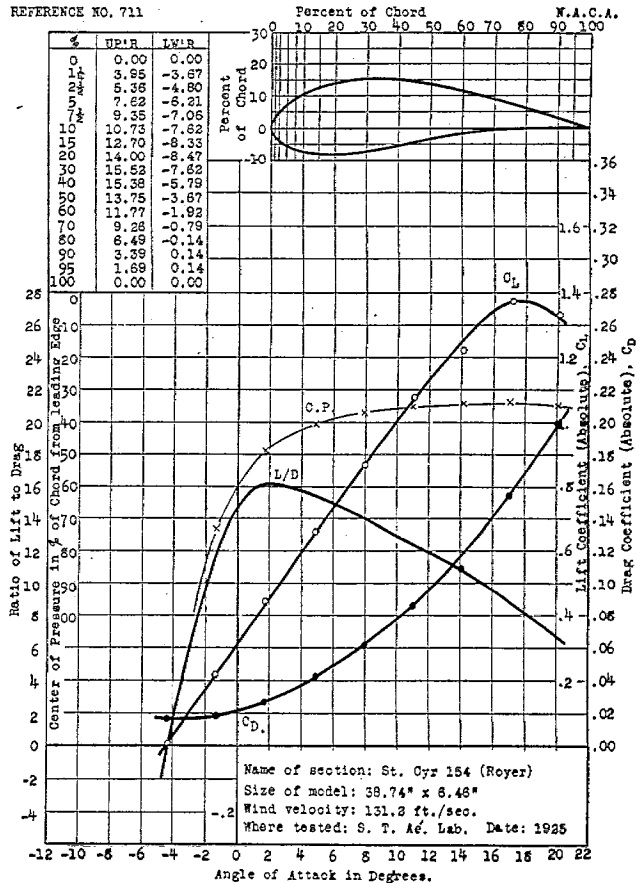
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REFERENCE NO. 710

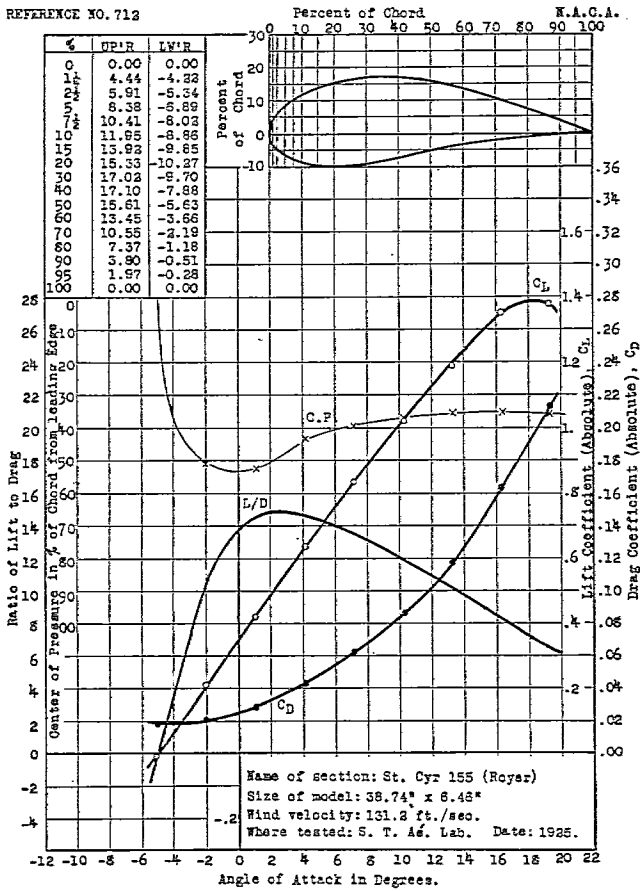


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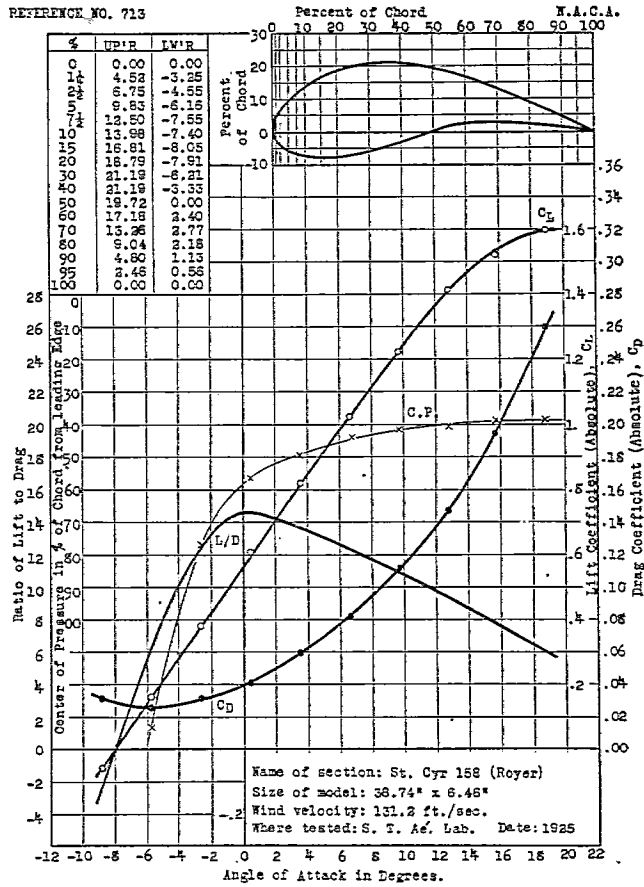


AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V

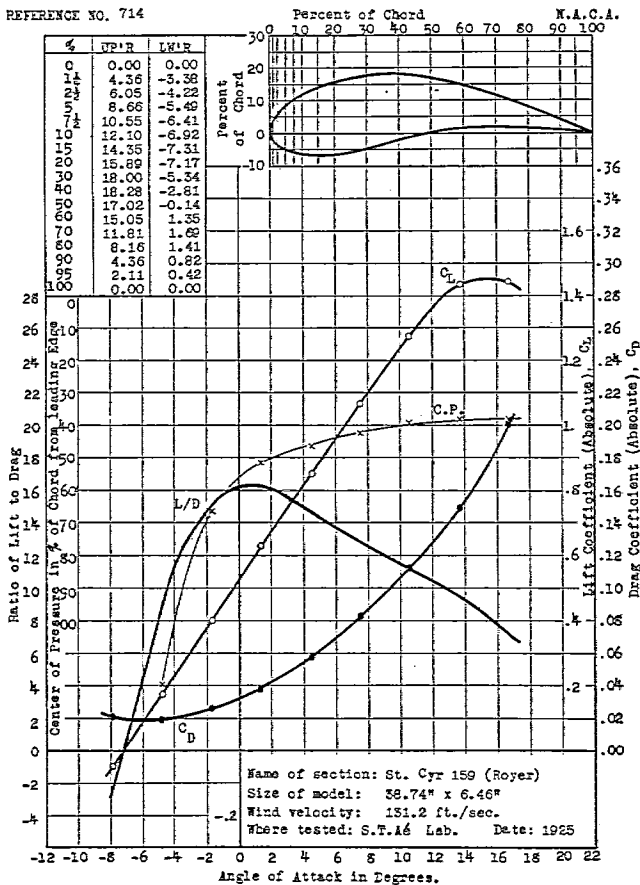
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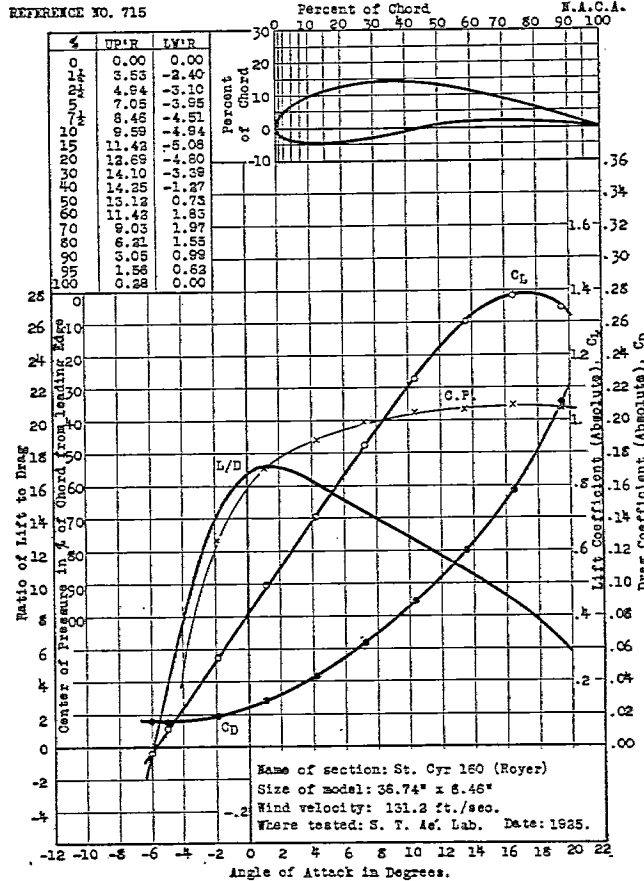
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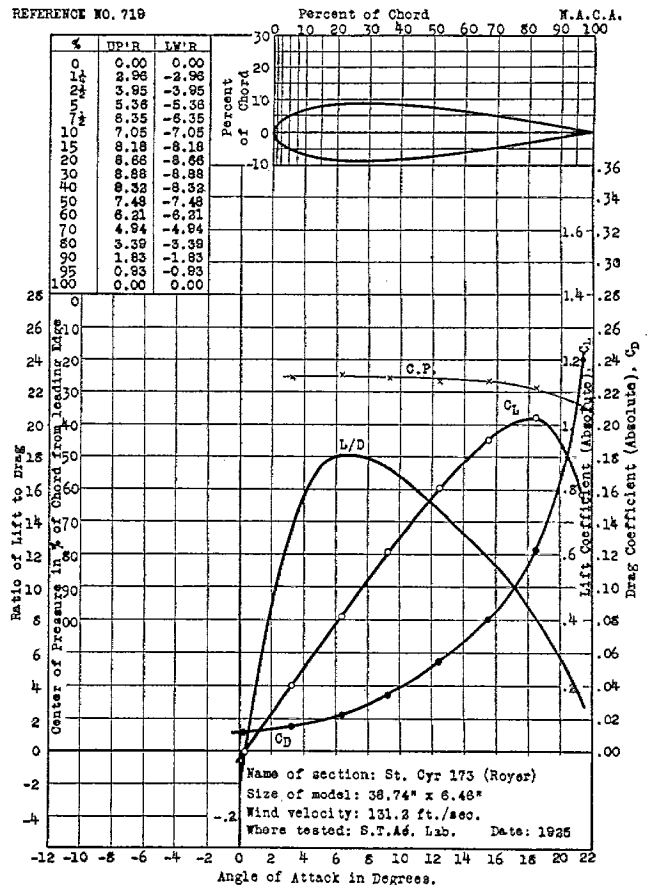
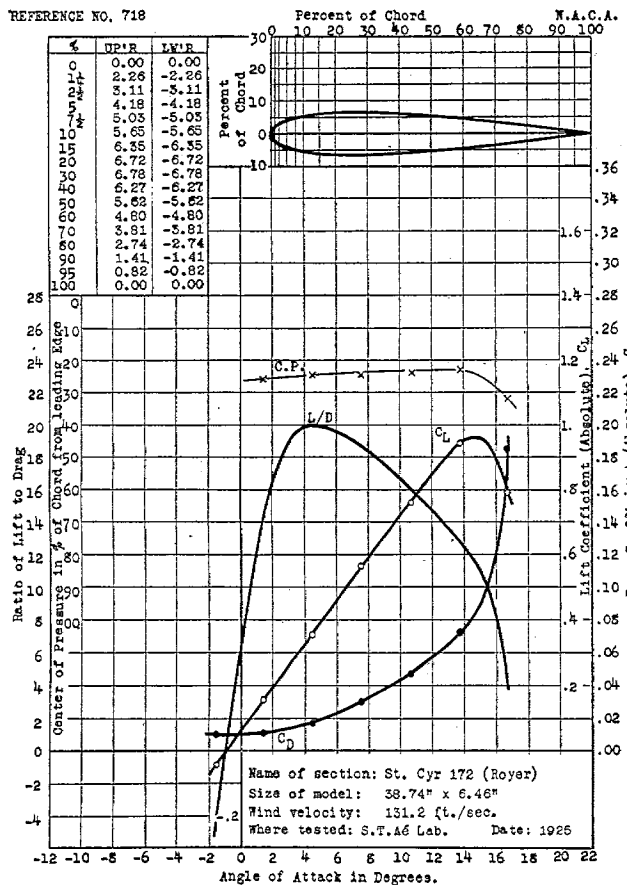
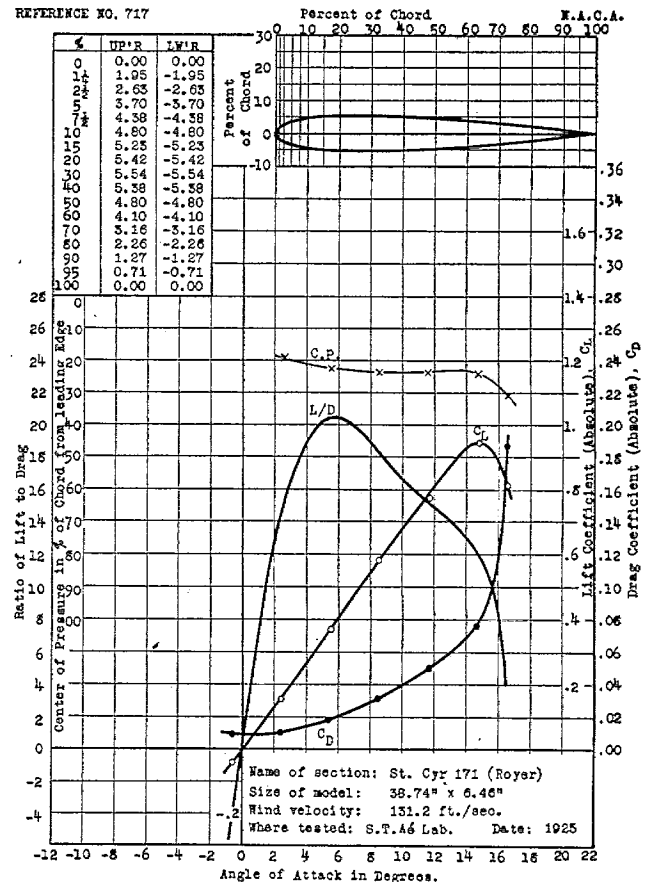
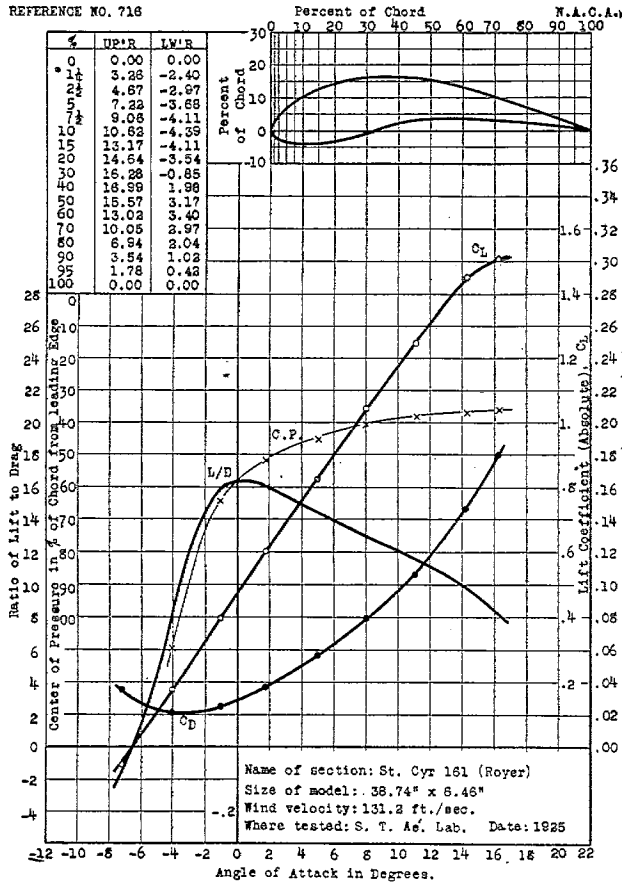


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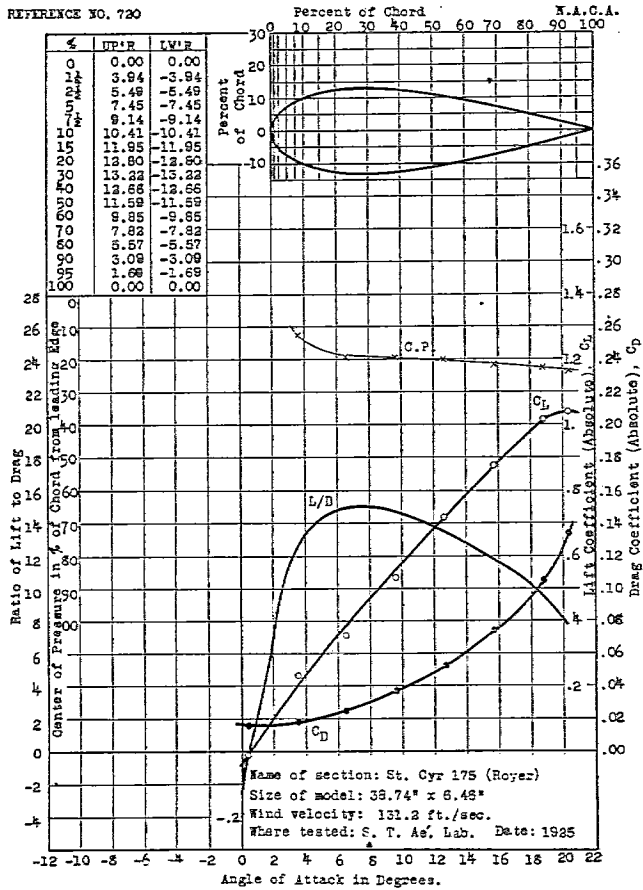
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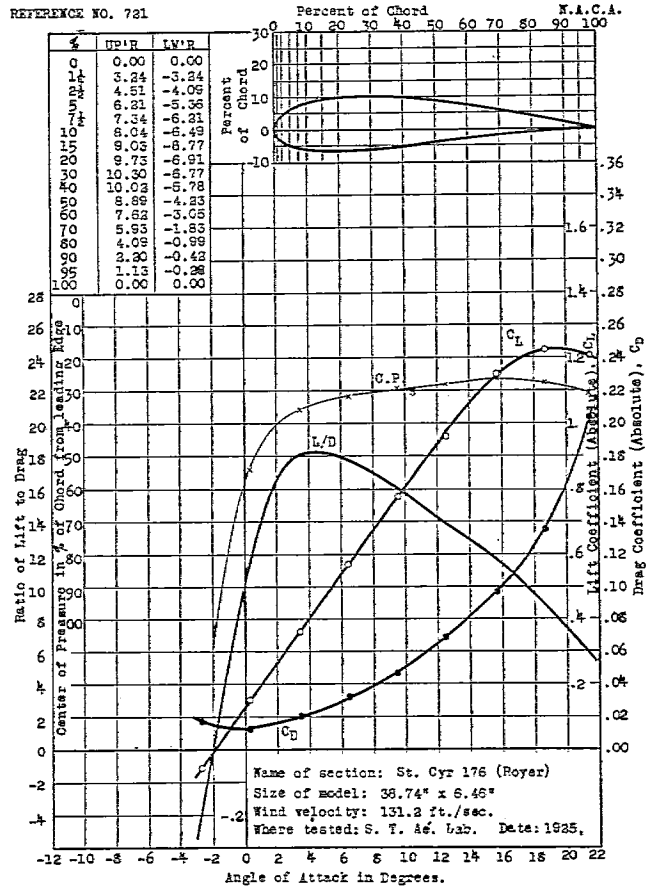


AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V

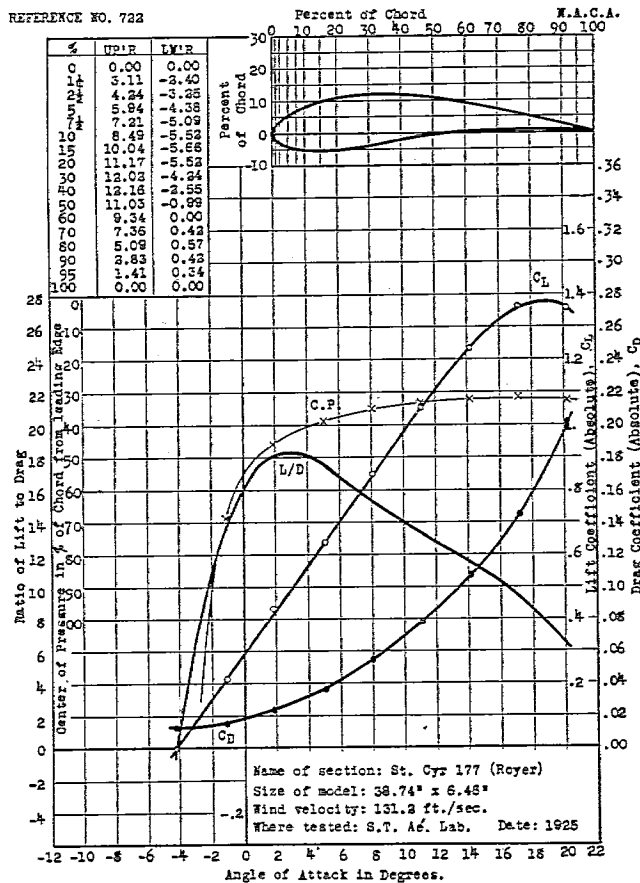
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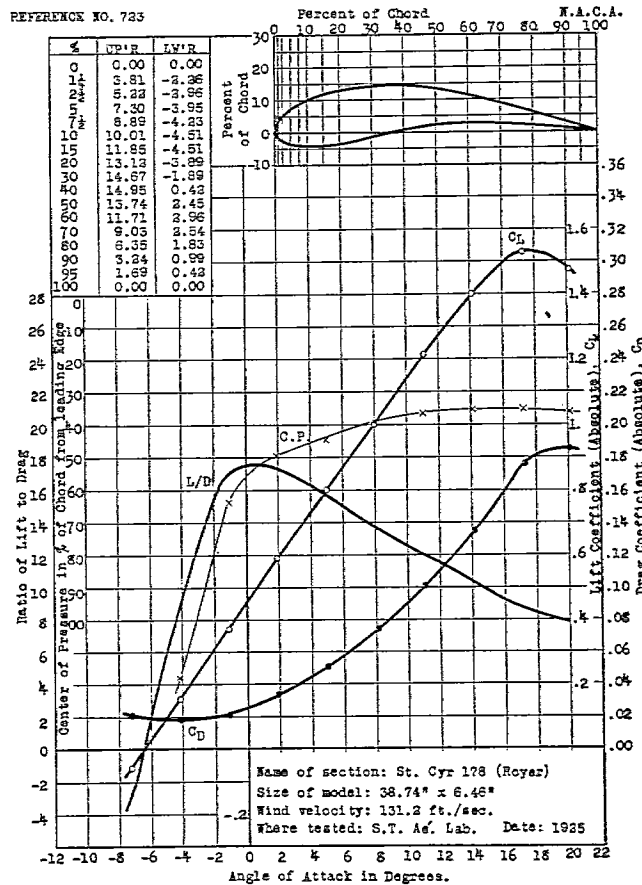
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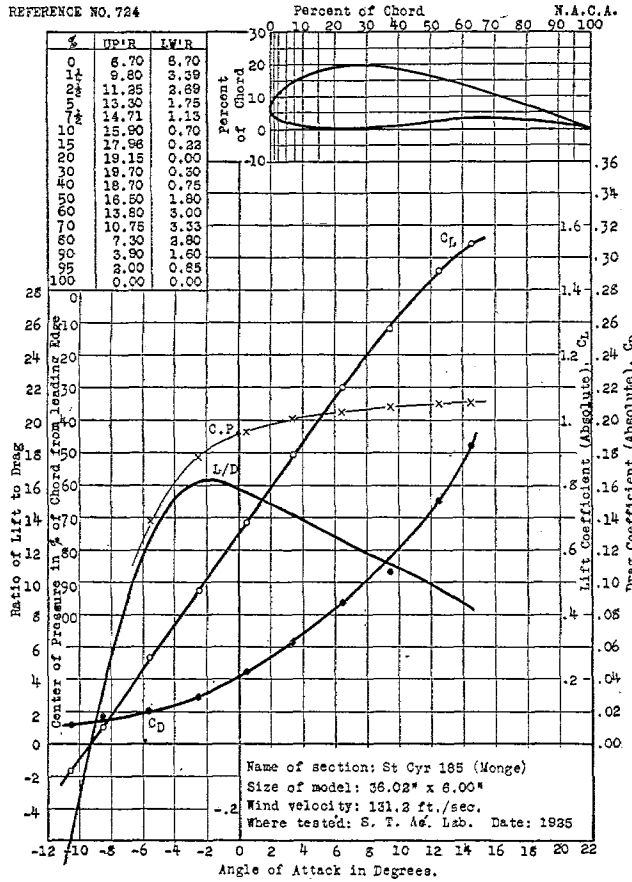
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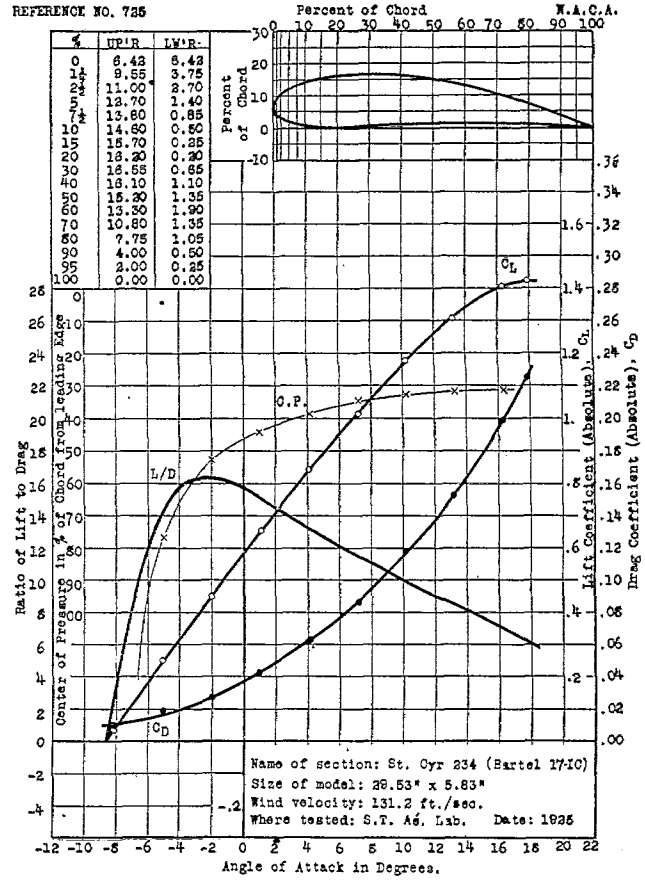
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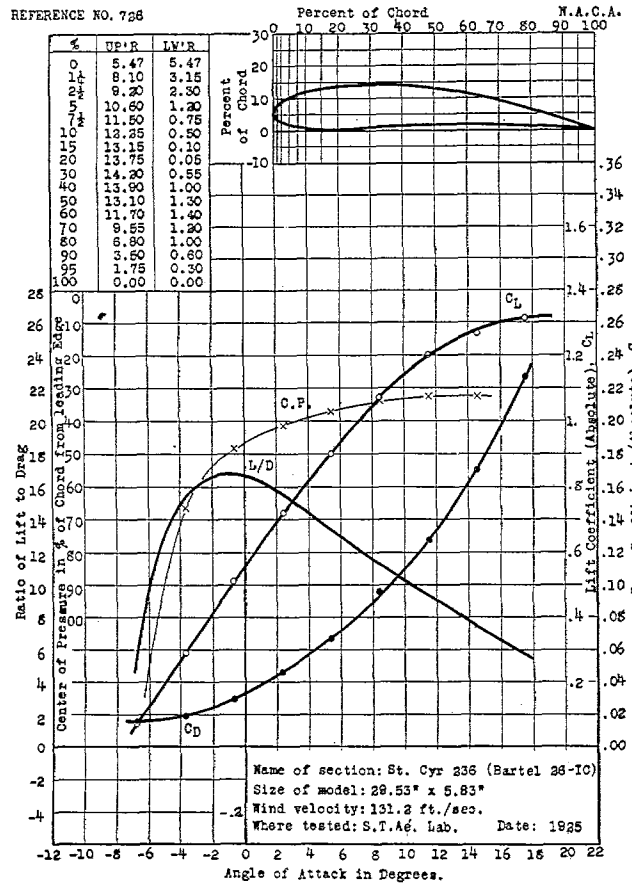
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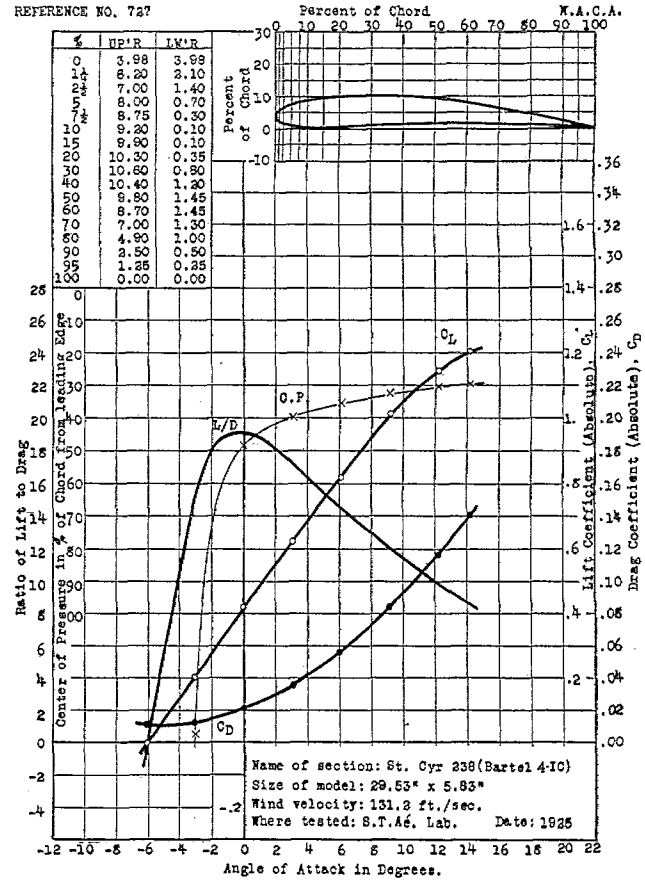
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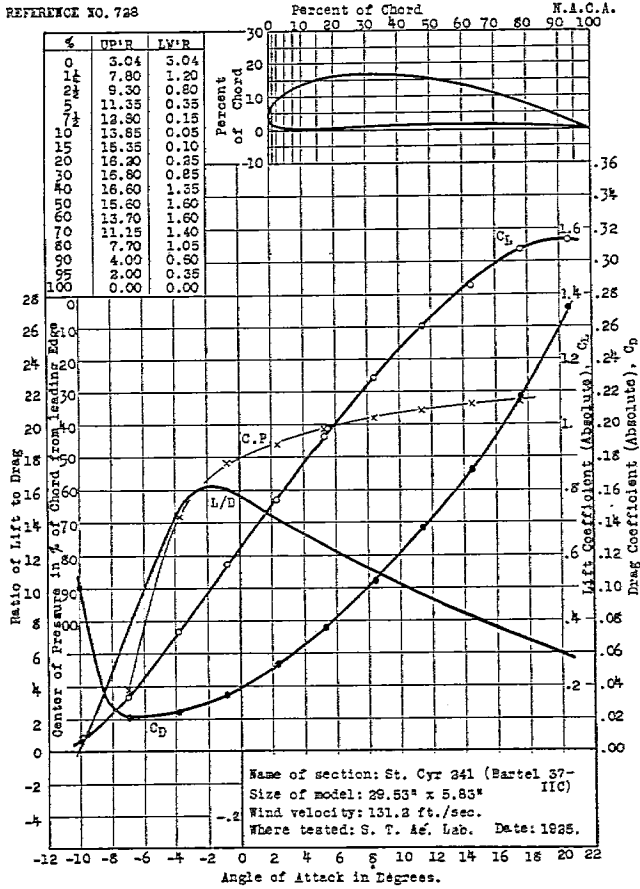


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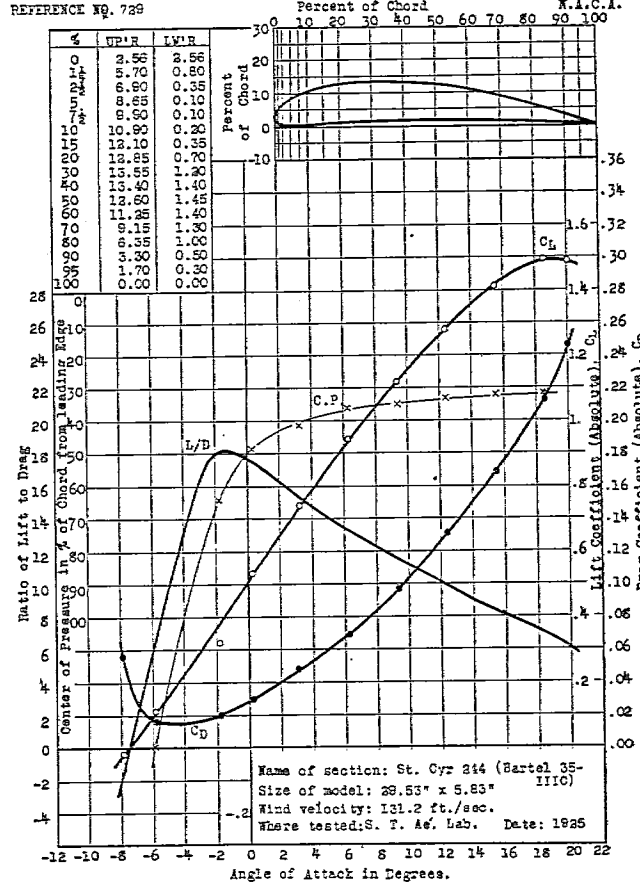


AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V

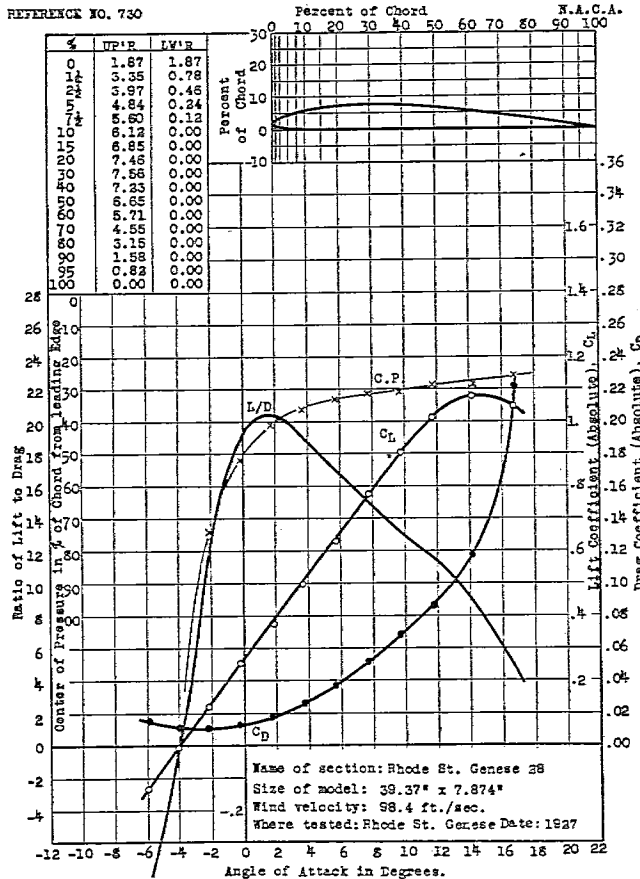
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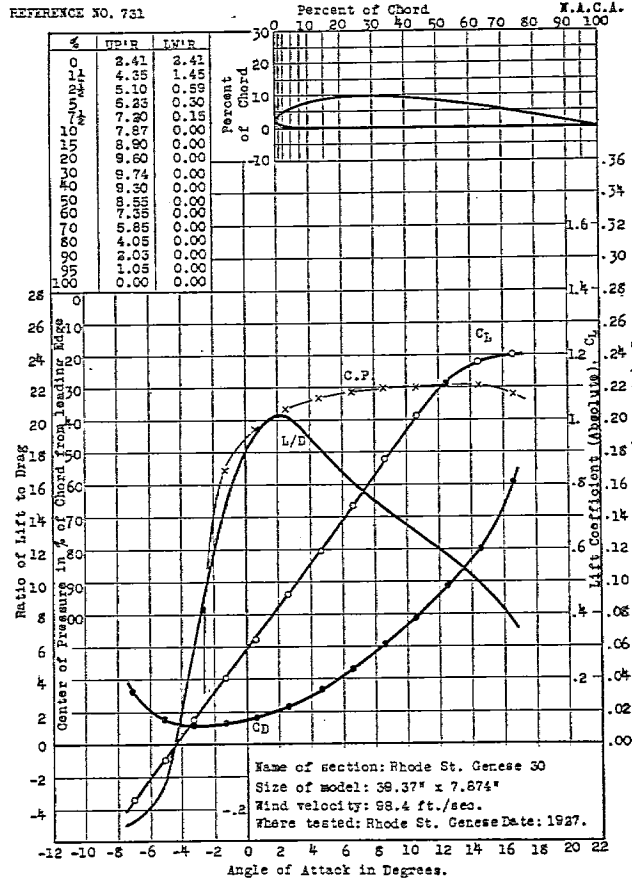
REFERENCE NO. 729



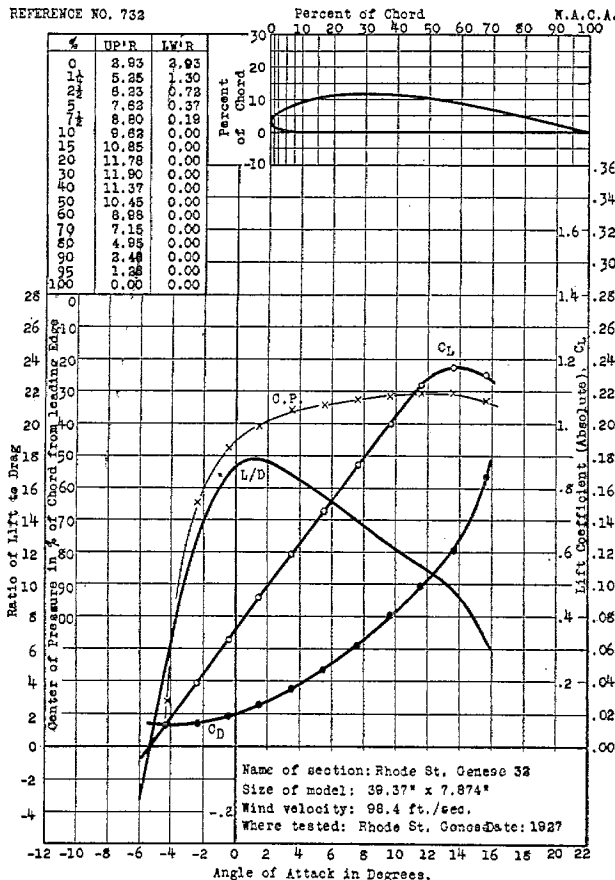
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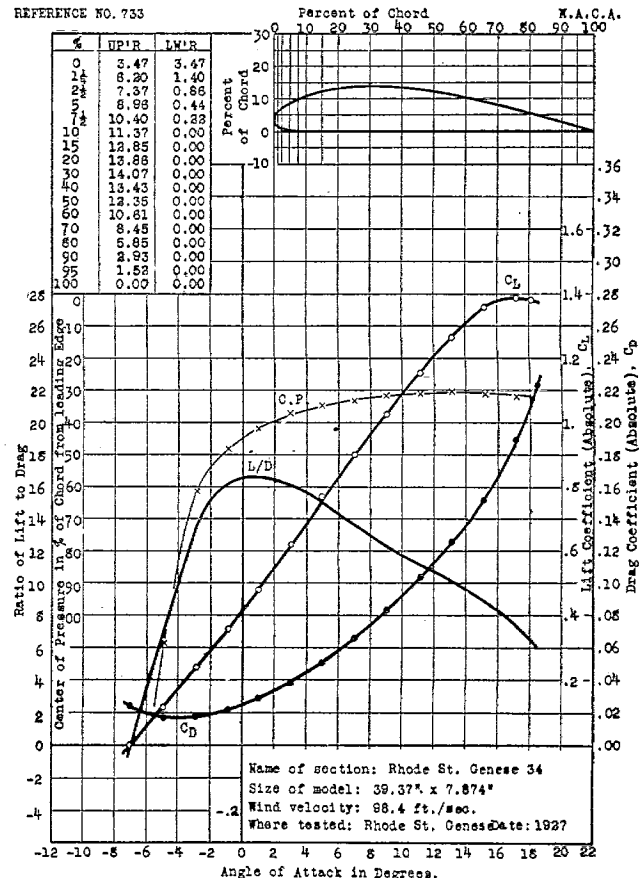
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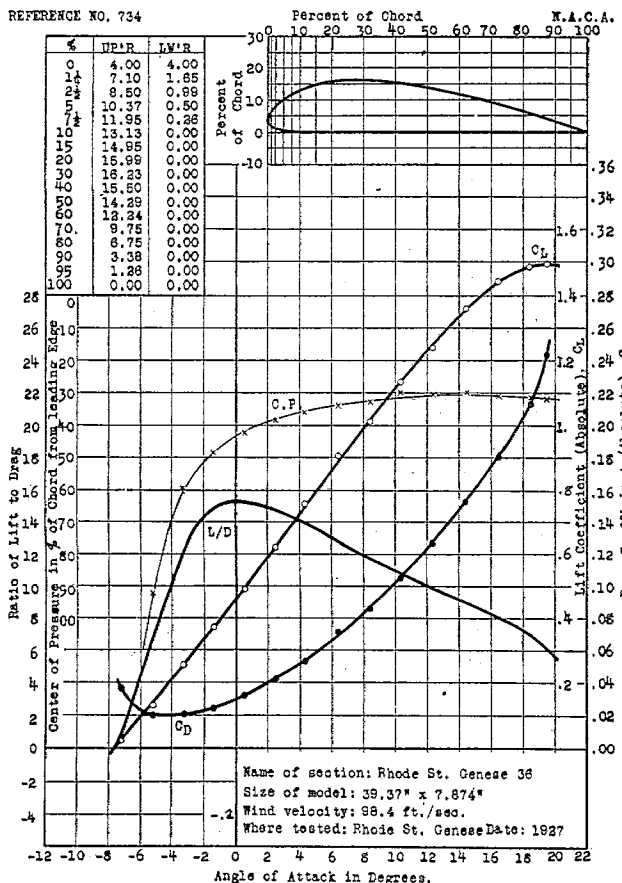
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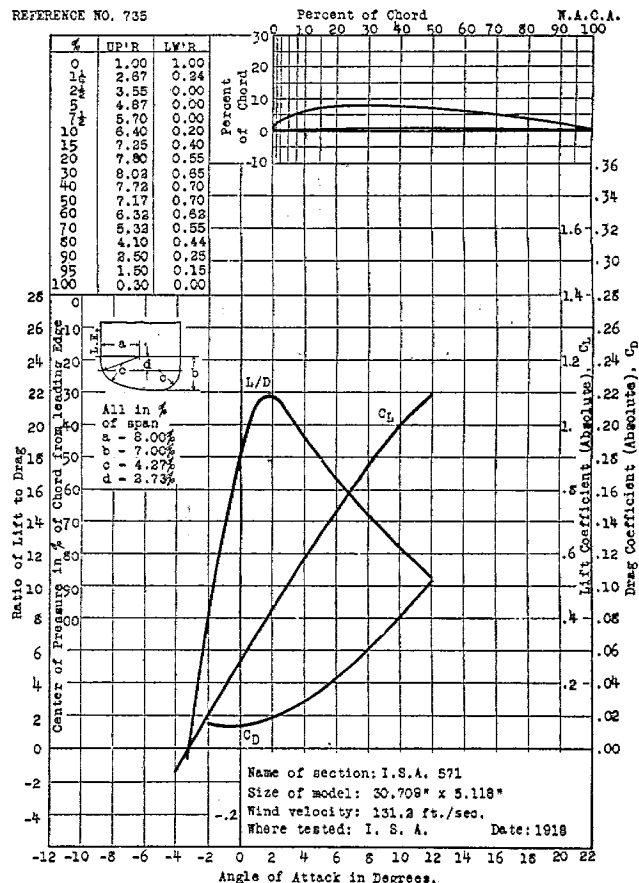
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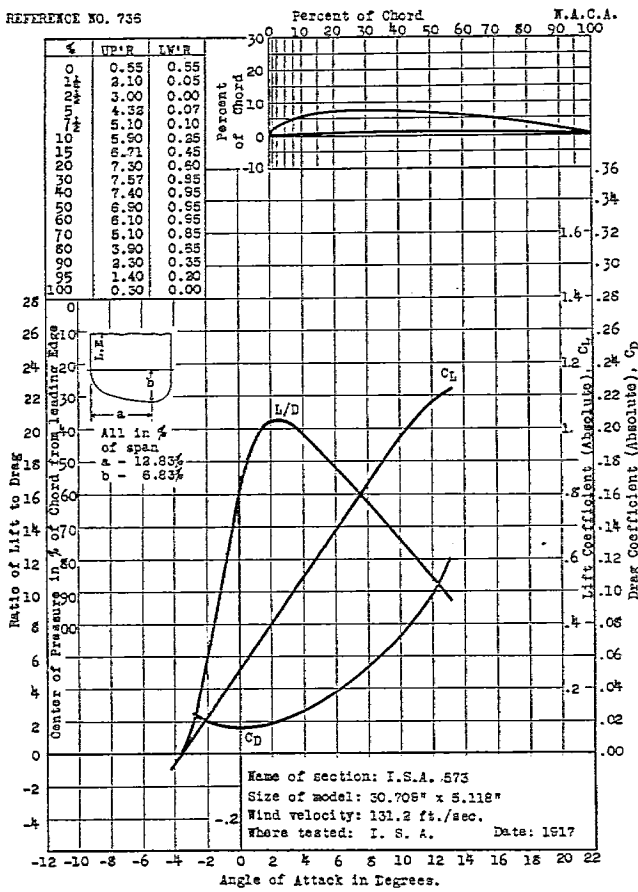


REFERENCE NO. 735

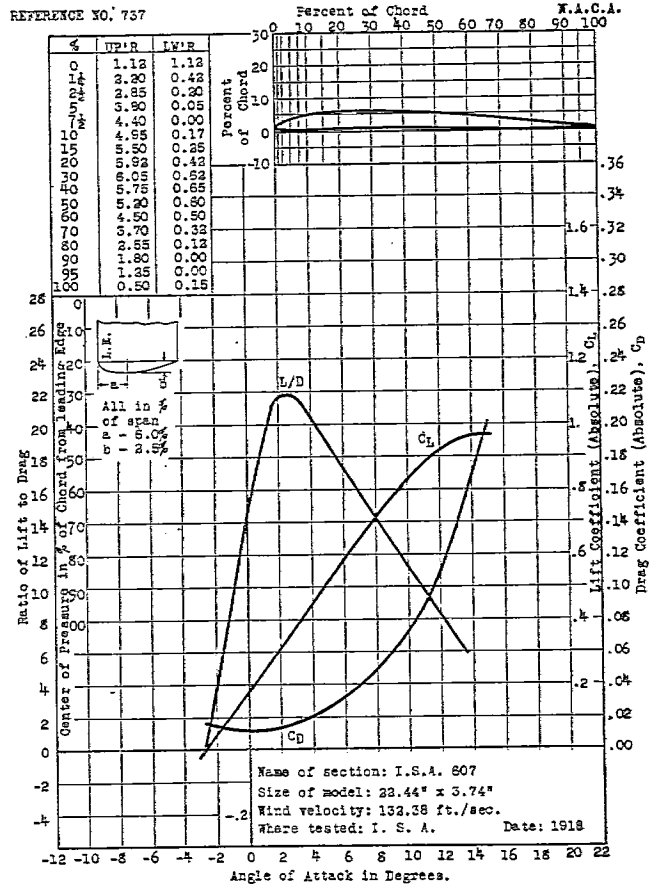


AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V

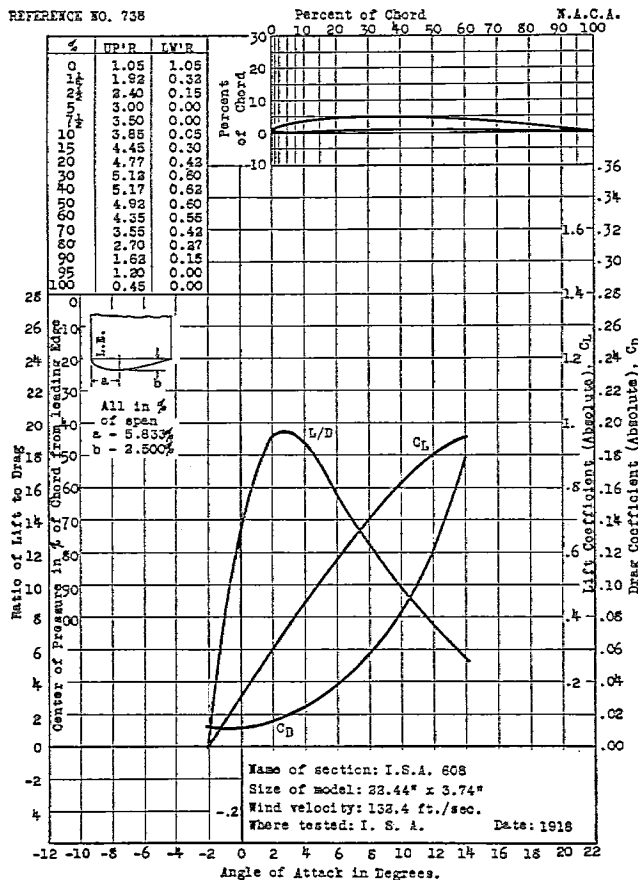
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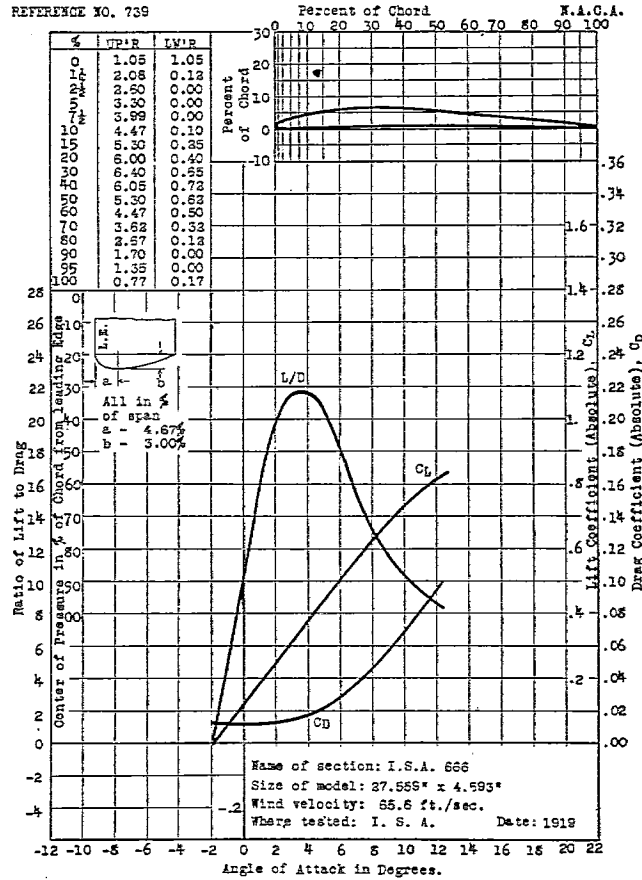
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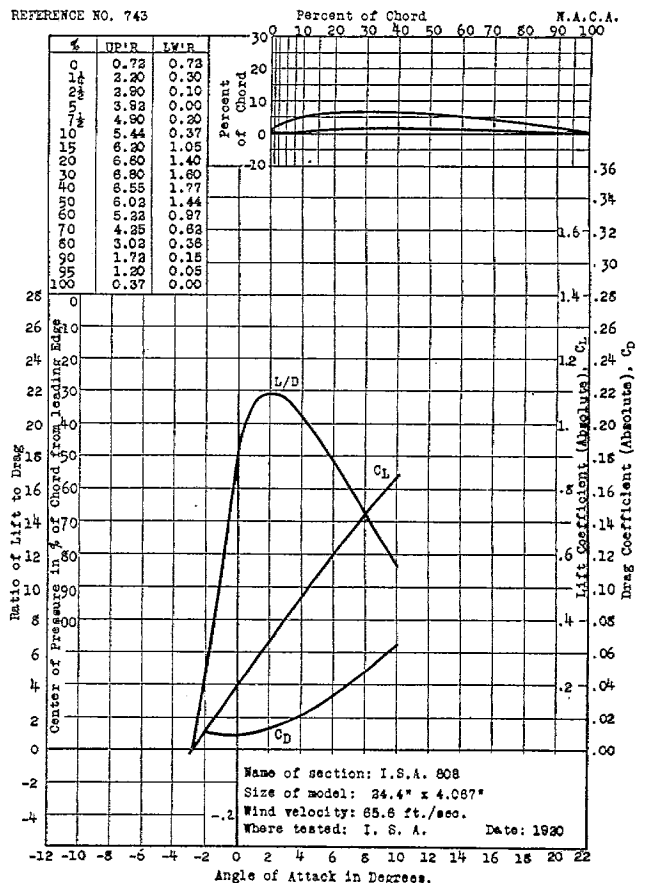
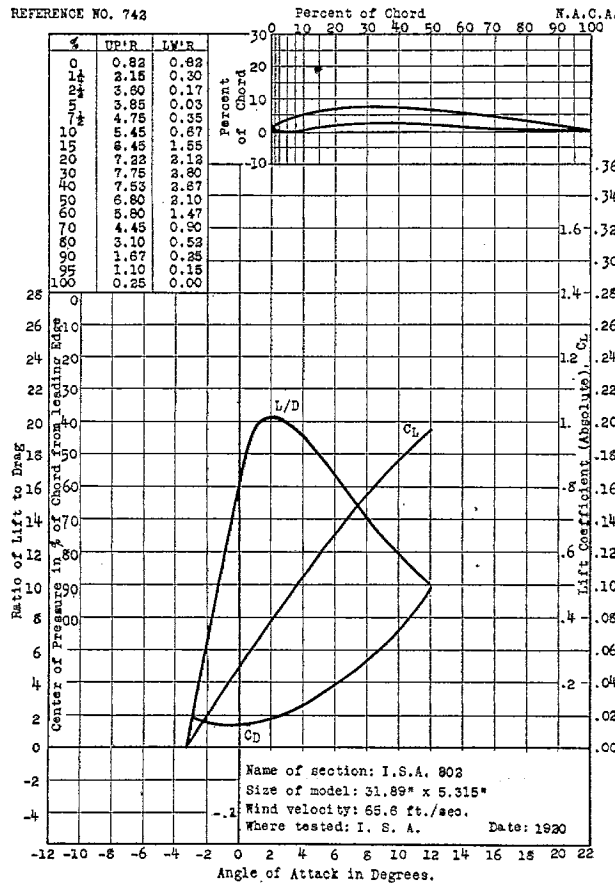
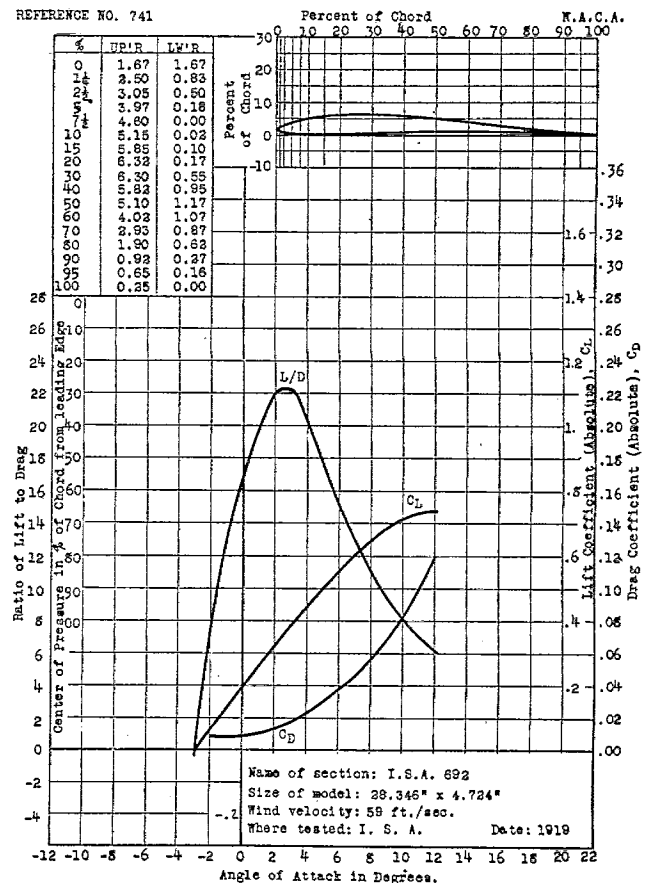
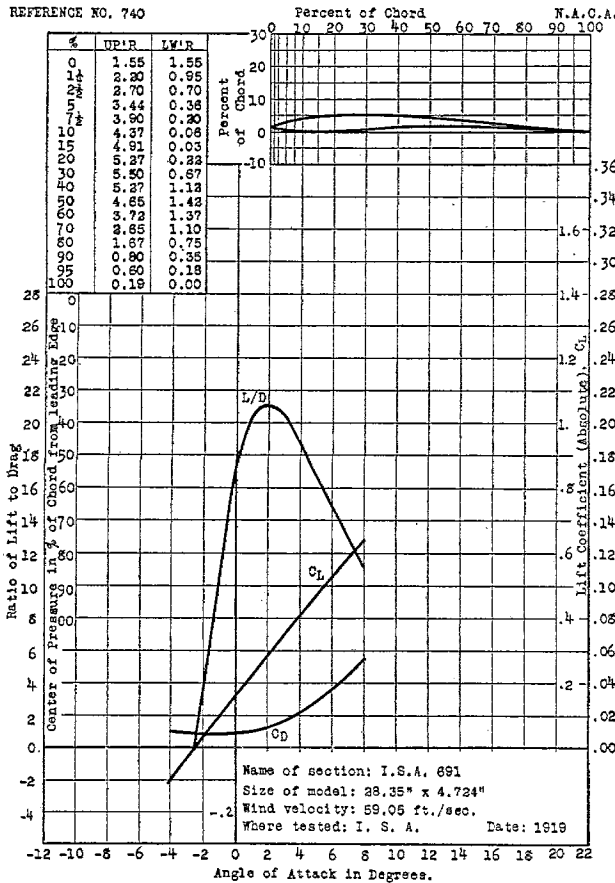


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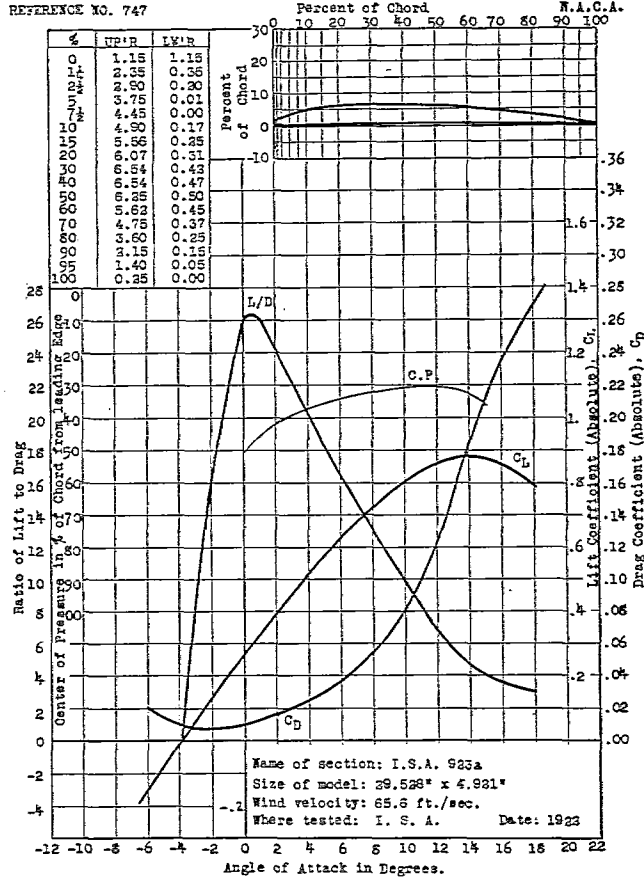
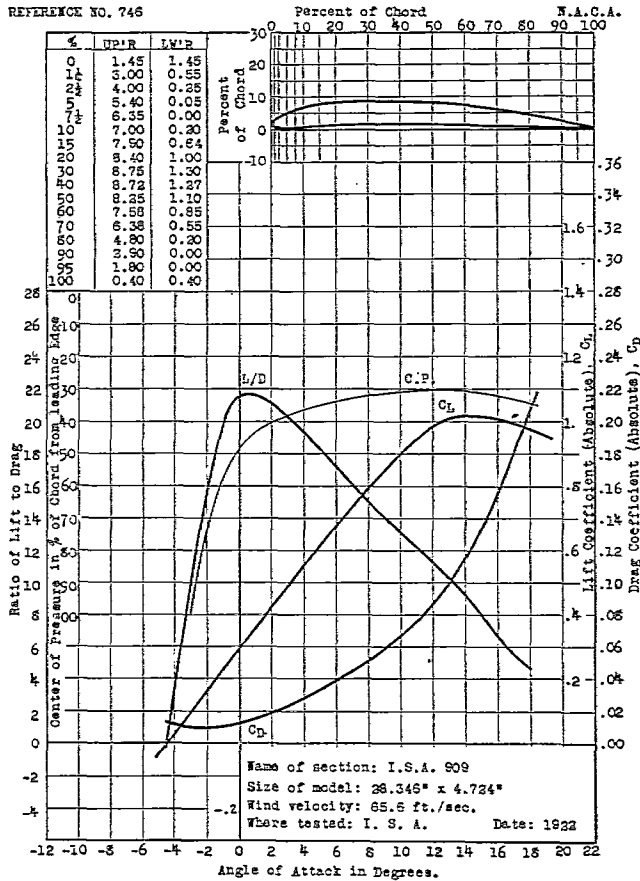
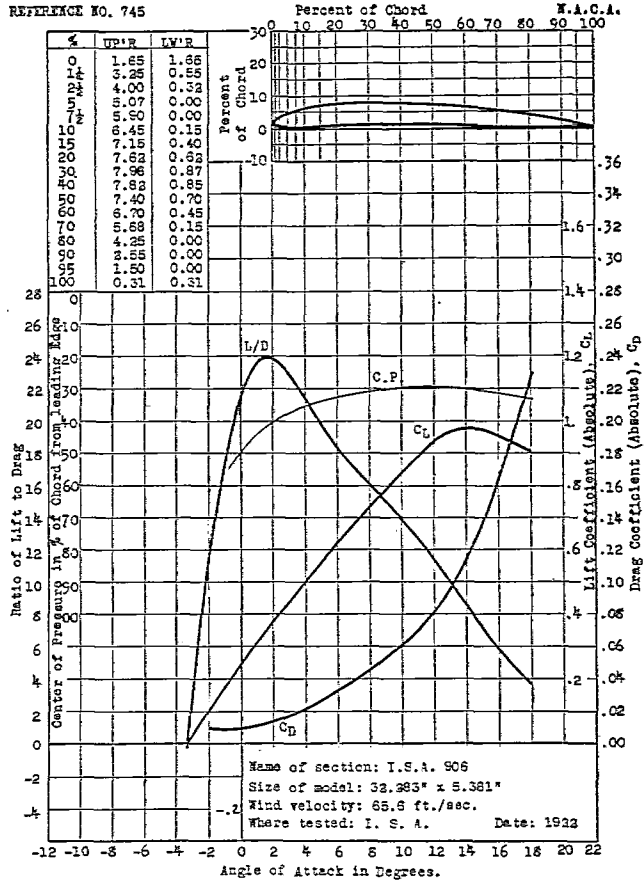
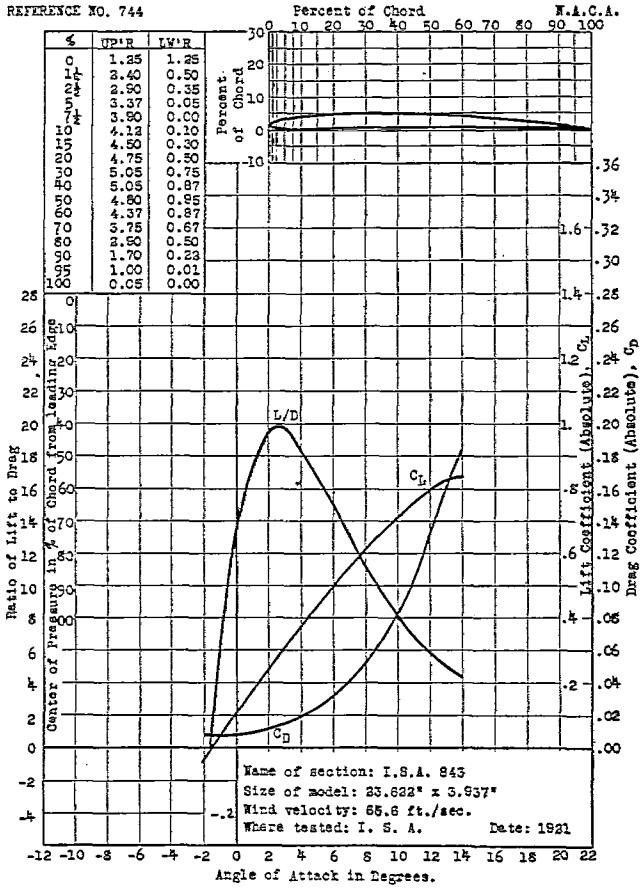


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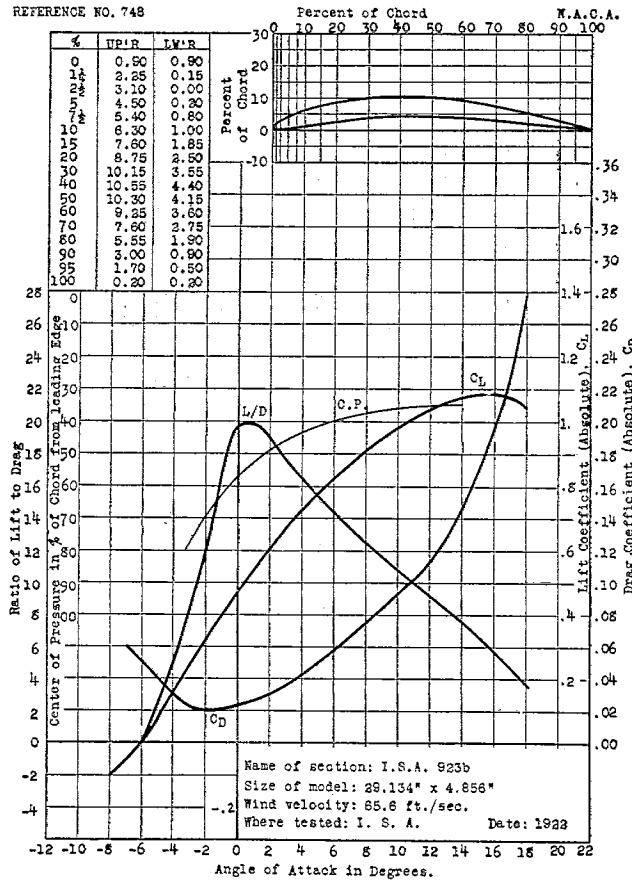




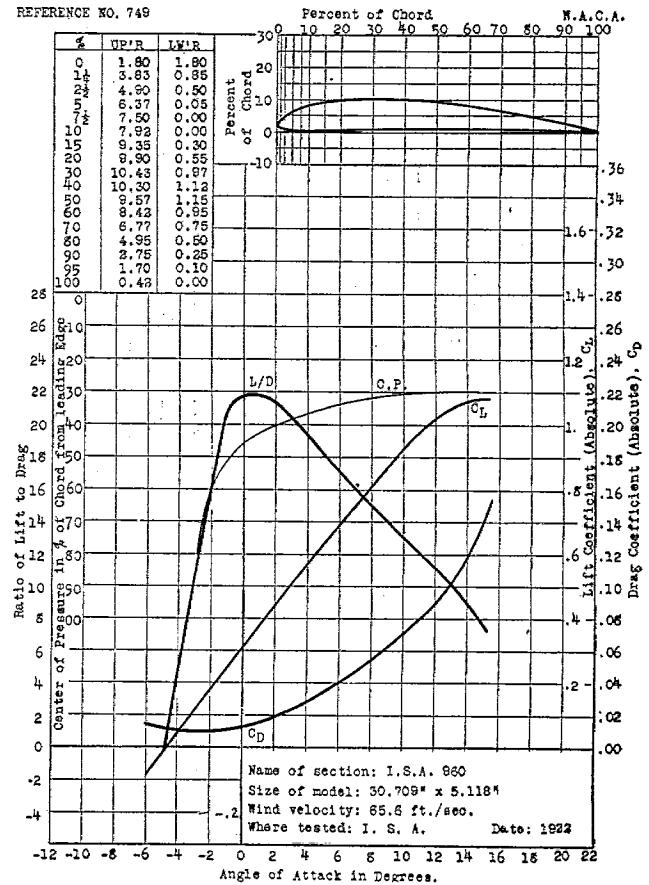
AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V



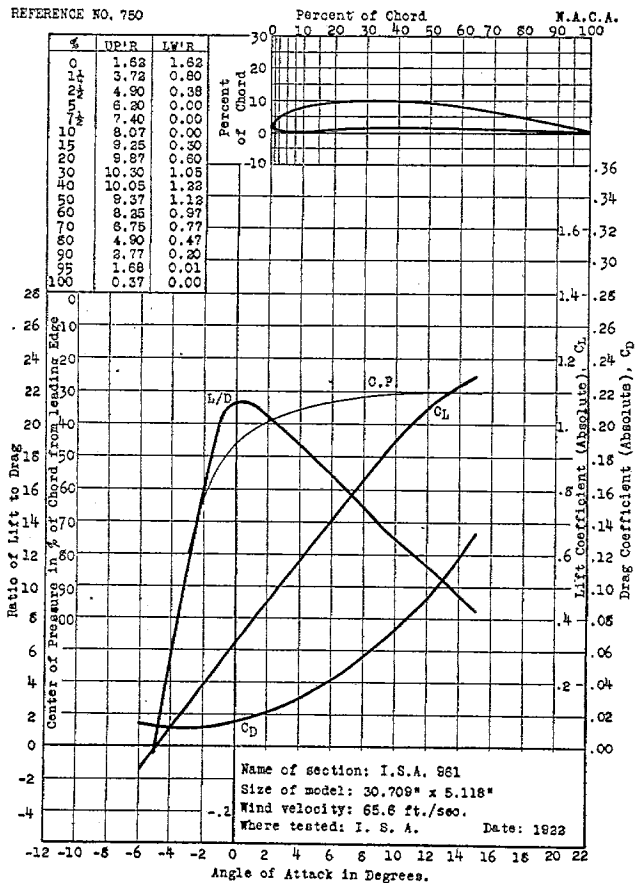
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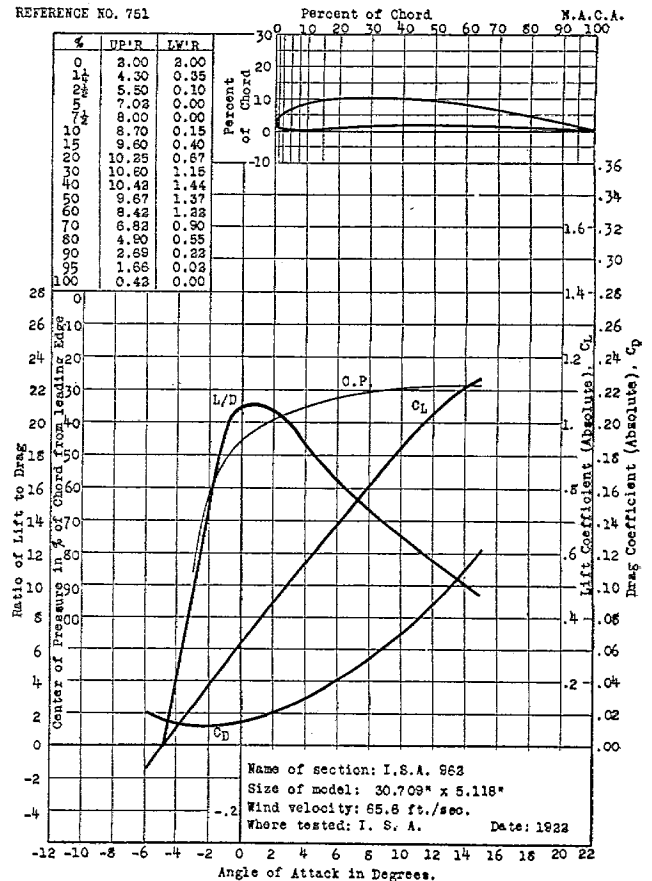
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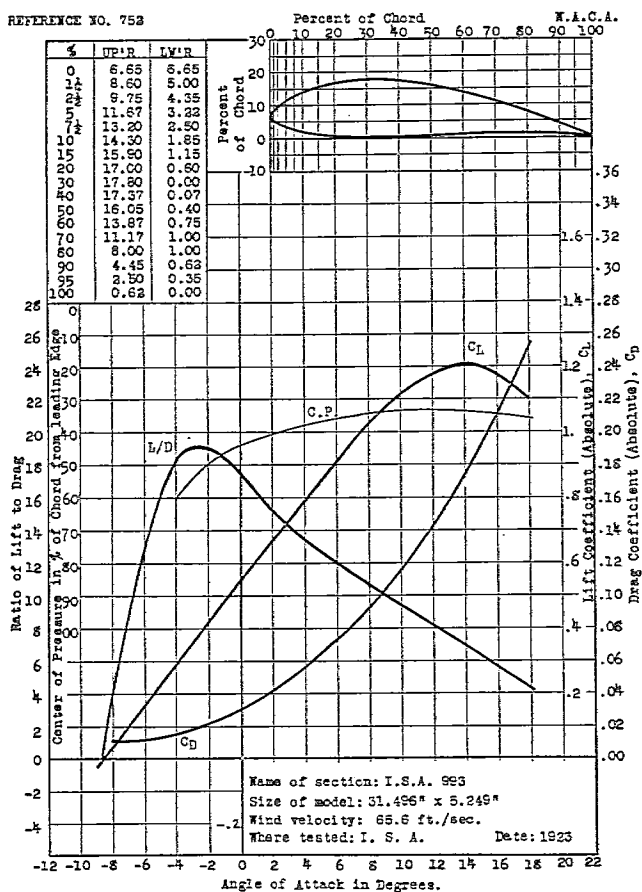


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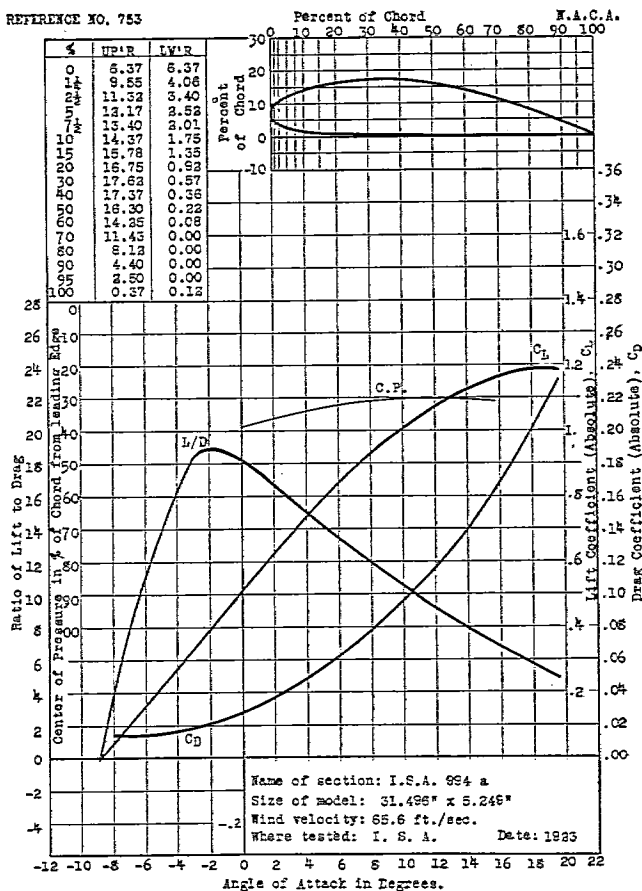


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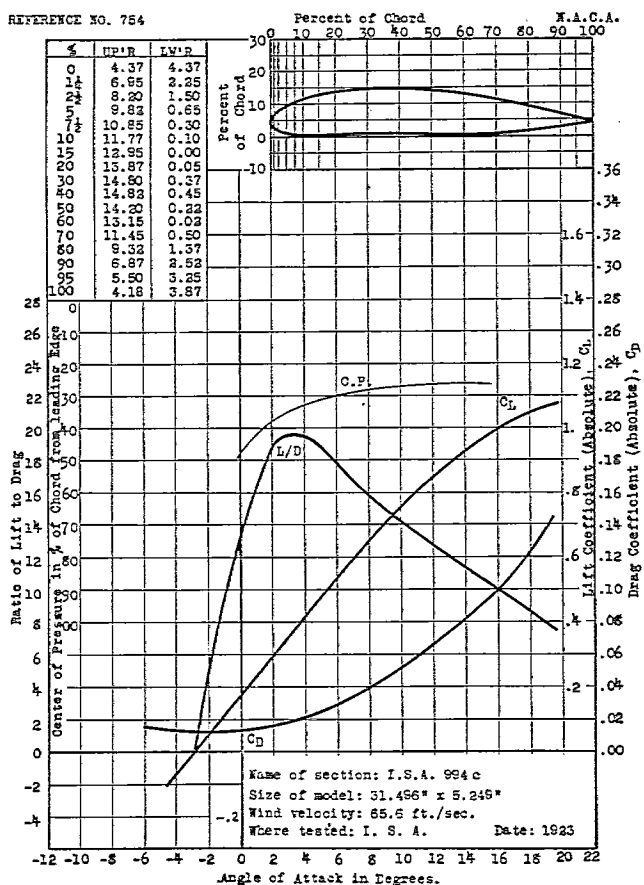
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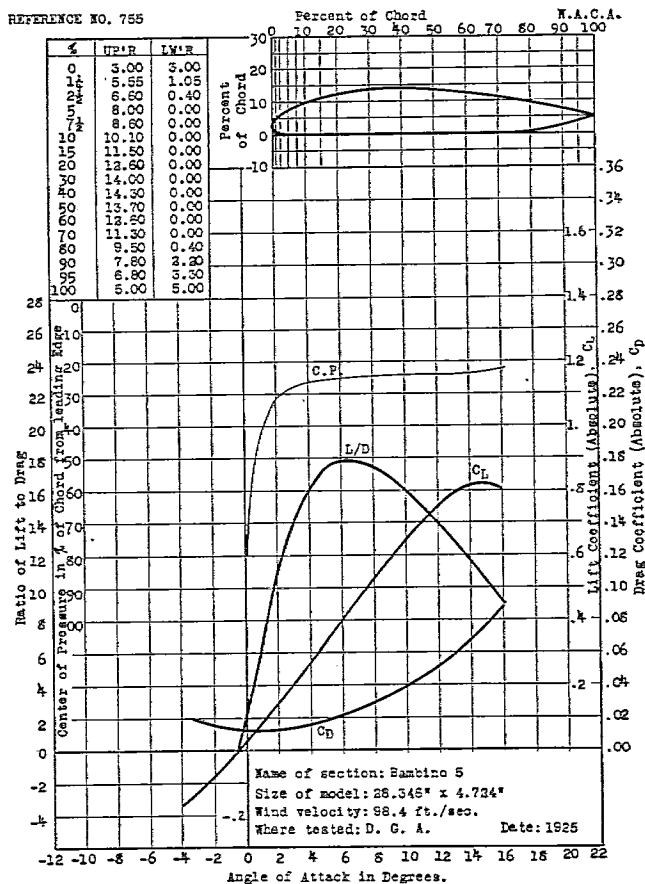
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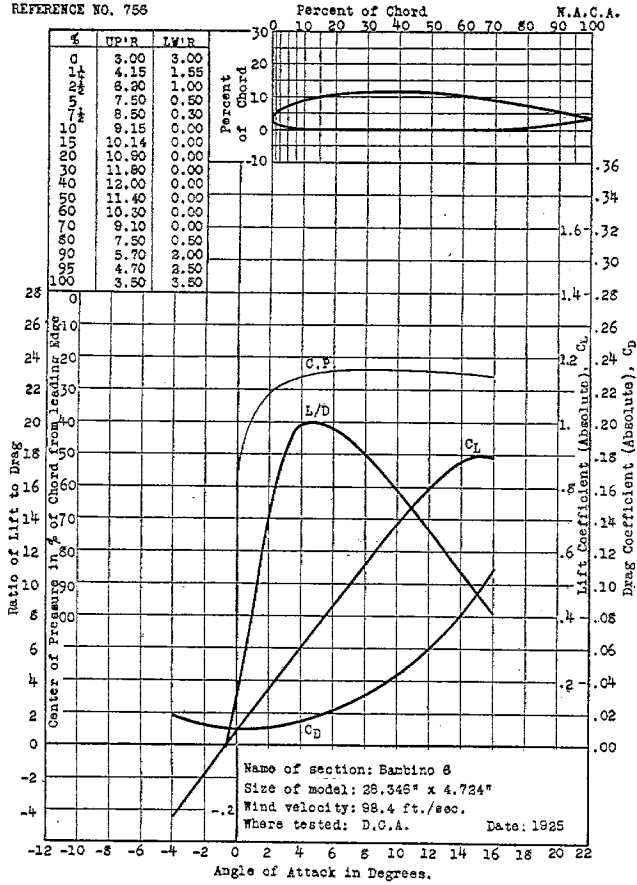
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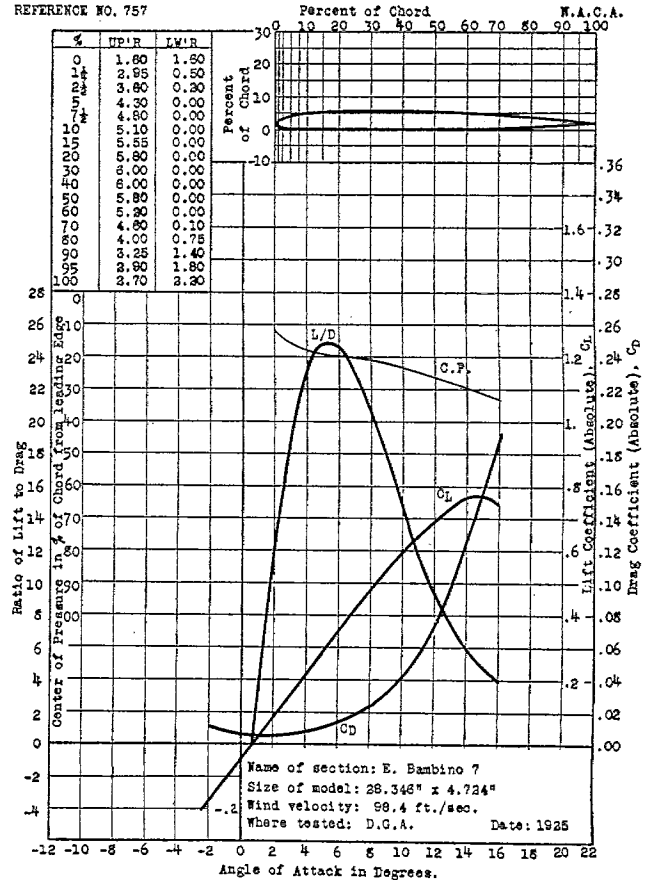
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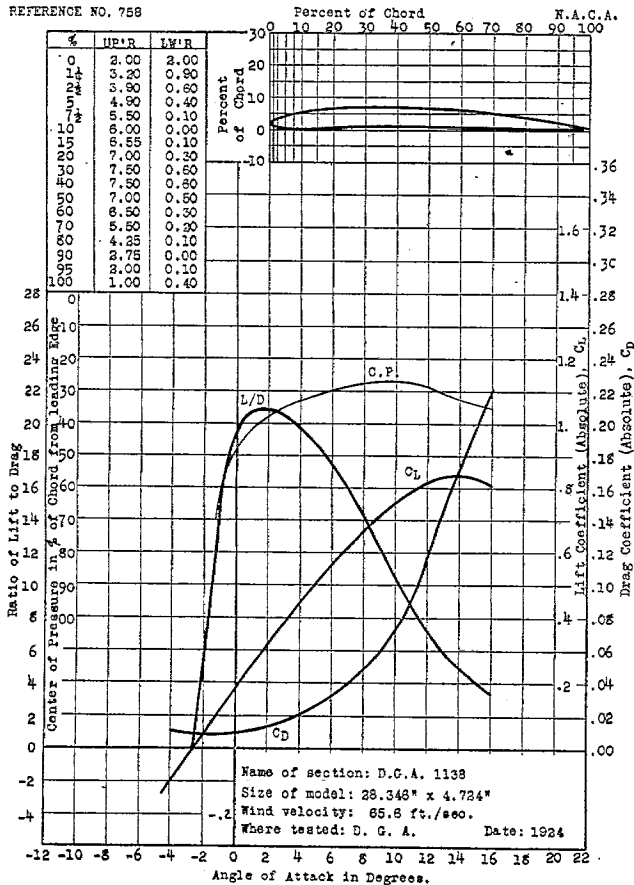
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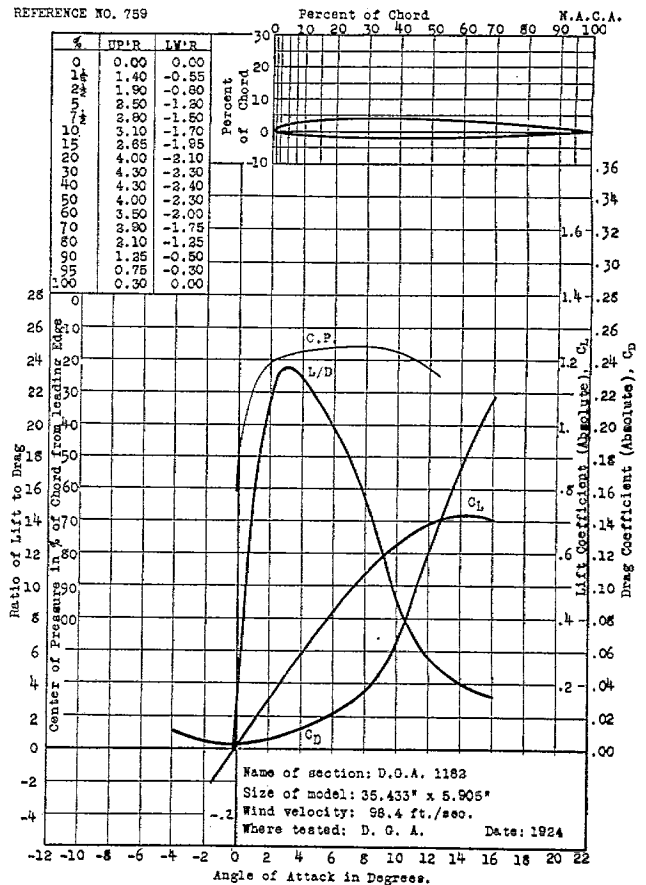
REFERENCE NO. 757



REFERENCE NO. 758



REFERENCE NO. 759



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TABLE OF ORDINATES NOT GIVEN ON INDIVIDUAL CHARACTERISTIC SHEETS

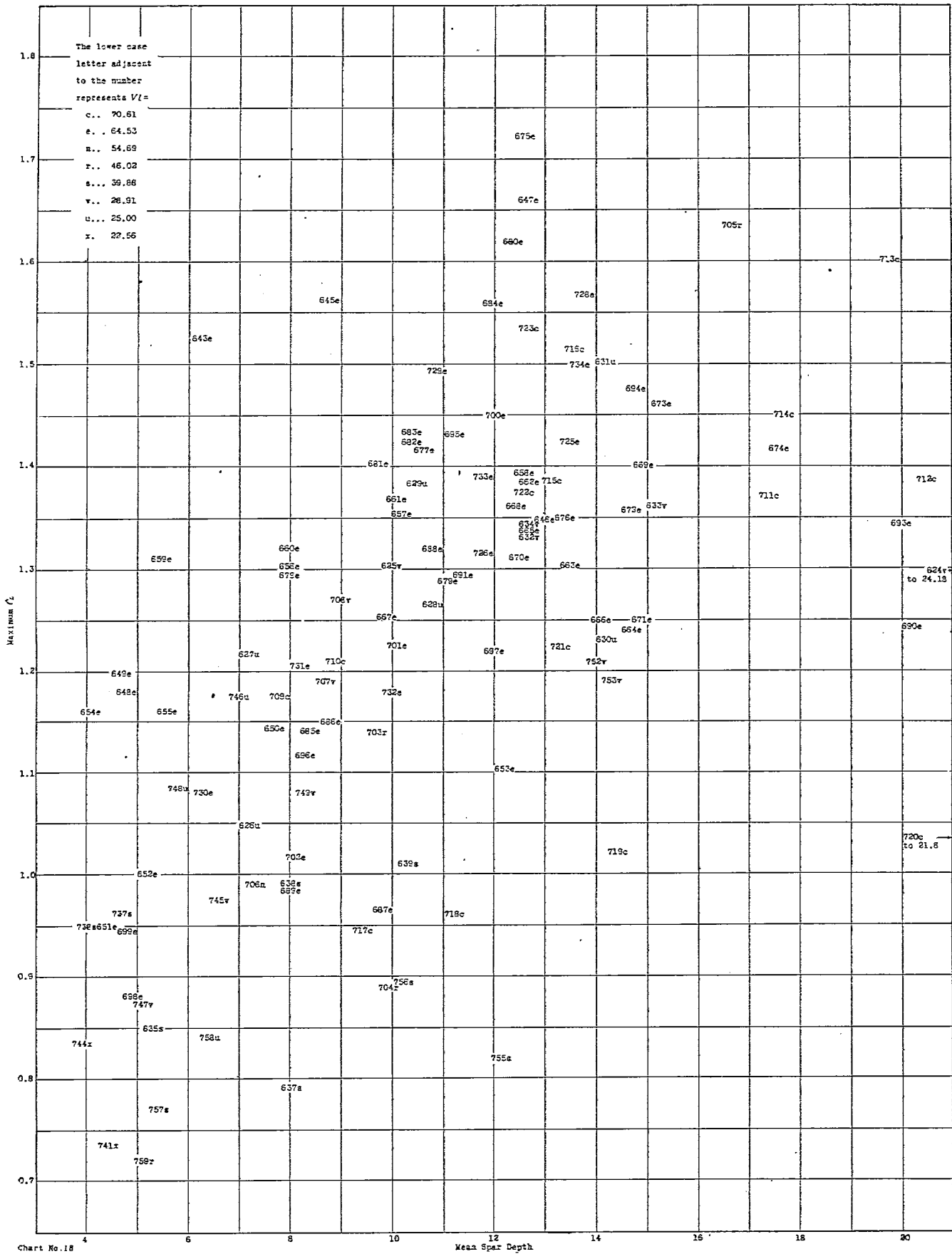
Ordinates for dotted section, at tip, where ratio of ordinate to chord differs from that of section at center of span

Additional ordinates required to give camber at stations, not given on individual characteristic sheets

Stations in per cent of chord	Reference 624 N. A. C. A. 81J (tapered)	
	Upper	Lower
0	3.06	3.06
1.25	3.94	2.00
2.50	4.28	1.66
5.00	4.74	1.24
7.50	5.06	0.91
10	5.31	0.68
15	5.61	0.35
20	5.79	0.17
30	5.76	0.02
40	5.41	0.01
50	4.81	0.11
60	4.05	0.23
70	3.15	0.34
80	2.17	0.37
90	1.11	0.25
95	0.58	0.13
100	0.00	0.00

Stations in per cent of chord	Reference 626 B-2 (Modified M-80)		Reference 627 C-2 (Modified M-80)	
	Upper	Lower	Upper	Lower
8.95		0.00		0.00
12.70	7.36		7.38	
22.50	8.28		8.58	0.78
25.00	8.96	0.78	8.92	0.98
35.00	8.70	1.06	8.82	1.12
45.00	8.40		8.20	
74.50		0.02		0.00
98.00			1.30	0.40
99.00			1.10	0.60

AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V



AERODYNAMIC CHARACTERISTICS OF AIRFOILS—V

