
REPORT No. 244

AERODYNAMIC CHARACTERISTICS OF AIRFOILS—IV

CONTINUATION OF REPORTS NOS. 93, 124, AND 182

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 series of airfoils designated N. A. C. A.-M1 to N. A. C. A.-M27 (Reference Nos. 506 to 532) were tested in the variable density wind tunnel of the National Advisory Committee for Aeronautics at a pressure of approximately 20 atmospheres.

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, 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 226. 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.	= 60.1° F.
Pressure	= 760 mm Hg.	= 29.92 in. Hg.
Humidity	= 0.	
Gravity	= 9.806 m/sec. ²	= 32.172 ft./sec. ²

¹ A previous collection of airfoil sections 1 to 503 and charts 1 to 12 may be found in N. A. C. A. Reports Nos. 93, 124, and 182.

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

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

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 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 wind velocity in feet per second and l a linear dimension, the chord, in feet.

In chart No. 13 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. 14 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. 15 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. 16 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.

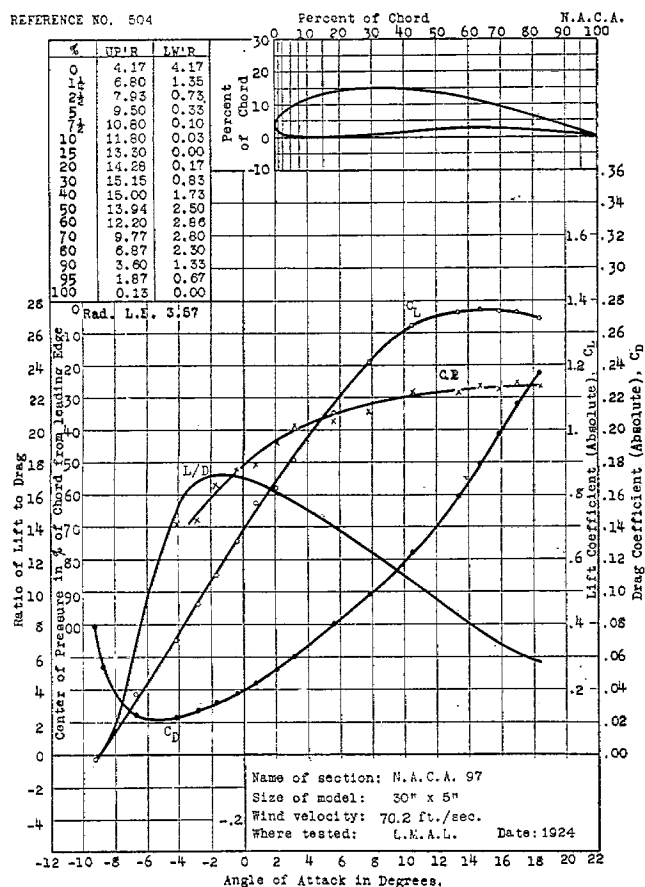
GROUP INDEX

Airfoil	Wind tunnel	Report reference number	Airfoil	Wind tunnel	Report reference number
UNITED STATES					
N. A. C. A. 97	L. M. A. L.	504	U. S. A. 49	McC F	571
N. A. C. A. 98	do	505	U. S. A. 50	do	572
N. A. C. A.-M1	do	506	U. S. A. 51	do	573
N. A. C. A.-M2	do	507	R-3	do	574
N. A. C. A.-M3	do	508	Glenn Martin 2 (Modified)	M. I. T.	575
N. A. C. A.-M4	do	509	Dayton-Wright 5	do	576
N. A. C. A.-M5	do	510	Dayton-Wright 6	do	577
N. A. C. A.-M6	do	511	U. S. A. 35	do	578
N. A. C. A.-M7	do	512	U. S. A. 40B	do	579
N. A. C. A.-M8	do	513	U. S. A. 45	do	580
N. A. C. A.-M9	do	514	Clark V	do	581
N. A. C. A.-M10	do	515	Clark W	do	582
N. A. C. A.-M11	do	516	Clark X	do	583
N. A. C. A.-M12	do	517	Clark Y	do	584
N. A. C. A.-M13	do	518	Clark Z	do	585
N. A. C. A.-M14	do	519	C-27	do	586
N. A. C. A.-M15	do	520	Halbronn 1-A	do	587
N. A. C. A.-M16	do	521	Hill 85-15	do	588
N. A. C. A.-M17	do	522	Glenn Martin 7	Göttingen	589
N. A. C. A.-M18	do	523	Glenn Martin 9	do	590
N. A. C. A.-M19	do	524	Glenn Martin 11	do	591
N. A. C. A.-M20	do	525	Glenn Martin 13	do	592
N. A. C. A.-M21	do	526	Glenn Martin 15	do	593
N. A. C. A.-M22	do	527	Glenn Martin 16	do	594
N. A. C. A.-M23	do	528	Glenn Martin 17	do	595
N. A. C. A.-M24	do	529	Glenn Martin 18	do	596
N. A. C. A.-M25	do	530	Glenn Martin 19	do	597
N. A. C. A.-M26	do	531	Glenn Martin 20	do	598
N. A. C. A.-M27	do	532	Glenn Martin 21	do	599
U. S. A. 5	do	533	GREAT BRITAIN		
U. S. A. 27	do	534	Fage & Howard A	N. P. L.	600
U. S. A. 35A	do	535	Fage & Howard B	do	601
U. S. A. 35B	do	536	Fage & Howard C	do	602
U. S. A. 27 with ordinates decreased 10 per cent.	W. N. Y.	539	Fage & Howard D	do	603
Albatross (Modified) A	do	540	Fage & Howard E	do	604
Albatross (Modified) B	do	541	Fage & Howard F	do	605
C-62	do	542	R. A. F. 15	L. M. A. L.	537
TX	do	543	R. A. F. 30	R. A. E.	606
D-2 (Modified M-80)	do	544	R. A. F. 31	do	607
Göttingen 387 (Tapered)	do	545	R. A. F. 32	do	608
N. W.	do	546	R. A. F. 33	do	609
D. T. T-1	do	547	GERMANY		
D. T. T-1 (Tapered)	do	548	Göttingen 274 (Daimler V)	Göttingen	610
NS-1	do	549	Göttingen 275 (Daimler VI)	do	611
DW-9	do	550	Göttingen 276 (Daimler VII)	do	612
N-6	do	551	Göttingen 279 (Daimler X)	do	613
N-7	do	552	Göttingen 280 (Daimler XI)	do	614
N-8	do	553	Göttingen 282 (Daimler XIII)	do	615
N-9	do	554	Göttingen 308 (M. V. A. H. 40)	do	616
N-10	do	555	Göttingen 309 (M. V. A. H. 41)	do	617
N-11	do	556	Göttingen 310 (M. V. A. H. 42)	do	618
N-12	do	557	Göttingen 314 (Hansa-Brandenburg)	do	619
N-13	do	558	Göttingen 315 (Hansa-Brandenburg III.5)	do	620
N-14	do	559	Göttingen 316 (Hansa-Brandenburg IV.5)	do	621
N-15	do	560	Göttingen 318 (Hansa-Brandenburg VI.5)	do	622
N-16	do	561	Göttingen 326 (Pfalz 55)	do	623
N-17	do	562	Göttingen 387	L. M. A. L.	538
N-18	do	563			
N-19	do	564			
N-20	do	565			
Sloane (Modified)	do	566			
U. S. A. 40	McC F	567			
U. S. A. 41	do	568			
U. S. A. 46	do	569			
U. S. A. 48	do	570			

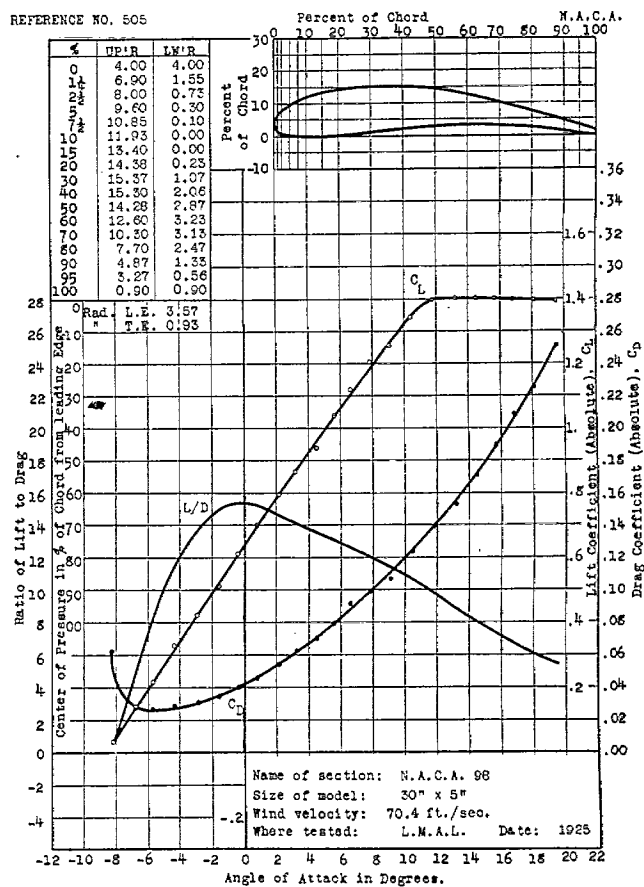
ALPHABETICAL INDEX

Airfoil	Report reference number	Airfoil	Report reference number
Albatross (modified) A	540	N-16	561
Albatross (modified) B	541	N-17	562
C-27	586	N-18	563
C-62	542	N-19	564
Clark V	581	N-20	565
Clark W	582	N. A. C. A. 97	504
Clark X	583	N. A. C. A. 98	505
Clark Y	584	N. A. C. A.-M1	506
Clark Z	585	N. A. C. A.-M2	507
D-2 (Modified M-80)	544	N. A. C. A.-M3	508
Dayton-Wright 5	576	N. A. C. A.-M4	509
Dayton-Wright 6	577	N. A. C. A.-M5	510
Dayton-Wright T-1	547	N. A. C. A.-M6	511
Dayton-Wright T-1 (tapered)	548	N. A. C. A.-M7	512
DW-9	550	N. A. C. A.-M8	513
Fage & Howard A	600	N. A. C. A.-M9	514
Fage & Howard B	601	N. A. C. A.-M10	515
Fage & Howard C	602	N. A. C. A.-M11	516
Fage & Howard D	603	N. A. C. A.-M12	517
Fage & Howard E	604	N. A. C. A.-M13	518
Fage & Howard F	605	N. A. C. A.-M14	519
Glenn Martin 2 (modified)	575	N. A. C. A.-M15	520
Glenn Martin 7	589	N. A. C. A.-M16	521
Glenn Martin 9	590	N. A. C. A.-M17	522
Glenn Martin 11	591	N. A. C. A.-M18	523
Glenn Martin 13	592	N. A. C. A.-M19	524
Glenn Martin 15	593	N. A. C. A.-M20	525
Glenn Martin 16	594	N. A. C. A.-M21	526
Glenn Martin 17	595	N. A. C. A.-M22	527
Glenn Martin 18	596	N. A. C. A.-M23	528
Glenn Martin 19	597	N. A. C. A.-M24	529
Glenn Martin 20	598	N. A. C. A.-M25	530
Glenn Martin 21	599	N. A. C. A.-M26	531
Göttingen 274 (Daimler V)	610	N. A. C. A.-M27	532
Göttingen 275 (Daimler VI)	611	NS-1	549
Göttingen 276 (Daimler VII)	612	N. W	546
Göttingen 279 (Daimler X)	613	R-3	574
Göttingen 280 (Daimler XI)	614	R. A. F. 15	537
Göttingen 282 (Daimler XIII)	615	R. A. F. 30	606
Göttingen 308 (M. V. A. H. 40)	616	R. A. F. 31	607
Göttingen 309 (M. V. A. H. 41)	617	R. A. F. 32	608
Göttingen 310 (M. V. A. H. 42)	618	R. A. F. 33	609
Göttingen 314 (Hansa-Brandenburg)	619	Sloane (modified)	566
Göttingen 315 (Hansa-Brandenburg III.5)	620	TX	543
Göttingen 316 (Hansa-Brandenburg IV.5)	621	U. S. A. 5	533
Göttingen 318 (Hansa-Brandenburg VI.5)	622	U. S. A. 27	534
Göttingen 326 (Pfalz 55)	623	U. S. A. 27 with ordinates decreased 10 per cent	539
Göttingen 387	538	U. S. A. 35	578
Göttingen 387 (tapered)	545	U. S. A. 35A	535
Halbroun 1-A	587	U. S. A. 35B	536
Hill 85-15	588	U. S. A. 40	567
N-6	551	U. S. A. 40B	579
N-7	552	U. S. A. 41	568
N-8	553	U. S. A. 45	580
N-9	554	U. S. A. 46	569
N-10	555	U. S. A. 48	570
N-11	556	U. S. A. 49	571
N-12	557	U. S. A. 50	572
N-13	558	U. S. A. 51	573
N-14	559		
N-15	560		

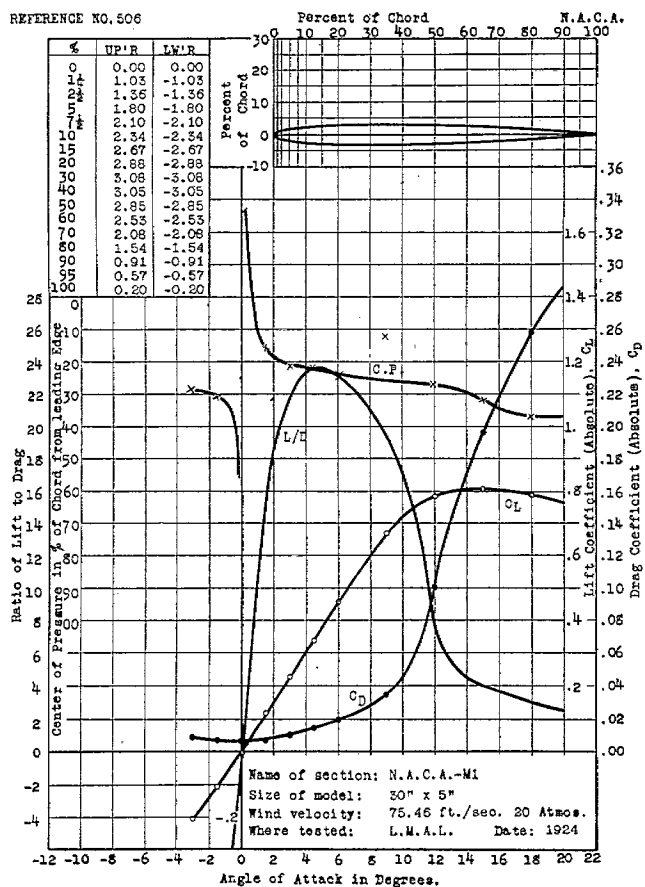
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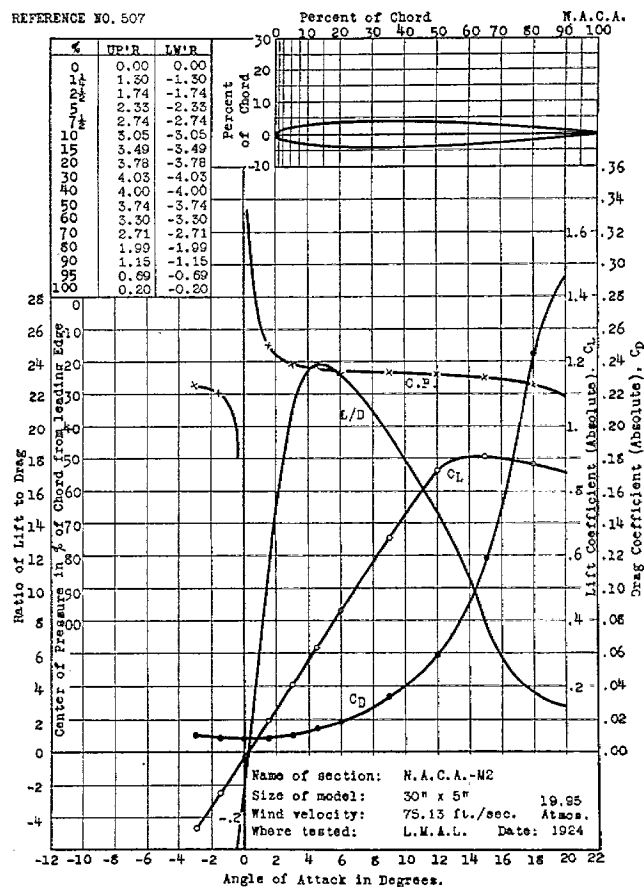
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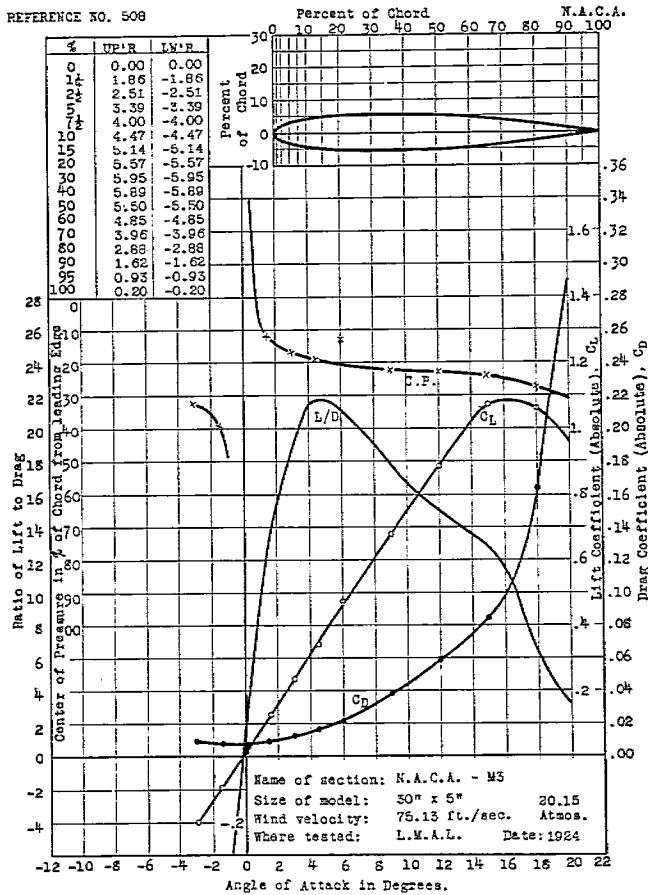
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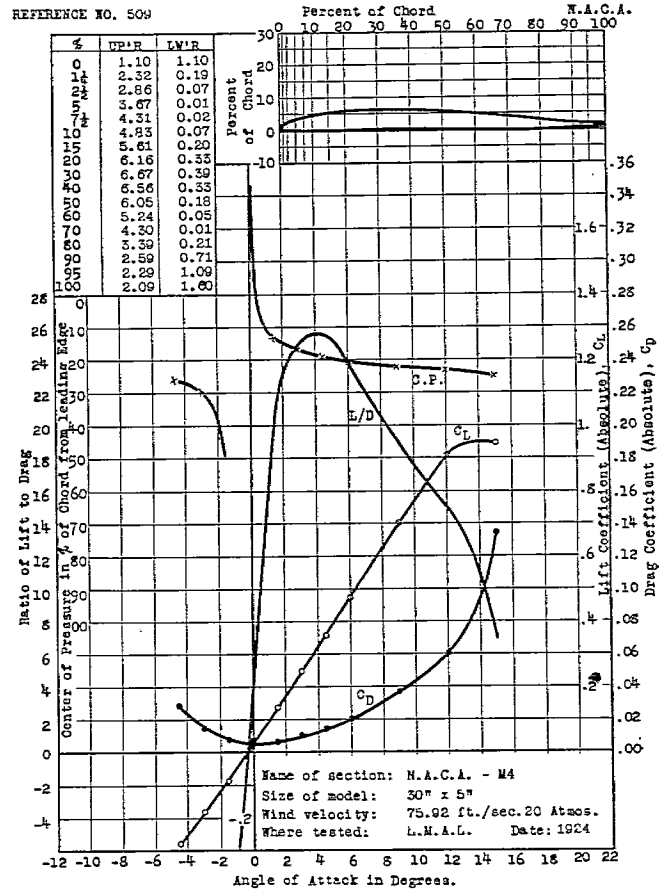
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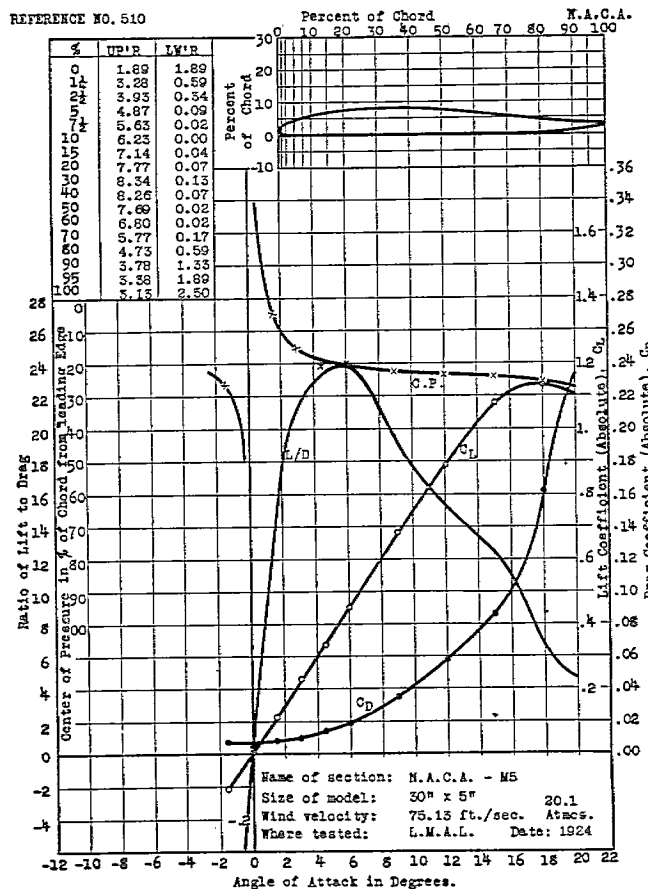
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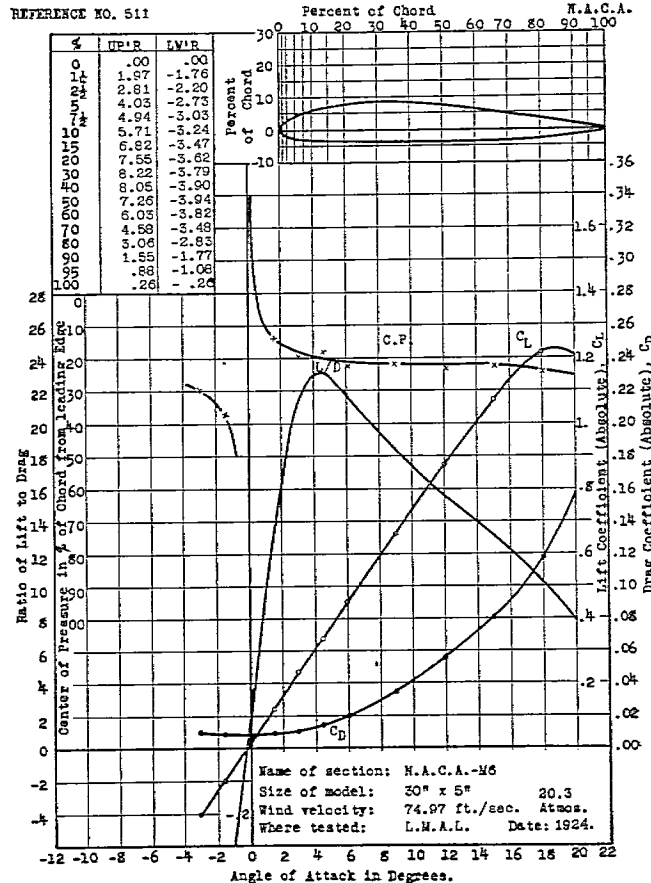
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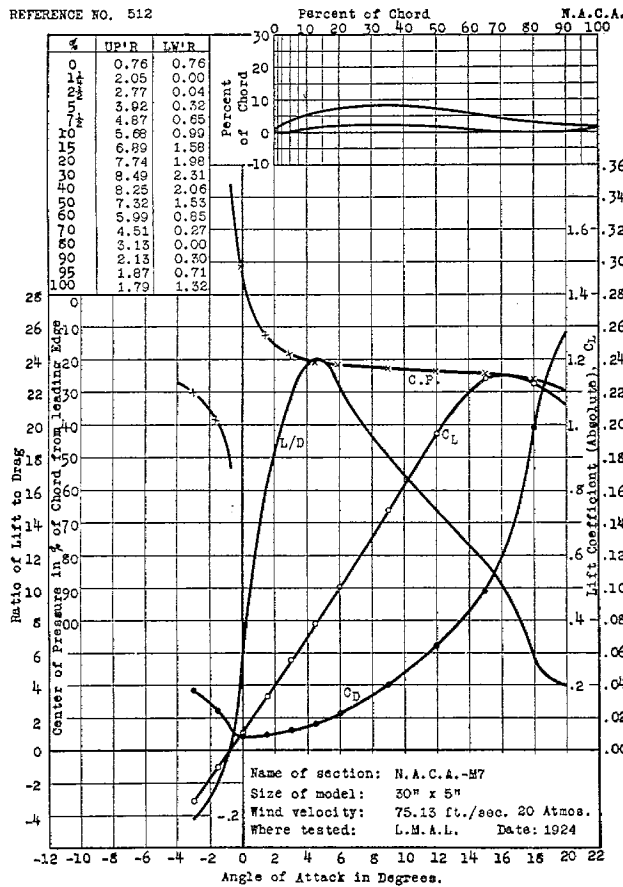
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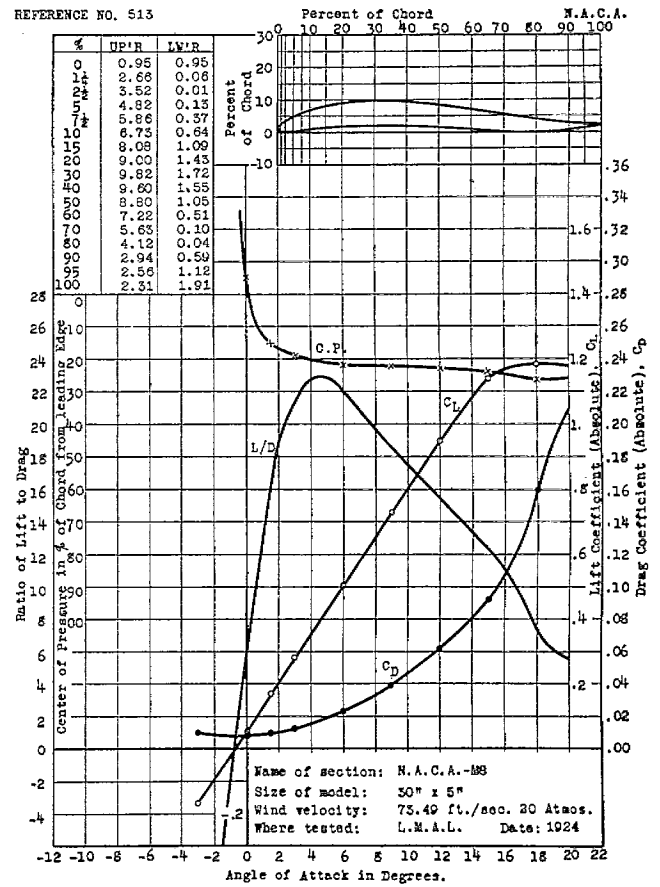
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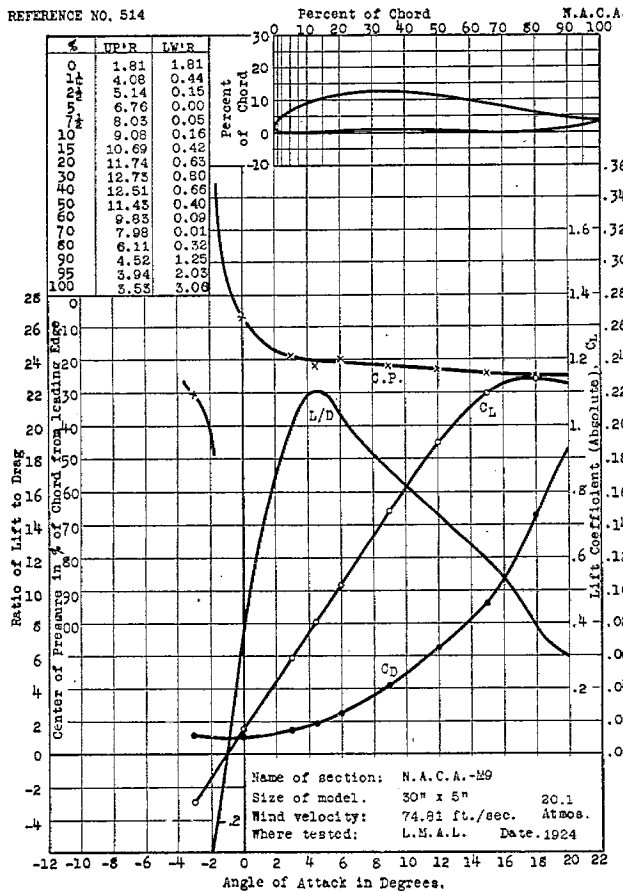
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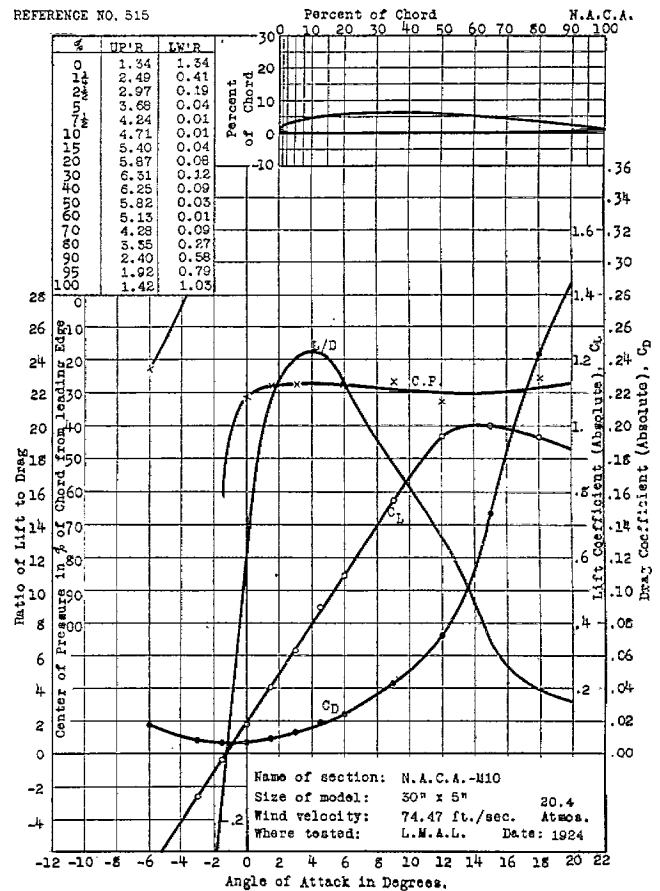
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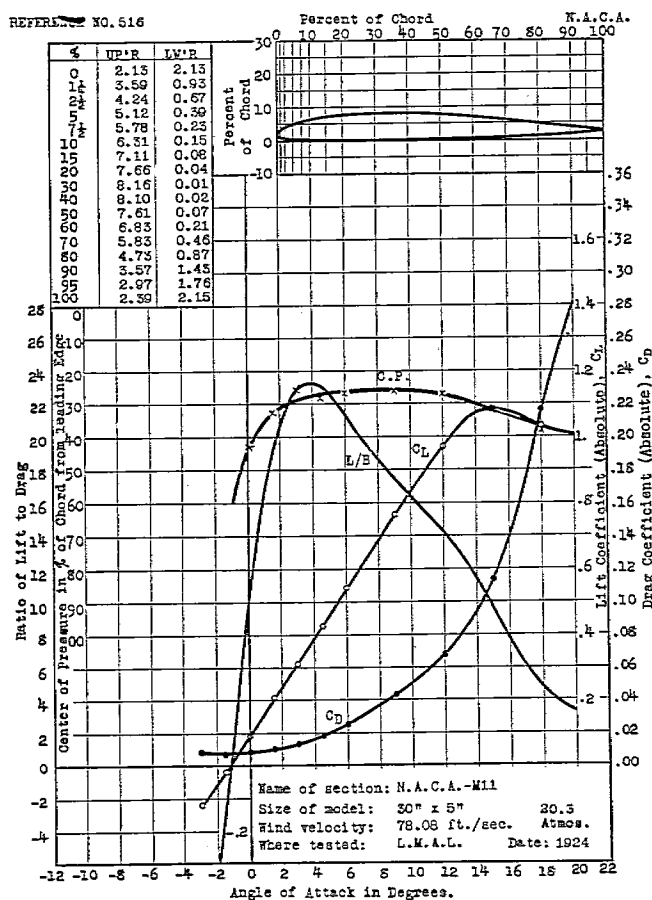
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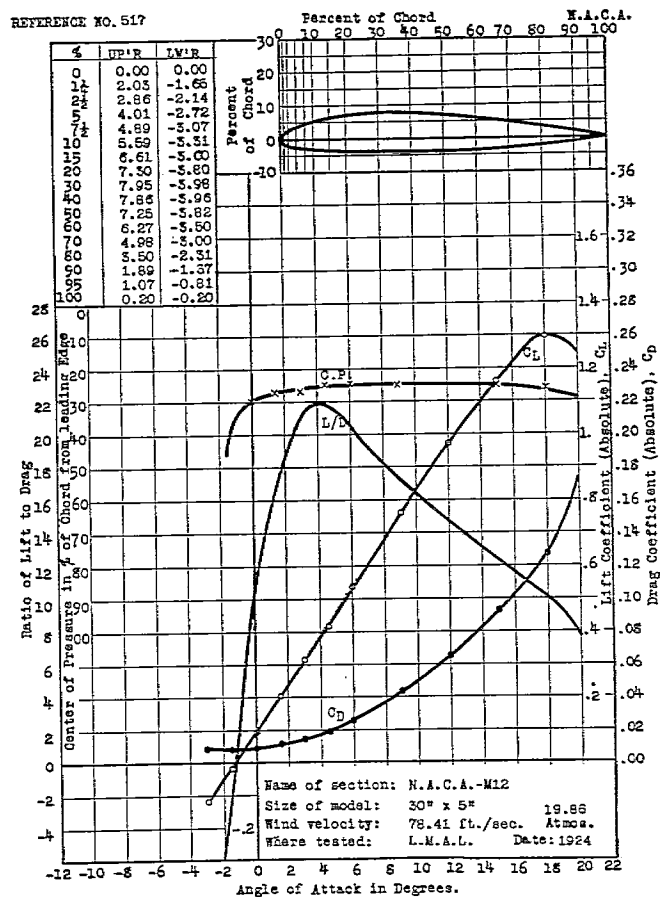
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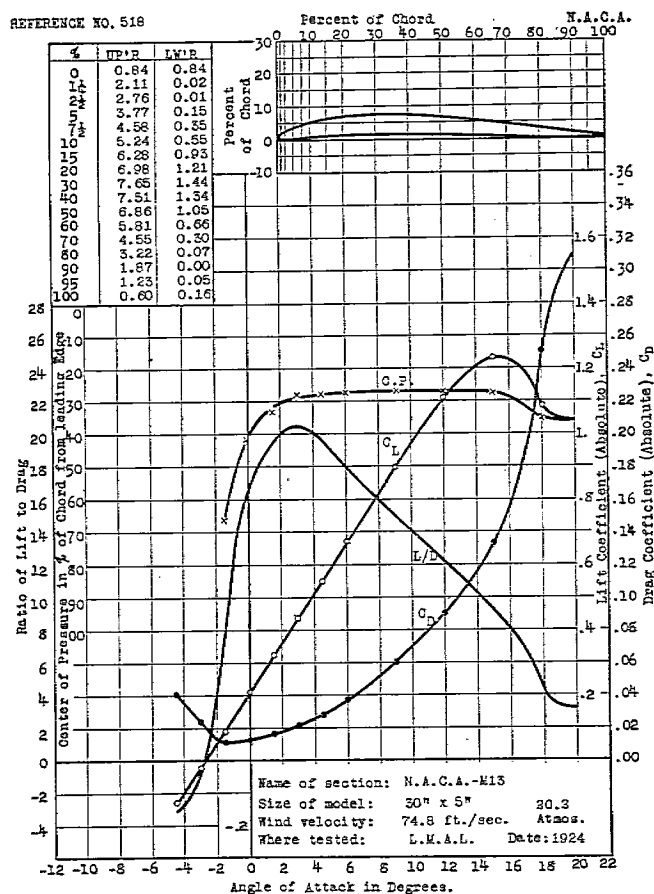
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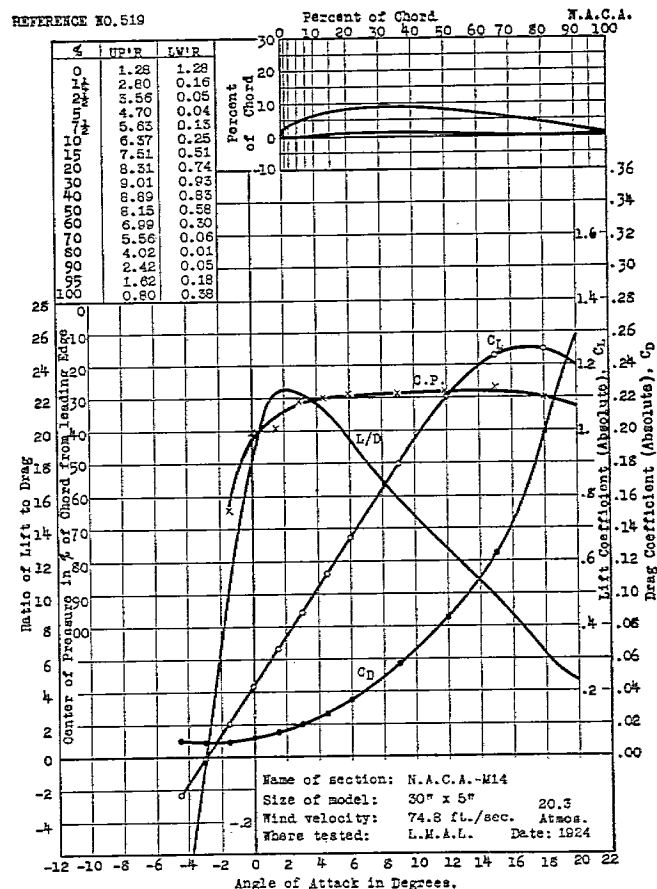
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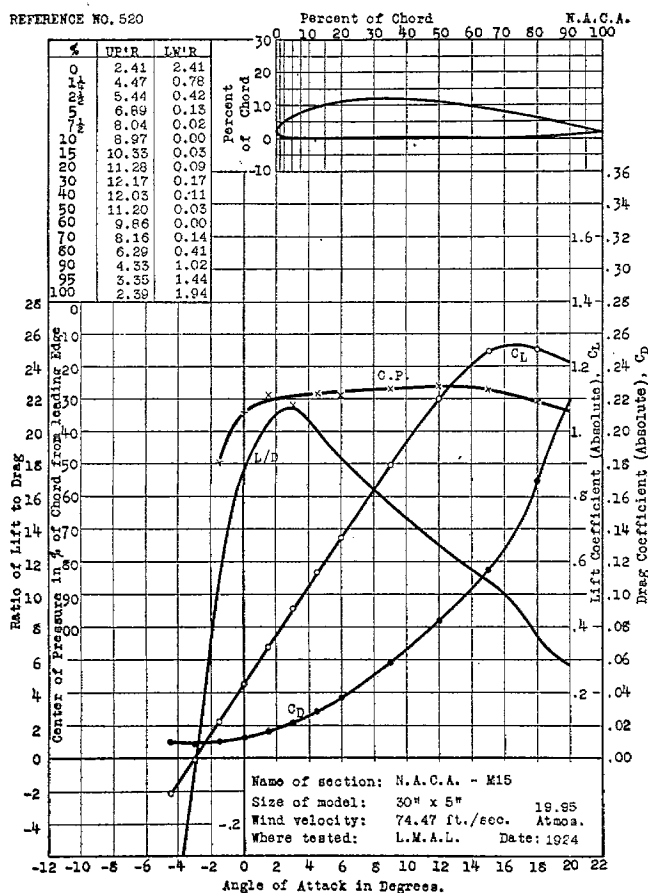
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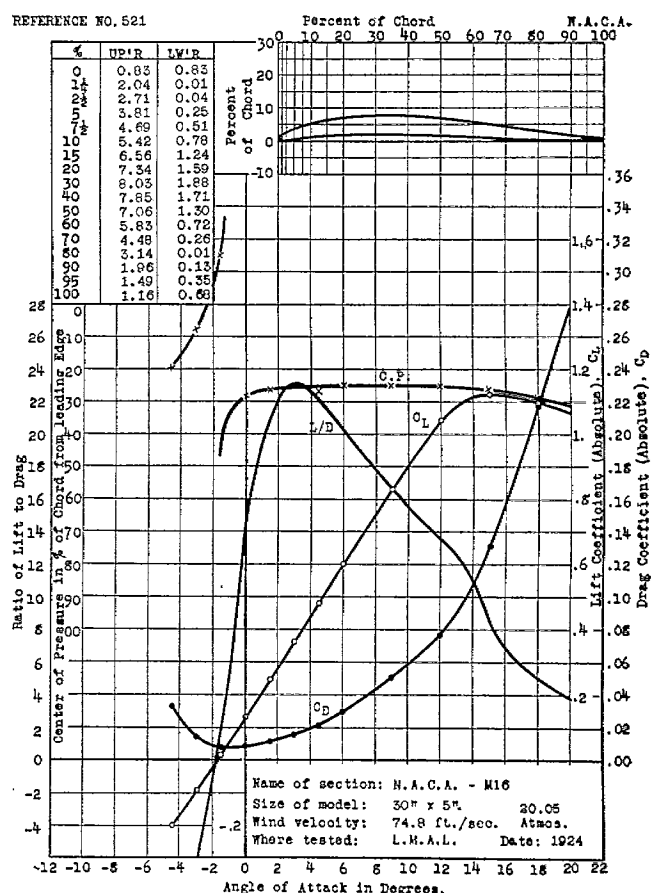
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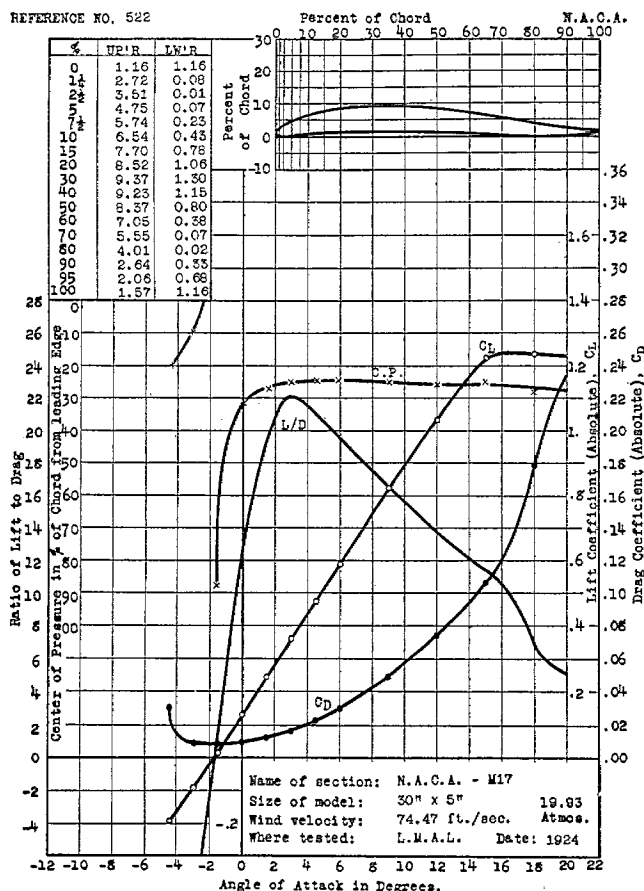
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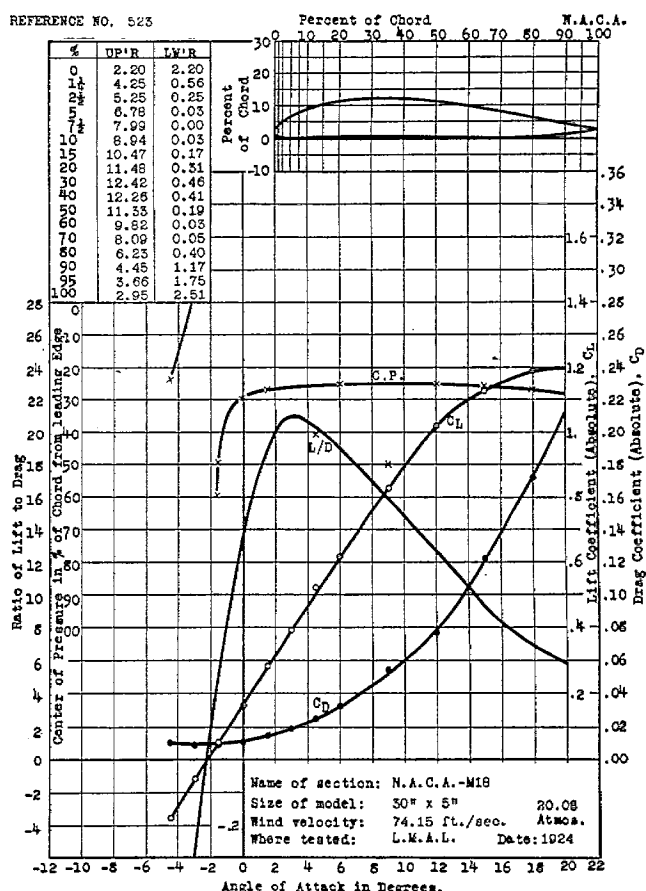
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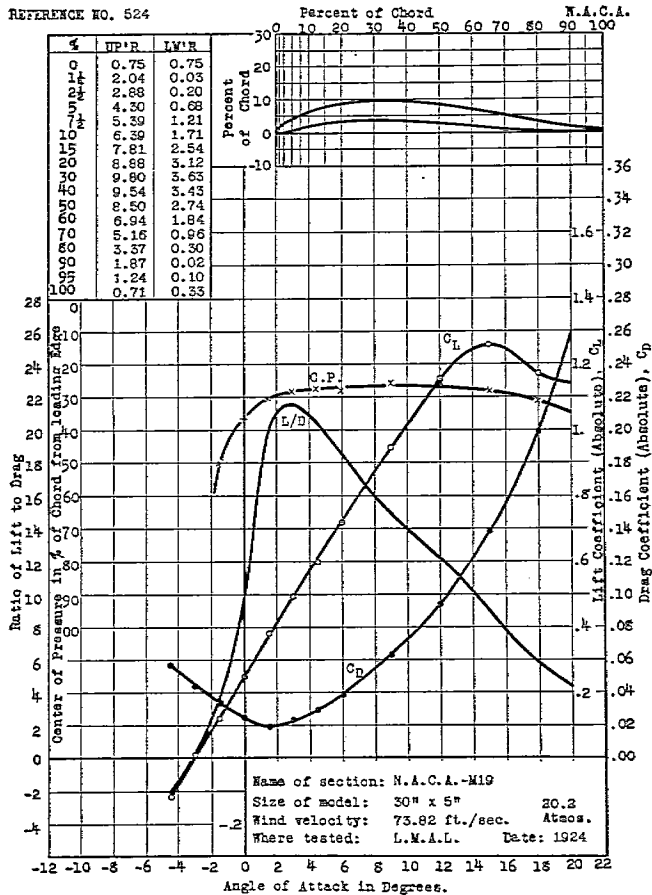
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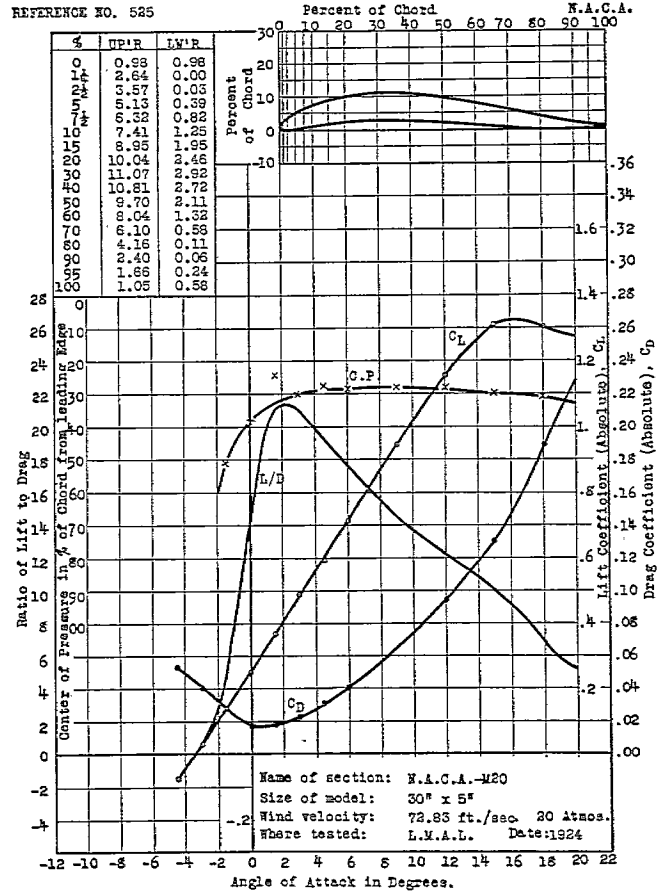
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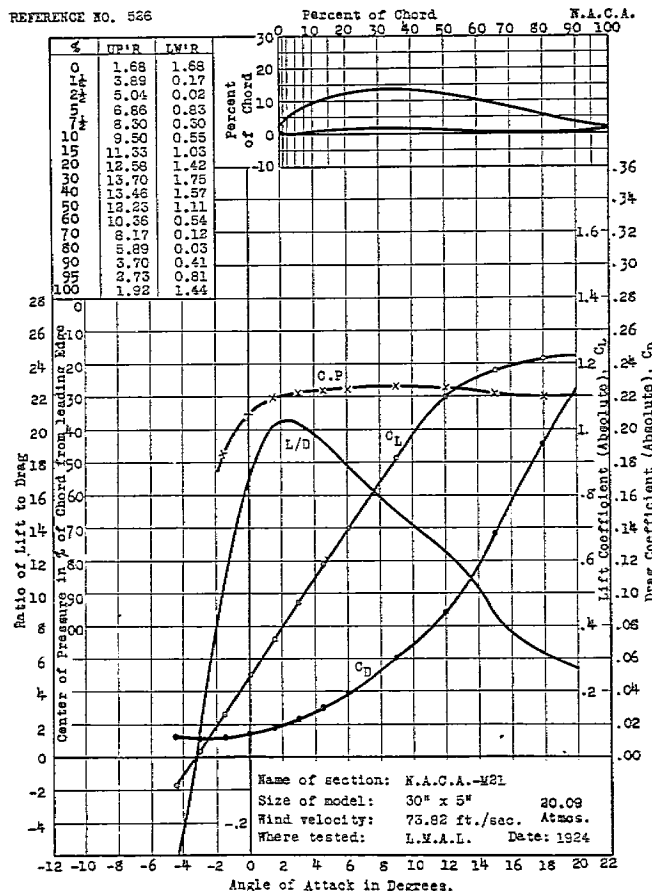
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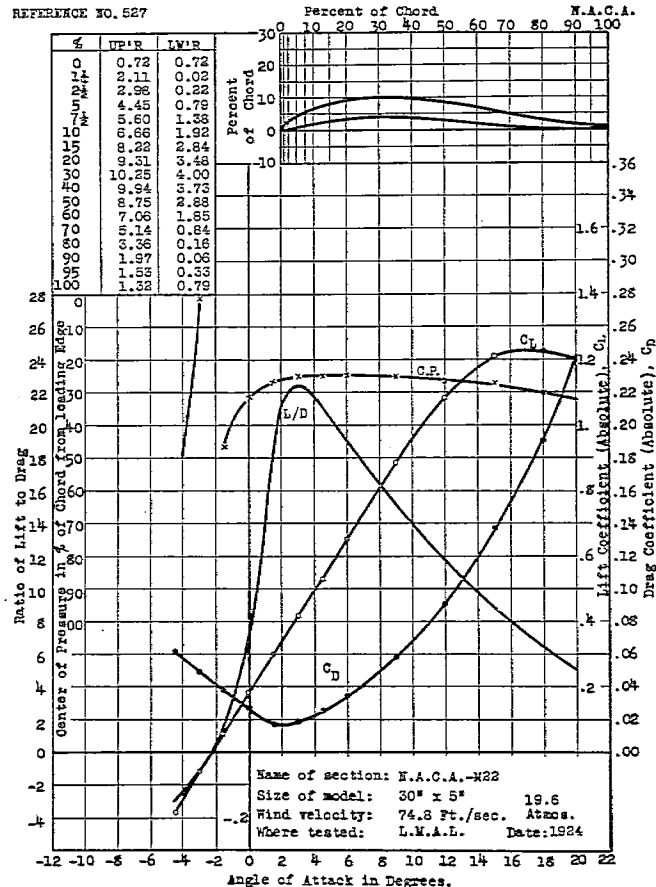
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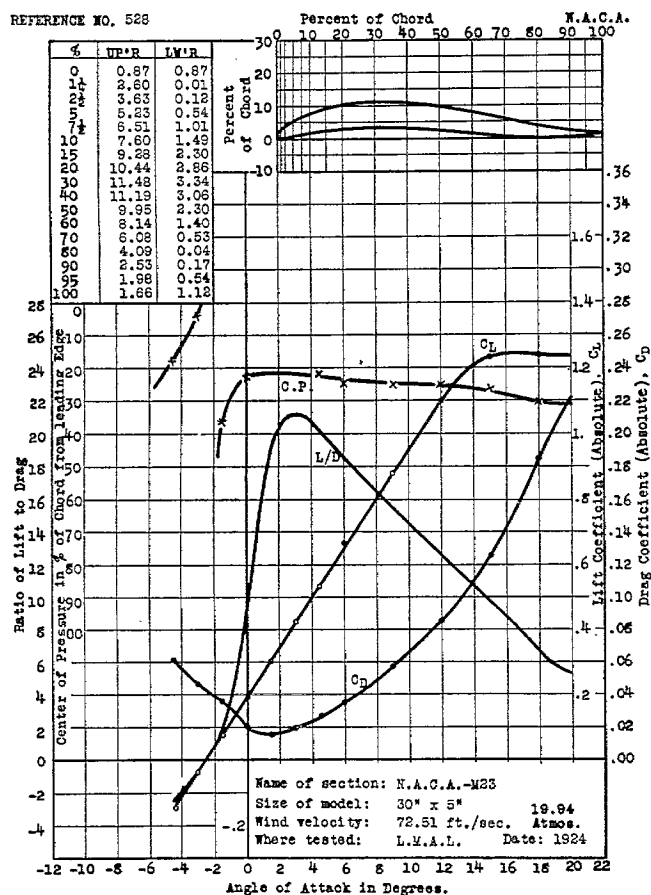
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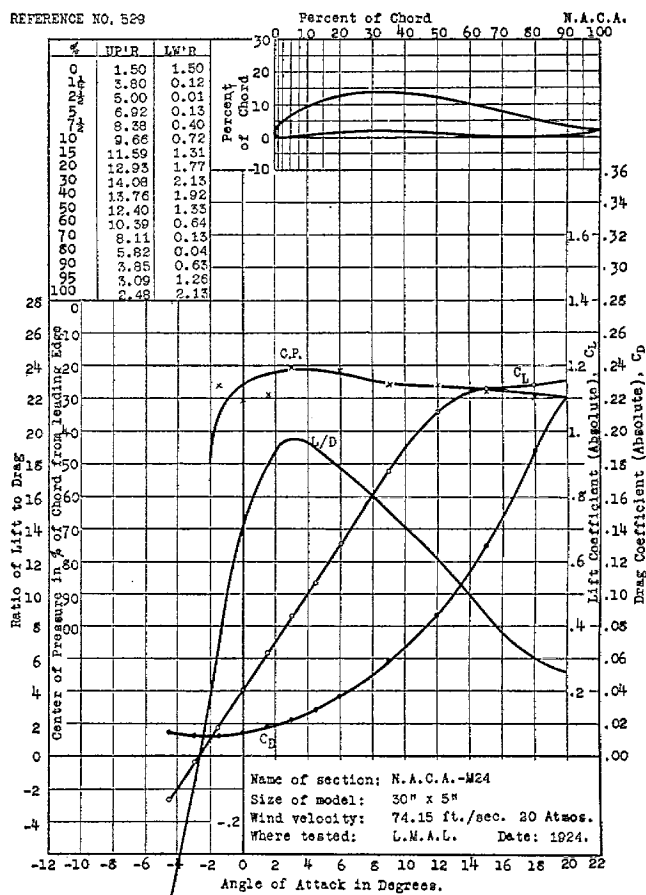
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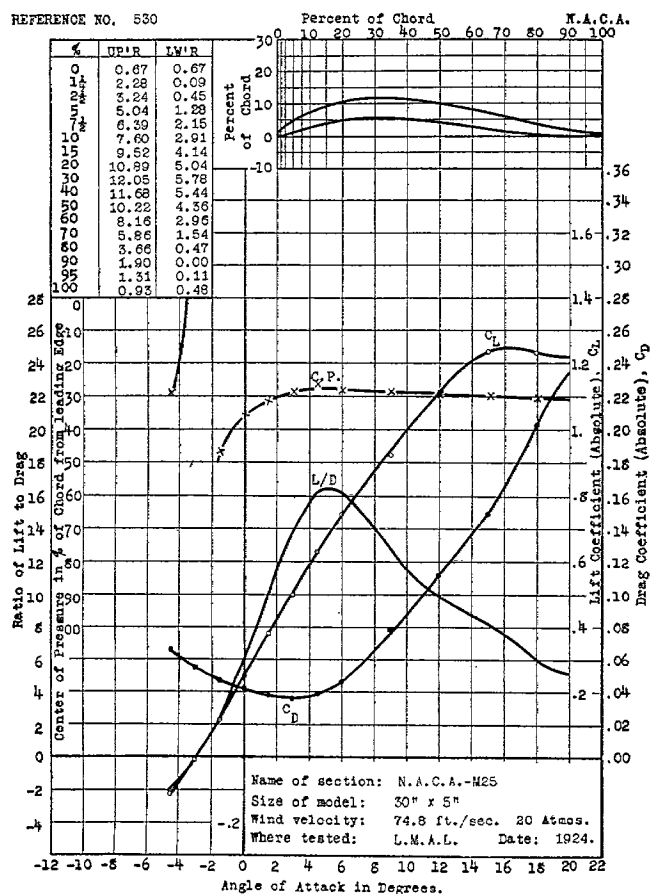
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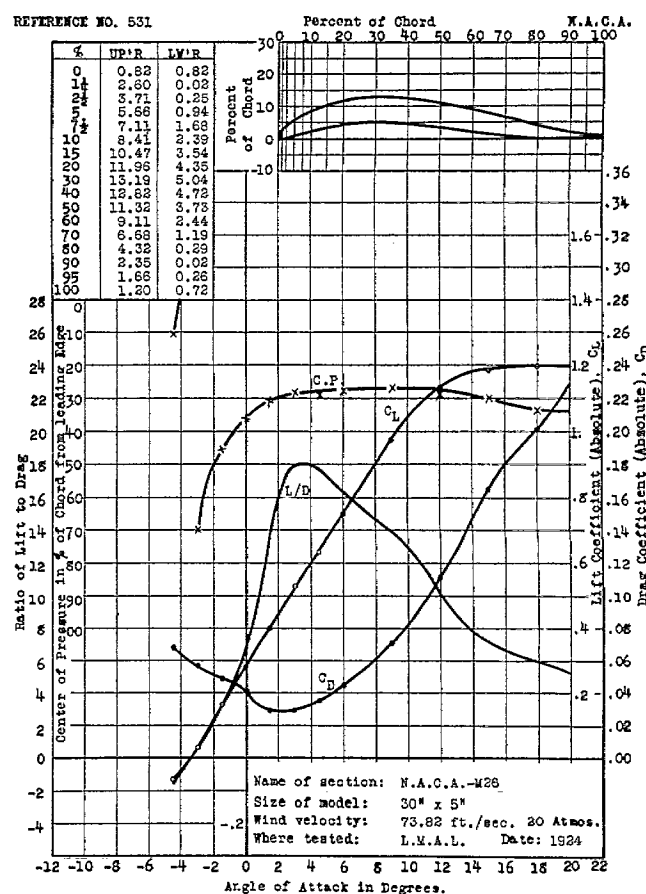
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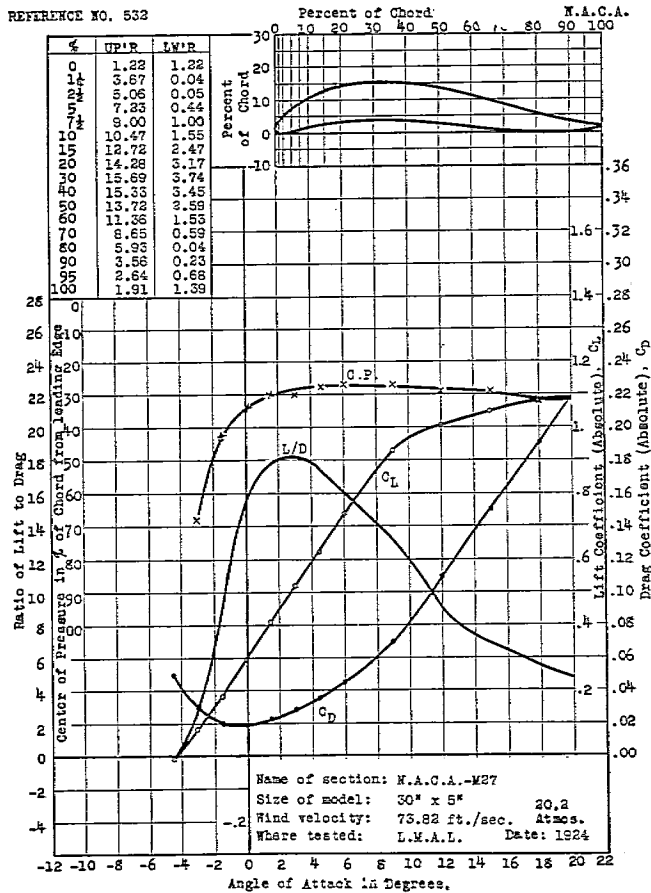
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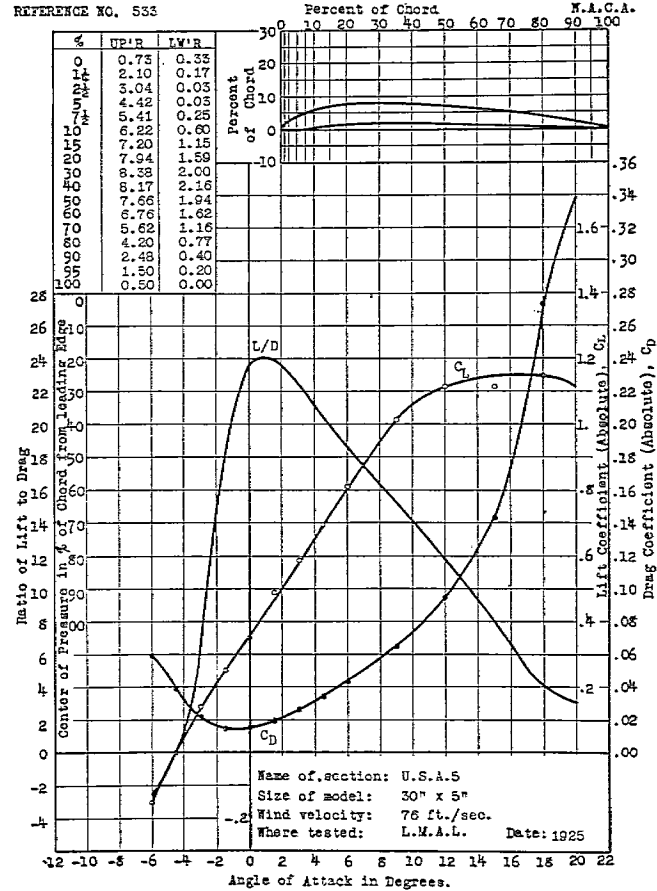
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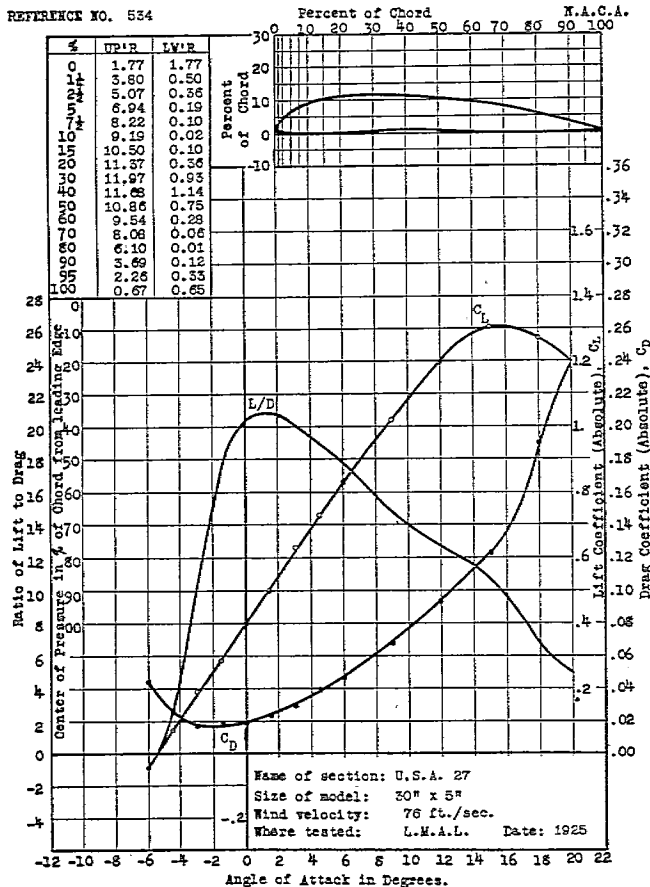
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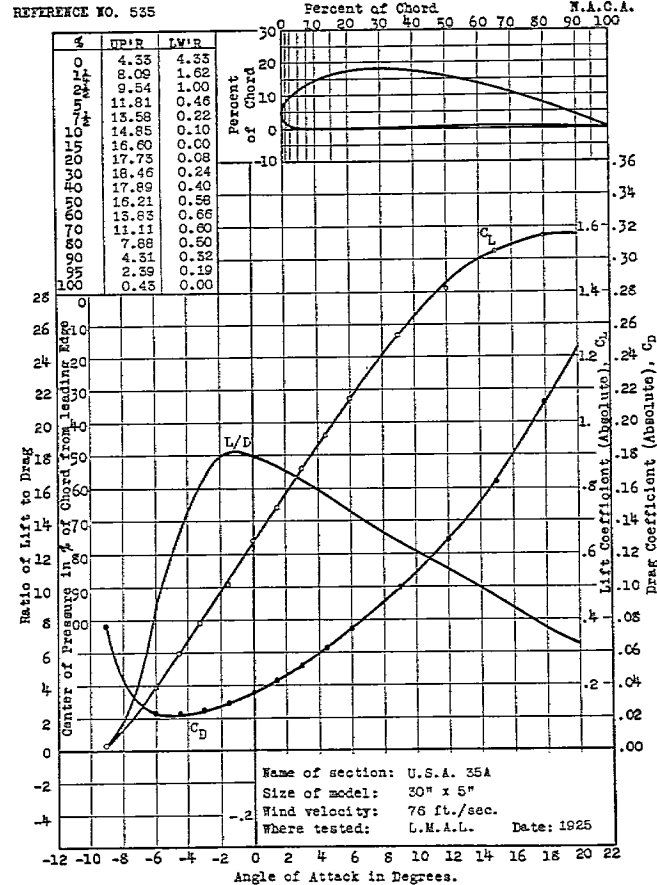
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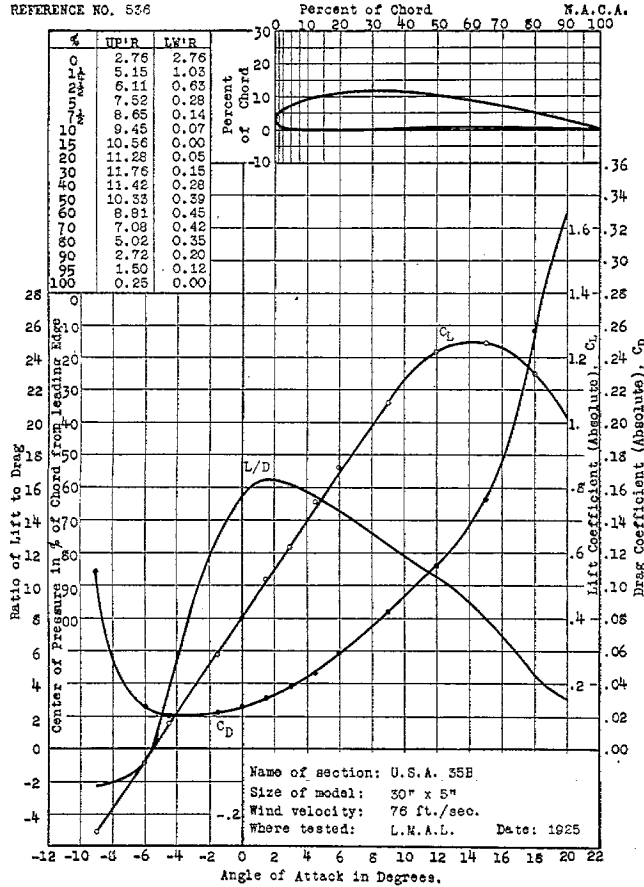
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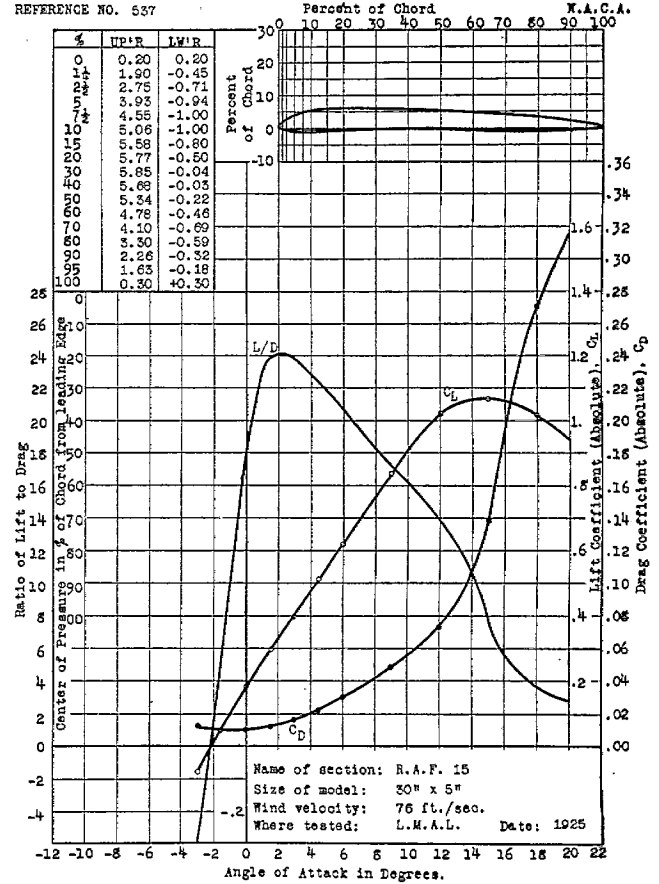
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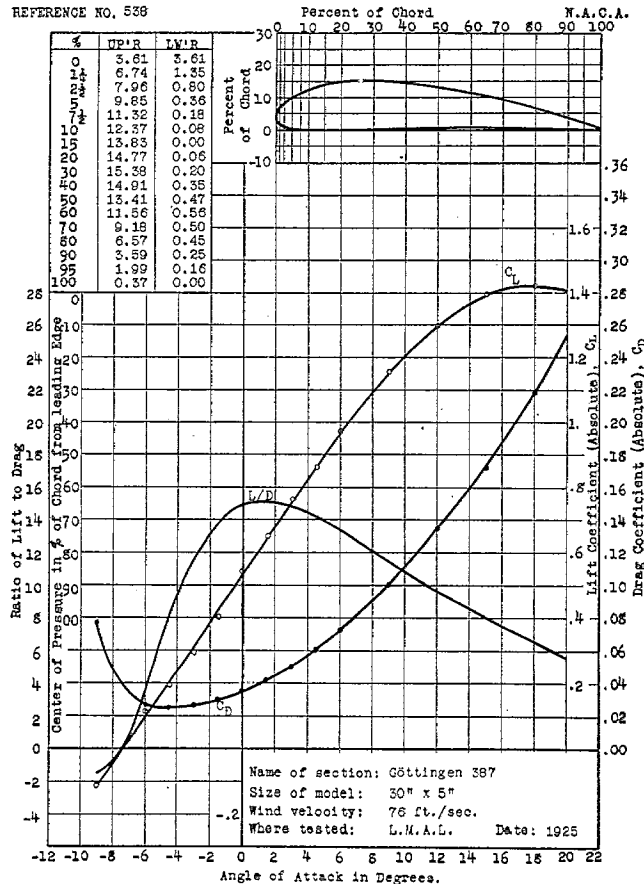
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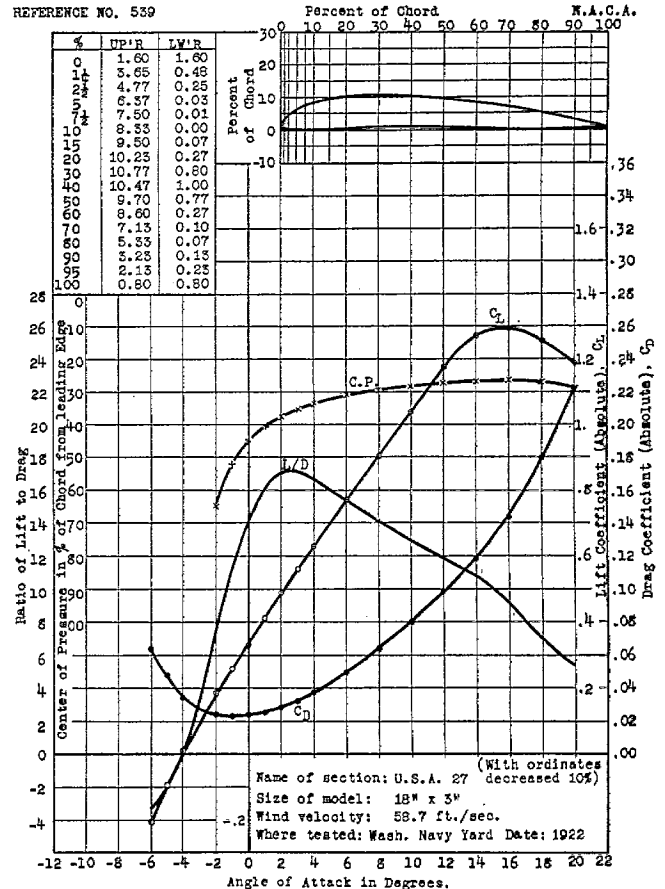
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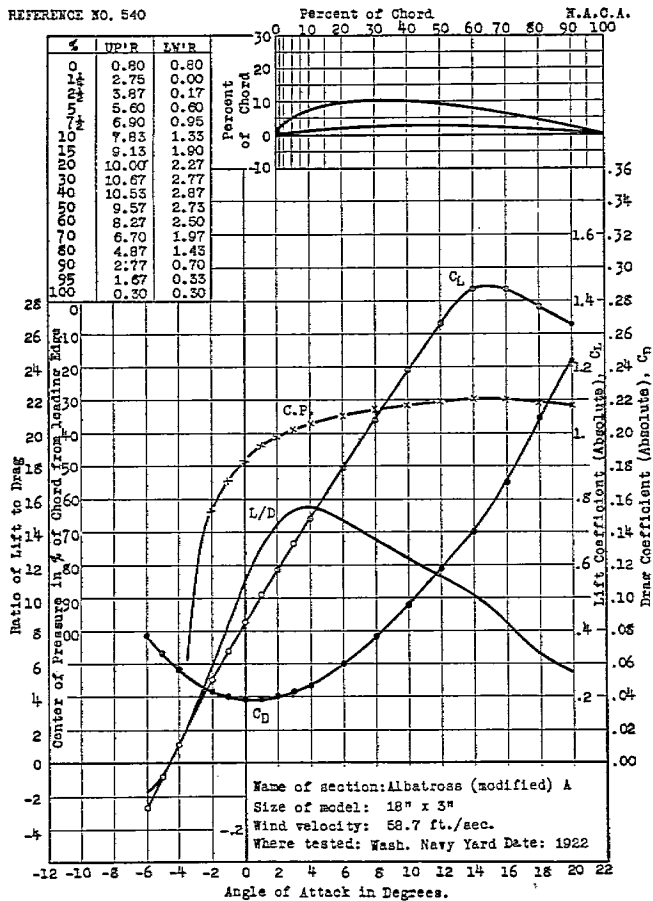
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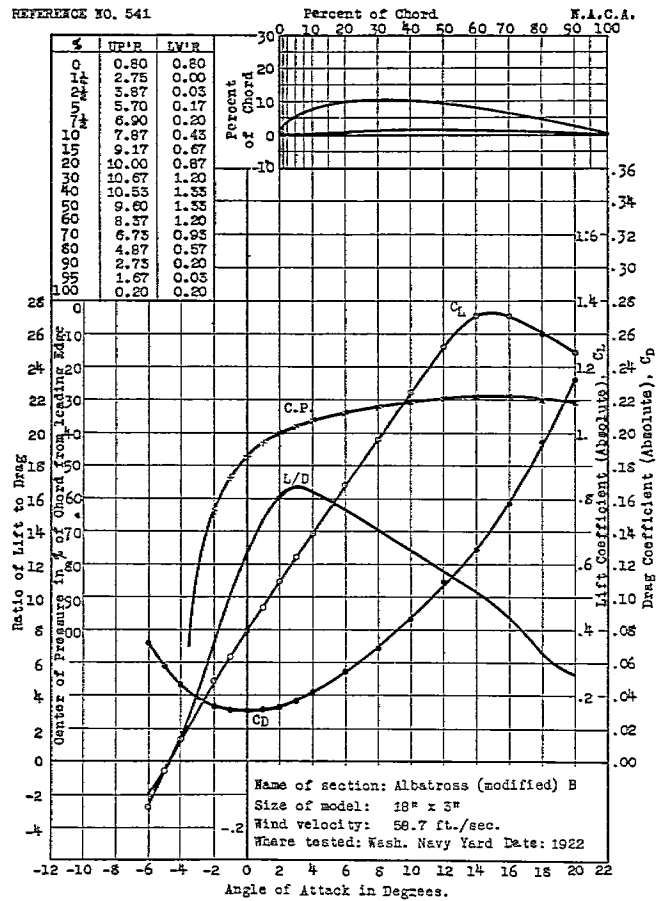
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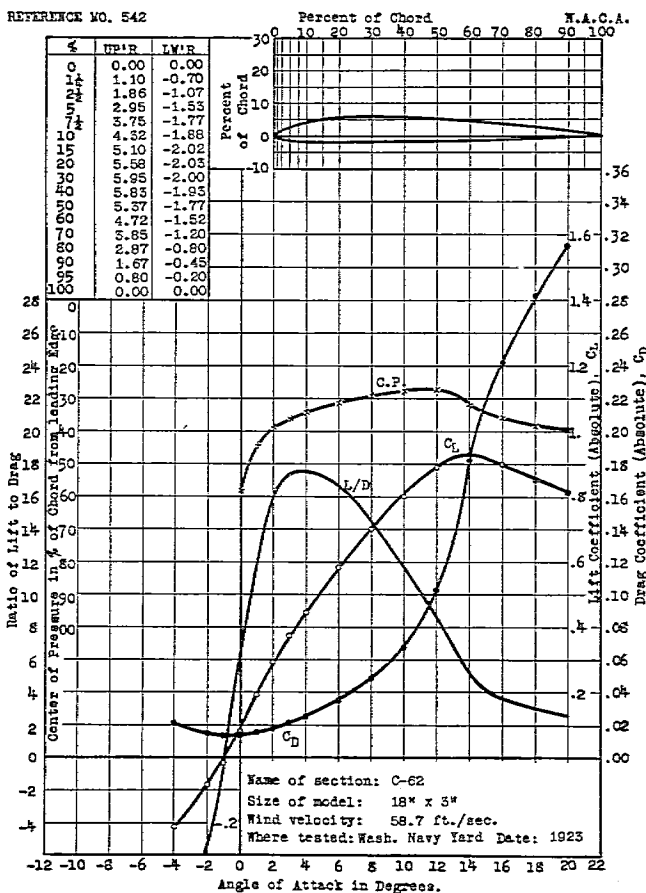
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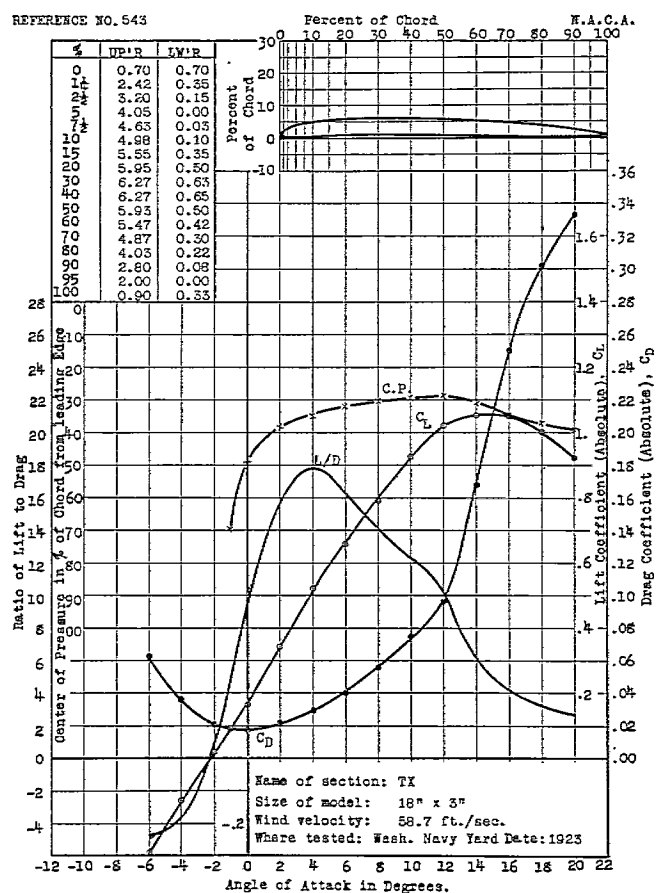
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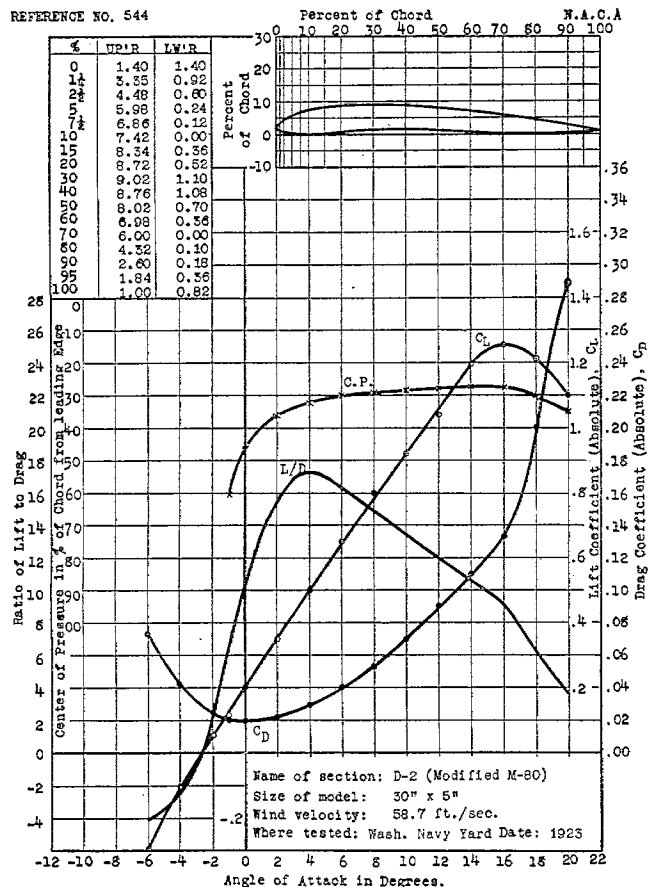
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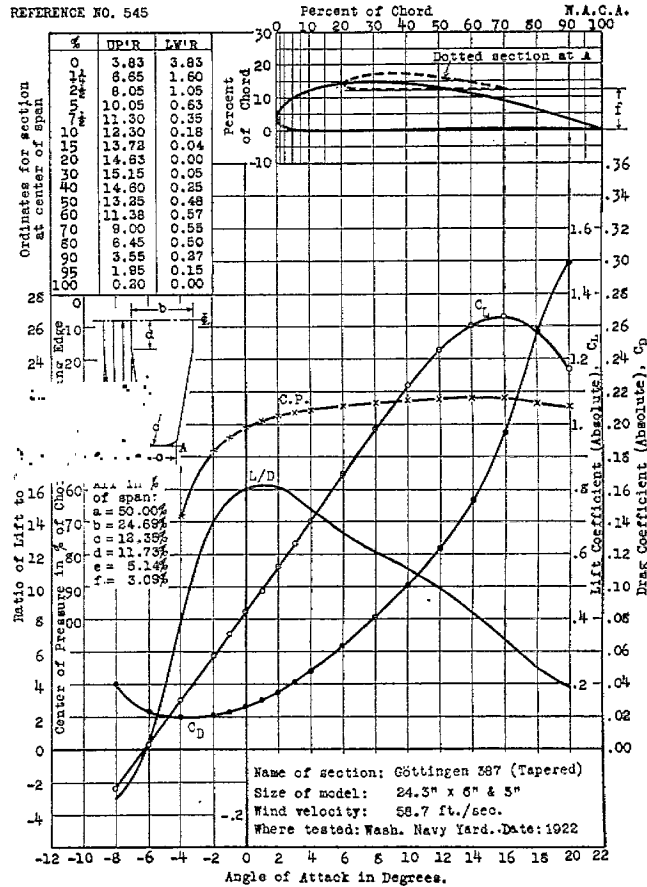
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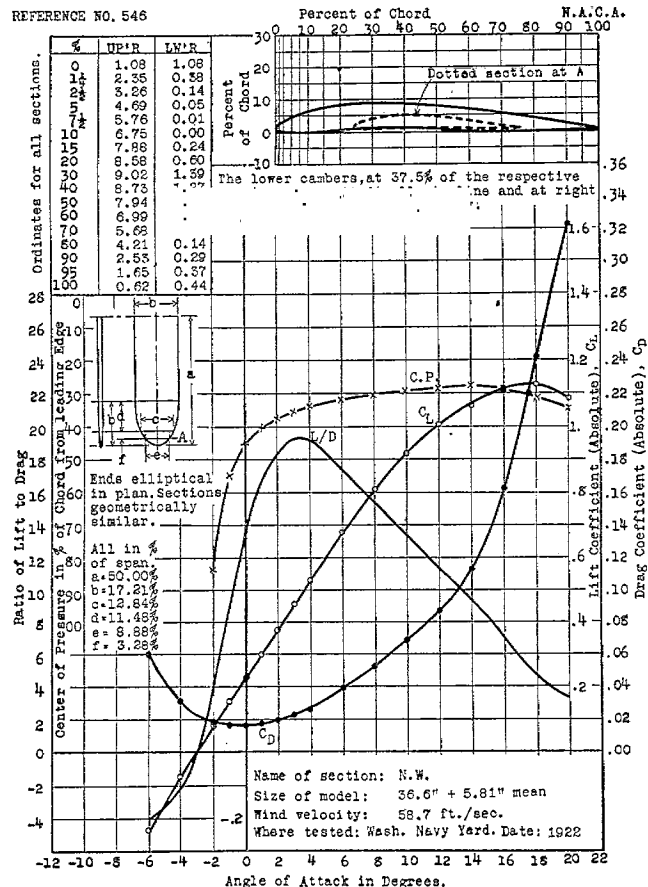
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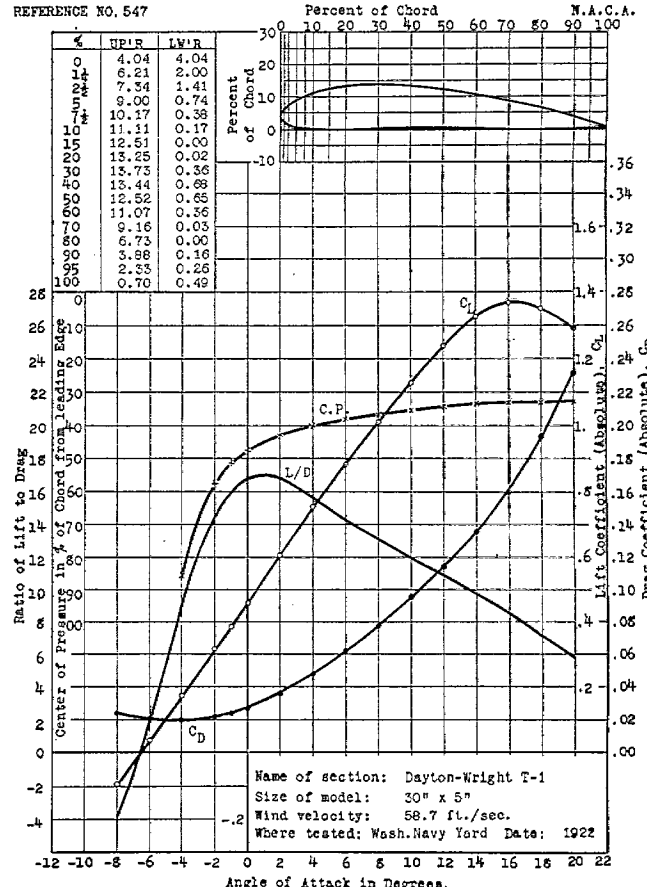
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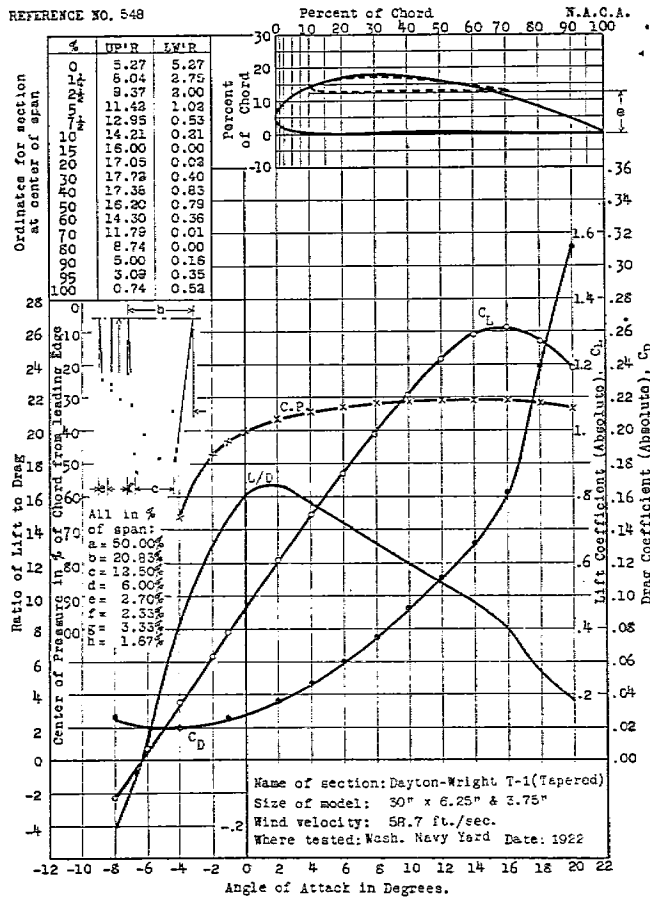
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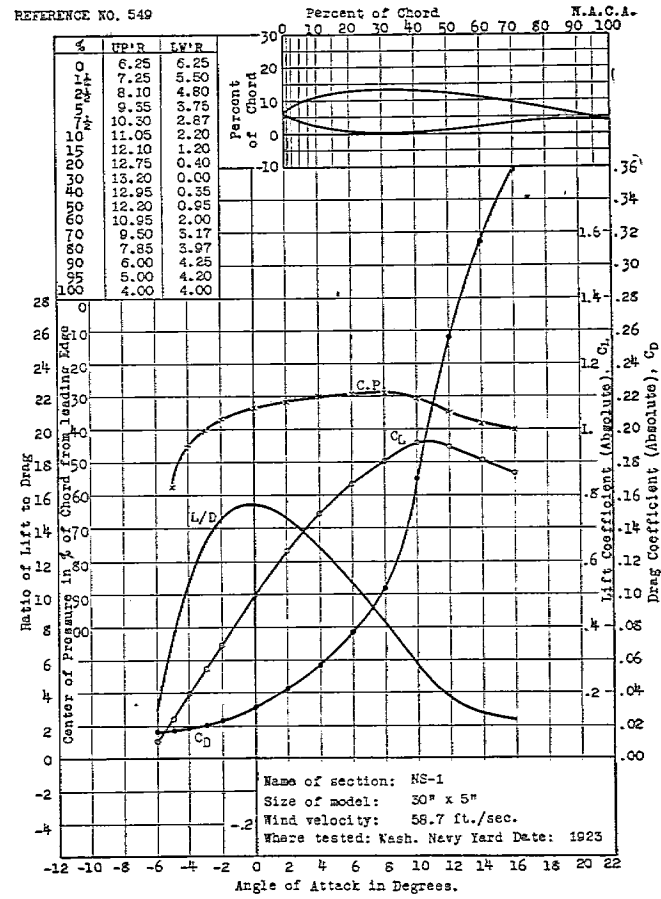
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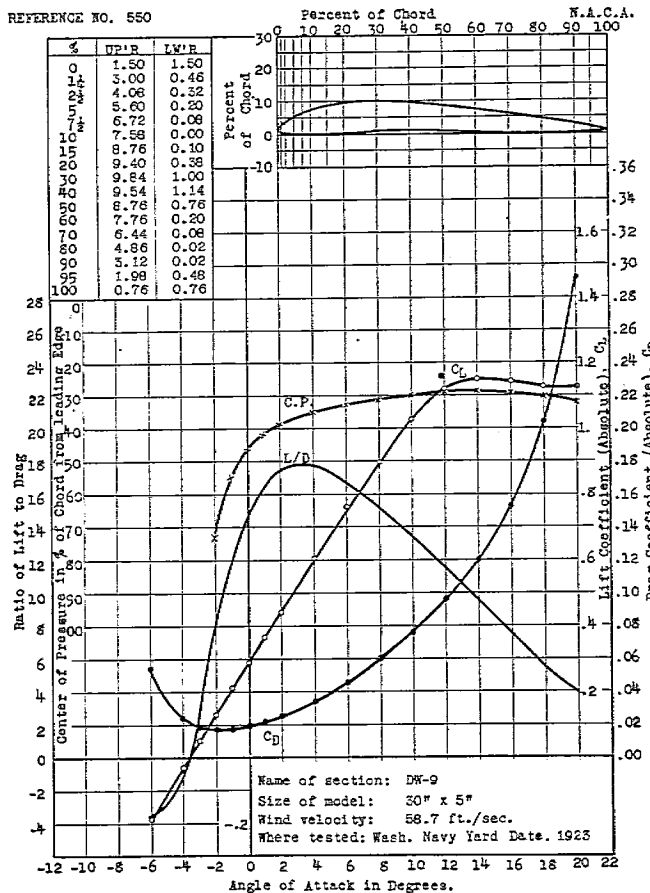
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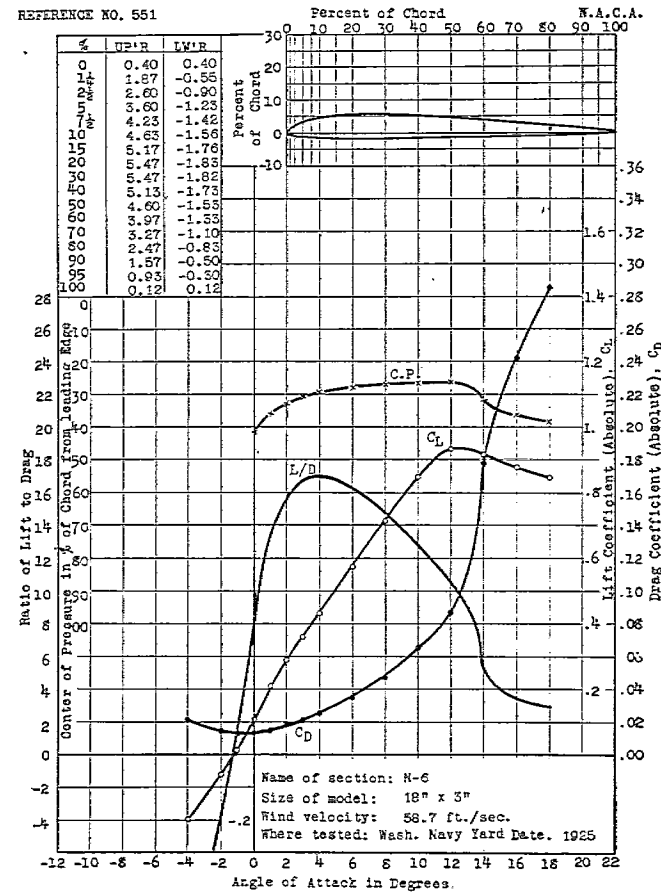
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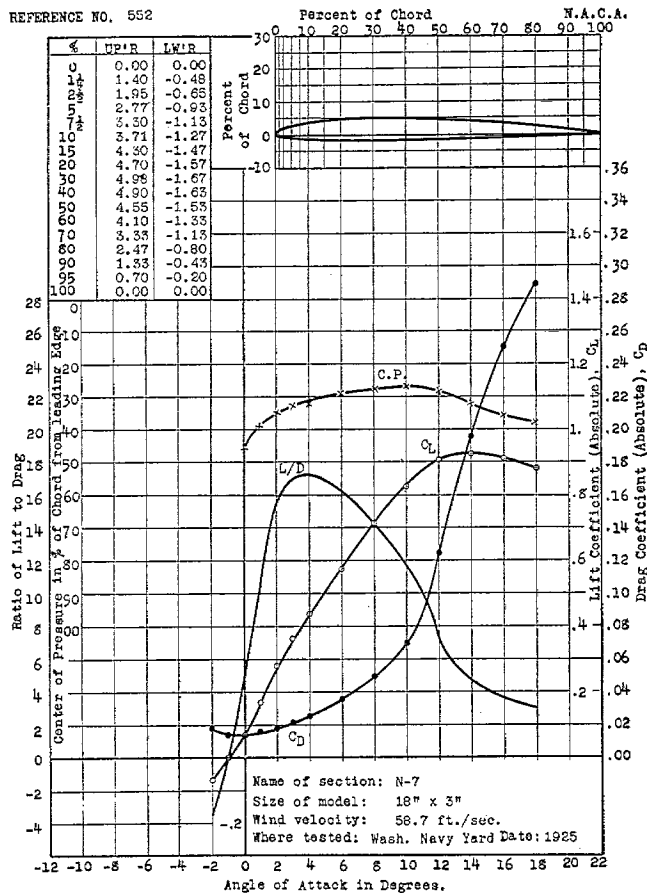
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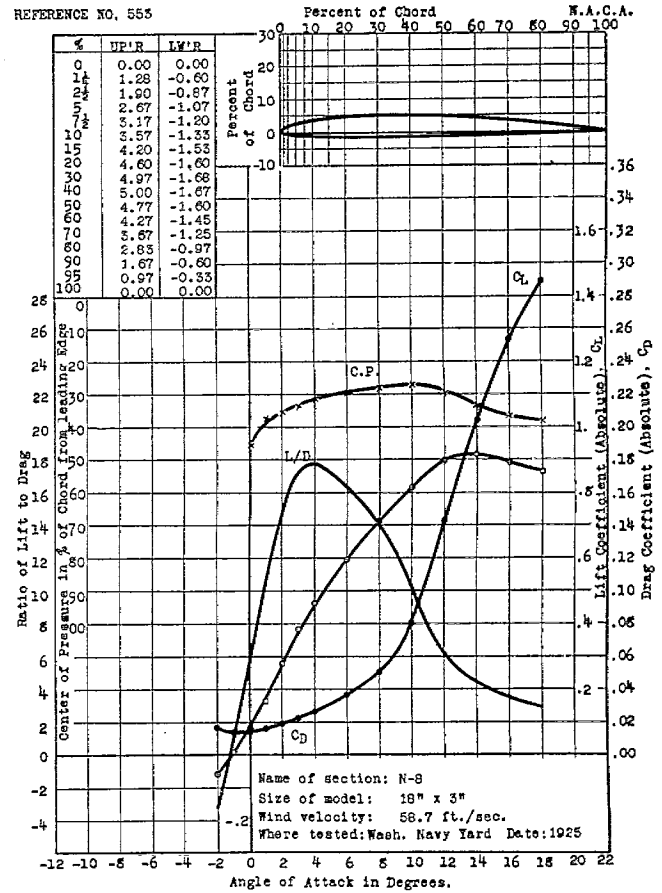
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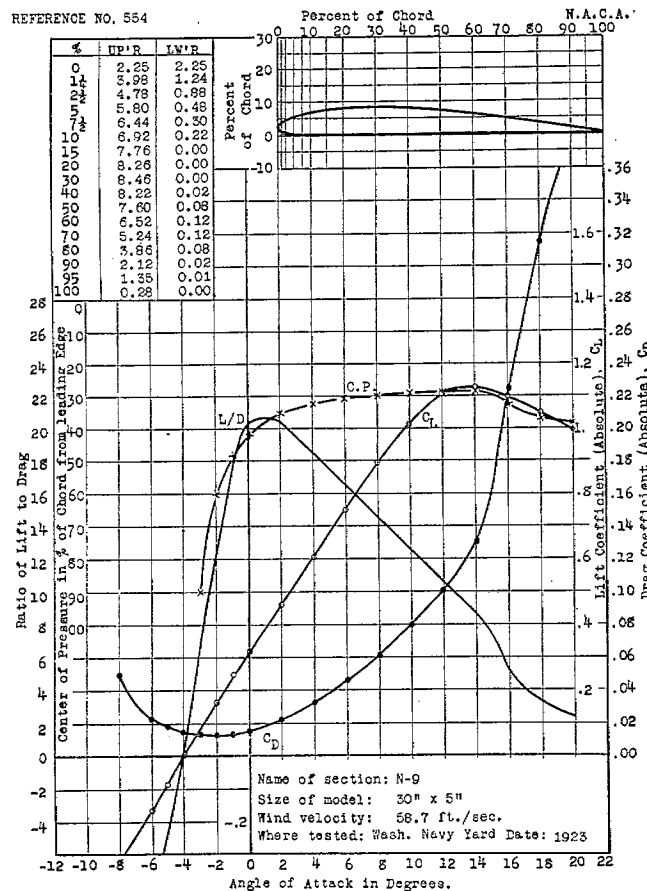
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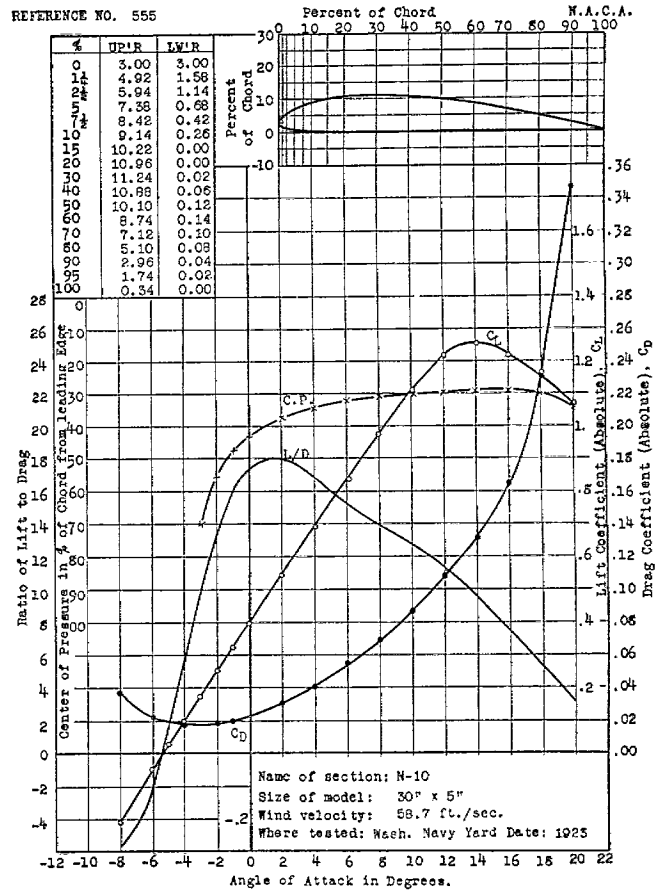
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REFERENCE NO. 554



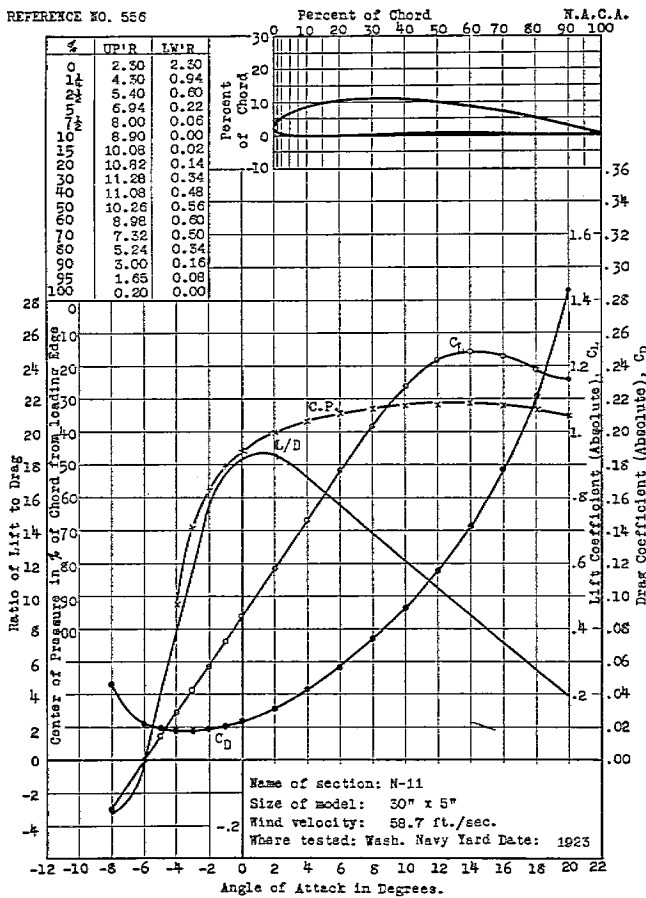
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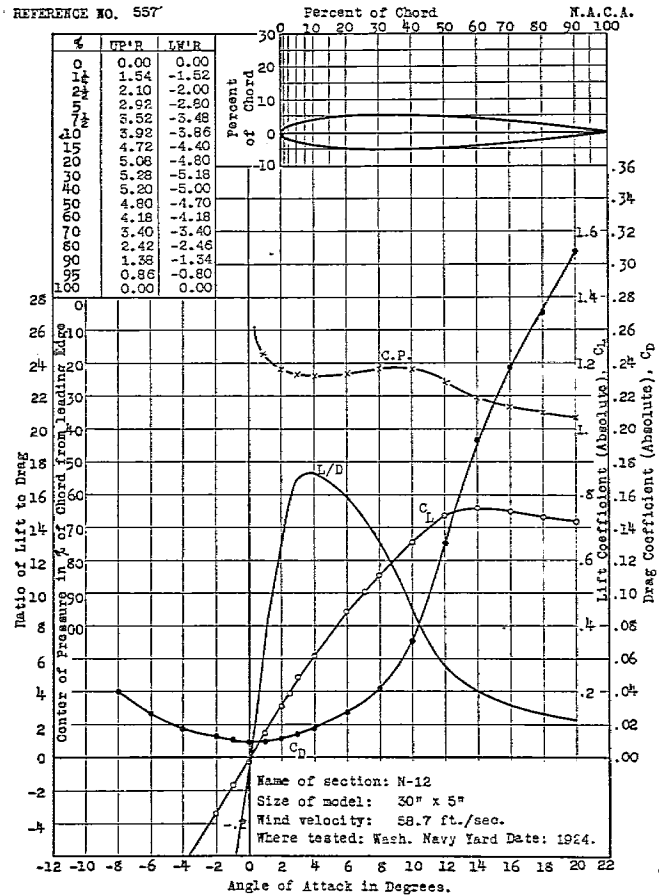
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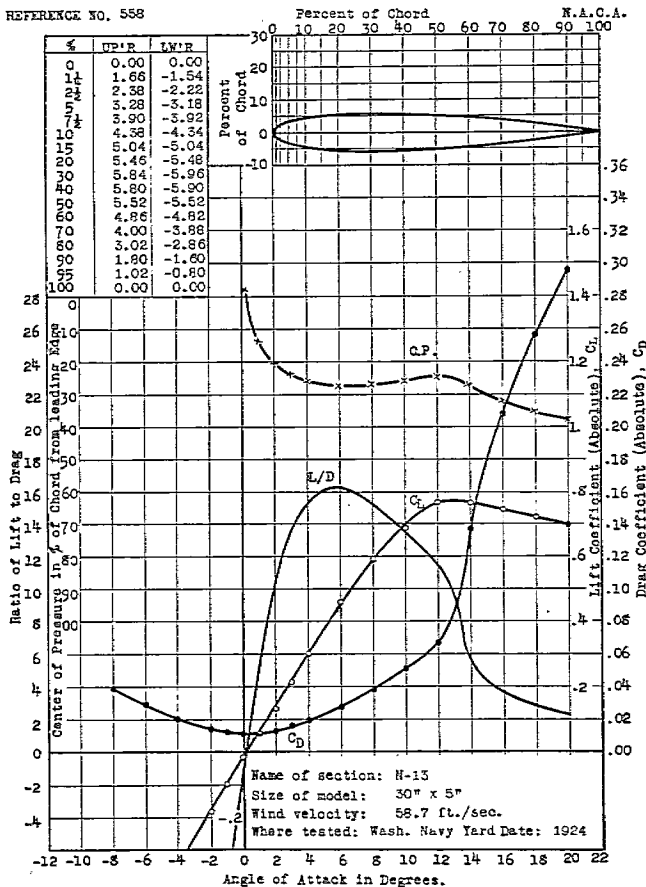
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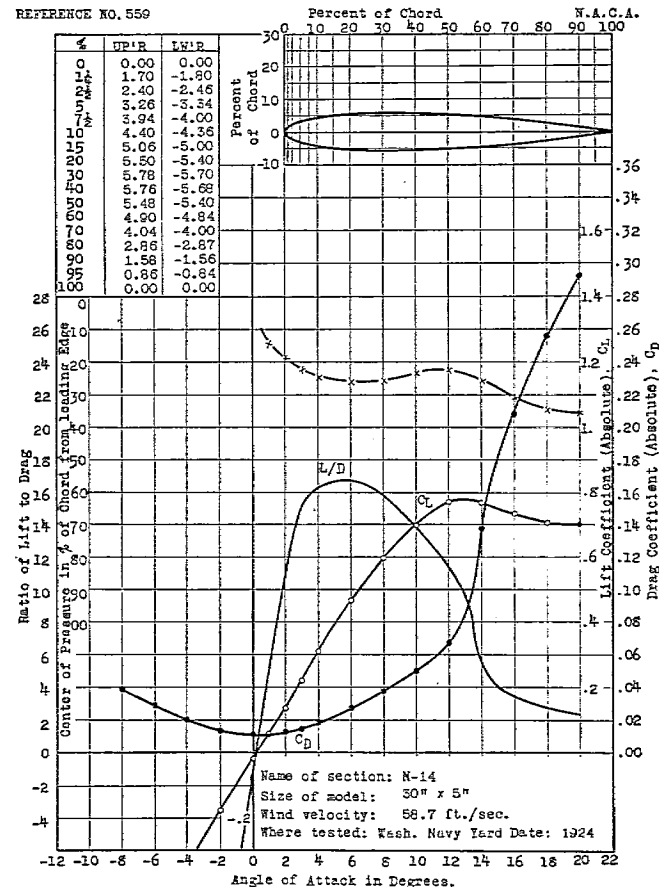
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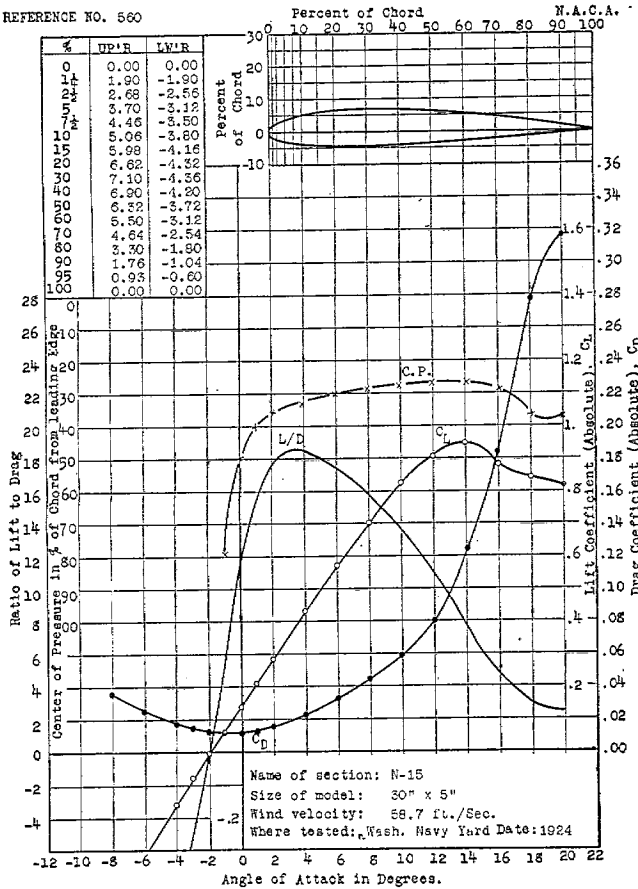
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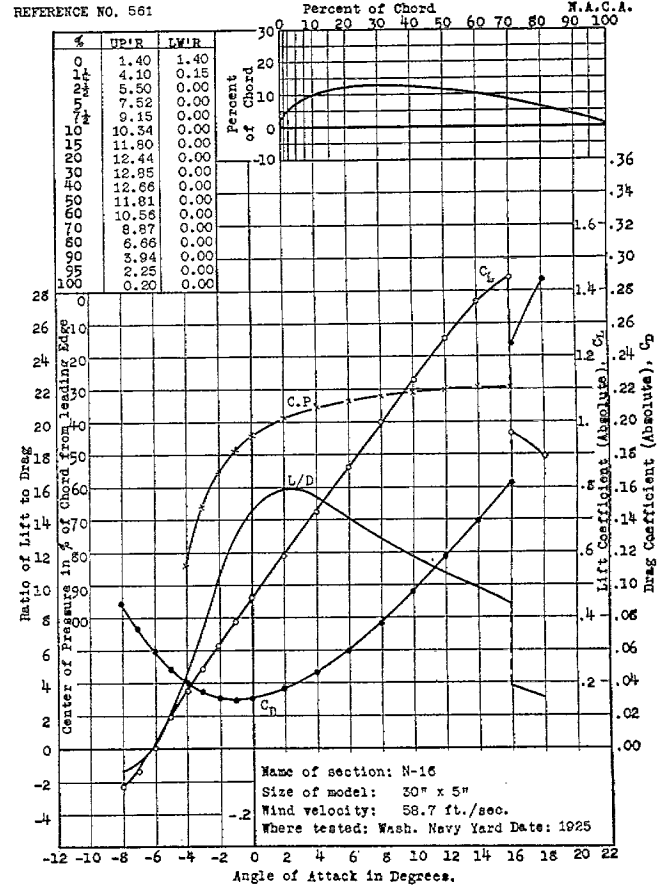
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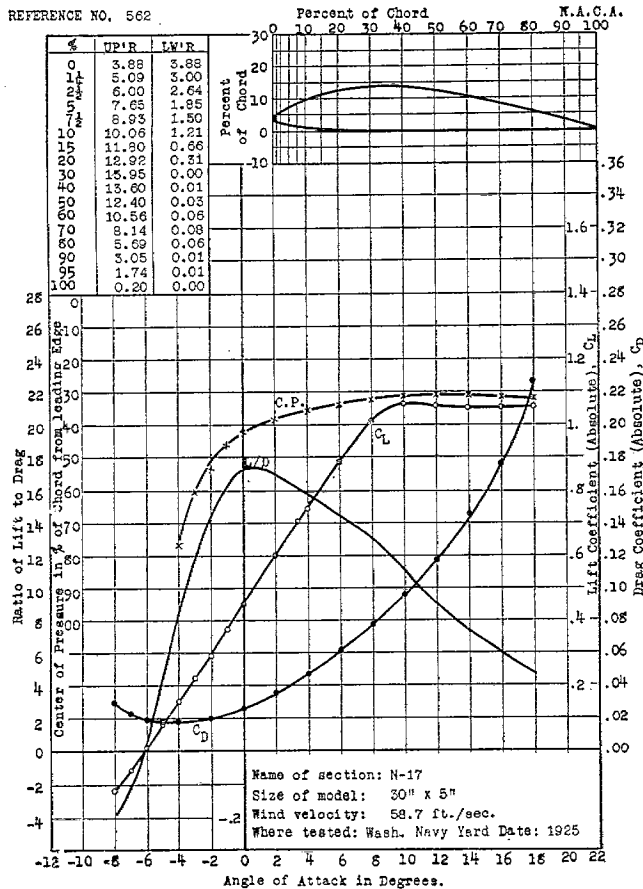
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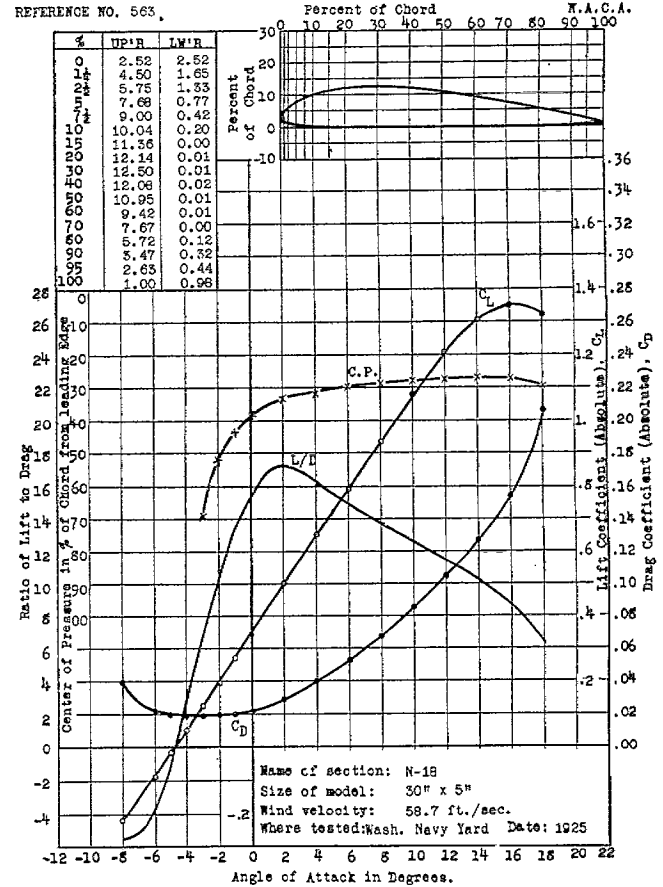
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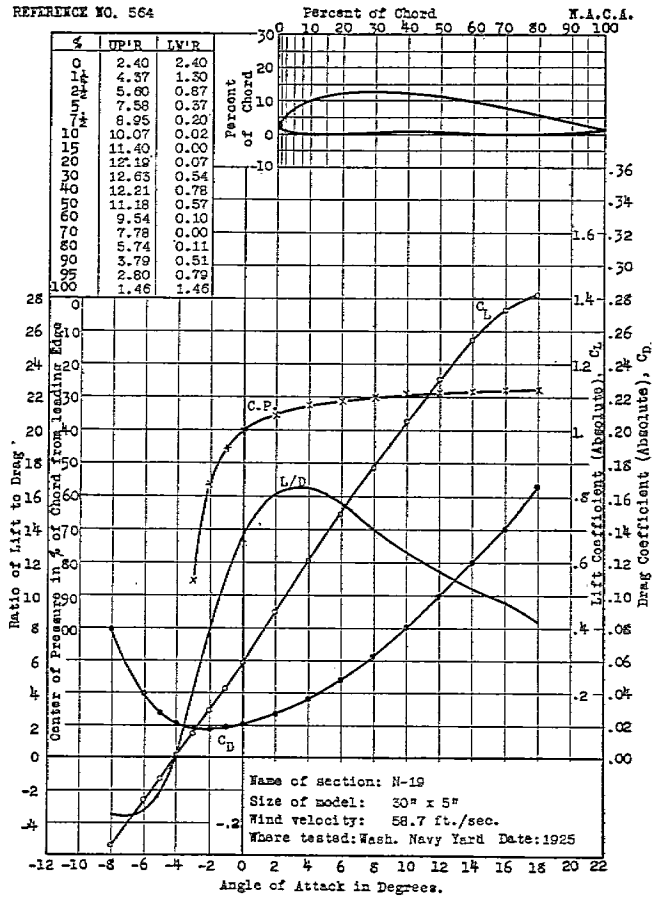
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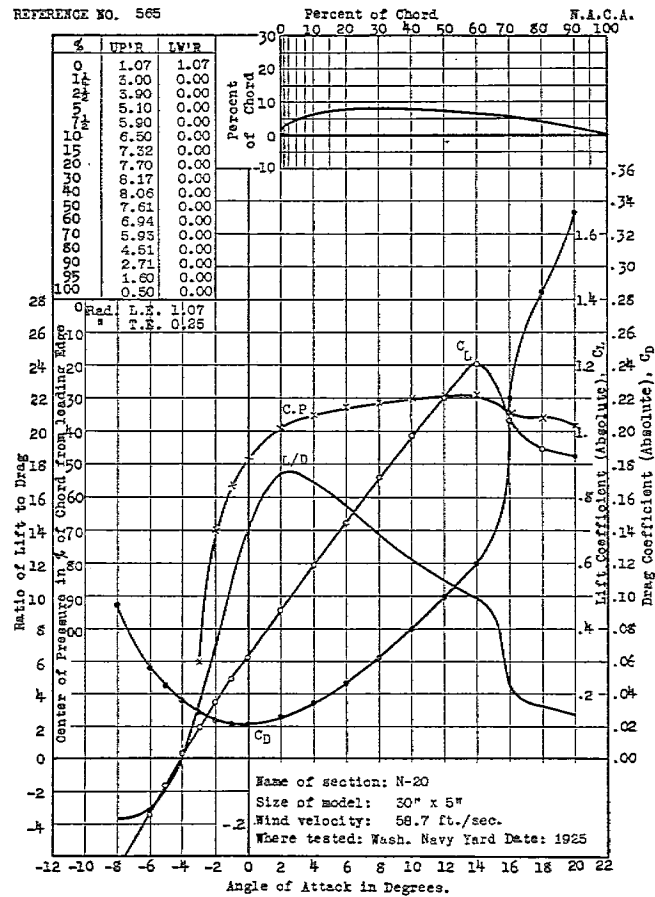
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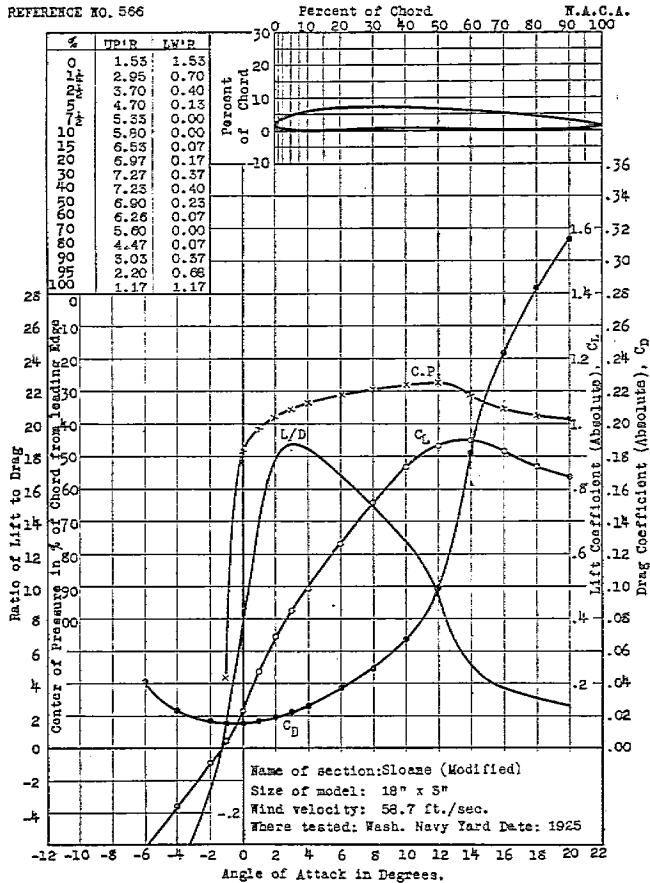
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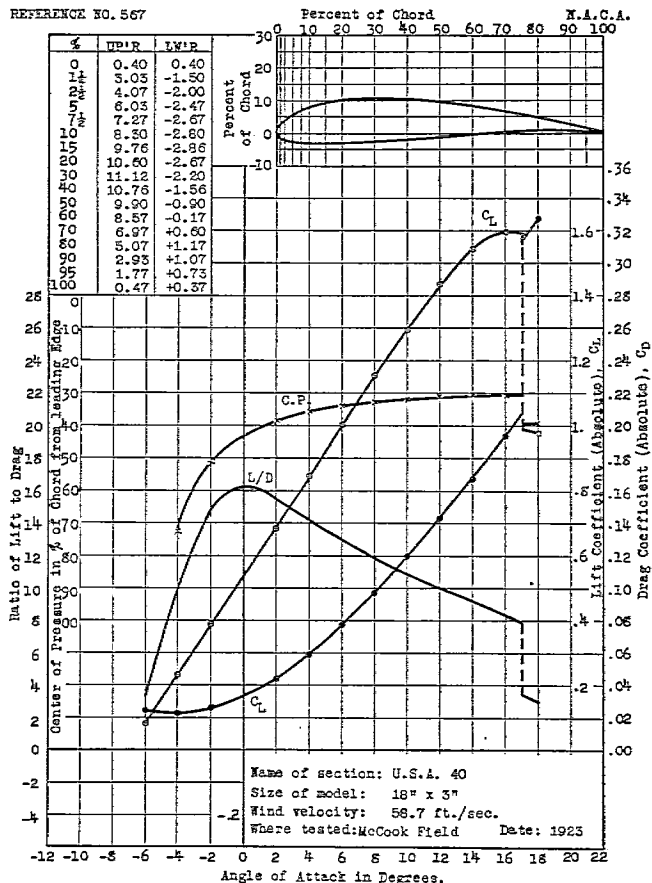
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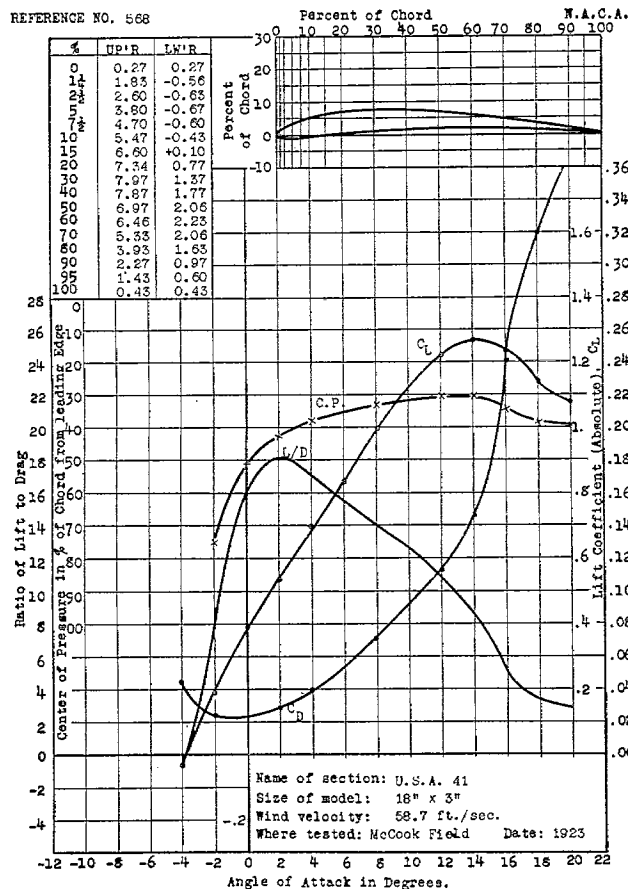
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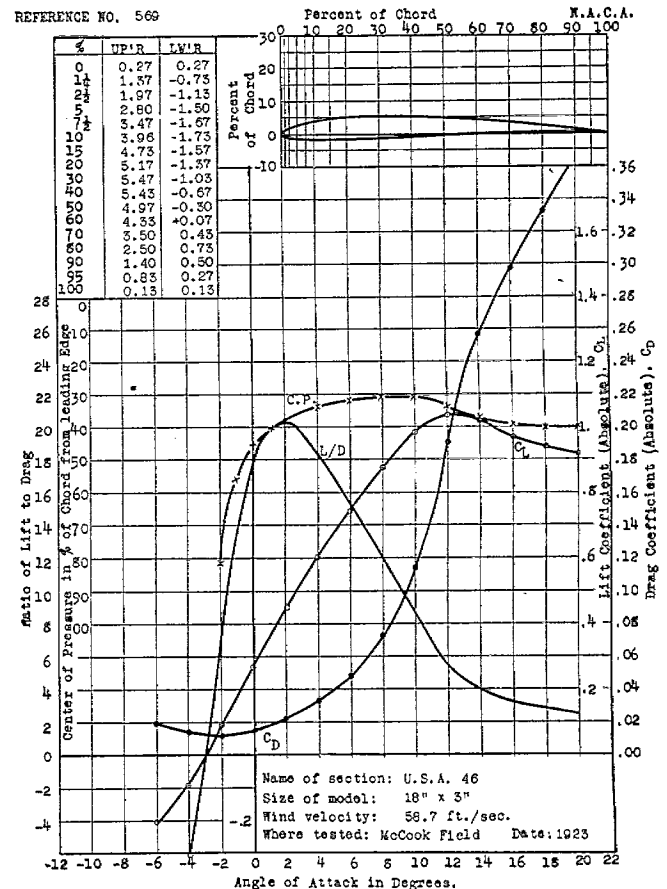
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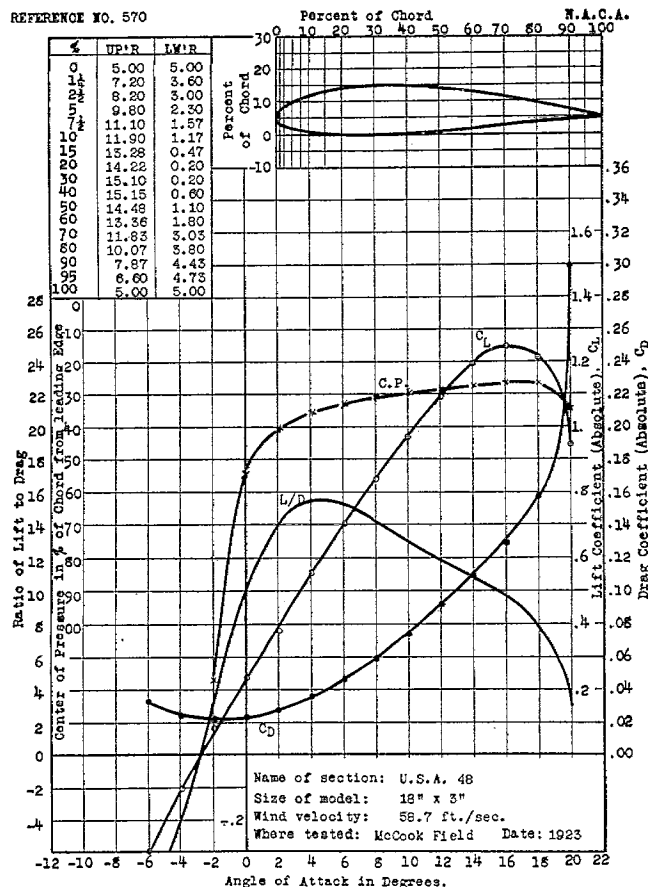
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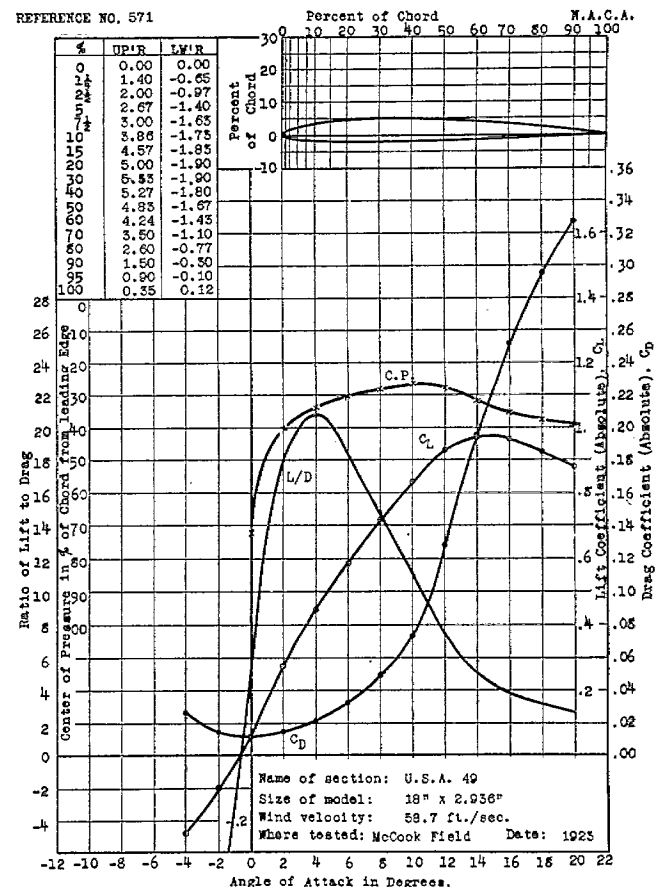
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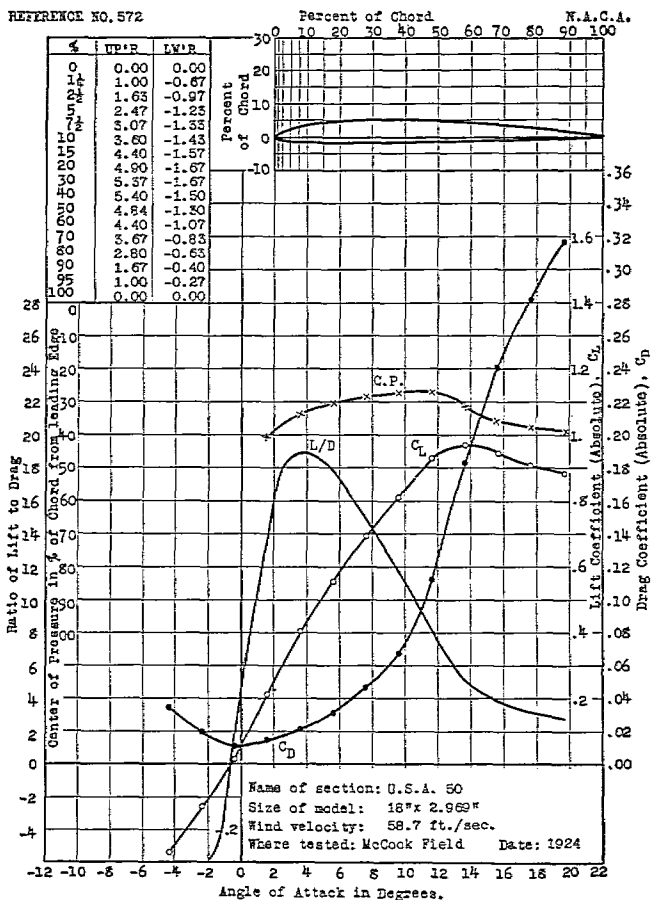
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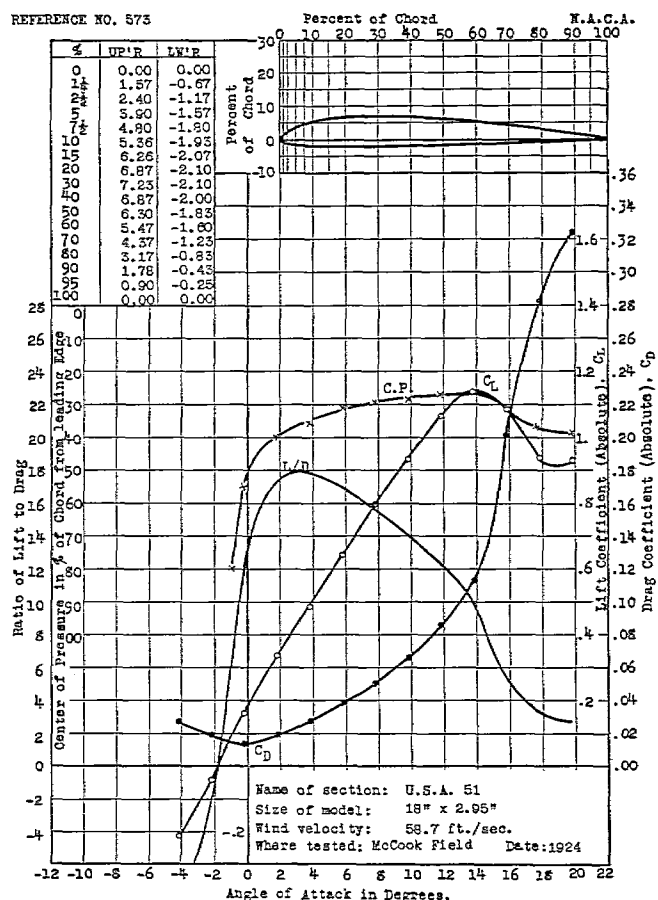
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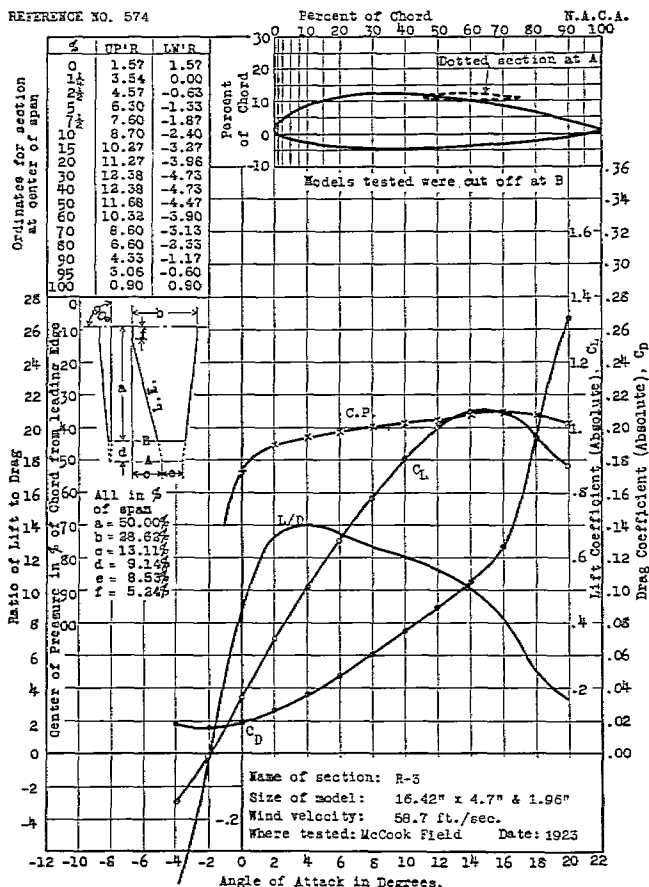
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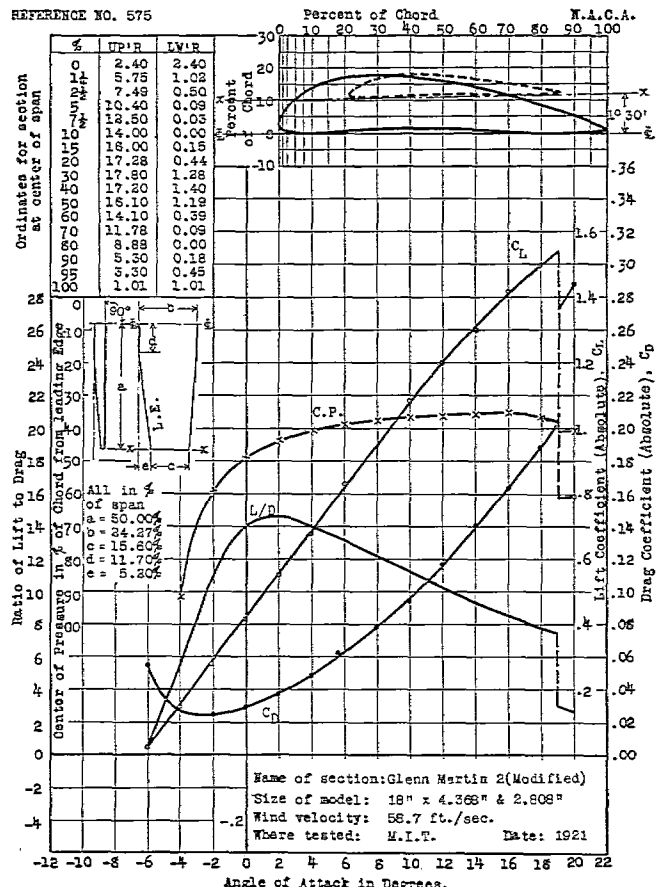
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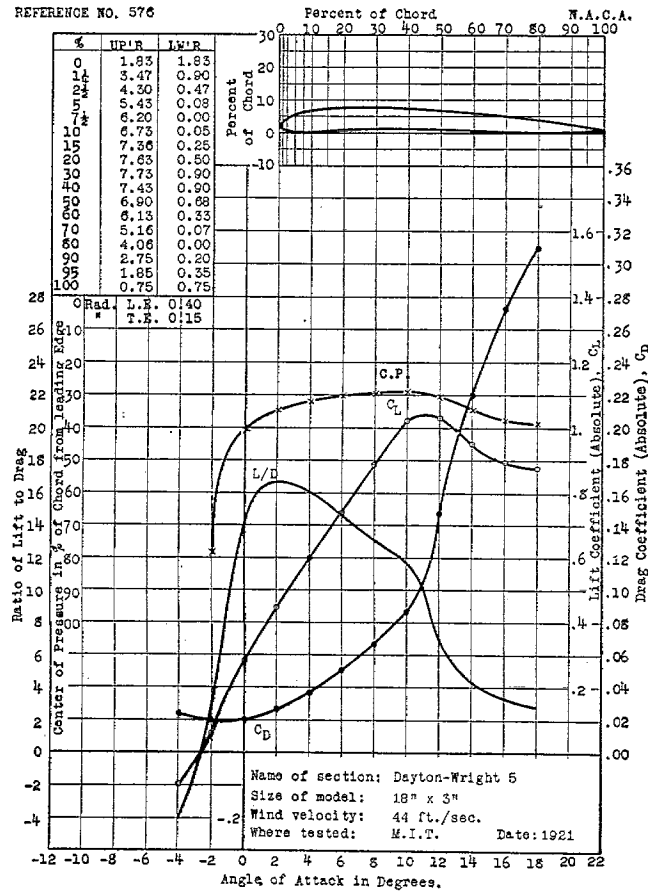
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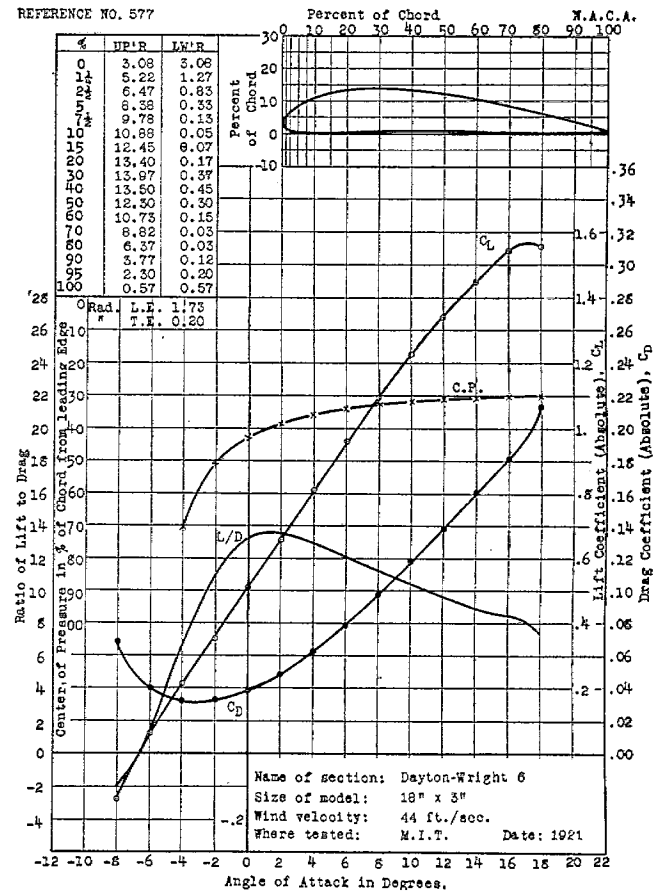
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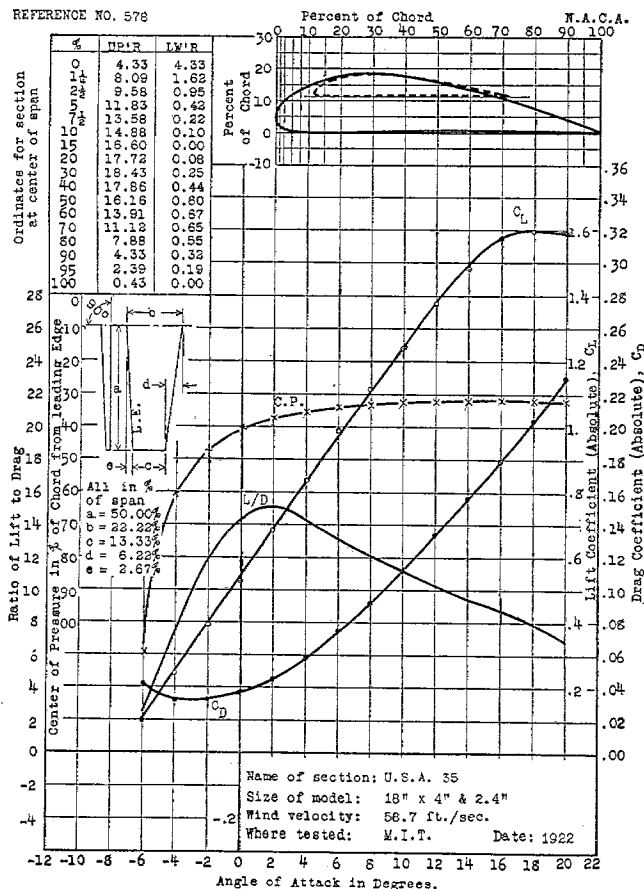
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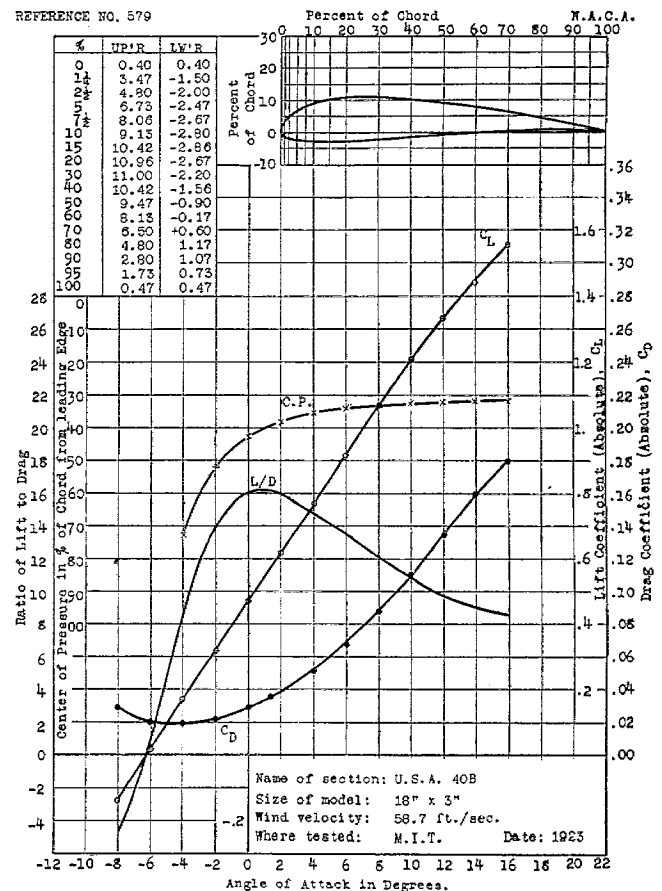
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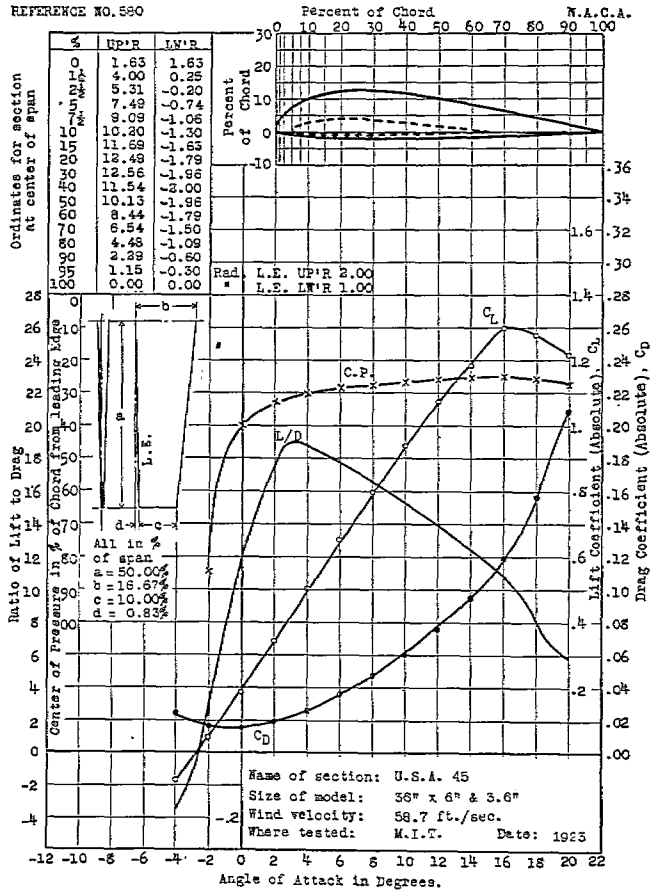
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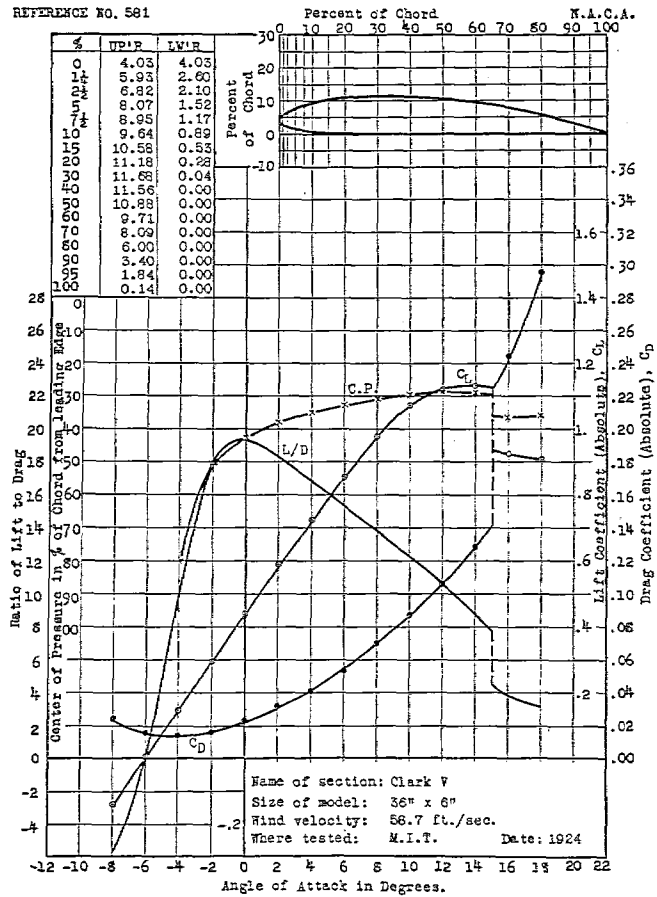
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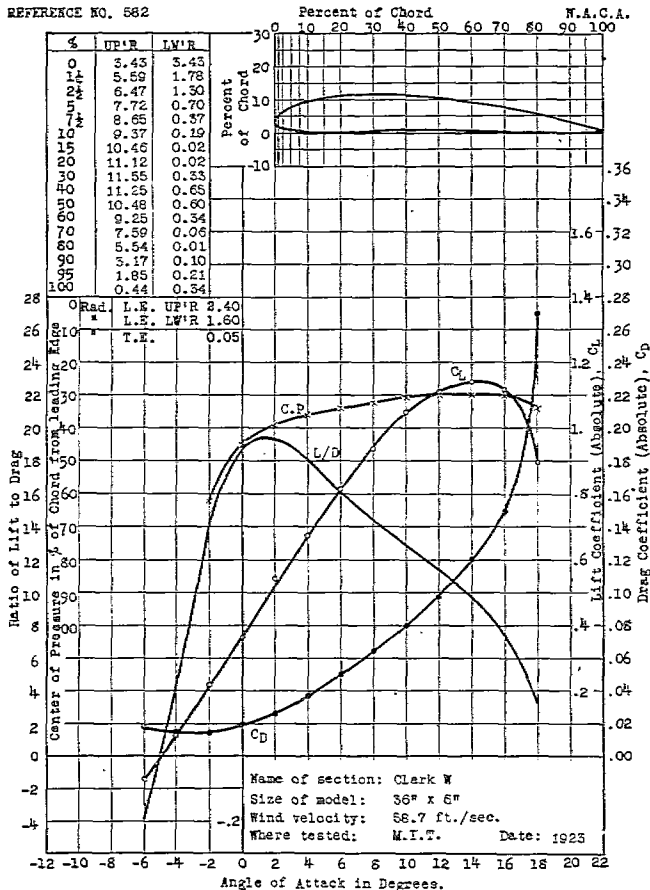
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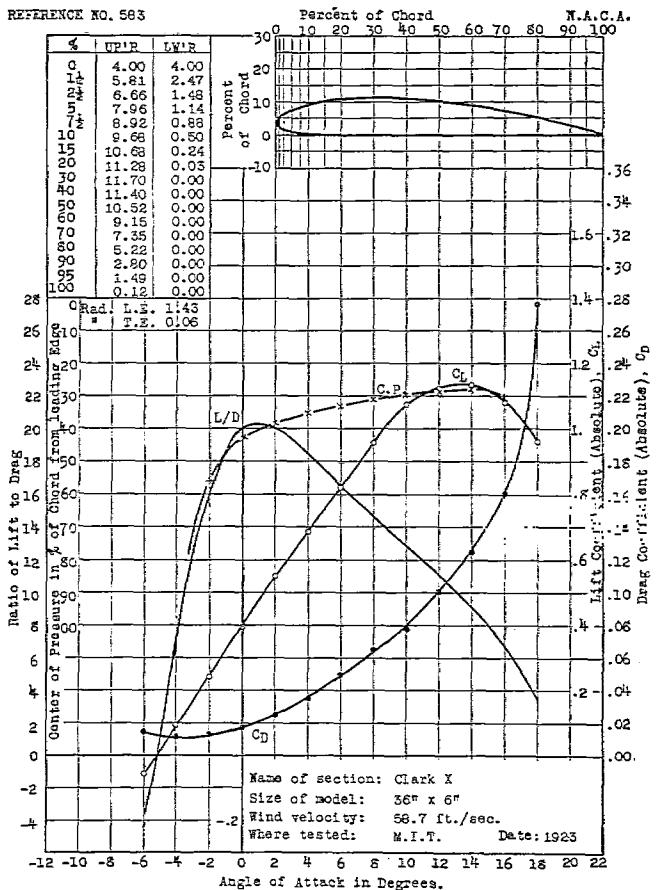
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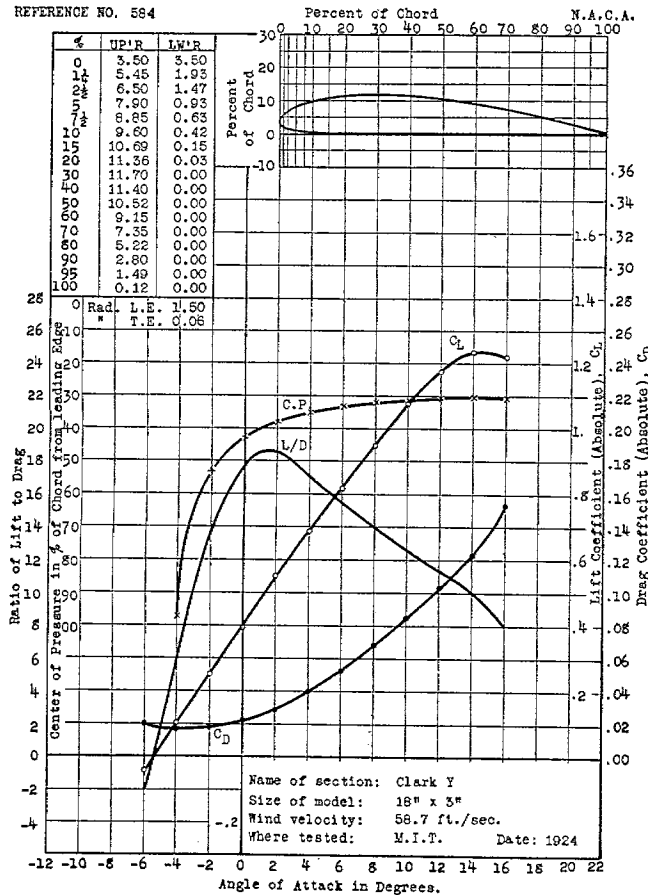
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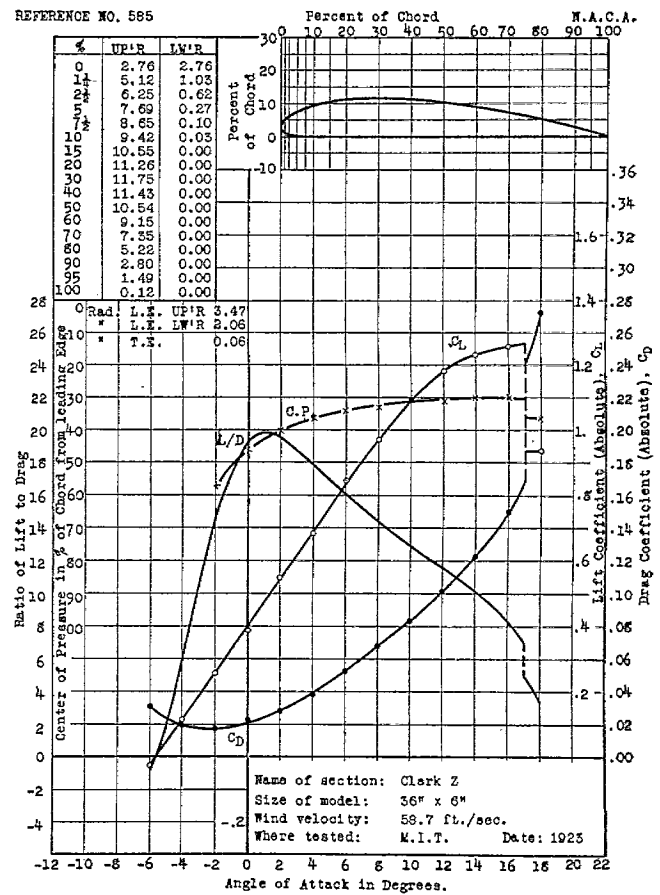
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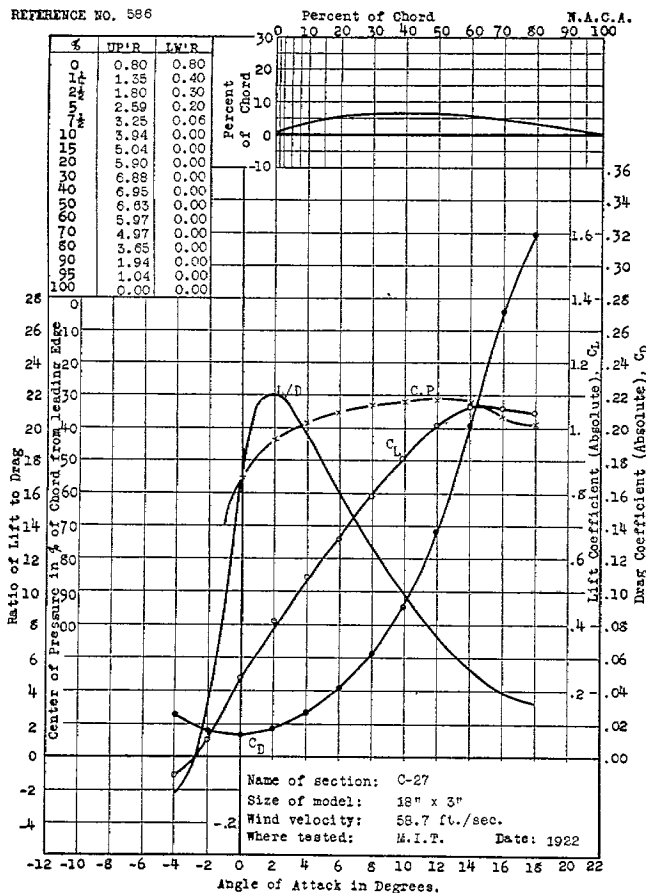
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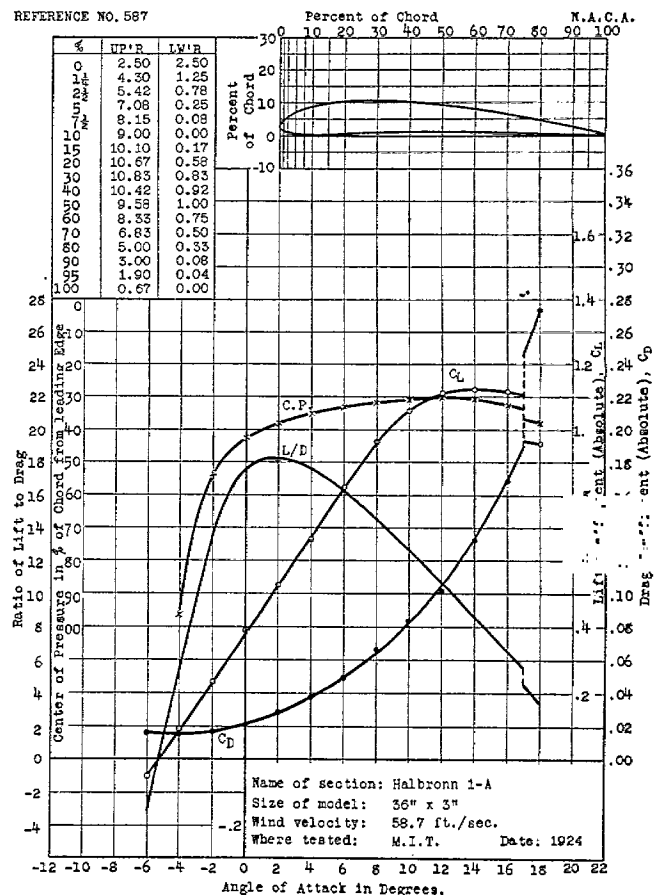
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REFERENCE NO. 586



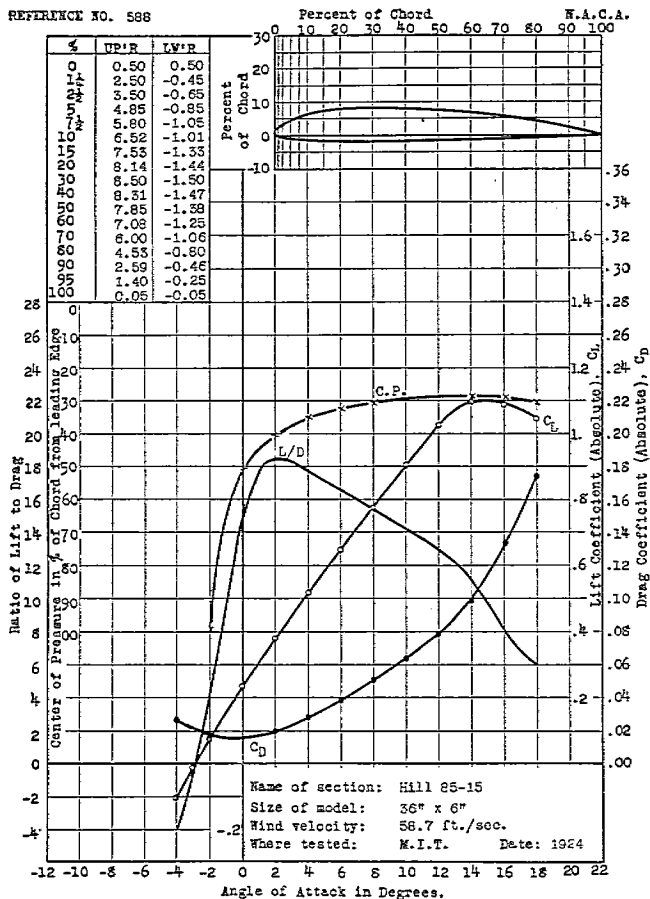
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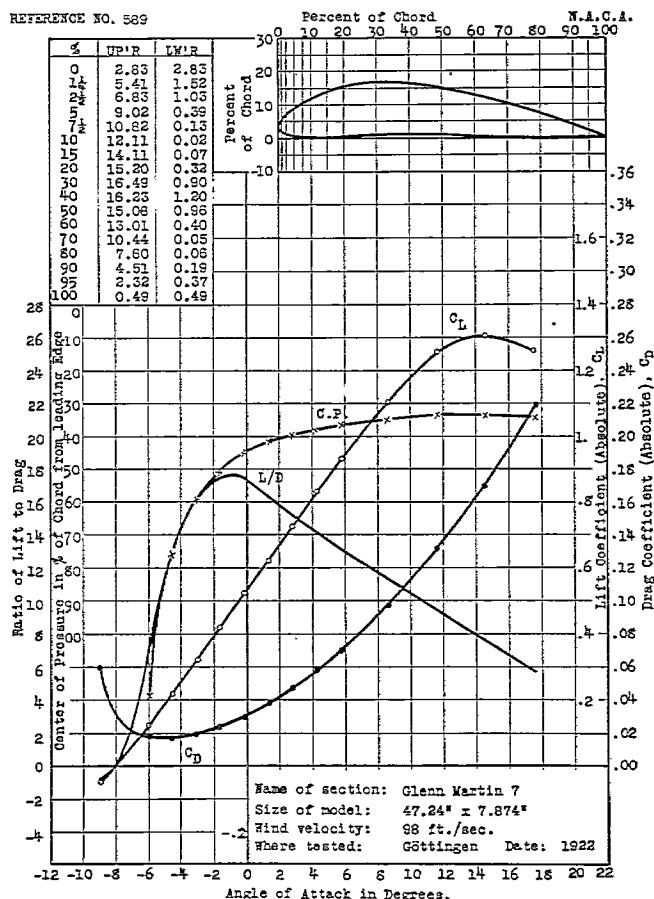
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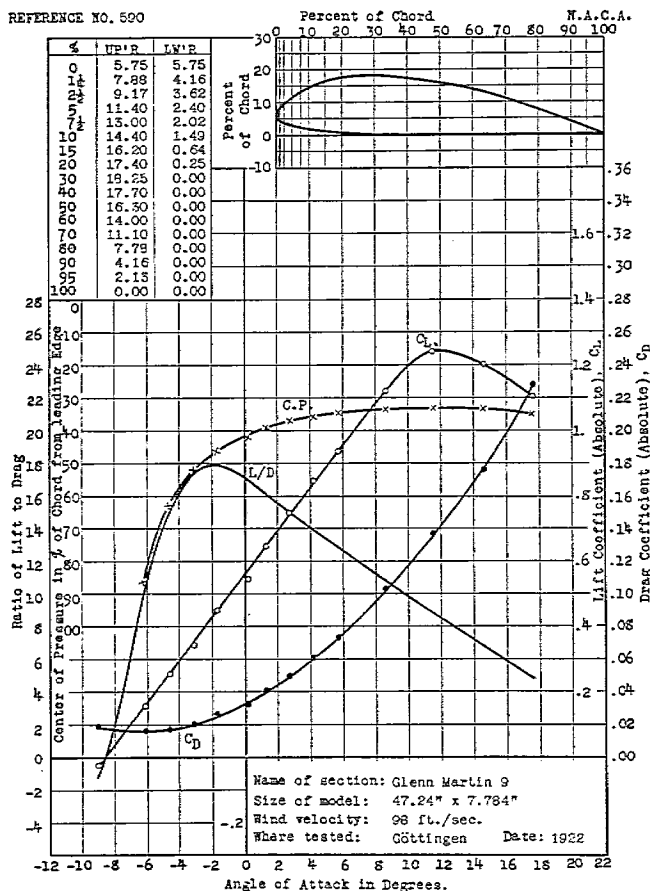
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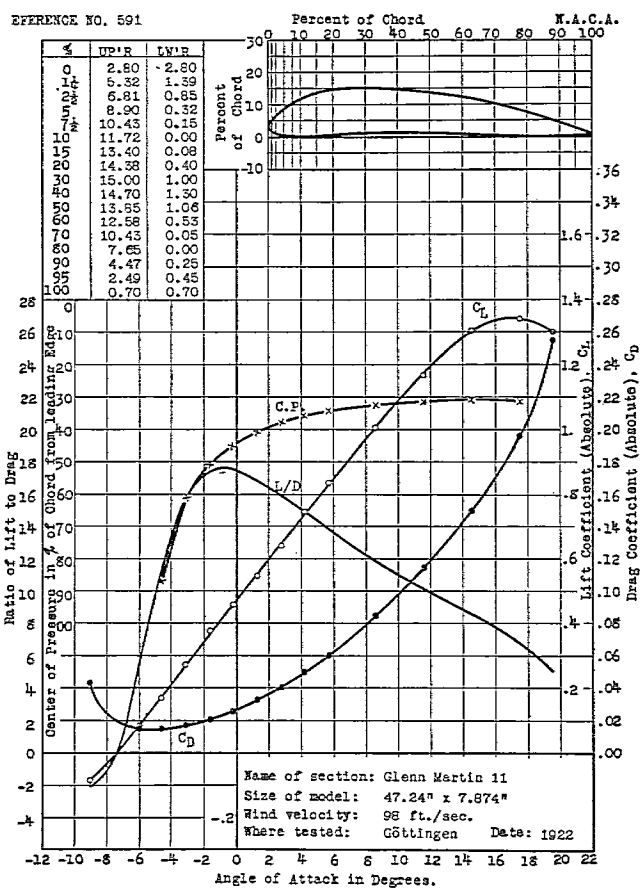
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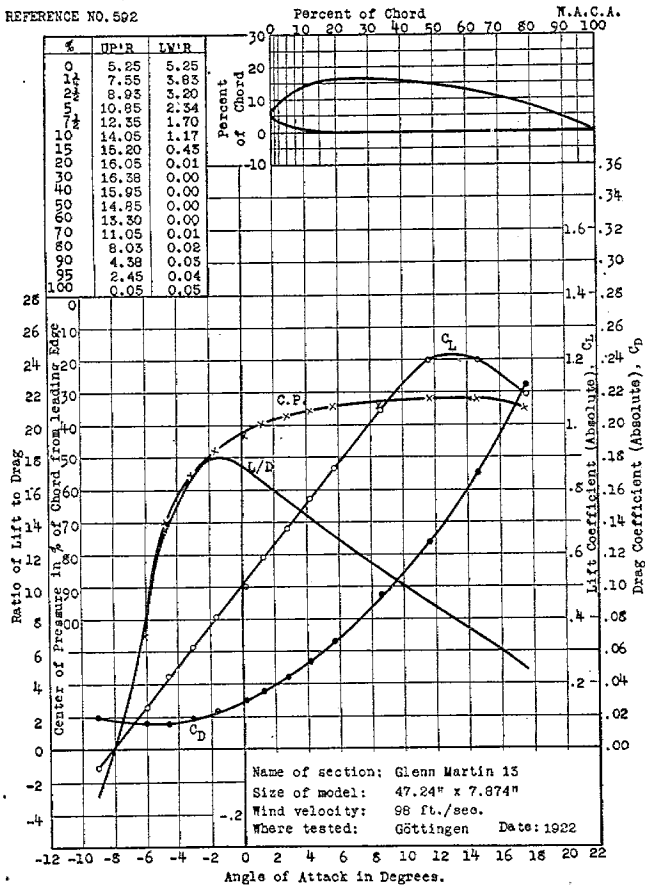
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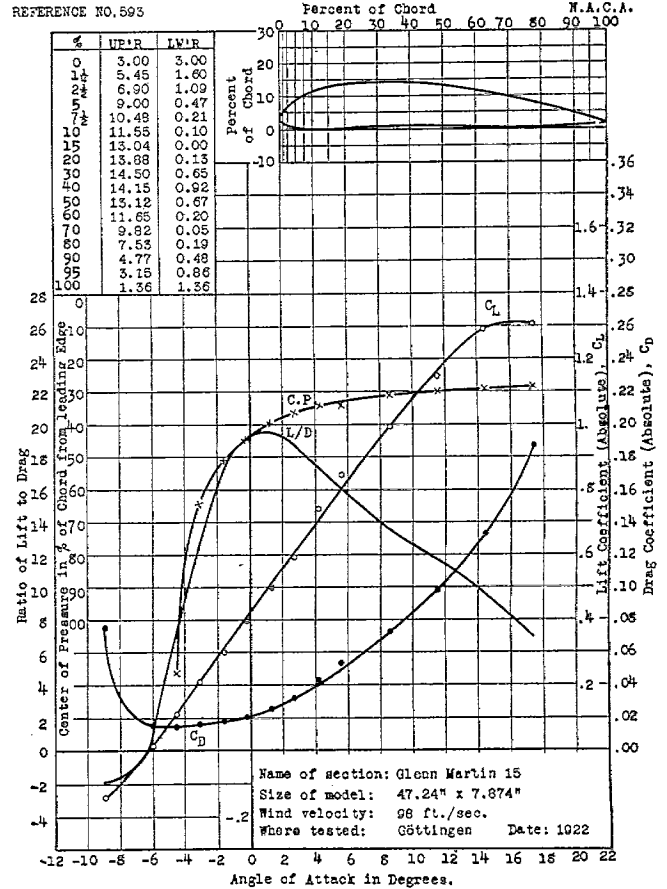
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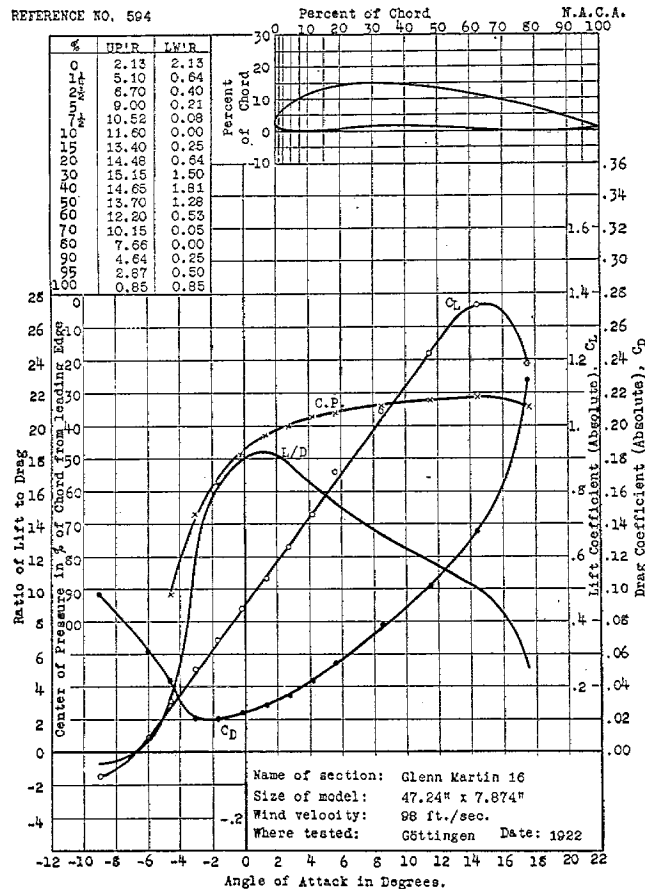
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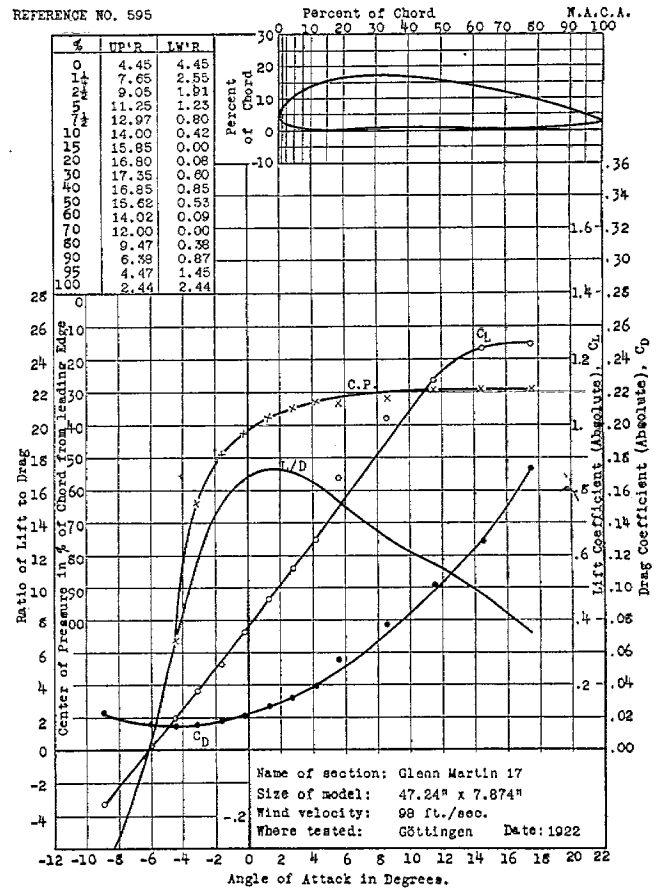
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REFERENCE NO. 594



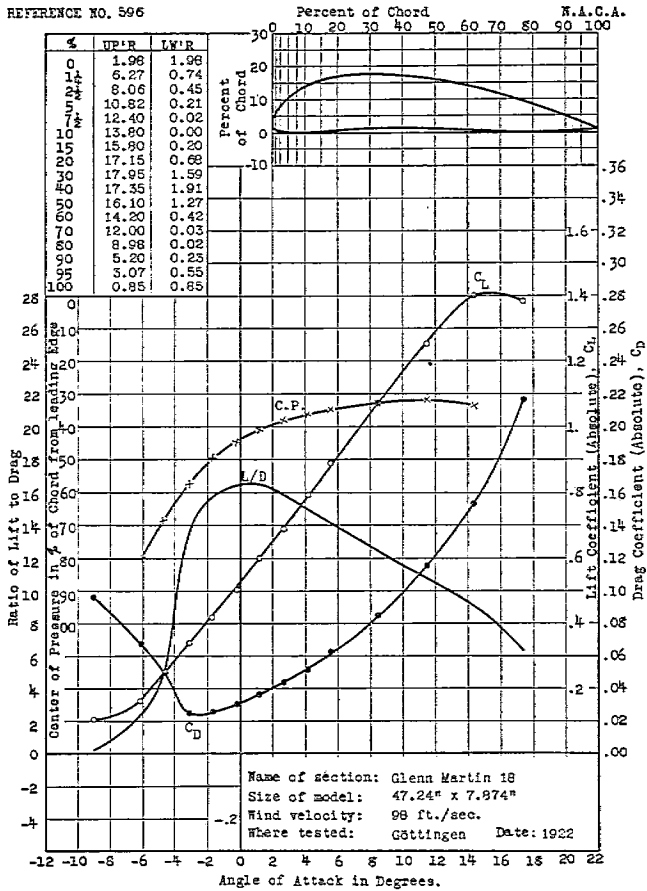
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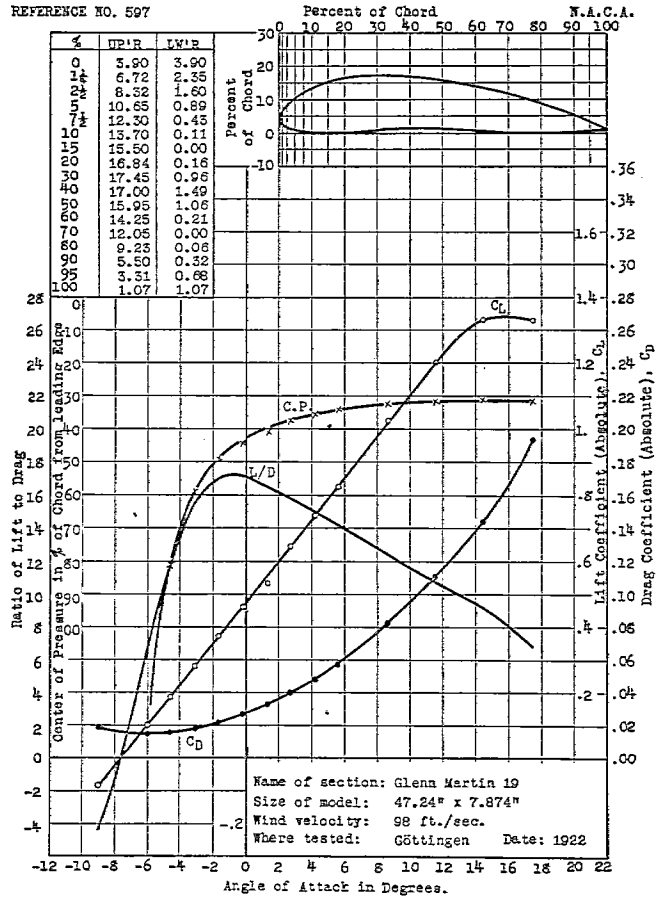
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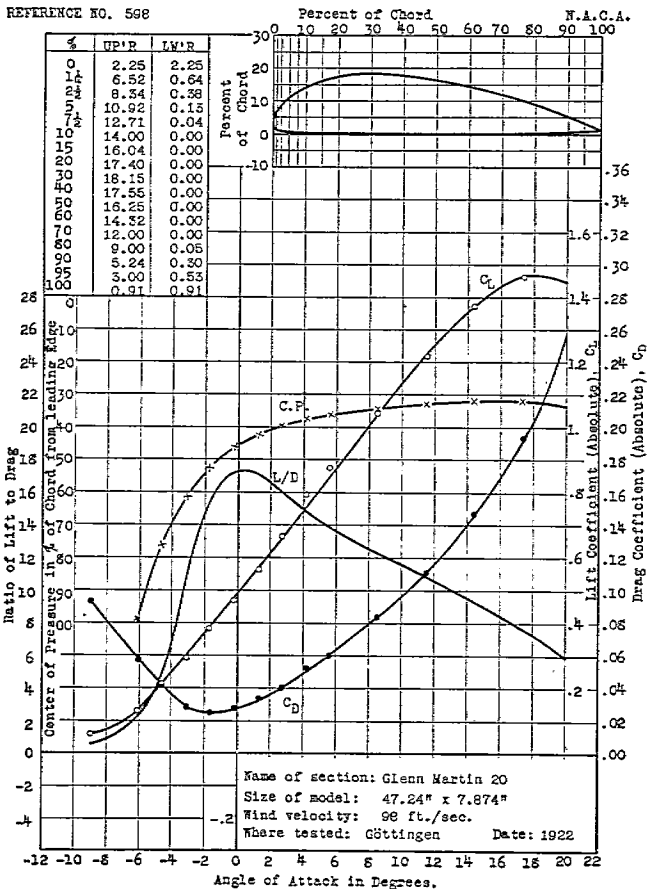
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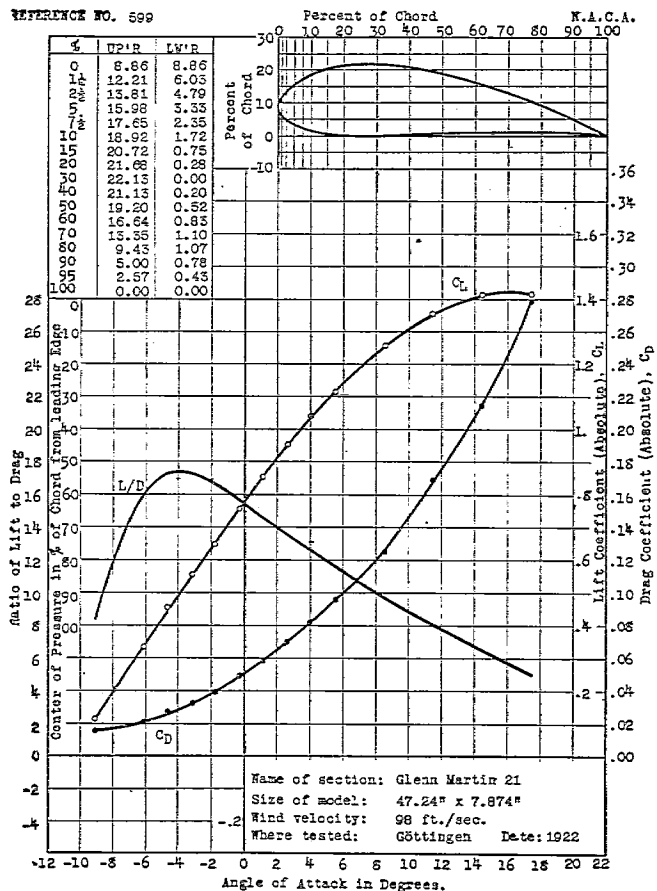
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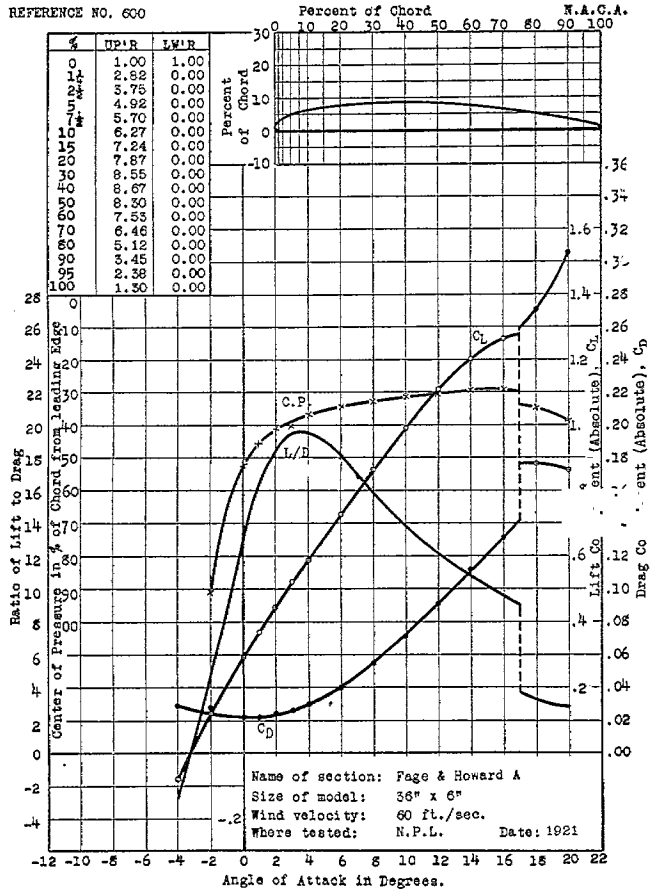
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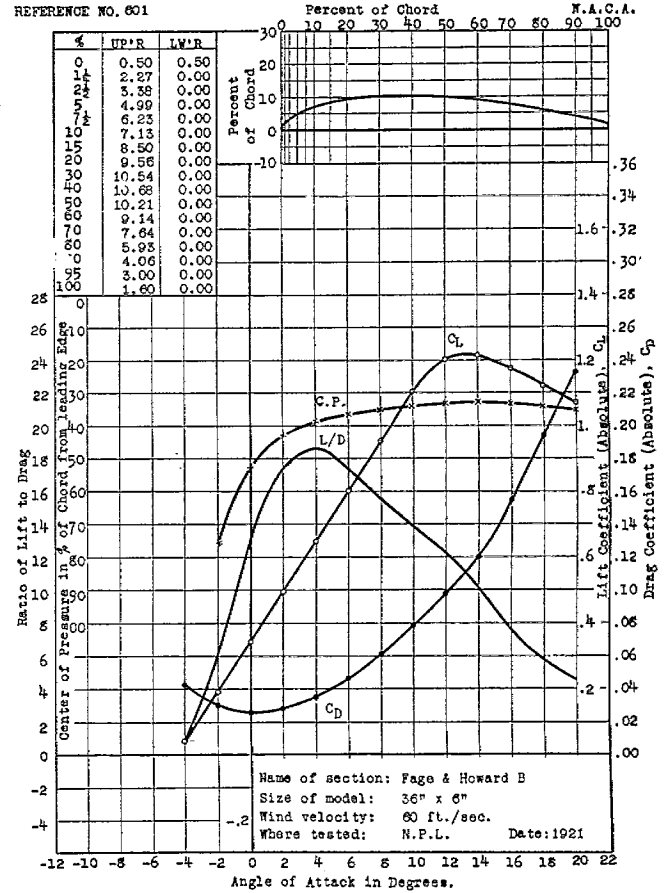
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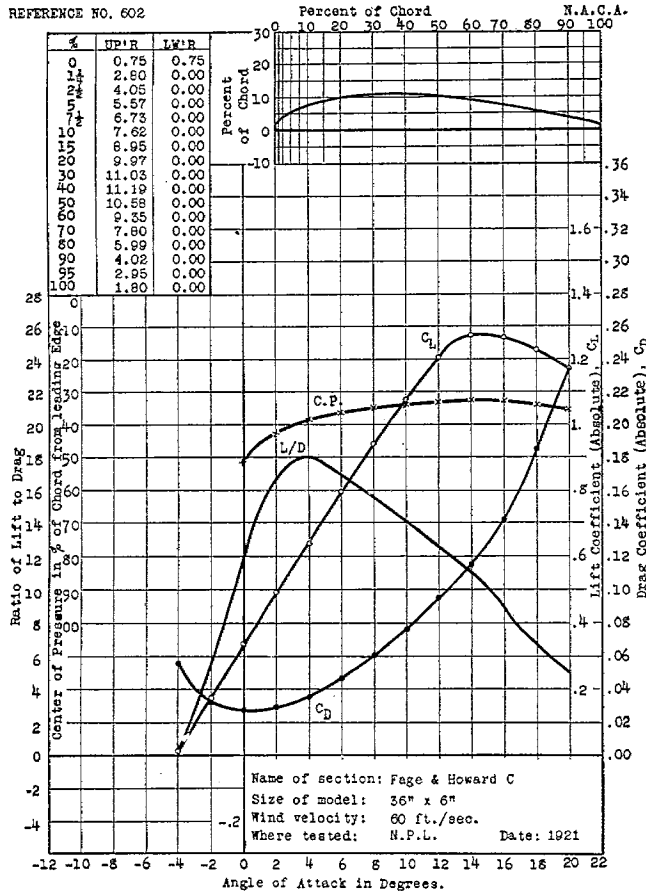
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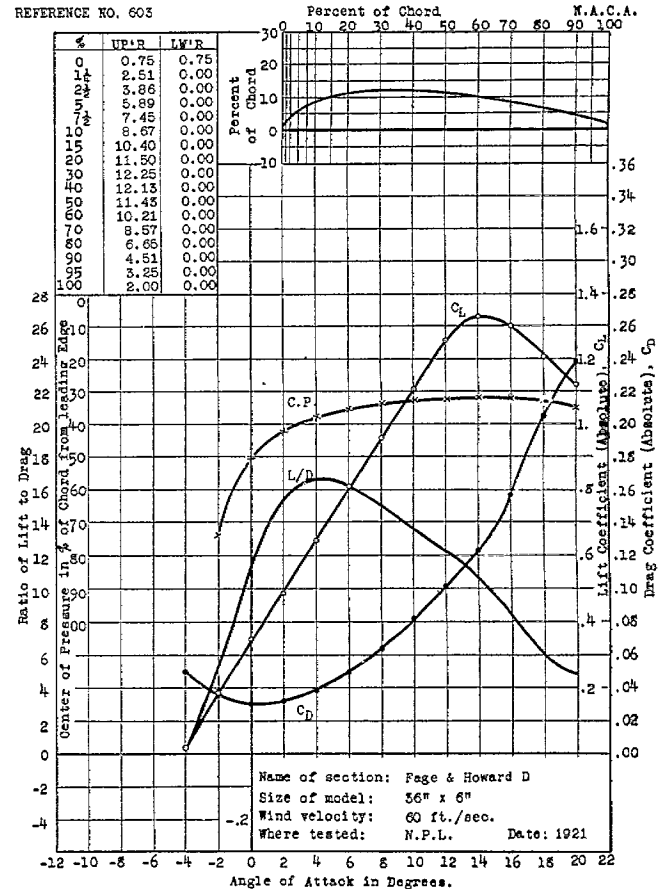
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REFERENCE NO. 602



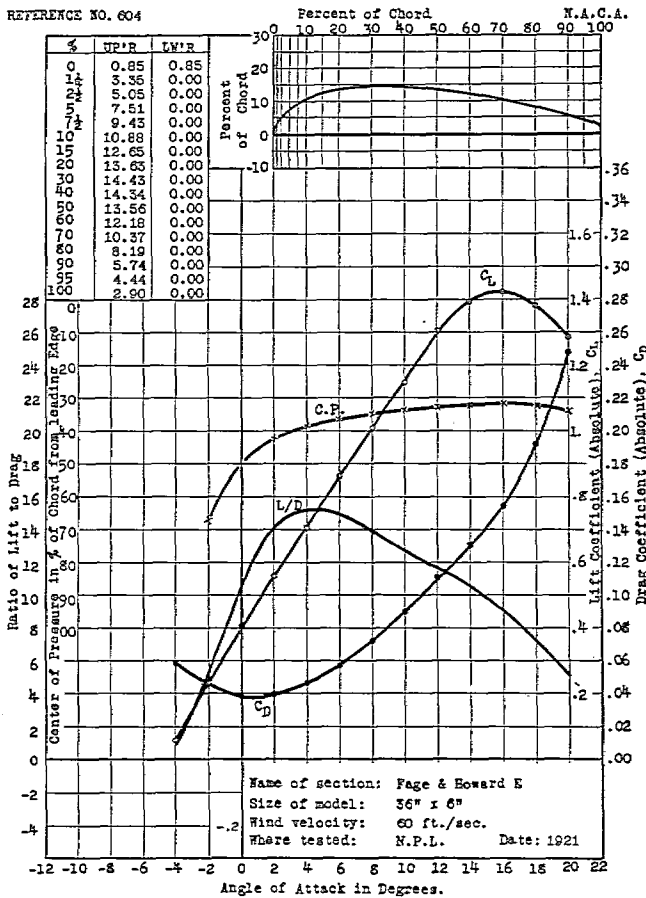
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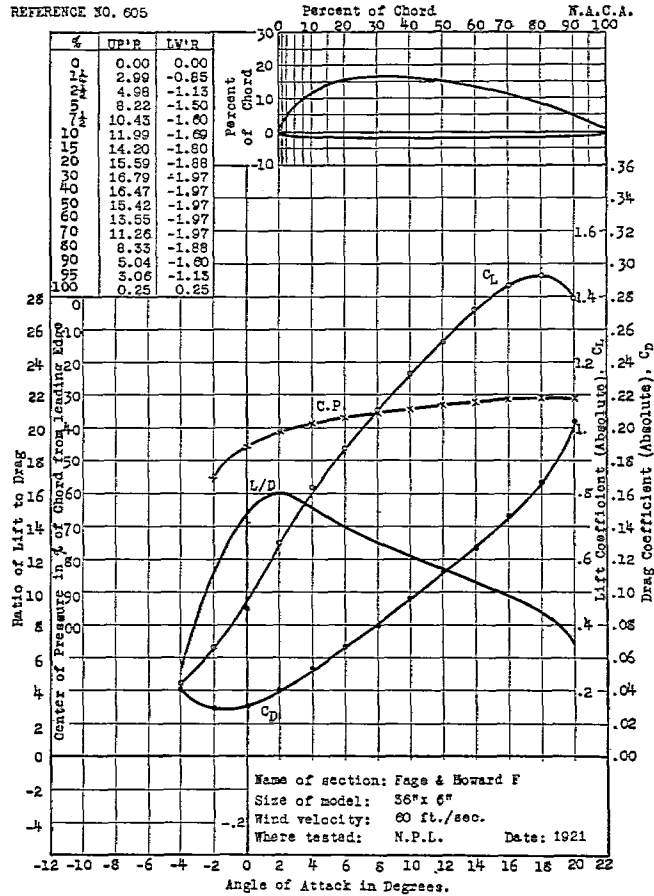
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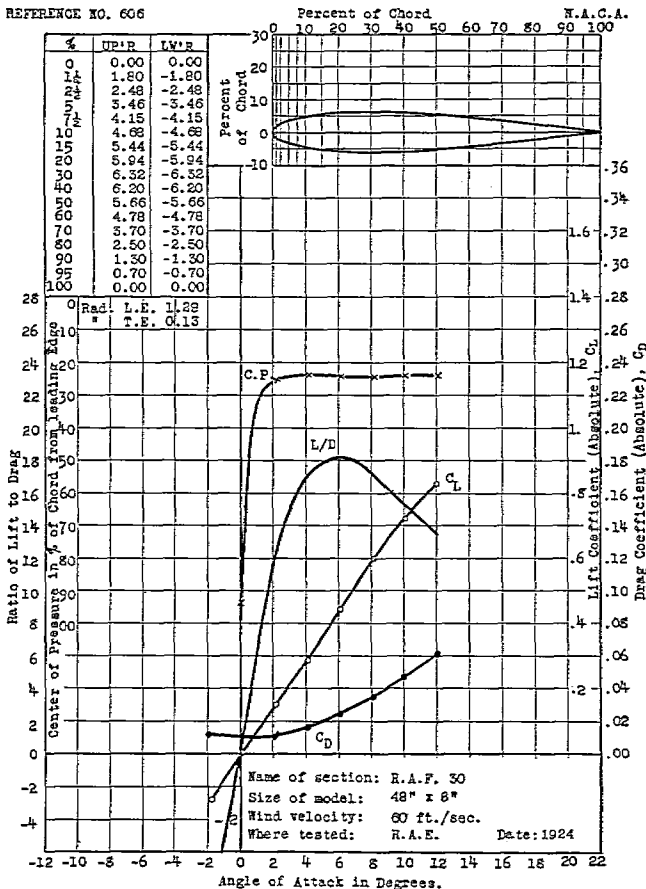
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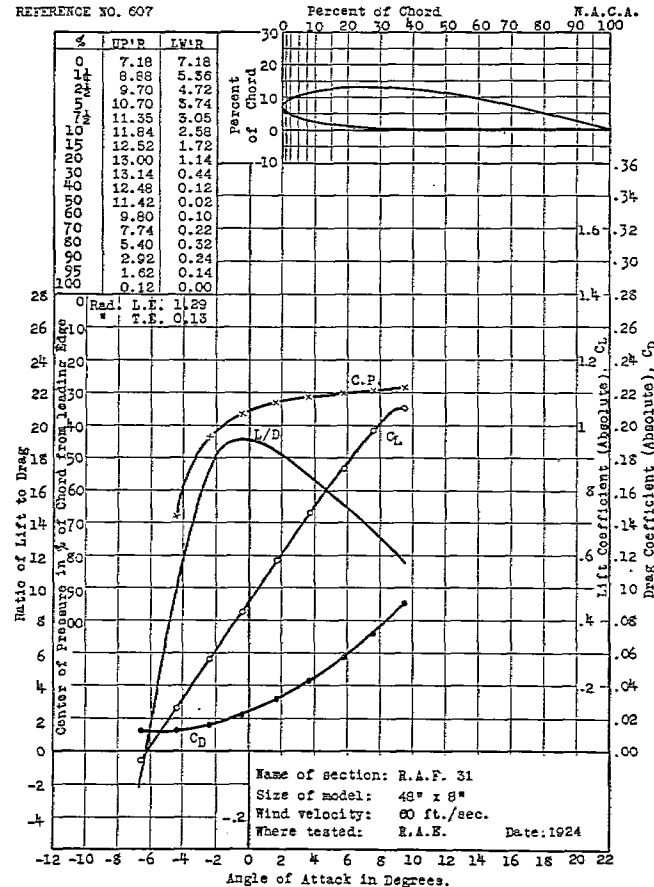
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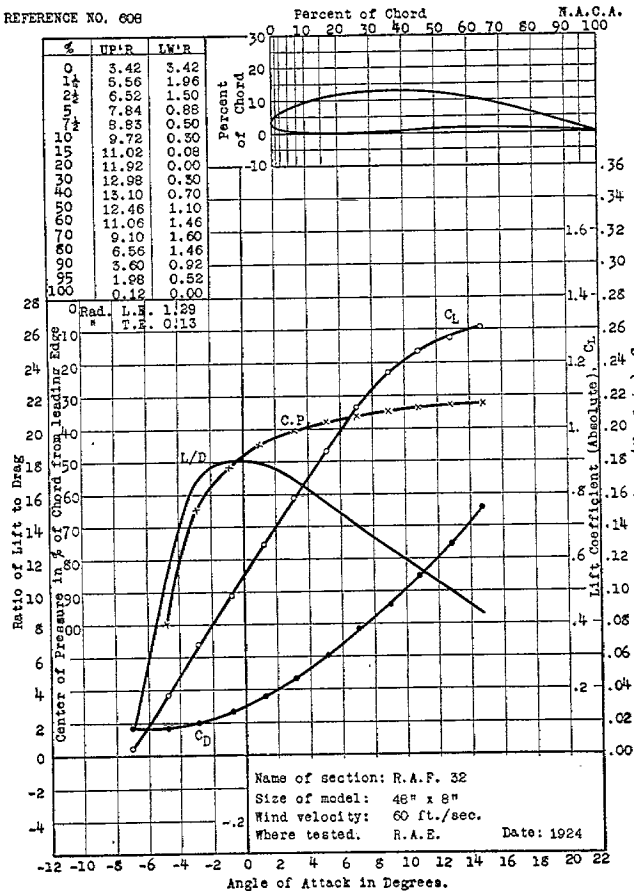
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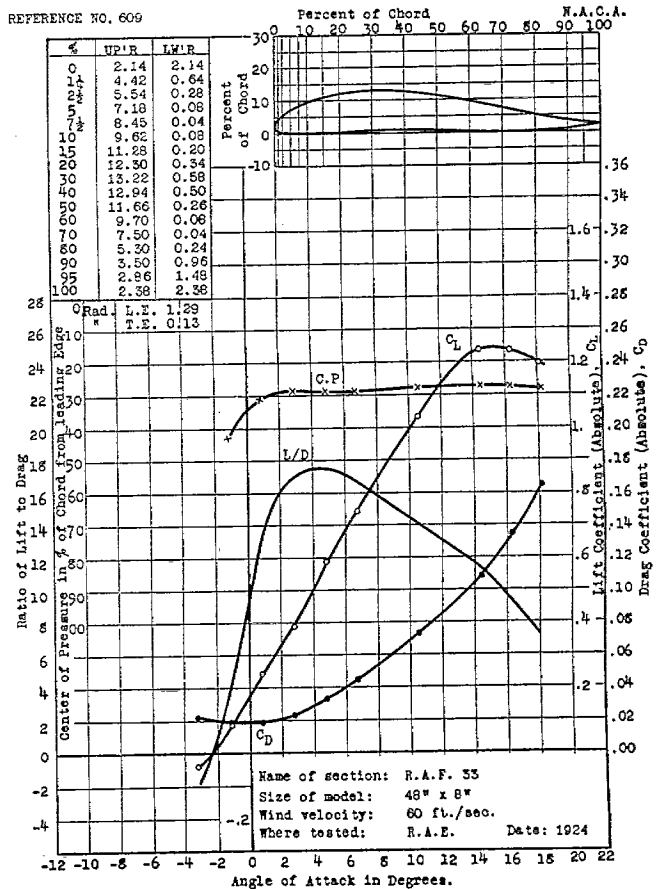
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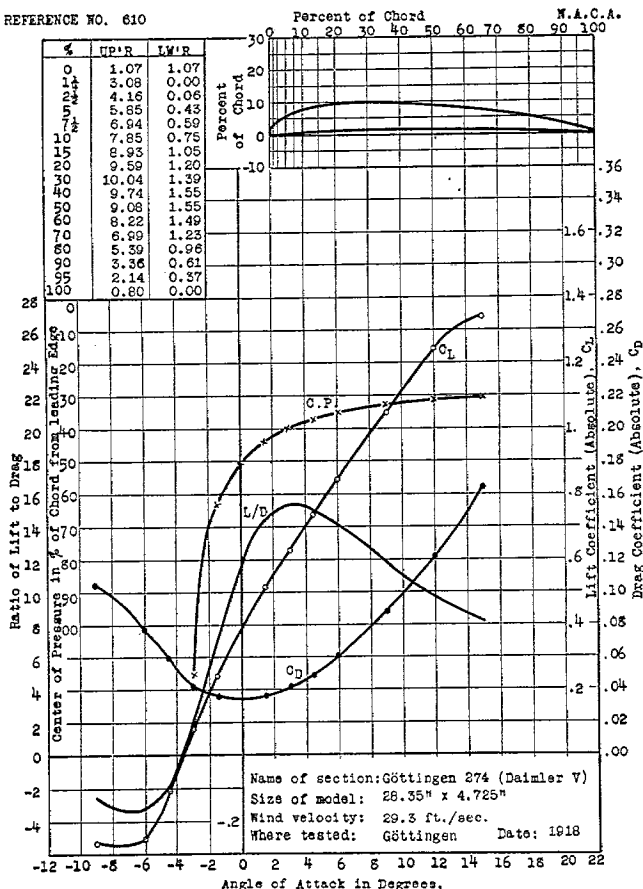
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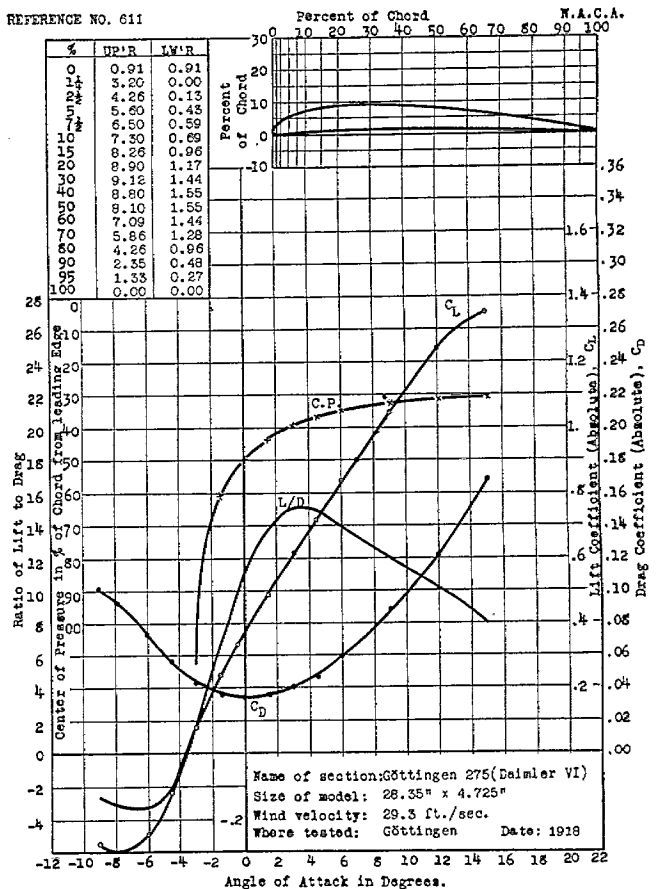
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REFERENCE NO. 610



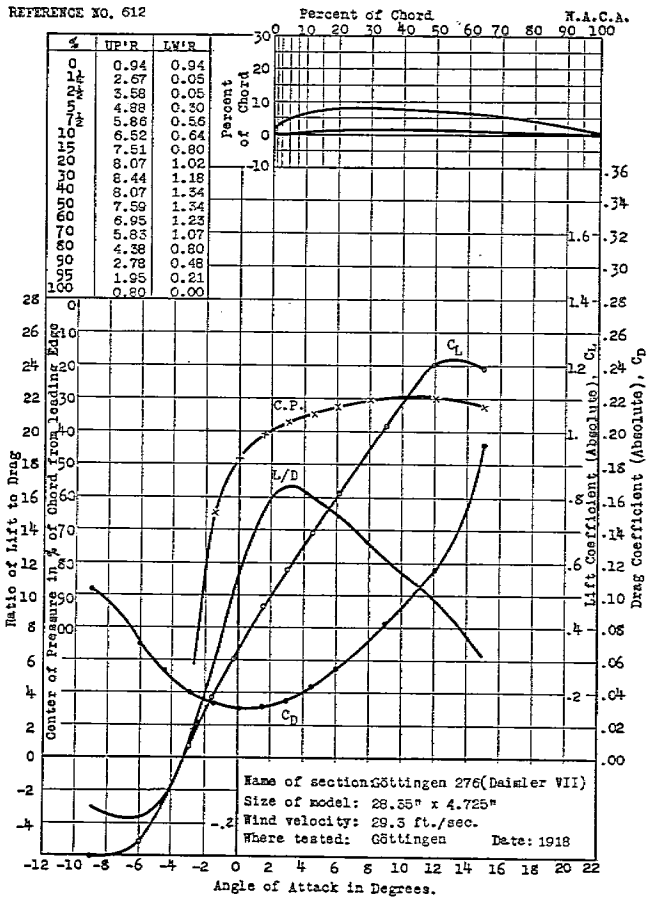
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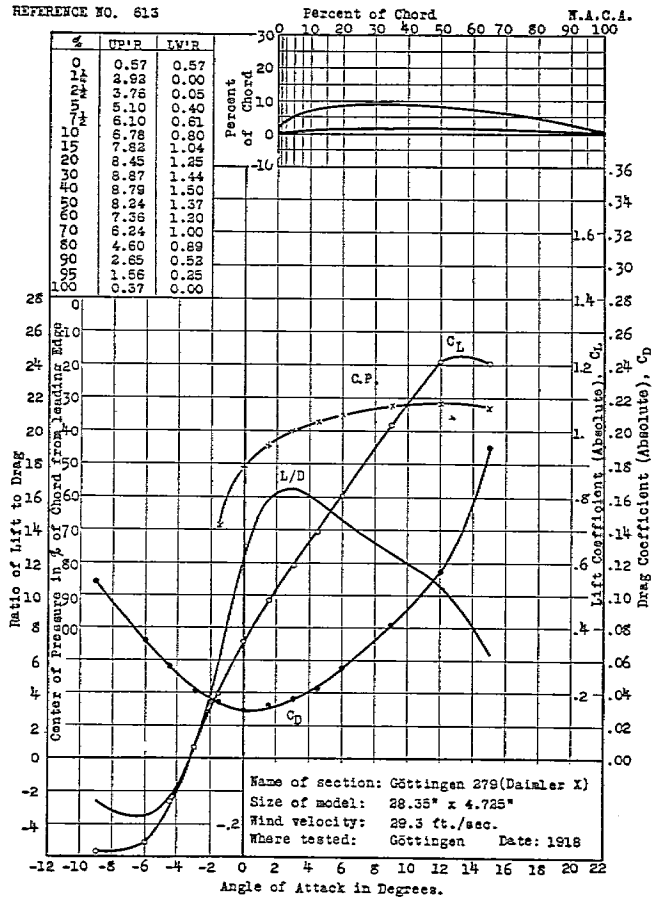
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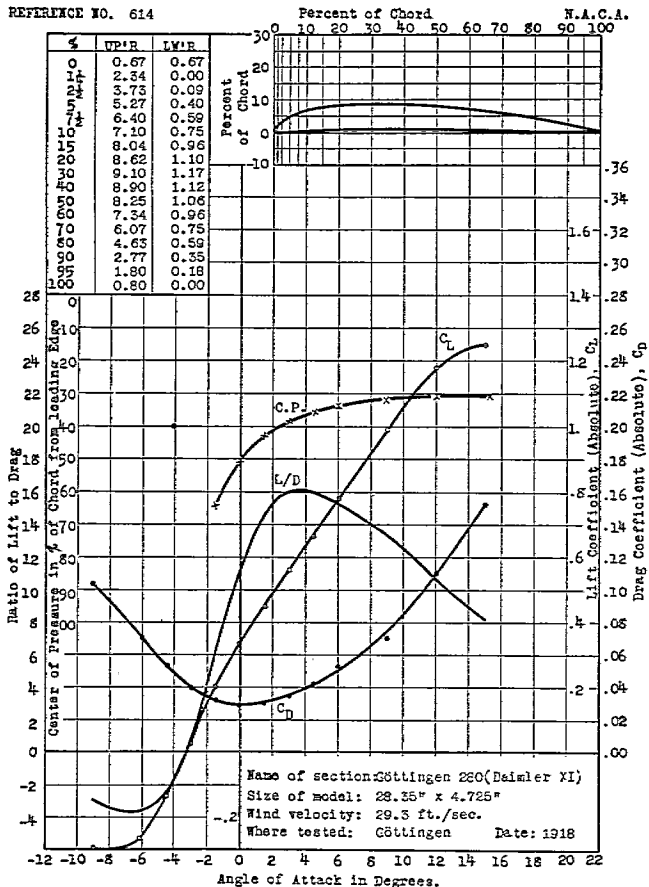
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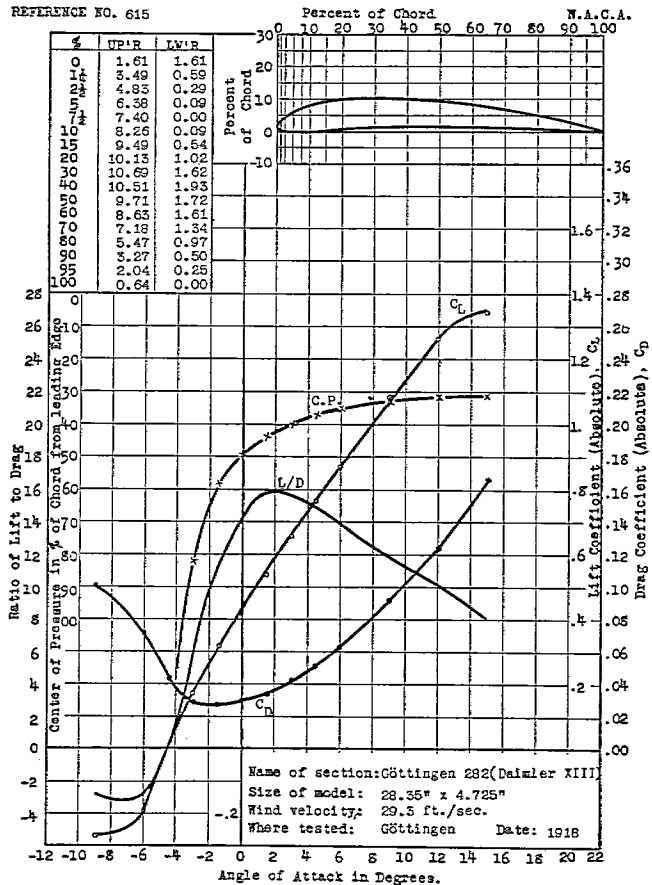
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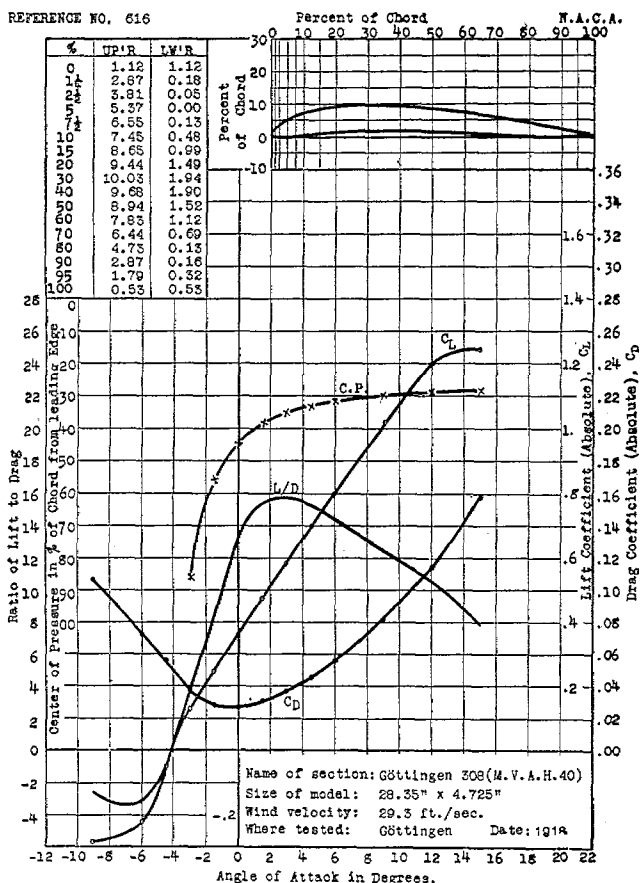
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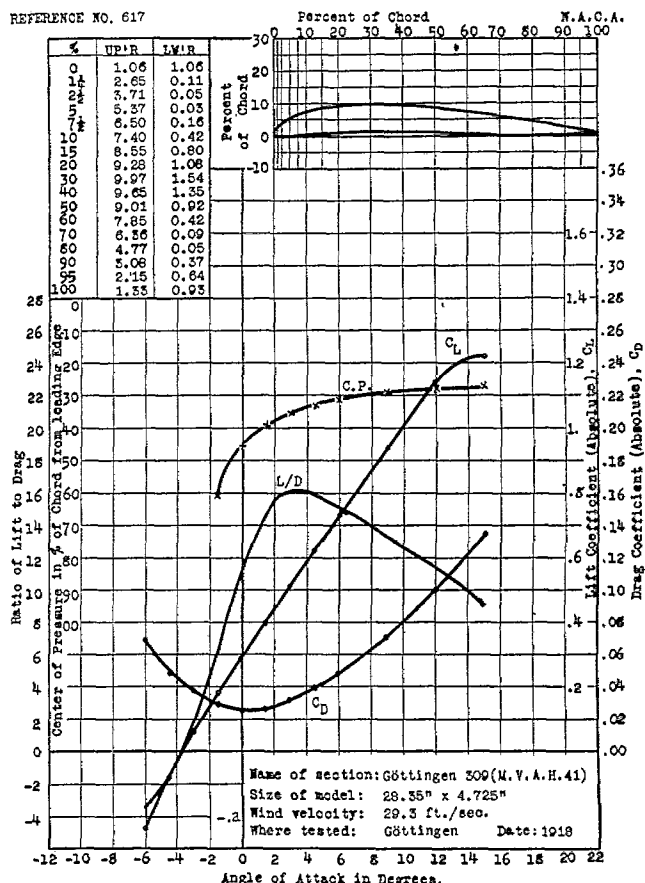
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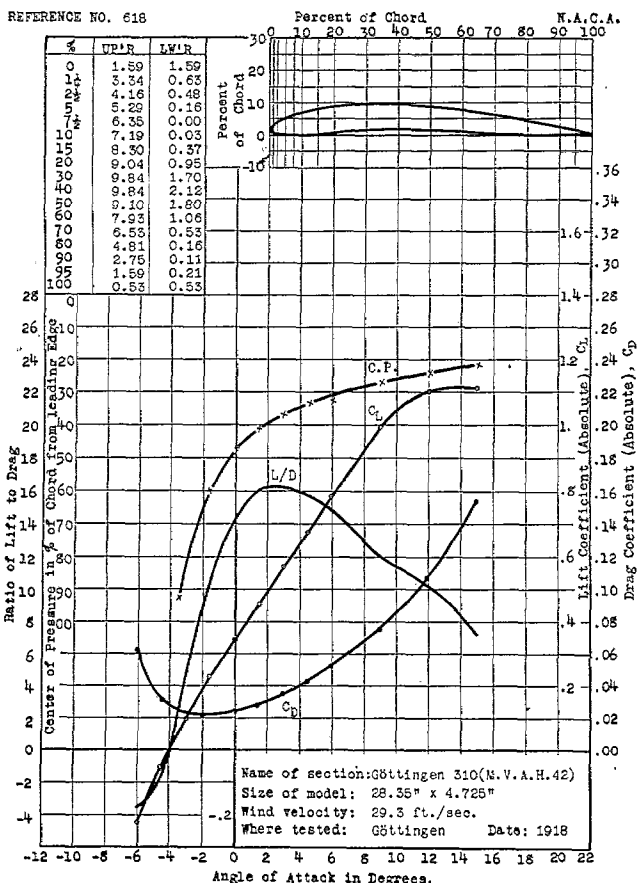
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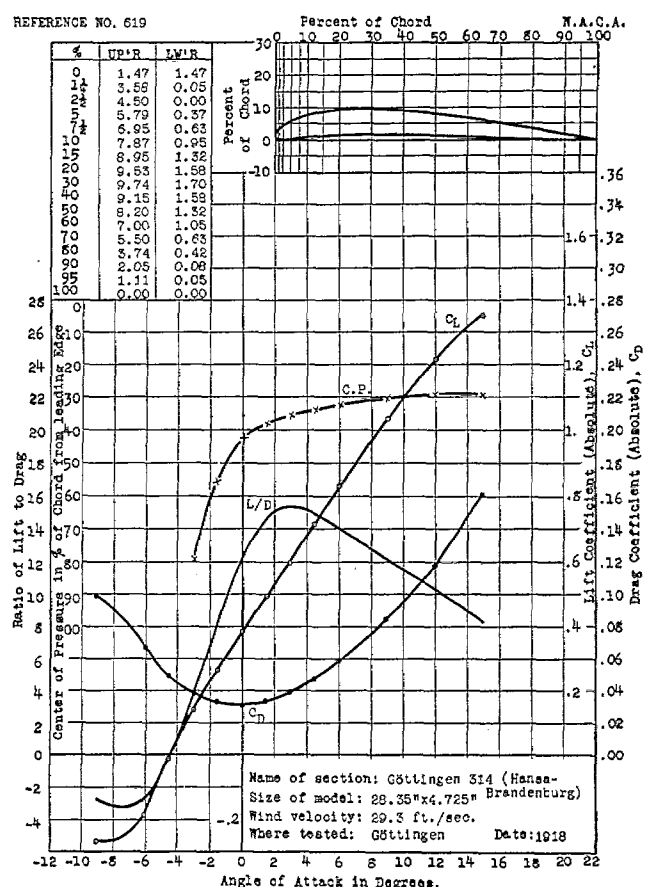
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REFERENCE NO. 618



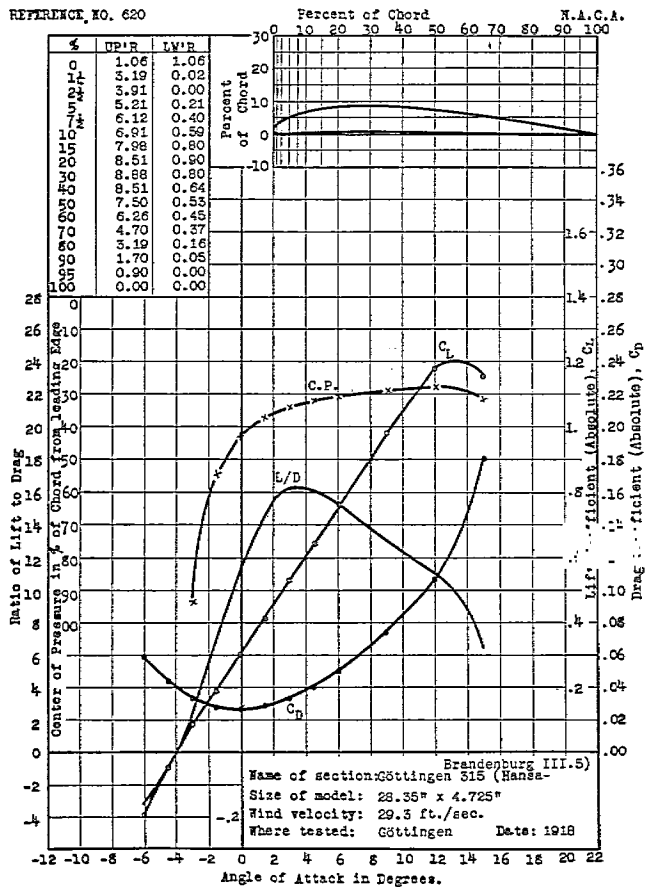
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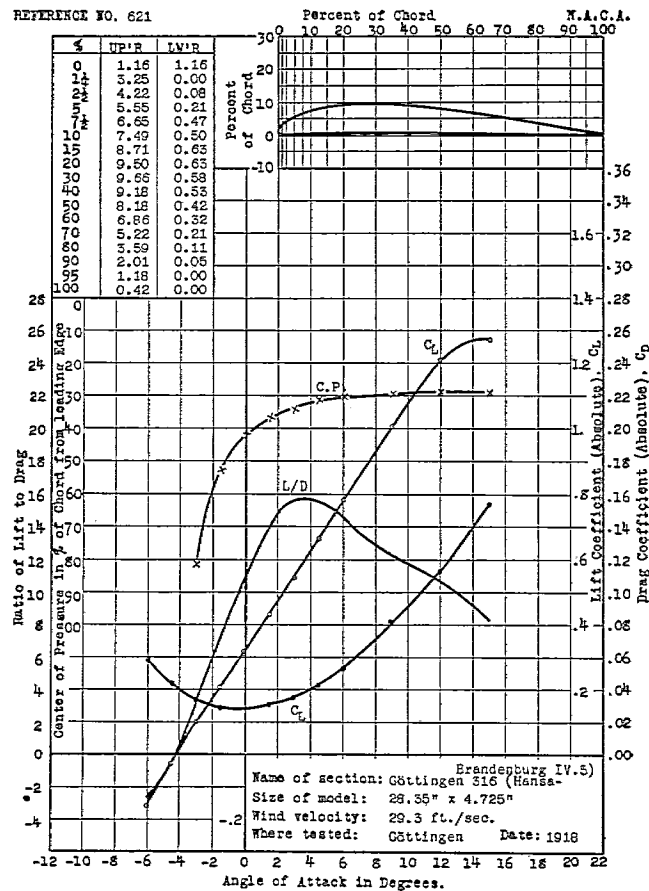
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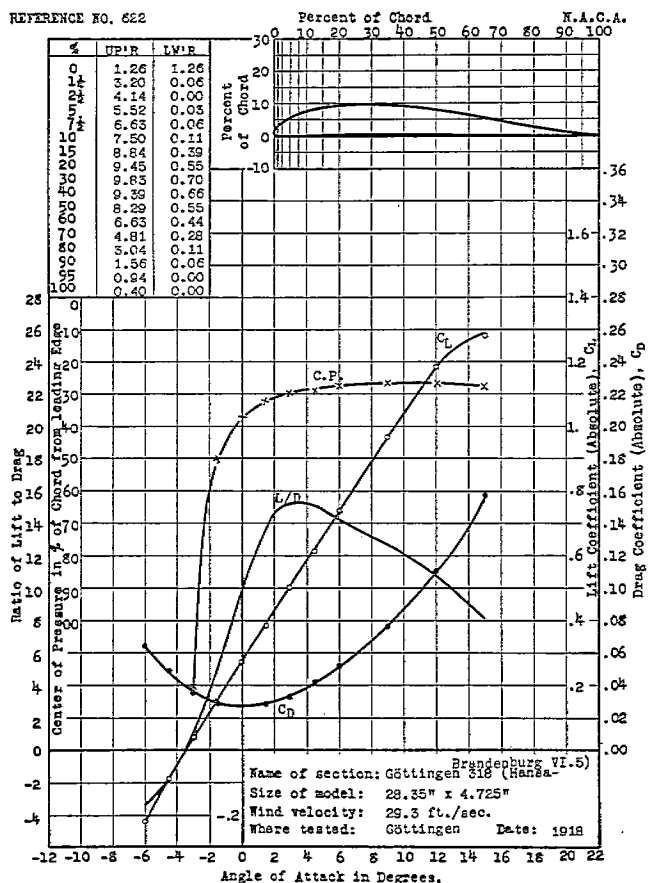
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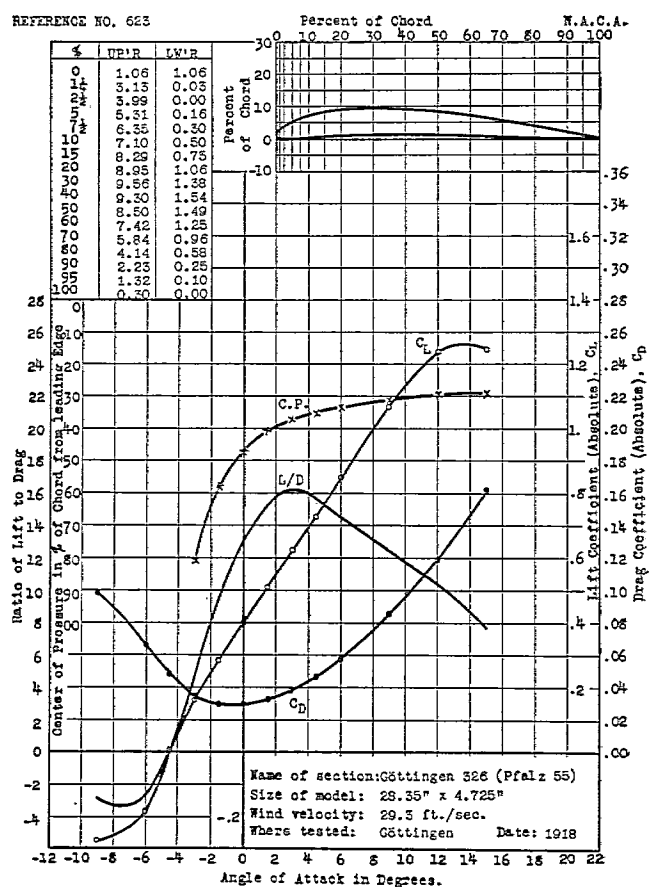
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REFERENCE NO. 622



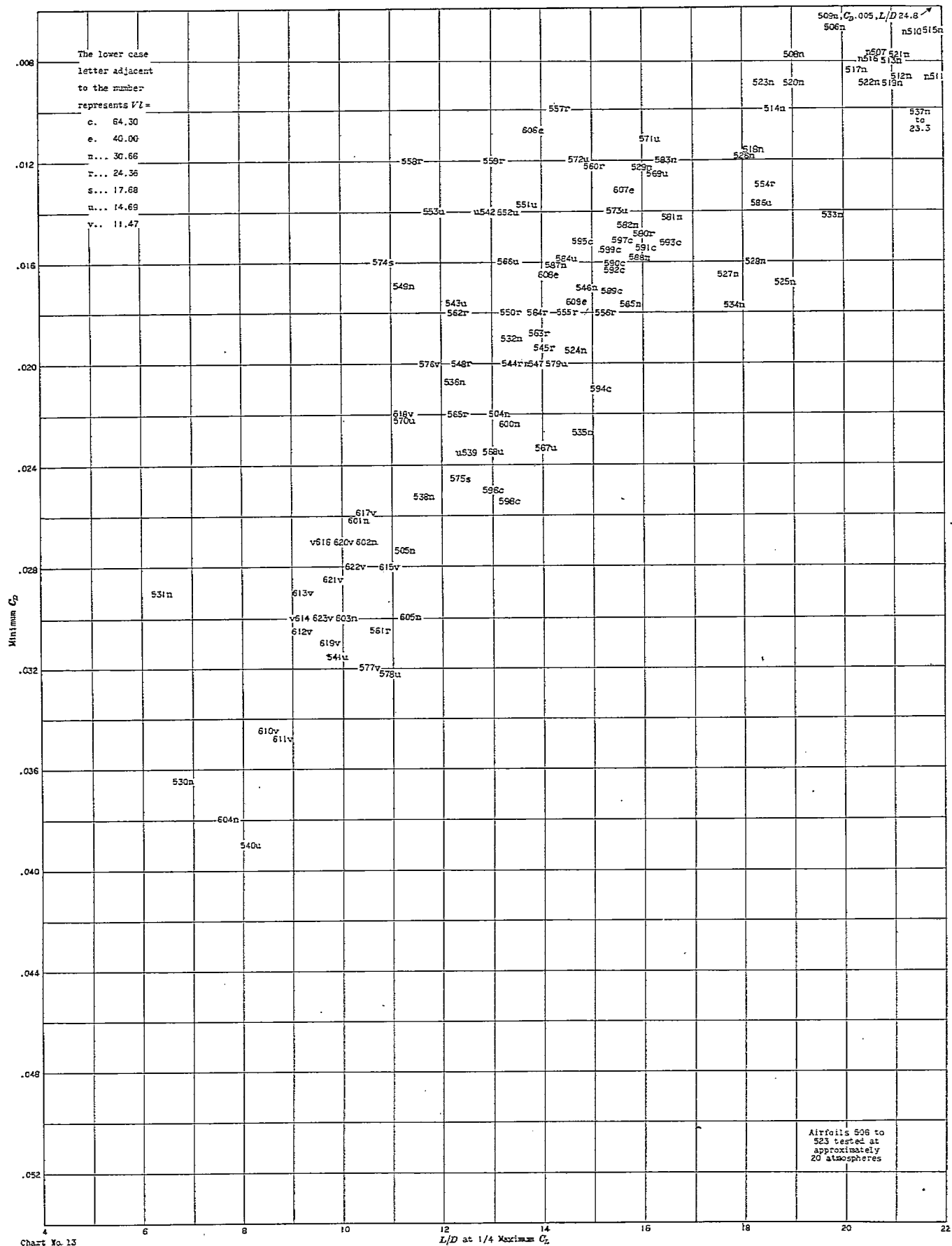
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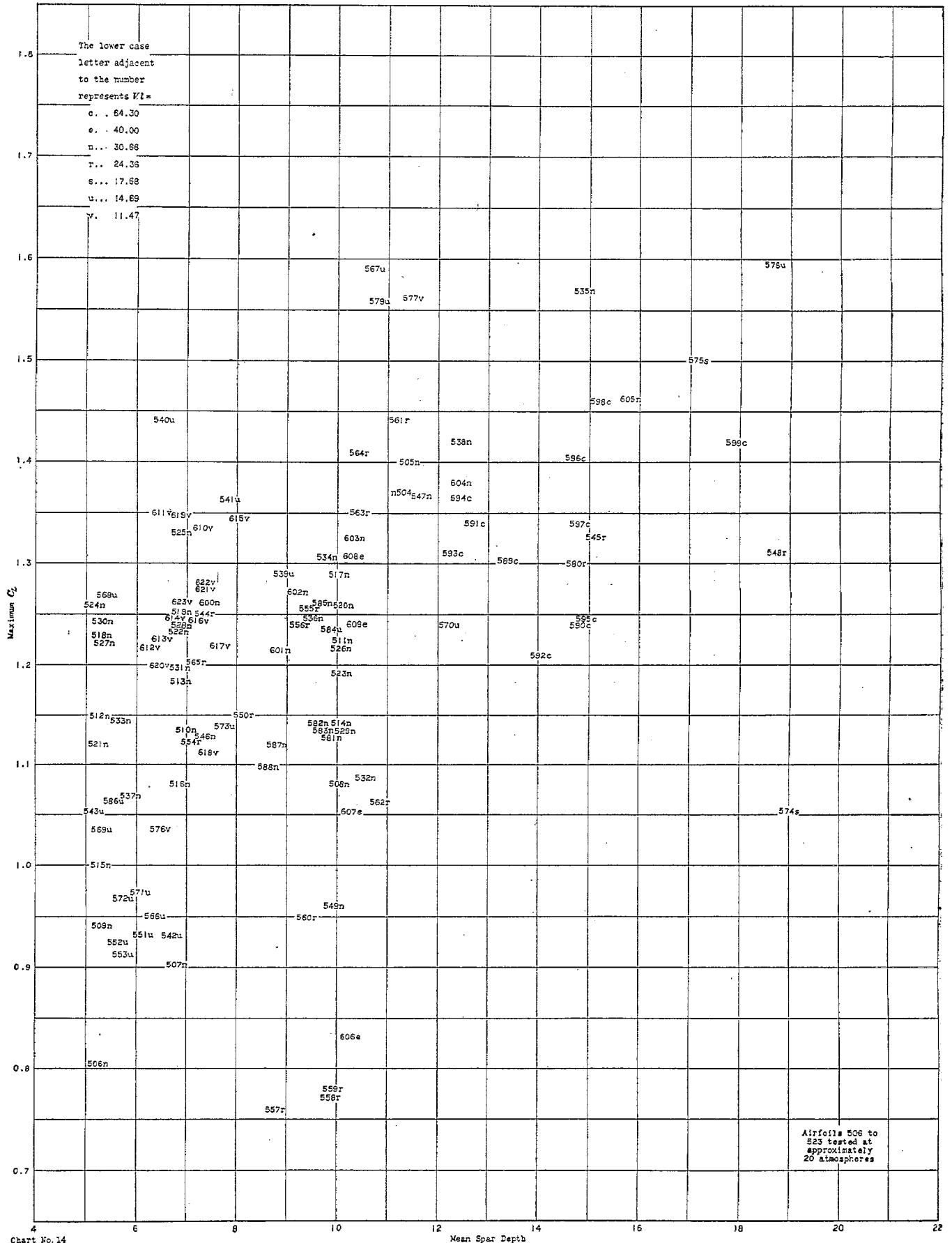


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