Aero. eng'g
Thesis
1925

THE EFFECT OF BIPLANE COMBINATION ON AIRFOIL CHARACTERISTICS

by

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Submitted in Partial Fulfillment of the Requirement
For the Degree of

Master of Science in Aeronautical Engineering.

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September 1, 1923.

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Course XVI

Cambridge, Massachusetts
September 1, 1923.

Professor A. L. Merrill,
Secretary of the Faculty,
Massachusetts Institute of Technology.

Dear Sir:

In accordance with the requirement for the degree of Master of Science in Aeronautical Engineering, we submit herewith a thesis entitled "The Effect of Biplane Combinations on Airfoil Characteristics".

We wish to express our appreciation to Professor E. P. Warner for his cooperation in the development of this research.

Respectfully submitted,

Signature Redacted

Signature Redacted

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Section I.

OBJECT OF INVESTIGATION

The object of this investigation is to make a complete test in the wind tunnel of a large number of biplane combinations having different proportions of stagger and gap/chord ratio, to derive a thoroughly accurate and systematic set of biplane correction factors from the results so obtained, and to verify the accuracy of the formulae from Munk's "General Biplane Theory" (ref. 9) by calculating corresponding results from them.

SECTION II.

REVIEW OF THE SUBJECT

The effects of biplane combinations on the aerodynamic characteristics of airfoils have been known in a general way for several years, but such knowledge as exists is based on scanty experimental data and on a theory which still lacks that exactitude of prediction necessary to win for it the authority of physical law. We shall review the theoretical and experimental sources of this knowledge in turn.

From the theoretical standpoint the effects of biplane combinations are bound up with the whole aerodynamical theory of airfoils. The only general theory dealing with the subject is the voxtex theory, which Lanchester in England first boldly applied as an explanation of the lift of wings, over twenty years ago, and by which he worked out a fairly complete descriptive account of the mechanism. Kutta in Germany and Joukowsky in Russia developed the mathematical details of the circulation for wings of infinite aspect ratio, i.e., of negligible end-effect. Then the whole school of German aerodynamicists, headed by Prandtl, took up the further theory of the effects caused by the trailing vortices, usually embodying their cogitations in exact mathematical language. In 1922, Munk, (ref. 1) also of the German school, made a quite complete application of the theory to biplanes, the previous work having been more or less restricted to monoplanes. The result is we now have a truly physical theory of the aerodynamics of airfoils, expressed in exact mathematical form, and capable of making some quite good predictions.

But although this theory is invaluable for the way in which it illuminates part of the mechanism behind the phenomena, it is still embryonic; it retains too many simplifying assumptions in its foundation, and must yet be worked out in greater detail before it will be adequate for obtaining exact numerical information. For instance, good agreement between theoretical and experimental values is restricted to about 8° of the ordinary flying range. The theory cannot predict maximum lift, or the flying range; and although the mechanism of the induced drag has been carefully worked out, that of the remaining part of the drag has not been elucidated with the same definiteness. In short, few calculations from the theory are now capable of being used as a routine method in the design room and drawing office.

On the other hand when we examine the empirical knowledge by which the airplane designer might predict the aerodynamical coefficients of biplanes, our satisfaction is not much greater. The only published data of this kind which we have been able to espy are incorporated in references 1 to 7, all of which only comprise wind tunnel tests on twelve biplane combinations of zero stagger and different gap chord ratios, and on six biplane combinations having miscellaneous stagger and gap chord ratios. These tests were performed by six different experimenters working in four different wind tunnels, each operating at a different wind speed, and the biplane models embodied five different types of airfoil ranging in size from 18" x 2".65 to 33".6 x 6". A comparison between the various results would be interesting, but a direct comparison is rendered impossible by the fact that with two exceptions no biplane combination with the same stagger and gap chord ratio was tested by different experimenters. In Section VII we shall make a detailed comparison between our own results and these previous results. So suffice it here to say that the gist of the previous work was a fairly good determination of the effect of gap chord ratio variation on lift, drag, and lift drag ratio, at zero stagger. Part of this data was summarized in "biplane correction factors" by which the aerodynamic coefficients of the airfoil as a monoplane must be multiplied in order to obtain the corresponding biplane coefficients. Practically no biplane correction factors were available to show how variation of the gap chord ratio at zero stagger would effect the moment and center of pressure coefficients, or the distribution of load between the two wings; and no correction factors were available to disclose how variation of stagger at various gap chord ratios would effect the lift drag ratio or the lift, drag, moment, and center of pressure coefficients.

Having thus briefly reviewed our subject it seems that at the present time the airplane designer can neither obtain from previously published experimental data or from theory, knowledge of the aerodynamic coefficients of biplanes commensurate in accuracy with that available for monoplanes. We therefore propose to make a complete test in the wind tunnel of a large number of biplane combinations, from gap chord ratio equal 0.50 to 2.00, and from stagger equal -40% to +60%. For each biplane combination we shall determine lift coefficients, drag coefficients, lift drag ratios, moment coefficients, and center of pressure coefficients, for angles of attack from -6^{0} to $+20^{0}$. We shall then use this data (1) to verify the accuracy of various biplane formulae taken from Munks "General Biplane Theory" (ref. 1), which represents the application of the vortex theory to biplanes; and (2) to calculate biplane correction factors at equal values of the lift coefficient for drag coefficient, lift drag ratio, moment coefficient, and center of pressure coefficient, and also biplane correction factors for the maximum lift coefficient, minimum drag coefficient, maximum lift drag ratio, and for the distribution of total lift and drag between the two wings.

It is desirable to calculate the correction factors by comparing biplane with monoplane results at the same lift coefficient instead of at the same angle of attack, because from the standpoint of the designer the weight of the airplane is the primary quantity known, and from the standpoint of the vortex theory the lift coefficient instead of the angle of attack is taken as the independent variable because all formulae are thereby simplified, and it is easier to calculate the angle if the lift coefficient is given, than the lift coefficient if the angle is given. In order to make these comparisons at equal lift coefficient it will be necessary first to plot all of our data, because in wind tunnel tests the angle of attack is the primary quantity and the lift is measured afterwards.

After having tested the veracity of the theoretical biplane formulae, and calculated correction factors from our data, we hope to be able in the statement of our conclusions

(1) to indicate which formulae represents the facts with sufficient accuracy to be immediately used as a routine method in the design room, and

(2) to present one or two small charts which shall summarize all the correction factors for biplane combinations from gap chord ratio equal 0.50 to 2.00 and stagger equal -40% to +60%.

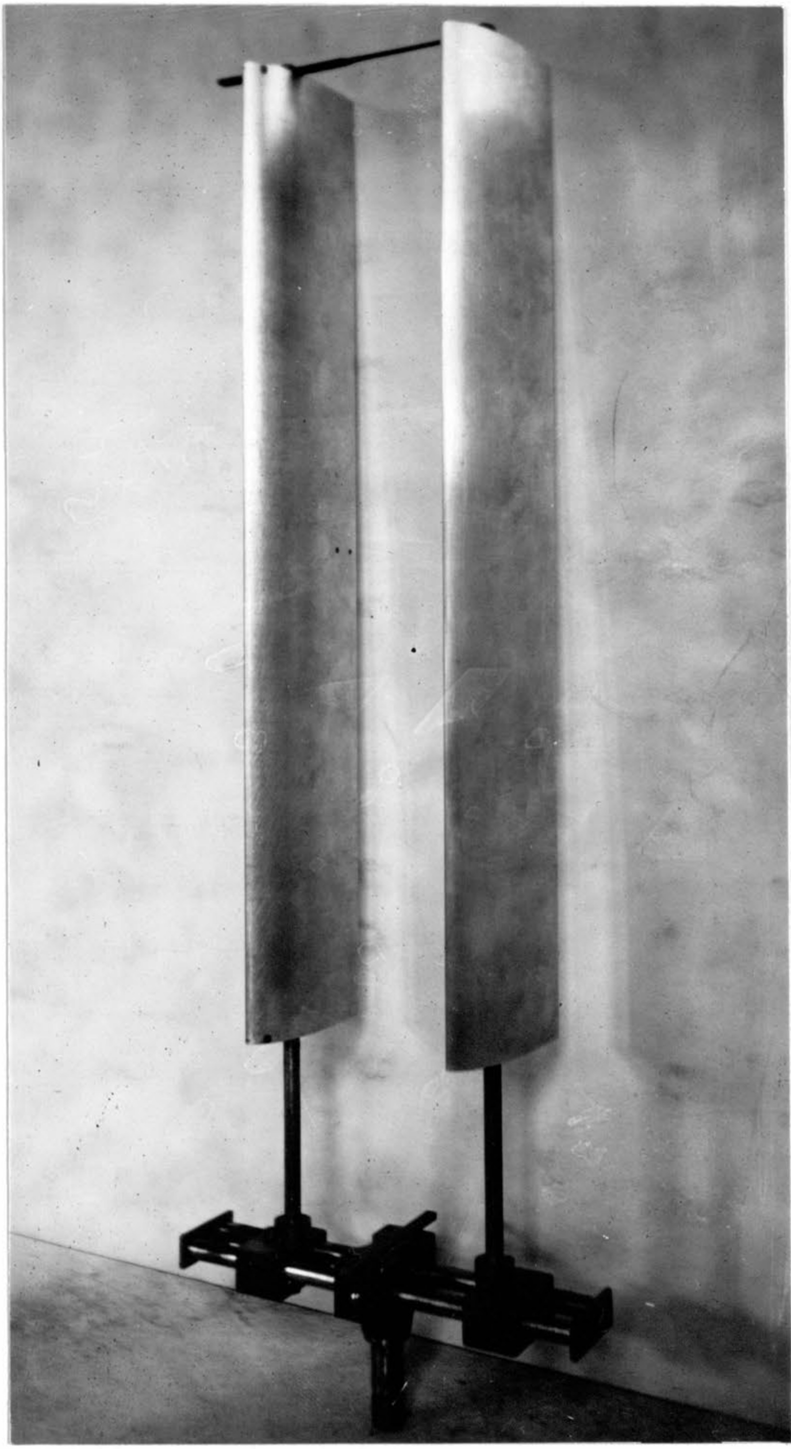
Section III.

DESCRIPTION OF APPARATUS

All of the tests were conducted in the M.I.T. 4'0 wind tunnel, with the N.P.L. type balance, at a wind velocity of 40.0 m.p.h. The standard apparatus of the wind tunnel was used for testing each airfoil as a monoplane, and for mounting the two biplane combinations in which each wing was tested separately in the presence of the interference of the other.

Each of the remaining combinations was tested as a biplane unit, and for this purpose we developed the type of mounting illustrated by Photos 1 and 2, and Plates 1 and 2. The complete biplane structure, consisting of balance crosshead, 2 spindles, 2 airfoils, and one strut, is shown in Photo 1. The balance crosshead and spindles are shown in complete detail by Plates 1 and 2. So suffice it to say that the crosshead was designed to screw into the balance head in place of the regular chuck for mounting monoplanes, and was equipped with all the gadgets necessary to align it transverse to the wind tunnel axis, to hold the two spindles firmly in alignment, and to quickly and accurately adjust the distance between their axes and the balance axis. In the Method of Procedure, p. 19, the method of mounting is described. All parts of the crosshead were constructed of brass, with the exception of the chuck (7), the two slider rods (5), and the spindles (2), which were of mild steel.

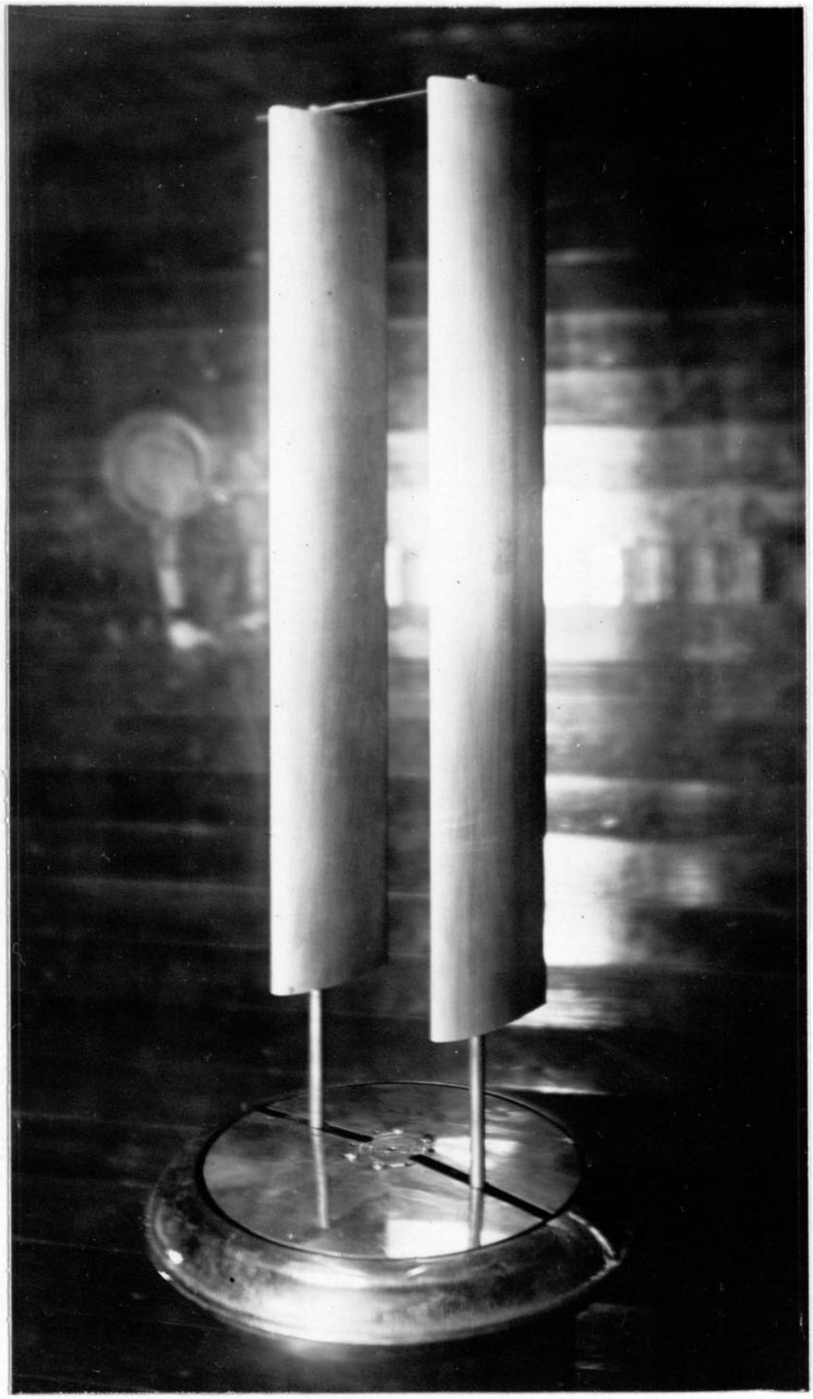
The airfoil models were of aluminum, 18" x 3", accurate to 0".0015. For the purpose of holding the two airfoils rigidly spaced at their upper end, three different lengths of strut were employed, PHOTO 1.



THE BIPLANE STRUCTURE

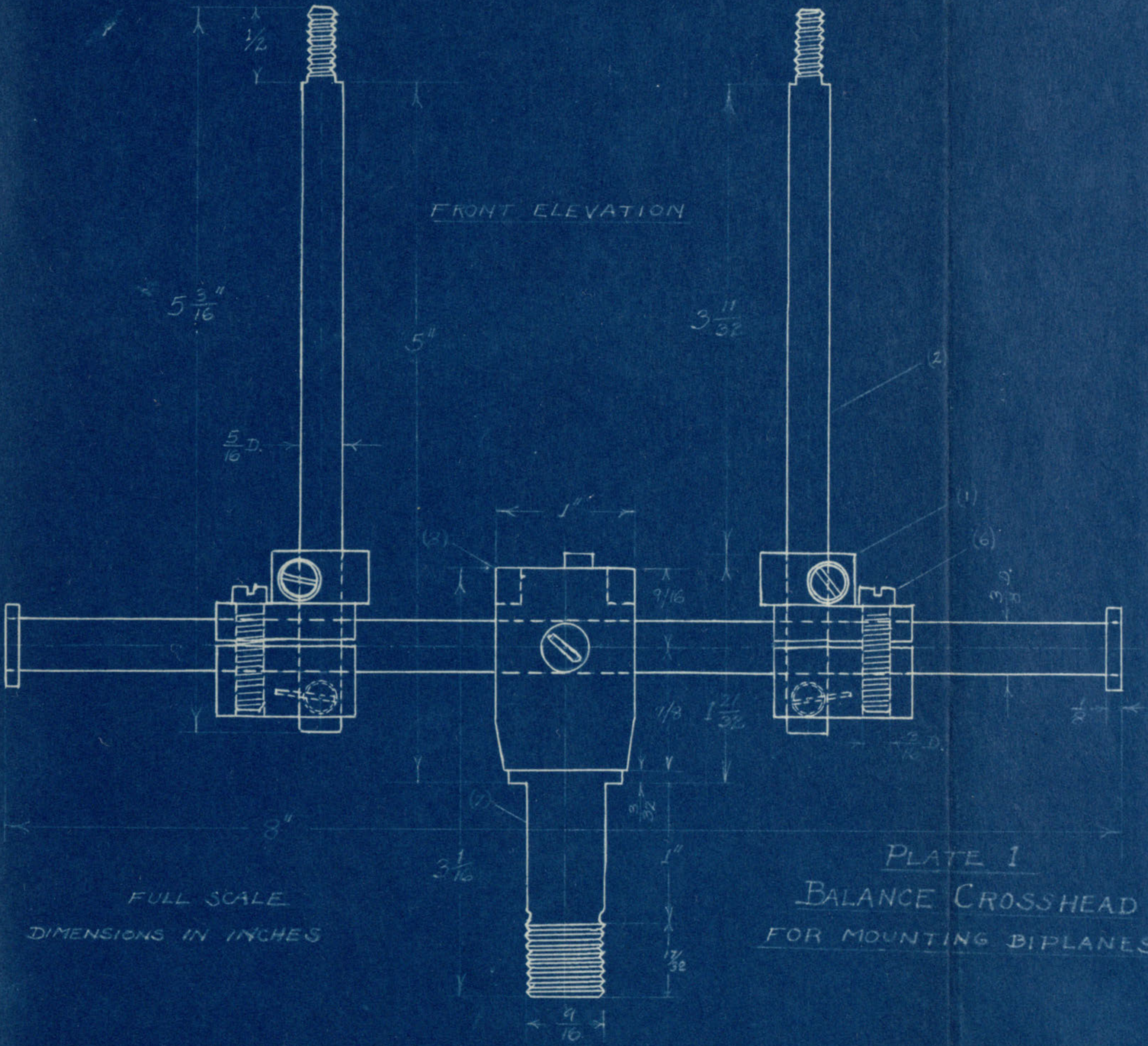
Composed of balance crosshead,
spindles, airfoils, and strut.

PHOTO 2.



BIPLANE MOUNTED IN WIND TUNNEL

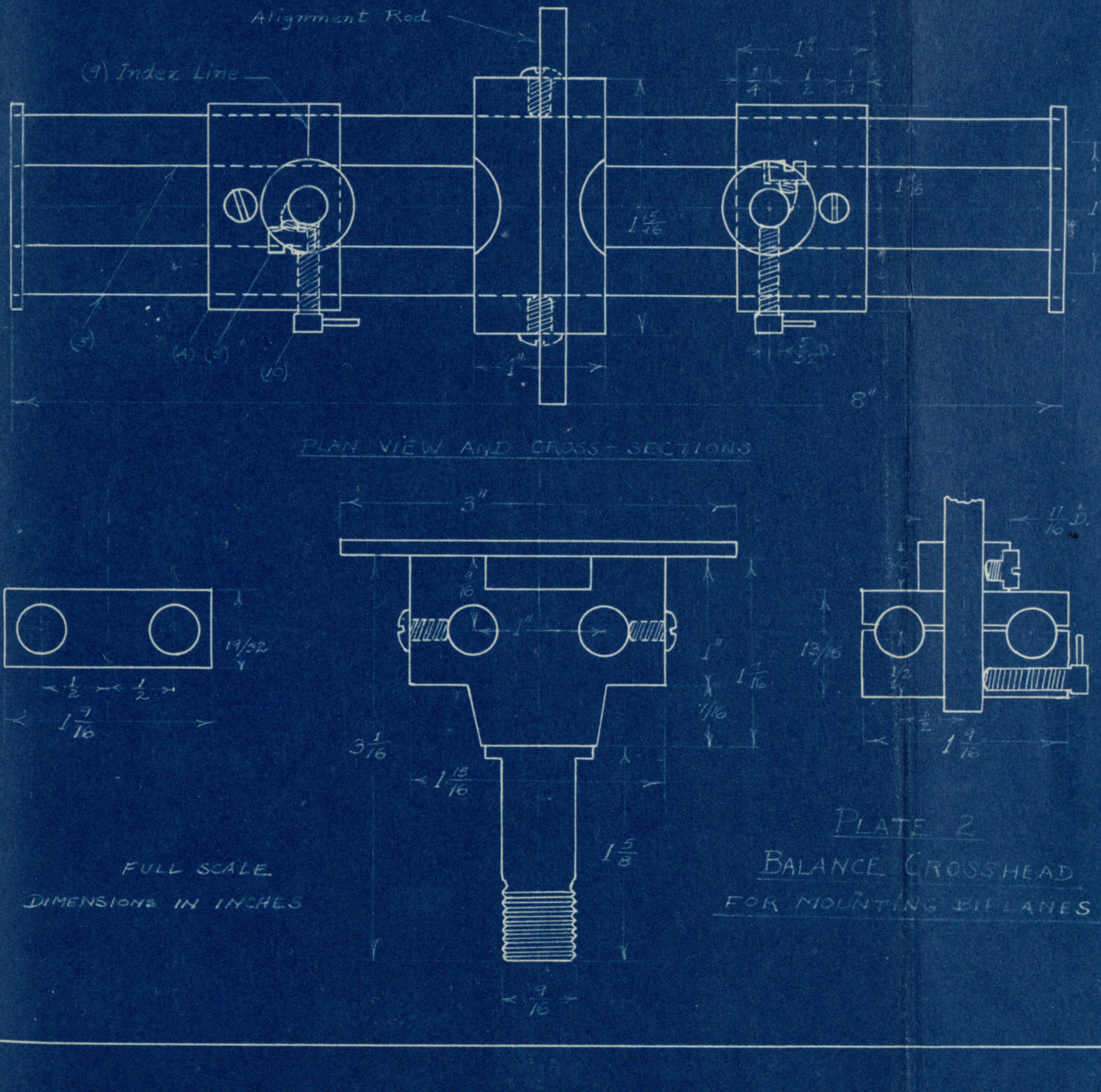
Balance crosshead protected
from wind by discoid case.



FULL SCALE
DIMENSIONS IN INCHES

PLATE 1

BALANCE CROSSHEAD
FOR MOUNTING BIPLANES



PLAN VIEW AND CROSS-SECTIONS

FULL SCALE

DIMENSIONS IN INCHES

PLATE 2

BALANCE CROSSHEAD

FOR MOUNTING BIPLANES

which we shall refer to as the long, medium, and short struts. Each strut was constructed of brass, was prong-shaped throughout half of its length, and was filed into a stream-line form, as far as possible. When a given strut had been attached to the biplane by means of two round-headed screws, the prong part of the strut was filled in with putty in order to decrease the resistance. This was also done of course when the effective resistance of the strut was measured separately.

It was found that the resistance of the balance crosshead was of the same order as that of the biplane model itself, so it was found desirable, in order to obtain more accurate values for the biplane drag, to protect the crosshead from the wind stream by means of some kind of a case. For this purpose we utilized a Cello hot watter bottle, which provided us with a hollow metal case, of discoid shape, 10".5 in diameter by 2".0 maximum thickness, which we shall hereafter refer to as the "discoid case." From the top of the discoid case a circular cover 8".0 in diameter was cut, and with the exception of $1\frac{1}{4}$" at its center it was slotted across one of its diameters. The bottom of the discoid case was attached to the top of the fairwater through which the balance head projected, and the cover was attached to the central black (8) of the balance crosshead. The bottom thus remained stationary while the cover rotated with the crosshead, and the slots in the cover permitted the distance between the spindles to be varied. The method of utilization is evident from Photo 2, which shows a biplane combination mounted in the wind tunnel, with the balance crosshead protected from the wind by the discoid case.

Section IV.

METHOD OF PROCEDURE

Each of the two U.S.A. 27 airfoils was tested twice as a monoplane, and the average (p. 103) taken as the standard to which to apply biplane correction factors.

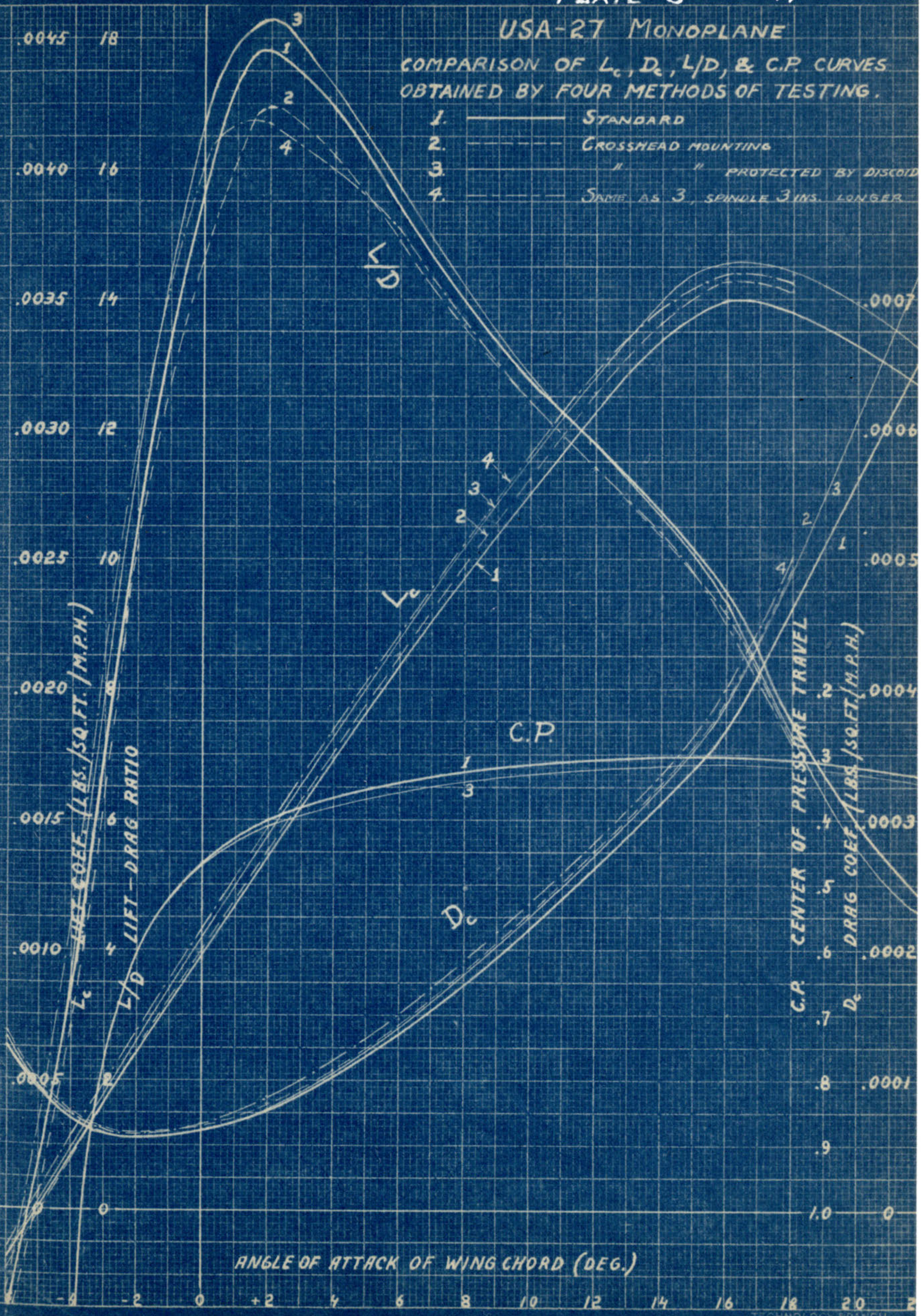
The upper and lower wing of two biplane combinations were then tested separately, in the presence of the interference of the other, at G/C = 1.00 and 1.67, and stagger = 0 (pp104-109). It was originally intended to test all the biplane combinations in this way, but the vibration of the two airfoils, due to the repulsion existing between them working against the elasticity of the material, was appreciable at G/C = 1.67, and at G/C = 1.00 it was entirely too large for accurate work when this lift was larger than 1.2#. It would have been possible to have rigidly fixed one of the two airfoils by means of an additional spindle supporting its upper end, but that would have increased the amplitude of vibration of the airfoil which was being tested, and the only way to decrease the latter would have been to decrease the wind speed.

It was not desirable to conduct the test at a wind speed below 40 m.p.h., since that is the standard speed at which most of the tests on airfoils have been conducted at M.I.T., and a direct comparision of results would thus be possible. So for the remainder of the tests we mounted the biplane model in the wind tunnel as a rigid unit, as described in Section III.

We then conducted a series of tests to determine whether the balance crosshead should be protected from the wind, and what spindle length was most desirable. We first tested a single U.S.A. 27 airfoil mounted on the balance crosshead exposed (p. 110). This showed that the resistance of the balance crosshead exposed was equal to about 3½ times the minimum drag of the airfoil, and thus necessitated the use of a protecting case, for which purpose we utilized the discoid case previously described. We then tested each of the two U.S.A. 27 airfoils twice as a monoplane, mounted on the balance crosshead protected by the discoid case, and with standard spindle length, i.e., projecting 5".00 above the balance head (pp.111-112). Owing to the presence of the discoid case within 3".0 of the end of the airfoil, the lift and drag were both increased by about 4%. In am attempt to eliminate this interference we increased the spindle length to 8".00, i.e., 3".00 longer than the standard length, and conducted the same number of tests as before (pp.114-115), but the average results (p.116) were not so good as the previous average (p.113), most likely due to the larger deflection error arising from the bending of the spindle. For the biplane tests we therefore decided to protect the crosshead by means of the discoid case, and to use the 5".00 spindle length. As an aid to comparison we have platted the results of the above mentioned preliminary tests in Plate 3. ~~See back of previous page.~~

The average value of the four tests on the U.S.A. 27 monoplane with crosshead mounting protected from the wind by discoid case, (p.113, and curve 3 on Plate 3) is taken as the standard to which to compare U.S.A. 27 biplane results and thereby obtain biplane correction factors. This procedure involves the assumption that the interference effects of the discoid case on the biplane are in the same proportion as for the monoplane. We later tested each of the two Göttingen 387 airfoils in the same way (pp147-150), and took the average results (p.151 and curve

PLATE 3



USA-27 MONOPLANE

COMPARISON OF L_c, D_c, L/D, & C.P. CURVES OBTAINED BY FOUR METHODS OF TESTING.

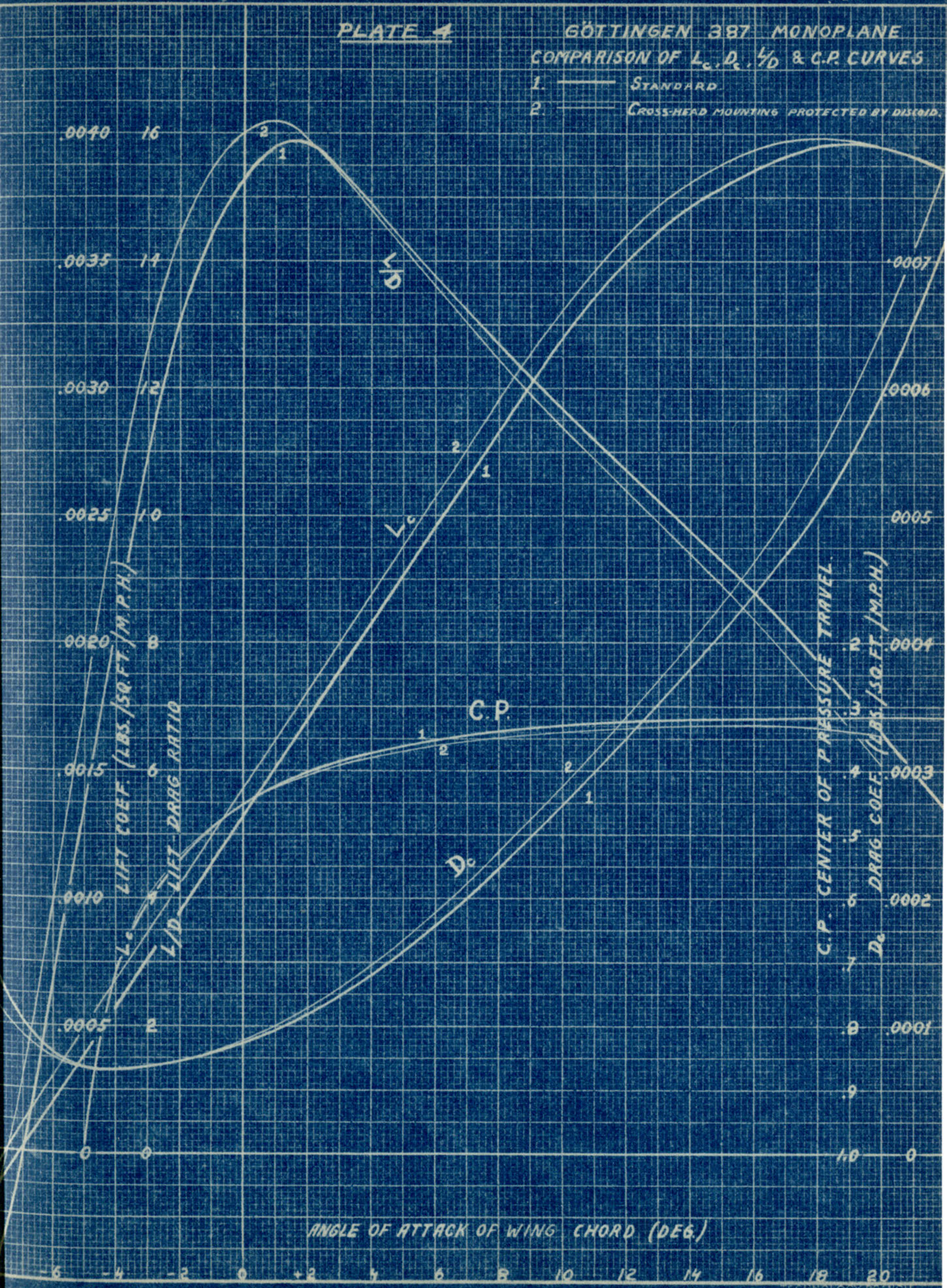


PLATE 4

GÖTTINGEN 387 MONOPLANE

COMPARISON OF L_c. D_c. L/D & C.P. CURVES

2 on Plate 4) as a basis to which to compare the Göttingen 387 biplane results.

We then proceeded to test twenty-nine U.S.A. 27 and twelve Göttingen 387 biplane combinations. In each test we measured L, D, and M, the moment about the balance axis prolonged, and then calculated L/D, $M_{l.e.}$, and C.P. The procedure in each case was as follows:

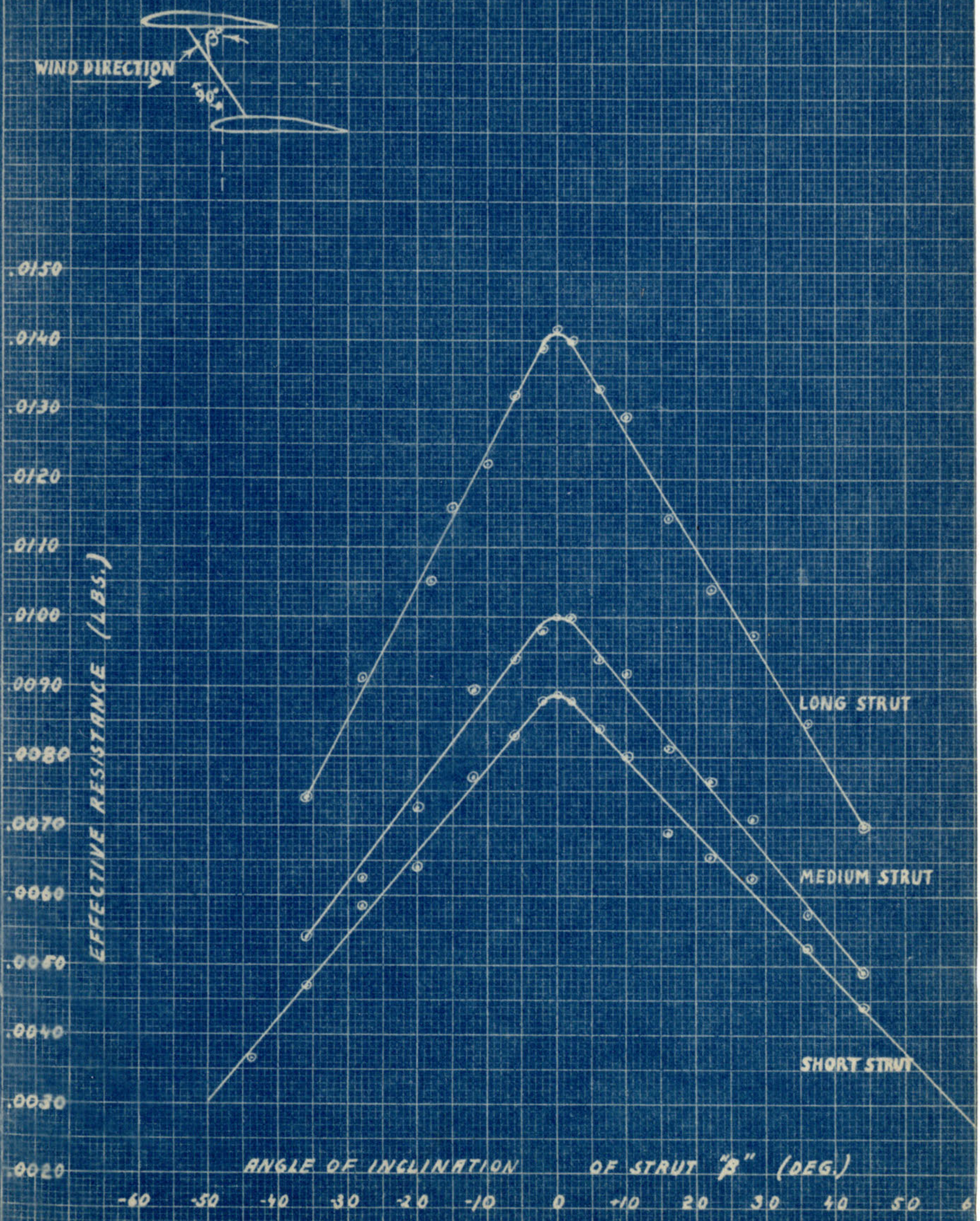
<u>The set up</u>. The cover of the discoid case was removed and the balance crosshead aligned transverse to the axis of the wind tunnel. Collars (1) were attached to the spindles (2) by screws (3), so that the distance from the top of the collar to the top of the spindle was 3-11/32". This made the distance from the balance head to the airfoil 5".00. The distance between the spindle axes was then adjusted by moving the slides (4) along the slider rods (5), and locking them in position by means of the slider clamp screws (6). The spacing was always previously calculated so that the chord of each airfoil would be equidistant from the balance axis; and the distance was laid off accurate to o".01 by laying a small steel rule flat on the upper surface of a slide (4), at the same time placing its end squarely against the side surface of the central block (8), and measuring from the latter to the index line (9) on the surface of the slide. The balance head was then rotated through the number of degrees of stagger which the given biplane combination was to have, and locked. The airfoils were screwed on to the spindles and aligned parallel to the tunnel axis by sighting along a batten. The spindles were then locked by the screws (10), the airfoils rigidly and accurately spaced at their upper ends by means of a strut, the discoid cover replaced, and the test was ready to begin.

<u>The test</u>. L_0, L_1, D_0, D_1, M_0, and M_1 were measured in the usual manner. The center of rotation at the upper end of the model was then located, and its coordinates, p and d (fig. 1, p. 96), measured. From p and d we then calculated a and h (fig. 1), the coordinates of the mean center of rotation. After correcting the drag for effective spindle resistance, D_s, and effective strut resistance, D_s, we calculated L, D, L/D, M_{1e}, and C.P. The values of the effective strut resistance had been previously measured so that in a given biplane test it was only necessary to take them from the curves on Plate 4a. This strut resistance was of course different for each angle of incidence of the biplane, whereas for a given pair of spindles the resistance was practically constant. Lift and moment corrections due to strut and spindles being not equidistant from the balance axis were negligible.

All of the original data for the 41 biplane tests and for the sixteen or seventeen other tests are given in Appendix B.

PLATE 4a.

CURVES OF EFFECTIVE STRUT RESISTANCE.



Section V.

ESTIMATION OF ERRORS

It is unnecessary to mention here the errors inherent in a wind tunnel equipped with an N.P.L. type balance. We shall discuss only those errors arising when our procedure departed from routine procedure.

(I) Mis-Alignment of biplane model. In setting up the biplane model the distance between the spindle axes and the balance axis could be set to the nearest 0".01, thus making the maximum error in gap equal to ± 0".01 at zero stagger. Likewise at the other end of the model the strut distance could be set within 0".01. The maximum error in G/C ratio would then be ± 0.003 at zero stagger, and the maximum error in stagger would be 0".01 sin 50°.2 = 0".01, i.e., ± 0.3%, at G/C = .50 and 60% stagger. In setting the number of degrees of stagger the balance head could be set to the nearest 0°.1, thus giving an error in stagger of ± 0°.05, or ± 0.1%, and a G/C error equal 0.0000. The sum of these factors gives a maximum error of ± 0.003 in G/C, and of ± 0.4% in stagger. Since the sum of the errors both in stagger and G/C can only produce an error of about ± 0.2% in L_c max., and L/D max., as shown by our final results, they are entirely negligible, and would have to be neglected even if they were not so, because they are so far within the wind tunnel error. No further mis-alignment of the biplane model took place due to the forces acting upon it during the course of the wind tunnel test because the balance crosshead, the airfoils, and the stiff strut at the top formed a very rigid structure.

(II) Mis-Alignment between the model axis and the balance axis, occurred to a greater or less degree when the airfoil was screwed into the spindle, but a larger misalignment occurred in the case of those models which were mounted on the balance crosshead due to the fact that the spindles supported thereon were not exactly parallel to the balance axis. These two factors, combined, served to give a small amount of roll and yaw to the model, which amounts can be estimated from the coördinates of the center of rotation measured at each end of the model. "A" and "h", the average values of these coördinates measured at each end (Notation p. 96), have been set down at the head of the tabulated records for each test, and are summarized in the following table.

		(1)	(2)	(3)
h	Aver.	.15	.86	.07
	Max.	.19	.92	.21
a	Aver.	.98	.79	.90
	Max.	.93	.74	.81

All values are positive, and are given in inches. Column (1) gives the average and maximum values of "a" and "h" for the eight monoplanes tested in the routine way, with spindle mounted directly in the balance head; (2) gives the corresponding values for the four monoplane tests conducted with the airfoil mounted on the balance crosshead protected from the wind by the discoid case, with spindle axis 0".75 from balance axis; (3) corresponding values for the 41 biplane tests.

From these values of "a" and "h" we have calculated the values in inches of roll and yaw at the upper end of the model.

		(1)	(2)	(3)
Roll	Aver.	.17	.08	.14
	Max.	.25	.15	.42
Yaw	Aver.	.04	.42	.21
	Max.	.14	.51	.38

In calculating the degrees of roll and yaw we divided the values in column (1) by 18.00 (= span of airfoil in inches) and multiplied by 57.3, whereas in the case of (2) and (3) we divided by 22.00 (= span of airfoil in inches, plus spindle distance from bottom of airfoil to axis of balance crosshead) and multiplied by 57.3. This method was followed because in the case of (1), a single airfoil mounted in the routine manner, the spindle was but a prolongation of the balance axis, and the mis-alignment was between the spindle axis and the airfoil axis; whereas in the case of (2) and (3) the mis-alignment between model axis and balance axis was due almost entirely to the fact that the spindle axes themselves were not parallel to the balance axis, the model axis being practically parallel to the spindle axes. The value of roll and yaw calculated in this way were:

		(1)	(2)	(3)
Roll.	Aver.	0°.5	0°.2	0°.4
	Max.	0°.8	0°.4	1°.1
Yaw	Aver.	0°.1	1°.1	0°.5
	Max.	0°.4	1°.3	1°.0

All angles of roll and yaw were positive, according to N.A.C.A. notation.

The effect of the mis-alignment in roll would be negligible. The wind direction would still be parallel to the wing chord, and the forces measured on the balance would be (the actual forces) X cos (angle of roll).
The cosine of the largest angle of roll recorded, 1°.1, is 0.9998, so the negligible error of only 1/50% would be involved. Even for 4°.0 of roll the error would be only ¼%.

The effect of yaw is more potent, because it puts the airfoil chord at an angle to the wind direction. The following % errors are taken from data on a Clark tractor biplane model tested at M.I.T.*

% Errors for angle of Yaw = +2°.0

Angle of attack	0°	6°	12°
Lift..............	-1.5	-0.7	-0.7
Drag..............	+2.6	+1.2	0
C.P...............	Less than ½% of chord.		

These values were calculated for a complete model at + 2° yaw, but for tests on airfoils only, the importance of accurate alignment is greatly lessened, because the forces which cause most of the difficulty arise principally from the fuselage and tail surfaces. If we assume that 25% of the error arises from the airfoils alone, and remember that the maximum yaw arising in any one of our tests was +1°.3, it would seem by comparison that in our case the maximum error due to yaw was less than +½% for drag, less than -¼% for lift, and entirely negligible as regards moment. Detailed calculations for our specific case appear unnecessary.

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* N.A.C.A. Report, 1919, p. 633.

(III) Spindle and Strut Resistance. In the case of the 41 biplane tests the effective spindle resistance, D_s, could not be determined to any greater degree of accuracy than ± 0.0009#, due largely to the fact that slightly different lengths of the spindle, as much as ± 1/20", were inevitably exposed each time the discoid case cover was removed and replaced. Likewise we believe that the error involved in determining the effective strut resistance, D_s, was about ± 0.0003#. This makes the sum of the deviations for effective strut and spindle resistance equal to ± 0.0012#, and involves the following errors in our biplane computation.

% Errors due to strut and spindles.

		$D_{Min.}$	L/D Max.	D at $L_{Max.}$
U.S.A. 27	Min.	±1.5	±1.0	±0.3
Biplane	Max.	±1.7	±1.1	±0.2
Gottinger	Min.	±1.3	±0.8	±0.2
387 Biplane	Max.	±1.4	±0.8	±0.2

All of these values really represent maximum % errors, the row designated "min." being calculated for G/C = 0.50, stagger = -40%, which involved the largest values of drag, while the row designated "max." was calculated for G/C = 2.00, stagger = 60%, involving the smallest values of drag. The maximum possible errors in measuring drag were thus about ±1.7% at $D_{min.}$, ±1.1% at L/D max., ± 0.6% throughout the flying range (4°-10°), and negligible when the lift was near its maximum. The average errors were of course about one half of these values, say 1, $\frac{1}{2}$, and $\frac{1}{4}$%, respectively.

The fact that the spindle axes were not quite equidistant from the balance axis, but were so spaced as to make the wing chords equidistant, as well as the fact that the strut usually protruded over one end of the model (Photo 1), produced no appreciable error in measuring moments. This was determined both by computation and by actual measurement.

(IV) Deflection and N.P.L. balance errors. Deflection of the biplane model would if anything be less than that of a single airfoil mounted in the usual manner, because in the case of the biplane any deflection in roll must cause distortion or slipping of the strut attached at the top. ~~Likewise spindle deflection at the top.~~ Likewise spindle deflection would be less because the spindles had a free length about 1."0 shorter than the usual free length. At the same time all the errors involved in the N.P.L. type balance, whether of deflection or otherwise, remain entirely negligible, even though the forces were doubled as compared to the forces on a single airfoil.

SUMMARY

We believe we have found and estimated approximately correctly most of the errors characteristic of the method we employed in conducting our tests. These errors are summarized in the following table, in which the Roman numerals refer to the sources of the error.

MAXIMUM % ERRORS.							
Sources of Error	L_c		D_c			L/D	
	0°-12°	Max.	Min.	At L/D max	Flying Range 4°-10°	Max.	Flying Range 4°-10°
(I)		±0.2				±0.2	
(II)	-0.3		+0.5	+0.5	+0.5	-0.8	-0.8
(III)	-		±1.7	±1.1	±0.6	±1.1	±0.6
Total Max. Error	-0.3	±0.2	+2.2	+1.6	+1.1	-2.1	-1.4

We have previously stated that the errors arising in the determination of M_c and C.P. were negligible, and we here see that the L_c errors are also negligible, but the errors for D_c min., and L/D max. could be over 2%, while throughout the flying range the errors for D_c and L/D could be as much as 1% and 1½% respectively. These are the maximum errors. The average errors would be about half as much. But even at their maximum these errors are no larger than the wind tunnel experimental error, which is considered to be about 2%. Taking the latter into account the maximum errors could be about 4% for D_c min. and L/D max., and about 3% for D_c and L/D throughout the flying range.

However, our final biplane correction factors (Plates 13, 14) have a greater reliability than this. They were obtained by comparing the data from 41 biplane tests and plotting smooth curves. We consider them to be accurate within ±1%.

But although these final generalized results have this degree of accuracy, the specific results from a given biplane test may not have. In conducting as many as 41 biplane tests it was inevitable that to one or two of them there should befall all of the maximum errors estimated above. Such was the lot of the U.S.A. 27 biplanes, G/C = 1.67, stagger = 0, and of the upper wing tested separately for the U.S.A. 27 biplane, G/C= 1.00, stagger = 0.

Such individual discrepancies as these have not vitiated the final results. By a comparison of the results as a whole they have been detected and eliminated.

Section VI.

ANALYSIS OF RESULTS

Section VII.

ANALYSIS OF RESULTS

The U.S.A. 27 airfoil was thoroughly tested as a monoplane, and in 31 biplane combinations; while the Göttingen 387 airfoil was tested as a monoplane, and in 12 biplane combinations. All of the biplane combinations tested are listed in the following table:

	G/C					
Stagger	0.50	0.75	1.00	1.33	1.67	2.00
-40%	u	ug	ug	ug	u	u
-20%		u	ug	u	$\overset{u}{-33\%}$	
0%	u	ug	uug	ug	uu	u
20%		u	ug	u	$\overset{u}{-33\%}$	
40%		u	ug	u		
60%	u	ug	ug	ug	u	u

g= Göttingen 387; u= U.S.A. 27; uu = U.S.A. 27 tested both as a biplane unit, and in addition each wing tested separately in the presence of the other.

The original data for these tests are tabulated in the order in which originally made, in Appendix B.

It must be remembered that this original data represents the forces acting on the biplanes in the presence of the interference of the discoid case. As mentioned in Section IV, p. 16, it was thought that the easiest way to correct for this interference would be to compare the biplane results with the results obtained from a monoplane tested in the same way (p. $\overset{113}{151}$). We made these comparisons at equal angles of attack, because to have done so at equal L_c would have necessitated plotting all the original data. Instead, we obtained biplane correction factors at equal α, for L_c, D_c, L/D, and M_c, (Tables 1-33). We then multiplied the aerodynamical coefficients for the U.S.A. 27 and Göttingen 387 monoplanes tested in the routine way (pp. 103, 146) by these biplane correction factors, and so obtained the true biplane values for the L_c, D_c, L/D, and M_c (Tables 34 - 55, 62 - 73); while the true biplane values for C.P. (Tables 56 - 61, 73 - 76) were more easily obtained by adding certain corrections to the original biplane data. Having thus arrived at true values of the biplane coefficients, we plotted them (Plates 5-12), and by reading values from the curves were able to check the accuracy of Munk's formulae (pp. 32-79) and to calculate biplane correction factors at equal values of the L_c (Tables 89-109).

Having thus outlined the use to which our original data was put, we shall now analyze in detail the results obtained.

I. Biplane Correction Factors at Equal α.

These factors (Tables 1 - 33) were obtained more or less as a by-product in the process by which we arrived at the true biplane values for the L_c, D_c, L/D, and M_c. They are not of as much significance as the correction factors obtained by making comparisons between the biplane and monoplane results at equal values of the L_c, because lift is really the primary datum in considering an airfoil, and the angle of attack at which the lift occurs is only a secondary consideration. Nevertheless, an analysis of these factors will doubtless repay the effort involved, for they show ––

(1) The values of all biplane coefficients in terms of the corresponding monoplane results at equal α,

(2) how the biplane coeffieicnts at equal α vary with stagger and G/C, and

(3) how for a given biplane combination the effects of a given stagger

and G/C vary with α.

We shall analyze in turn the correction factors at equal for L_c, D_c, L/D, and M_c.

1. Lift Coefficient. - For a given biplane combination the correction factors are practically constant from $\alpha = 0^\circ$ to $\alpha = 12^\circ$ or 14°. Thus for the U.S.A. 27 biplane, G/C = 1.00, stagger = 0, the values are ---

α°	0	2	4	6	8	10	12	14
Correction Factor	.85½	.86½	.87	.86½	.85½	.86½	.86½	.87½

The average value is .86½ ± .01, while the corresponding average for the Göt. 387 is .85½ ± .01, thus making the average for the two, 0.86. The constancy of the correction factors from 0° to 12° - 14° for a given biplane combination, and the good agreement between the U.S.A. 27 and Göt. 387 results, are shown to better advantage by plotting the factors for each combination, but we consider it unnecessary to include the chart so obtained here. In the way illustrated above we have found the average factors for all the biplane combinations tested and tabulate them below.

Table 75
Biplane Correction Factors for L_c, $\alpha = 0^\circ$ to 13°.
U.S.A. 27, and *Göt. 387 Airfoils.

	Gap/Chord					
Stagger	0.50	0.75	1.00	1.33	1.67	2.00
60%	.89	.92½ *.91½	.93½ *.95	.89 *.90½	.95	.96
40%		.90	.90 *.90	.90		
20%		.84½	.88½ *.85½	.94		
0%	.76½	.82 *.82	.86½ *.85½	.89½ *89½	.86½	.94
-20%		.78	.86½ *.86½	.89		
-40%	.69½	.77 *.78½	.82½ ".84½	.87 *.85	.88½	.91½

The data of Table 75 are plotted in our final Chart, Plate 13, and given a series of smooth curves which we believe are accurate within ±1%, and from which we take the following values as a comparison to Table 75.

Table 76

Biplane Correction Factor For L_c, 0° - 13°
Applicable to Airfoils having a Max. Camber = 10 to 16%.

	Gap/Chord					
Stagger	0.50	0.75	1.00	1.33	1.67	2.00
60%	.89	.92	.94	.95	.95½	.96
40%		.89	.91½	.93		
20%		.94½	.88½	.91		
0%	.76½	.82	.86½	.89½	.91½	.94
-20%		.80	.84½	.88		
-40%	.69½	.77½	.83	.86	.89	.91½

We shall now consider whether the factors in Table 76 are applicable to any airfoil. From the standpoint of the vortex theory the lift of an airfoil may be divided into two parts, lift due to curvature, and lift due to angle of attack.

For a monoplane,

Lift coefficient*due to curvature = $2\pi \sin\beta_0$ ....(1)
" " " " angle of attack=$2\pi \sin\beta$ ......(2)

While for a biplane,

Lift coefficient due to curvature = $2\pi \sin\beta_0 B_0$.......(3)
" " " angle of attack = $2\pi \sin\beta B$**.....(4)

If comparisons are then made at equal angles of attack (equal β) for monoplane and biplane, the biplane correction factor for the lift coef. due to curvature is

$$\frac{2\pi \sin\beta_0 B_0}{2\pi \sin\beta_0} = B_0 ,$$

and for the lift coef. due to angle of attack is

$$\frac{2\pi \sin\beta B}{2\pi \sin\beta} = B .$$

* C_L. Munk's nomemcla. See our App.A.

B and B_0 are theoretically determined constants (ref. 9) which depend only on the biplane combination, i.e., on the amount of stagger and G/C, so that these biplane correction factors for the two individual components of the lift coefficient are independent both of airfoil profile and angle of attack. But the lift due to angle of attack increases as the angle increases, while the lift due to curvature remains constant for a given airfoil. Therefore the biplane correction factor for total L_c will be at least slightly different for every airfoil and every angle of attack. Precisely it will be equal to —

$$\frac{\sin\beta_0\cdot B_0 + \sin\beta\cdot B}{\sin\beta_0 + \sin\beta} = B + (B_0-B)\cdot\left\{\frac{\sin\beta_0}{\sin\beta} - \frac{\sin^2\beta_0}{\sin^2\beta} + \dots\right)\dots\dots(5)$$

The value of this is $(B_0 - 1)$ when $\beta = \beta_0$, and gradually approaches B as the angle of attack is increased. Thus far the U.S.A. 27 airfoil, G/C = 1.00, stagger = 0; $B = .854$, $B_0 = .925$, and the theoretical and experimental values of the biplane correction factors are -

$\alpha°$	0	2	4	6	8	10	12	14
Theor.	.91½	.89½	.88½	.87½	.87½	.87	.87	.86½
Exper.	.85½	.86½	.87	.86½	.85½	.86½	.86½	.87½

The agreement here is good from 6° - 14°, but the predictions of the vortex theory are usually restricted to this range anyway. It might be inquired as to why the biplane lift could not be determined directly by using formulae (3) and (4), but that cannot be done, as shown by a detailed computation, p. 55, because these formulae represent a solution of the two - dimensional problem only. But we can compare results obtained from (3) and (4) with those obtained from (1) and (2), and thus get biplane correction factors, based on the assumption that the effect of the lateral dimensions (the 3rd dimension) is proportionately the same for both monoplane and biplane.

From formula (5) we see that for a given biplane combination the value of the biplane correction factor depends on β_0 and β. β_0 represents the curvature effect, while $\beta = 0$ represents the angle of attack at which the moment about the center of the wing is zero. Since both of these factors are a function of camber, we should expect airfoils of approximately equal camber to have approximately equal biplane correction factors. Our experimental results show this to be true for the U.S.A. 27 with maximum camber equal 10.98%, compared to the Göt. 387 with maximum camber equal 15.14%. And a comparison of the correction factors for these two airfoils with the limited data previously published for the thin Eiffel 13 bis, R.A.F. 6c, F.A.F. 15%, and Eiffel 36 airfoils, shows that the latter are always about 5% lower than the former.* From formula (5) we also see that as the angle of attack (β) is changed the biplane correction factor must change, but our experimental results show that the deviation from the average taken between $0^\circ - 12^\circ$ is only about ±1% for the U.S.A. 27 and Göt. 387 airfoils.

Summing up, we can therefore say of the factors given in Table 76, that they are not of any especial significance, but afford a convenient means of comparing the lift of different biplane combinations throughout the flying range ($0^\circ - 13^\circ$), and are accurate within ±1% for airfoils having a maximum camber of from 10 to 16%.

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* For a detailed comparison see Section VII.

2. Drag Coefficient - The biplane correction factors at equal α for D_c (Tables 11 - 19) are invariably larger than 1.00 for minimum drag, and show a steady decrease from that point onwards as α increases. However, they remain fairly constant from 6° to 16°, throughout which range an average value can be taken from which the deviations will not usually be greater than ± 2%. The Göt. 387 results as a whole agree with the U.S.A. 27 results within about 3% from α = 0° to 14°. The range of variation of the factors from 6° - 16°, as well as the lack of a closer agreement between the results for the two airfoils, does not justify a tabulation similar to that made for L_c factors in Table 75. The effect of stagger is much more pronounced than that of G/C, whereas the biplane correction factors for D_c at equal L_c, as we shall see on p. 66, are affected in exactly the opposite way.

3. Lift - drag Ratio. The correction factors at equal α (Tables 20-24) vary definitely for a given biplane combination as α is increased. They increase very little with stagger between $\alpha = 0°$ and 16°, the variation being within ± 2% from the average, but they increase rapidly as G/C is increased. The results for the U.S.A. 27 and Göt. 387 airfoils agree within about 2% from $\alpha = 0°$ to 14°.

4. Moment Coefficient - The correction factors for M_c (Tables 25-27) for a given biplane combination are fairly constant from about 4° to 14°, sometimes over a larger range, and sometimes not at all. We would expect constant factors from about 0° to 14°, because within that range $L_c \propto \alpha$, and the curves of M_c vs. L_c are practically straight lines radiating from a focus. As stagger is increased from -40% to 0% there is a slight decrease* in M_c, of from 1 to 5%; whereas

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* Decrease here means a decrease in the absolute value of the pitching moment about the L.E.

from stagger = 0 to 60% there is a decided decrease, of from 15 to 25%. The effect of negative stagger is thus negligible; the effect of positive stagger potent. The effect of increasing G/C is to decrease the M_c, but not to so great an extent as does stagger. The M_c correction factors for the Göt. 387 airfoil are effected to a smaller extent by variations of stagger and G/C than is the U.S.A. 27, so that the latter has higher values at negative staggers and lower values at positive staggers.

* * * * * * * * * *

This concludes the analysis (so-called) of the biplane correction factors at equal α for L_c, D_c, L/D, and M_c. They are not of much significance. They befell us as a by-product from the procedure by which we tried to obtain true values of the biplane aerodynamic coefficients. We hoped to correlate them in some useful way. In the care of the correction factors for L_c, from 0° to 13°, we succeeded, and consider the bother repaid.

We shall now proceed to consider the data on the upper and lower wings tested separately.

* * * * * * * * * *

II. Loading on Upper and Lower Wings.

The upper and lower wings were tested separately in the presence of the interference of the other for two U.S.A. 27 biplane combinations (stagger = 0, and G/C = 1.00, 1.67). We consider this data to be very reliable for G/C = 1.67 but not so reliable for G/C = 1.00, because during the test of the latter biplane the wings vibrated rather violently, whereas comparatively little vibration occurred in the case of the former. The L_C, D_C, L/D, M_C, and C.P. for each wing are tabulated with the Original Data, pp. 104-109. while the fractions of the total biplane lift and drag on each wing are listed on Table 34. We shall examine the aerodynamic coefficients for each wing in reverse of the order mentioned.

1. Center of Pressure. The vortex theory indicates that for unstaggered biplanes there should be little difference between the C.P. on the upper and lower wings. Our C.P.'s for G/C = 1.00 are in exact agreement from $\alpha = 0°$ to $18°$, but they differ by 4% of the chord for G/C = 1.67. There is nothing to indicate that these latter values are in error, for a combination of them in such a way as to give the C.P. of the biplane as a whole (Table 34) checks within $1\frac{1}{4}$% with the corresponding values obtained when the biplane was tested as a unit (Table 58). The same holds true for the C.P.'s at G/C = 1.00. Our data is therefore insufficient either to gainsay or verify the theory, and we have not been able to find any published data of this specific type.

2. Moment Coefficient. The M_C's for the upper wing are smaller than those for the lower wing at small angles of attack, and larger at large angles of attack. This holds true both at

G/C = 1.00 and 1.67, and checks with the results for the R.A.F. 6c biplane (ref. 2).

3. Lift coefficient. Distribution of lift between the upper and lower wings. The most significant way to deal with the lift on the upper and lower wings is to express the lift on each wing as a fraction of the total lift of the biplane. This is done in Table 34. The values there tabulated show that in general the lift on the upper wing is greater than on the lower except possibly at negative angles of attack. At G/C = 1.00 the load on the upper wing, expressed as a fraction of the total biplane lift, increases from 0.50 at 4° angle of attack to 0.54 at 20°; while at G/C = 1.67 the corresponding loads are 0.53 and 0.55. These figures show in a general way the distribution of lift between the upper and lower wings, but the manifold advantages to be gained from a more careful detailed design of wings justifies a thorough analysis of the load distribution from both theoretical and experimental standpoints.

From the standpoint of the vortex theory the lift on each wing of a biplane is considered to be the sum of primary and secondary lifts (ref. 1). The primary lift is the sum of lift and counterlift; it is that part of the entire lift of a wing which is produced by the interaction of the uniform flow with the circulation and counter-circulation flow around the wing. The secondary lift is a component of the mutual forces acting between parts of the whole biplane, consisting in this case of the repulsion between the upper and lower wings, increasing the lift of the upper and decreasing the lift of the lower by equal amounts.

For a biplane without stagger the upper and lower primary lifts are equal, for the induction at the upper and lower wing is almost equal, and therefore the changes of lift are equal. But a secondary difference is induced between the primary lifts due to the change of "effective stagger" as the angle of attack is changed. The "effective stagger" is not measured parallel to the wing chord, but more nearly parallel to the direction of flight. For the effects of aerodynamical induction are determined by the position of the vortex layer behind the wings, and the direction of this layer nearly coincides with the direction of flight. The "effective stagger" must therefore always be considered whether the biplane is staggered or not. For an unstaggered biplane it is directly proportional to the gap and to the lift coefficient. Due to it the change of induced upper and lower lift coefficient is

$$C_{L_1} = \frac{C_L^2}{\pi B}\,\frac{S}{b^2}\,\frac{G}{b}\left[\frac{b}{R}\left(\frac{1}{k^2}-0.5\right)\right]^{*} \qquad (6)$$

This quantity must be added to the absolute lift coefficient of the forward wing, and subtracted from that of the rear wing. It constitutes the only appreciable change of upper and lower primary lift on an unstaggered biplane.

We shall now analyze the secondary lift, which is a repulsion between the two wings. This repulsive force is produced both by the circulation flow and the vertical flow around the wings. The component due to the vertical flow is proportional

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* Ref. 9, p. 24. For notation see our Appendix A.

to the square of the angle of attack, and expressed as a quantity to be added to the upper and subtracted from the lower absolute lift coefficient, it is

$$\sin^2\beta \cdot v \; .^{*} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

On the other hand, the component due to the circulation flow is proportional to the square of the lift, and is

$$\frac{C \cdot C_L^2}{2\,\pi^2 \cdot B^2}{}^{**} \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (8)$$

Adding (7) and (8) we get the total secondary lift coefficient which must be added to the lift coefficient of the upper wing and subtracted from that of the lower:

$$C_{L_2} = \sin^2\beta \cdot v + \frac{C \cdot C_L^2}{2\,\pi^2 \cdot B^2} \; . \; . \; . \; . \; . \; (9)$$

The first term of this expression is proportional to the square of the angle of attack, while the second is proportional to the square of the lift. But lift arises both from curvature and from angle of attack. So for a given biplane the lift due to angle involves a double repulsive force, that arising from both (7) and the part of (8) due to angle; whereas the lift due to curvature involves a single repulsive force, that arising from the part of (8) due to curvature. Thick wing biplanes therefore have smaller repulsive forces than thin wing biplanes, and upper and lower lifts are more equal for the former.

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* Ref. 9, p. 26. For notation see our Appendix A.
~~** Ref. 1, p. 15.~~

Calculations for a specific case, however, show that at equal values of the lift coefficient this factor causes negligible differences of loading for a thin wing as compared to a mediumly thick wing. The theoretical curves, showing the fraction of total biplane lift on the upper wing plotted against lift coefficient, coincide for the R.A.F.6_c (max. camber 6.95%) and the U.S.A. 27 (Max. camber 10.98%), both biplanes being at G/C = 1.00, and zero stagger. The corresponding experimental curves do not so agree, but for the reasons previously stated the latter results are considered inaccurate. It seems safe to say that differences of curvature cause negligible differences of secondary lifts.

By adding the secondary lift coefficient (9) to the change of primary lift coefficient (6), we obtain

$$C_{L_1} + C_{L_2} = \pm \left[\frac{C_L^2}{\pi B} \; \frac{S}{b^2} \; \frac{G}{b} \; \frac{b}{R}\left(.5+\frac{1}{k^2}\right)\right] \pm \left[\sin^2\beta v + \frac{CC_L^2}{2\pi^2 B^2}\right] \ldots (10)$$

This expresses the equal and opposite amounts by which the upper and lower lift coefficients of an unstaggered biplane are changed. The first term of formula (10) must be added to the upper wing and subtracted from the lower at negative angles of attack, and vice versa at positive angles of attack. The second term is always added to the upper, and subtracted from the lower. According to the method of this formula we have calculated the lift on the upper wing of the three biplane combinations for which we have experimental data to serve as a basis of comparison. For one of these we give the detailed computations.

R.A.F.6c Biplane.*

Gap/Chord = 1.03, Stagger = 0, Aspect ratio = 6.

We calculate $S/b^2 = 1/3$, $G/b = \frac{1.03}{6} = 0.172$.

From curves of the original data we find that

$$\beta = 0^\circ \text{ when } \alpha = 0.^\circ3.$$

From ref. 9, Tables I and III, we obtain the following values:

$$B = 0.858, \quad C = 1.88, \quad v = 0.078, \frac{b}{R}\left(\frac{1}{k^2} - 0.5\right) = 0.671 .$$

We calculate $C_L = 0.0143\, C_L^2$, $C_L = 0.078 \sin^2\beta + 0.130\, C_L^2$.

It is then easy to calculate the value of C_{L_1} and C_{L_2} for each angle of attack. These are tabulated in Table 77.

Table 77.

Amount, $(C_{L_1} + C_{L_2})$, by which upper lift coef. (C_L) is increased.

R.A.F.6c Biplane

Gap/chord = 1.00, Stagger = 0 , Aspect ratio = 6.

			$C_L \times 10^3$	$C_L \times 10^3$		
β°	$L_c \times 10^5$	$C_L \times 10^3$	$14.3 \cdot C_L^2$	$78 \sin^2\beta$	$130\, C_L^2$	$(C_{L_1} + C_{L_2}) \times 10^3$
-6.3	-67	-260	1	1	9	11
-4.3	-30	-118	0	0	2	2
-2.3	7	28	0	0	0	0
-0.3	46	178	0	0	4	4
1.7	87	340	-2	0	15	13
3.7	127	498	-4	0	32	28
5.7	161	630	-6	1	51	46
7.7	195	650	-8	2	75	69
9.7	222	868	-11	3	98	90
11.7	253	990	-13	4	127	118
13.7	276	1076	-17	5	151	139
15.7	297	1160	-19	6	174	161
17.7	295	1150	-19	7	171	159
19.7	277	1080	-17	9	151	143

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* Original data taken from ref. 2, Table 2.

In the 2nd and 3rd columns the lift coefficients of the biplane as a whole are tabulated. C_{L_1} and the two components of C_{L_2} are tabulated in separate columns so that the relative importance of each of these three factors can be gauged. It is evident that the compenent of the secondary lift which arises from the circulation flow, viz.,

$$\frac{C \cdot C_L^2}{2\,\pi^2 \cdot B^2} = 0.130\ C_L^2\ ,$$

is by far the most important factor of the three involved. The other two, listed in the 4th and 5th columns could be omitted without causing an error of more than 1.1% in determining the % of lift on the upper wing. That amount is too large to be neglected, however.

The fraction of total biplane lift on the upper wing is equal to

$$0.50 + (C_{L_1} + C_{L_2})/2 \cdot C_L, \ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

where C_L is the lift coefficient of the biplane as a whole. The values of this fraction were calculated for the R.A.F. 6c, and also for the U.S.A. 27 at G/C = 1.00 and 1.67, according to the method of computation illustrated above. The experimental values are listed next to the theoretical values in Table 78.

Table 78

Theoretical and experimental values of the Lift on the Upper Wing, expressed as a fraction of the total biplane lift.*

Stagger = 0, Aspect ratio = 6.

	U.S.A. 27 Biplane						R.A.F.6c Biplane		
	G/C = 1.67			G/C = 1.00			G/C = 1.03		
α°	$L_c \times 10^5$	Theor.	Exper.	$L_c \times 10^5$	Theor.	Exper.	$L_c \times 10^5$	Theor.	Exper.
-6	-22	.51	.61	-16	.50	.89	-67	.52	.40
-4	26	.50	.60	17	.50	.18	-30	.51	.32
-2	58	.51	.54	48	.51	.41	7	.50	.83½
0	91	.52	.54	77	.52	.46	46	.51	.62½
2	126	.52	.53	107	.53	.48	87	.52	.57½
4	162	.53	.53	143	.54	.50	127	.53	.54½
6	191	.53	.53	169	.54	.51	161	.53½	.53
8	223	.54	.53	199	.54	.51	195	.54½	.53
10	256	.54	.53	226	.55	.51	222	.55	.53½
12	284	.54	.53	255	.56	.52	253	.56	.54
14	314	.55	.54	282	.57	.52	276	.56½	.55½
16	337	.55	.54	306	.57	.52	297	.57	.56
18	351	.55	.55	325	.57	.53	295	.57	.54
20	343	.55	.55	329	.58	.54	277	.56½	.49

L_c = lift coef. of the biplane as a whole.

We shall consider each of the three biplanes in turn. U.S.A. 27, G/C = 1.67. When compared at equal values of L_c, the theoretical and experimental values check within .01, from L_c = .00126 upwards, or from about $\alpha = 1^\circ$ upwards. U.S.A. 27, G/C = 1.00. There is a constant difference of about .04 between the theoretical and experimental values, from L_c = .00107 ($\alpha = 2^\circ$) upwards. It is evident that the experimental values are too low. The fraction of lift on the upper wing at $\alpha = 0^\circ$ should be at least .50, whereas the experimental value is only .46. R.A.F.6c, G/C = 1.03. Experimental and theoretical values check within an average of .01 from L_c = .00127 (4°) to L_c maximum.

* The lifts for the lower wing will of course be the complements of these values.

Thus, in general, the theoretical values check with the experimental values from $L_c = .00125$ (about 0.4 L_c max.) to L_c max., or from about an angle of attack, of 4°, to the burble point. The exception is the U.S.A. 27 biplane, G/C = 1.00, the data for which have previously been shown to be unreliable. For all three biplanes, however, there is a wide divergence between the theoretical and experimental values above or below the limits of agreement just mentioned. But the theory is not supposed to make accurate predictions outside of that range anyhow. Within that range it appears safe to calculate the lift on the upper wing by making use of formula (10). But in the form stated the use of this formula is rather tedious. We therefore suggest the following simplification. It is evident from from (10) that for a given gap and aspect ratio the fraction representing the lift loading on the upper wing is directly proportional to the lift, provided we neglect the term, $\sin^2\beta v$. This term does not usually amount to as much as $\frac{1}{4}$% of the total lift for angles of attack below 16°. We neglect it and reduce formulae (10) and (11) to the approximate form;

$$(\text{Frac. of lift on upper}) = 0.50 + \frac{C_{L_1} + C_{L_2}}{2 \cdot C_L} = 0.50 + KC_L,$$

where K is a function only of gap/span and aspect ratios. This can be expressed in the alternative form,

$$(\text{Frac. of lift on upper}) = 0.50 + K_1 L_c \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

This represents a straight line, having its origin at $L_c = 0$, (Frac. of lift) = 0.50; and of slope K_1; and is only applicable for values of the $L_c > .000125$. Values of K_1 can be calculated for any gap/span and aspect ratios. For aspect ratio equal 6.00 ,

G/C	K
1.00	23.5
1.67	16.1

By supplying these values of K_1 in equation (12) we have obtained the following:—

Table 79

Fraction of lift on upper wing.

$L_c \times 10^5$	G/C	
	1.00	1.67
125	.53	.52
150	.53½	.52½
175	.54	.53
200	.54½	.53
225	.55½	.53½
250	.56	.54
275	.56½	.54½
300	.57	.55
325	.57½	.55
350	.58	.55½

A comparison of these values with the laboriously attained values of Table 78, shows that Table 79 is if anything the more accurate of the two.

In conclusion, therefore, we recommend equation (12) as a ready method of calculating the lift on the separate wings of an unstaggered biplane. It is applicable from $L_c = .00125$ to L_c max., and gives results as accurately as the experimental data justifes. Our analysis has been restricted to biplanes without stagger. The vortex theory indicates that stagger accentuates the load on the upper wing, but no experimental data are avilable. More experimental work is also needed to determine the distribution of lift at angles of attack below 4°.

We shall now proceed to consider the distribution of the total drag of the biplane between the upper and lower wings.

4. Distribution of Drag between upper and lower wings.

Our results for the U.S.A. 27 biplane are given in Table 34. For the sake of ready comparison with the results for the R.A.F.6c,* we here reproduce the percentage of total drag on the upper wing.

Table 80.

% of Drag on Upper Wing.

α°	(1)	(2)	(3)
-6	$54\frac{1}{2}$	44	$45\frac{1}{2}$
-4	$56\frac{1}{2}$	$46\frac{1}{2}$	47
-2	$55\frac{1}{2}$	48	$48\frac{1}{2}$
0	50	$49\frac{1}{2}$	$49\frac{1}{2}$
2	$48\frac{1}{2}$	50	$50\frac{1}{2}$
4	$49\frac{1}{2}$	$51\frac{1}{2}$	$51\frac{1}{2}$
6	$49\frac{1}{2}$	52	$52\frac{1}{2}$
8	$50\frac{1}{2}$	54	$54\frac{1}{2}$
10	51	55	$55\frac{1}{2}$
12	$51\frac{1}{2}$	56	56
14	54	$56\frac{1}{2}$	56
16	55	$57\frac{1}{2}$	$50\frac{1}{2}$
18	57	57	$48\frac{1}{2}$
20	52	55	49

(1) U.S.A. 27, $G/C = 1.00$, (2) U.S.A. 27, $G/C = 1.67$, (3) R.A.F. 6c, $G/C = 1.03$. Stagger = 0, and aspect ratio = 6, in each case. See Table 78 for L_c's.

One would expect that for an unstaggered biplane the drag would be equal on upper and lower wings at zero angle of attack, since the mutually induced downwash is then equal at both wings, and the "effective stagger" is also zero. In our experimental results this equal distribution occurs at 0° (1), 2° (2), and 1° (3). Starting from this position of equal distribution, as the angle of attack is decreased the effective stagger is increased, the induced downwash becomes less for the upper wing, and therefore the % of drag on the

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* Ref. 2, Table 2.

upper wing would decrease; and vice versa for increased angle of attack. Our data is in agreement with this reasoning. (2) and (3) show a uniform increase of the % on the upper wing from -6° to $+16^{\circ}$, while (1) shows a uniform increase for positive angles of attack, but does not show a decrease for negative angles. This discrepancy is due to experimental error, for there are also irregularities in the lift readings for the negative angles of attack.

After the uniform increase of the upper % of drag from -6° to $+16^{\circ}$, there occurs a decided decrease, thus indicating that above about 16° the interference of the front (lower) wing actually decreases the drag of the upper wing. The front wing seems to shield the rear. All three of the tests show this effect. ~~All thre~~

Since we know of no facile theoretical means of calculating the drag on each wing, we shall now try to correlate the results of these three tests so as to obtain a more generalized expression for the % of drag on the upper wing. When the values of Table 80 are plotted, first with the lift coefficients and then with the angles of attack as ordinates, it is seen that (1) is about 4% below (3) at equal L_c, and about 3% below at equal α, throughout the range $0^{\circ} - 14^{\circ}$. It has previously been pointed out that the % of lift on the upper wing was also too low for this same test, viz., the U.S.A. 27 biplane at G/C = 1.00. It appears that in testing the upper wing of the biplane combination, the wind speed was temporarily too low, or the angle of attack shifted through $\frac{1}{2}^{\circ}$ or so. This constituted our first test, and we were more or less inexperienced at the time. We shall therefore neglect the values (1).

The curves of (2) and (3), versus α, lie on approximately the same straight line,

$$\%\text{ Drag on upper} = 50 + \frac{\alpha^\circ}{2}\ , \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

from $\alpha \doteq -4^\circ$ to $+14^\circ$. While the curves of (2) and (3), versus L_c, are parallel straight lines, from $L_c = 0$ to L_c max.

$$\left.\begin{array}{lll} \text{For } G/C = 1.03, & \text{Frac. of drag on upper} & = .48 + 33.3\ L_c \\ \text{For } G/C = 1.67, & \text{"}\quad\text{"}\quad\text{"}\qquad\text{"}\quad\text{"} & = .46 + 33.3\ L_c \end{array}\right) \ldots(14)$$

None of the plotted points deviate from these straight lines by more than ± $\frac{3}{4}$%. The average deviations are much less.

As an easy means of calculating the drag on each wing of a biplane we therefore recommend equations (14). They appear applicable to any biplane (aspect ratio equal 6) having the gap chord ratios indicated.

This concludes our analysis of the loading on the upper and lower wings.

* * * * * * * * * * * * * * * *

We shall now consider the aerodynamic coefficients of the biplane as a unit. In connection with each coefficient we shall verify the accuracy of predictions from the vortex theory (Munk's formulae), and derive biplane correction factors applicable at equal values of the lift coefficient.

III. Aerodynamical Coefficients of the Biplane as a Unit.

These coefficients, obtained by the Method of Procedure outlined in Section IV, are listed in Appendix C, Tables 34 to 76 inclusive. We shall consider them according to the order in which they are there tabulated.

1. Lift Coefficients - These are listed in Tables 35 - 41 (U.S.A. 27), and 62-64 (Göt. 387), and are plotted against angles of attack as ordinates in Plates 5 - 7 , and 10, 12 respectively. The plotted points are not shown on the plates, because they would simply lead to confusion, with so many curves in close proximity. The deviations do not exceed ±0.00002 #/ft.^{2}/mph. These curves show at a glande the effect of stagger and G/C variations on the lift. They are useful as a means of determining

(1) the different angles of attack at which the same lift is produced by different biplane combinations, and

(2) the different lifts which occur at the same angle of attack. They also constitute the best method of smoothing out or eliminating inaccurate data, and so improve the reliability of the results. Thus by glancing at Plates 5 and 7 one can immediately see that the curves for the U.S.A. 27 biplane combination, G/C = 1.67, stagger = 0, are out of place, and that the values of L_c and D_c which they represent are evidently too small. A comparison of these values (Tables 39 , 46) with the results obtained when each wing of the biplane was tested separately (Table 34), shows that the two do not agree, and that the latter are correct. We therefore discord the results obtained when this specific biplane combination was tested as a unit,

although shifting the angle of attack by 0°3 would probably account for the discrepancy.

No further mention of the plates need be made, except to call attention to the scale marked RATIO FACTOR, which is erected on the left hand side of Plates 5-7. This scale shows the ratio of the biplane lift to the maximum lift of the monoplane having the same wing area. It is a convenient means of comparing monoplane and biplane characteristics.

For atstaggered biplane the primary lift, due to curvature and angle of attack, is principally effected by interference, and change of "effective gap" as the angle of attack is changed. The interference effect is principally an increase of lift within the same limits for either positive or negative stagger; while increase of effective gap causes an increase of lift, and vice versa. The effective gap is measured practically perpendicular to the direction of flight; it is increased for positive stagger with positive angle of attack, and decreased for negative stagger with positive angle of attack. Thus as a whole, the effects of interference and effective gap have like signs for positive stagger, and opposite signs for negative stagger. The influence of positive stagger on lift should be much more pronounced than that of negative stagger. The L_C curves for the Göt. 387 (Plate 10) and U.S.A. 27 biplanes (Plate 6) demonstrate this very strikingly. On the former plate the curves for the negative stagger almost coincide, whereas those for positive stagger are comparatively far apart.

According to theory, at zero lift the angle of attack should be the same for both monoplane and all biplanes having the same wing section. Because the angle of attack for a specific L_c is composed of

(1) the original angle belonging to the wing section and the L_c,

(2) the additional angle due to induction, and

(3) the additional angle due to interference, and

at zero lift (2) and (3) are equal to zero. A first glance at Plates 12, 5, and 10, would seem to indicate that our results check with this theoretical prediction, for on these plates the L_c curves certainly converge to a narrow band at zero lift. But a careful analysis shows that the deviations are too large to attribute to experimental errors. If we consider the error to be in the angle of attack, we find that the deviations from the average value of the angles of attack at zero lift are about as follows:

	Average deviations	Maximum deviations
Plate 5	±0°.2	±0°.6
6	±0°.4	±0°.8
7	±0°.2	±0°.4
10	±0°.2	±0°.4
12	±0°.2	±0°.3

Since the models, when set up in the wind tunnel, were accurately aligned to within 0°.1, it is hard to see how the maximum deviations tabulated above can be attributed to experimental error. On the other hand, if we consider the errors to be in the measurement of lift near its zero value, we find the following approximate deviations in L_c :

	Average deviations	Maximum deviations
Plate 5	±.00003	±.00008
6	±.00004	±.00012
7	±.00003	±.00009
10	±.00003	±.00005
12	±.00003	±.00005

For the biplanes tested, ±.00012 corresponds to 0.144#, and ±.00003 corresponds to 0.036#. It is difficult to see not only how an error of 0.144# could be made, or even how an error of 0.036# could have slipped in. We therefore believe that the different angles of attack, which our results indicate occurred at zero lift, cannot be attributed to experimental error, but can doubtless be accounted for by some of the factors neglected in the development of the theory.

We shall now make a few detailed comparisons between the values of lift and angle of attack obtained by us and those predicted by the vortex theory. We can compare lifts at equal angles of attack, or compare angles of attack at equal values of the lift. But so far as we know there are as yet no straightforward formulae by which the lift for a given angle of attack can be calculated. The formulae* —

$$\left.\begin{array}{l}\text{Lift due to curvature} = 2\pi\,\text{Sq.}\ \sin\beta_0\cdot B_0 \\ \text{" " " angle of attack} = 2\pi\,\text{Sq.}\ \sin\beta\cdot B\end{array}\right\}\quad(14)$$

apply only to the two-dimensional biplane, and so give lifts very much higher than the three-dimensional actuality, as shown by the following table.

Table 81.

U.S.A. 27 Biplane, G/C=1.00, Stagger = 0.
Lift coefficient due to curvature = 0.00080.

$\alpha°$	(1)	(8)	(3)
-2	-30	50	62
0	17	97	84
2	65	145	118
4	112	192	150
6	160	240	181
8	208	288	208
10	255	335	237
12	302	382	266
14	348	428	293

(1) $L_c \times 10^5$ due to angle of attack.
(2) Theoretical $L_c \times 10^5$, calculated by equations (14).
(3) Experimental $L_c \times 10^5$.

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* Ref. 9, p. 31.

The lack of agreement is evidently the fault of the 2 - dimensional values of the lift arising from angle of attack. Due to aerodynamical induction arising from the lateral dimensions, the angle of attack must be increased for equal values of L_c. But such corrections to the angle of attack involve very clumsy calculations.

It is much easier to start from the lift as the primary datum, and compare angles of attack at equal values of the lift. In doing this we can make use of a formula ready developed by Munk.

$$\alpha_2 = \alpha_1 - \frac{C_L}{\pi}\left[\left(\frac{S_1}{k_1^2\, b_1^2} + I_1\right) - \left(\frac{S_2}{k_2^2 b_2^2} + I_2\right)\right] \quad * \ldots\ldots\ldots (15)$$

By the method of this formula we have calculated the theoretical values of α , compared to the experimental values in Tables 82 - 83.

Table 82

(1) Theoretical and (2) Experimental values of the angle of attack expressed in degrees.
Göt. 387 Biplane, Stagger = 0.

		Gap/Chord.					
		0.75		1.00		1.33	
C_L	$L_c \times 10^5$	(1)	(2)	(1)	(2)	(1)	(2)
0	0	-7.1	-8.0	-7.1	-7.2	-7.1	-7.3
.2	51	-3.5	-3.9	-3.7	-3.8	-3.7	-3.9
.4	102	0	-0.4	-0.4	-0.7	-0.7	-0.9
.6	153	3.4	3.0	2.9	2.5	2.5	2.1
.8	205	6.9	6.5	6.2	5.7	5.6	5.2
1.0	256	10.4	9.7	9.5	8.8	8.8	8.3
1.2	307	13.9	13.7	12.8	12.1	11.9	11.4
1.4	358	18.1	19.1	16.9	16.5	15.8	15.4

Table 83

(1) Theoretical and (2) Experimental Values of the Angle of Attack, Expressed in Degrees.

U.S.A. 27 Biplane, Stagger = 0.

		Gap/Chord											
		0.50		0.75		1.00		1.33		1.67		2.00	
C_L	$L_c x10^5$	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
0	0	-5.0	-6.2	-5.0	-5.5	-5.0	-5.5	-5.0	-5.2	-5.0	-5.0	-5.0	-5.2
.2	51	-1.5	-2.4	-1.7	-2.0	-1.9	-2.2	-1.9	-2.3	-2.2	-2.1	-2.2	-2.7
.4	102	2.1	1.5	1.8	1.5	1.4	1.0	1.1	0.8	0.9	1.1	0.8	0.3
.6	153	5.8	5.4	5.2	5.0	4.7	4.1	4.3	3.9	3.9	4.2	3.8	3.3
.8	205	9.5	9.4	8.9	8.6	8.2	7.5	7.6	7.1	7.2	7.5	7.0	6.5
1.0	256	13.7	14.2	12.7	12.4	11.8	10.6	11.1	10.5	10.5	10.9	10.3	9.8
1.2	307	-	-	16.7	17.5	15.6	15.1	14.7	14.4	14.0	14.3	13.8	13.4
1.3	353	-	-	-	-	17.9	18.8	16.9	17.2	16.2	17.7	-	-

An analysis of these two tables shows that the theoretical curves of L_c plotted against α will be parallel to the experimental curves, the constant difference between the two being 0°.4. The average differences between the theoretical and calculated values of the angle, from L_c = .00025 (C_L = 0.1), to 0.9 Lc max., are as follows for each biplane combination.

Stagger = o

Gap/chord

	0.50	0.75	1.00	1.33	1.67	2.00
U.S.A. 27	0°.4	0°.3	0°.5	0°.4	-0°.3	0°.5
Got. 387	-	0°.4	0°.4	0°.4	-	-

The theoretical angles are in each case larger than the experimental angles, with the exception of the values for the U.S.A1 27 biplane, stagger = 0, G/C = 1.67. But the experimental values for this biplane combination have previously been shown to be in error, and need not be considered further here. The average of the deviations tabulated above is 0°.4. We can therefore say that for unstaggered biplanes, having any gap chord ratio, the angle of attack for a given value of the lift, from 0.1 to 0.9 L max., can be calculated (by formula (15)) to within 0°.4 . This deviation is always positive for U.S.A. 27 and Göt. 387 biplanes, so that for these biplanes the exact angle can be obtained by subtracting 0°.4 from the theoretical value.

The foregoing applies only to unstaggered biplanes. We shall now consider the effect of stagger on the angle of attack required to produce a given lift. Referring back to formula (15) it is apparent that for a given value of the lift coefficient (C_L), on a biplane of given aspect ratio (S/b^2), the angle of attack (α) is a function only of the induction factor "k" and the interference factor "I". The induction factor "k" is the ratio of the span of a monoplane to the span of the equivalent biplane having the same induced drag under the same conditions. The values of "k" were determined by Munk empirically.* He states that stagger does not materially affect them; they depend only on the Gap/span ratio of the biplane. The interference factor "I" is approximately a function of Gap/chord ratio only. Munk states** that "I" varies somewhat with stagger and wing section, but that the entire result is not much affected if an average value of "I" is taken for each Gap/chord ratio.

Since "k" and "I" are little affected by stagger, therefore the angle of attack for equal lifts is not materially affected by stagger. So runs the theoretical argument, but in our experimental results, tabulated below for the Göt. 387, at G/C = 1.00, the differences between the angles of attack for the several staggers are not negligible.

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* General Theory of Th~~e~~in Wing Sections." N.A.C.A. Report 114.

** Ref. 9.

Table 84

Göt. 387 Biplane, G/C = 1.00 (Plate 10).

Comparison between experimental values of the angle of attack (degrees) required to produce equal lifts at various staggers.

C_L	$L_c x 10^5$	Stagger					
		-40%	-20%	0%	20%	40%	60%
0	0	-6.9	-7.5	-7.2	-6.8	-7.7	-7.4
.2	51	-3.7	-3.9	-3.8	-3.5	-4.0	-4.4
.4	102	-0.5	-0.8	-0.7	-0.4	-1.0	-1.4
.6	153	2.5	2.4	2.5	2.7	2.0	1.6
.8	205	5.7	5.5	5.7	5.9	5.2	4.6
1.0	256	8.9	8.7	8.8	9.0	8.2	7.5
1.2	307	12.4	12.2	12.1	12.1	11.2	10.6
1.4	358	19.1	17.1	16.5	15.9	14.8	13.9

These values are plotted in Plate 15, together with the corresponding results for the U.S.A. 27 Biplanes at gap/chord ratio equal 0.75 and 1.00. An inspection of these curves shows that for the Göt. 387 biplane, G/c=1.00, the effect of negative stagger is entirely negligible, while the effect of positive stagger is to cause an appreciable decrease in the angle. For the U.S.A. 27, G/C = 1.00, there is a uniform decrease in angle as the stagger increases from -40% to +60%; there occurs a small decrease at negative stagger, and a more rapid decrease at positive stagger. The exact amounts are tabulated below.

Table 85

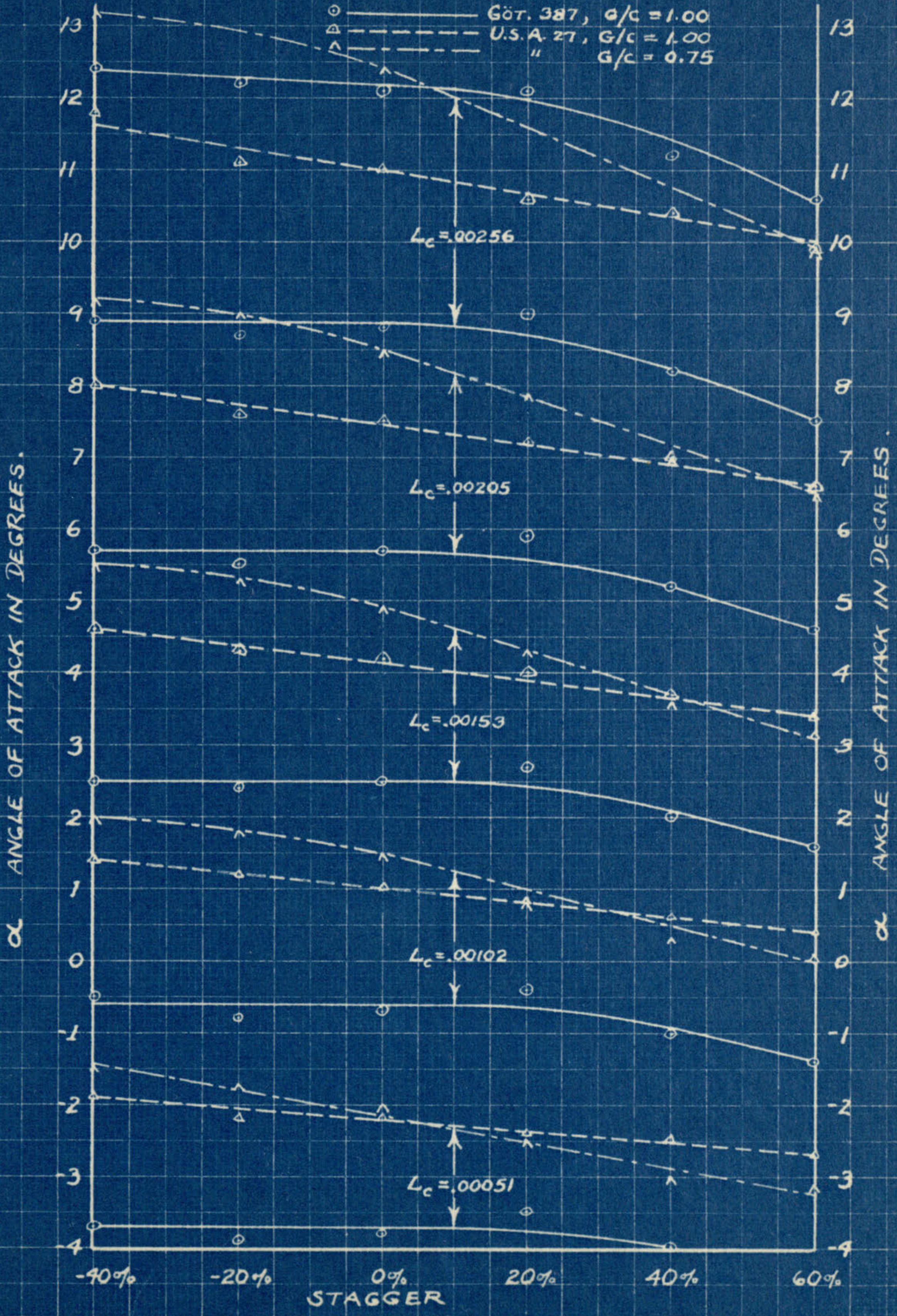
Amounts (in degrees) by which the angle of attack corresponding to equal lifts is decreased when the stagger is increased from -40% to +60%.

CL	$L_c x 10^5$	(1)	(2)	(3)	(4)	(5)
.2	51	0.7	0.6	0.8	1.7	1.6
.4	102	0.8	0.6	1.0	2.1	2.1
.6	153	0.9	0.6	1.2	2.4	2.7
.8	205	1.2	0.7	1.4	2.8	3.4
1.0	256	1.4	0.8	1.6	3.3	4.6

(1) Göt. 387, G/C = 1.00 (2) U.S.A. 27, G/C=2.00 (3) G/C=1.00 (4) G/C = 0.75, (5) G/C = 0.50.

PLATE 15.

CURVES SHOWING THE ANGLE OF OF ATTACK (α) REQUIRED TO PRODUCE EQUAL LIFTS AT VARIOUS STAGGERS.



In each case, with one or two exceptions, the effect of positive stagger is much more pronounced than that of negative, so that the decrements of angle tabulated above are due chiefly to the change of stagger from 0% to 60%. This is due to the fact that the effects of interference and effective gap have like signs for positive stagger, and opposite signs for negative stagger, as explained in the third paragraph, of this discussion on <u>lift coefficients</u>. As shown by the figures in columns (2) and (5), the decrements of angle due to stagger are about four times larger at G/C = 0.50 than at G/C= 2.00. But this influence of G/C on the potency of the stagger is only apparent. It is due to the fact that the stagger has been expressed as a % of the chord. 60% stagger at G/C = 0.50 corresponds to an angle of stagger equal to $49\overset{\circ}{.}3$, while 60% stagger at G/C = 2.00 corresponds to an angle of only $16\overset{\circ}{.}7$, the ratio between the two being about 4:1

It is apparent that the decrements of angle due to stagger (Table 85) are too large to be neglected, even though the average deviations would be only about half the size of the amounts there tabulated if average values of "k" and "I" are used in calculating the angles. This is further strikingly shown by the curves of L_c plotted against α in Plates 6, 7 and 10. If the effects of stagger on ~~ø~~ α were negligible, the L_c curves in Plate 6 would be grouped in three narrow bands, corresponding to the three gap/chord ratios; the curves in Plate 7 would be grouped in two narrow bands; and the curves in Plate 10 would practically coincide in one narrow band. But such is not the case; appreciable angles separate the curves.

Summary. In this analysis of biplane lift coefficients we have compared the theoretical and experimental values (1) of lift coefficients at equal angles of attack, and (2) of angles of attack at equal lift coefficients.

(1) Calculation of L_c's for given α's was tried by means of the 2-dimensional formulae (14). These formulae give values of L_c very much too high, unless the α's are increased to correct for the aerodynamical induction arising from the lateral dimensions. But such corrections involve unnecessary labor.

(2) It is easier to calculate α's at equal L_c's by means of formula (15). This we did for ten unstaggered U.S.A. 27 and Göt. 387 biplanes having gap/chord ratios from 0.50 to 2.00. The theoretical α's so obtained were almost uniformly $0.^\circ4$ too high.

Formula (15) applies only to unstaggered biplanes. Munk states that stagger does not materially affect the α required for a given L_c. Our data show that the average amounts by which α was decreased when the stagger was changed from -40% to +60% were $1.^\circ2$ at G/C = 1.00, and $2.^\circ5$ at G/C = 0.75. The average decrements were directly proportional to the stagger expressed in degrees. The effect of positive stagger was twice that of negative (averages), so that in the specific cases mentioned above the decreases of α due to positive stagger were $0.^\circ9$, and $1.^\circ9$, respectively.

It is evident that induction factors "k", and interference factors "I" should be calculated for stagger. Meantime we recommend our L_c correction factors at equal α, 0°-13°, (Table 1-10, and Plate 13) as a quick means of finding the lift on staggered biplanes.

* * * * * * * * * * * * * * * * *

2. Drag Coefficients - These are listed in Tables 42 - 47 for the U.S.A. 27, and 65-67 for the Göt. 387 biplanes, and are plotted against angles of attack as ordinates in Plates 5 - 7, and 10, 12, respectively. To avoid confusion the plotted points are not shown on the plates, but the deviations do not exceed 3x10^{-6} #/sq.ft/m.p.h. (=0.0036# for the biplanes).

By means of these curves we have been able to make comparisons between the experimental values of the drag, and the theoretical values calculated by the method of Munk's formula:

$$C_{D_2} = C_{D_1} - \frac{C_L^2}{\pi} \left[\frac{S_1}{b_1^2 \, k_1^2} - \frac{S_2}{b_2^2 \, k_2^2} \right] * \text{............}(16)$$

These comparative values are tabulated in Tables 86 and 87.

Table 86
(1) Theoretical and (2) Experimental values of the Drag Coefficient ($D_c \times 10^6$).

Göt. 387 Biplane, Stagger = 0.

		Gap/Chord					
		0.75		1.00		1.33	
C_L	$L_c \times 10^5$	(1)	(2)	(1)	(2)	(1)	(2)
.0	0	97	125	97	106	97	108
.2	51	70	74	69	72	69	72
.4	102	91	90	89	90	86	90
.6	153	134	127	128	123	121	123
.8	205	201	190	191	180	189	176
1.0	256	292	267	275	251	258	248
1.2	307	400	365	375	338	351	332
1.4	358	545	500	512	453	478	446

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* Ref. 9, p. 26

Table 87

(1) Theoretical and (2) Experimental Values of Drag Coefficient ($D_c \times 10^6$)

U.S.A. 27 Biplane, Stagger = 0.

		Gap/chord											
C_L	$L_c \times 10^5$	0.50		0.75		1.00		1.33		1.67		2.00	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
.0	0	92	105	92	95	92	95	92	98	92	95	92	93
.2	51	62	65	62	63	61	63	61	63	60	60	60	65
.4	102	78	78	76	75	74	75	71	70	68	70	67	67
.6	153	127	125	123	118	117	112	110	105	105	104	103	98
.8	205	205	195	186	181	186	172	174	163	164	160	161	153
1.0	256	303	290	290	268	273	240	256	239	241	235	234	227
1.2	307			410	395	385	355	361	339	338	334	331	318
1.3	333					457	558	428	415	401	415	386	380

An inspection of these tables shows that —

(1) for the Göt. 387 biplanes the theoretical values of the drag agree with the experimental values within ±5%, from $L_c = .00050$ to $.00200$ (-4° to 6°) while,

(2) for the U.S.A. 27 the same agreement occurs from $L_c = 0$ to $.00200$ (-5° to 8°).

In each case the theoretical values are too low for values of $L_c < 0.00100$, and too high values of $L_c > 0.00100$, while at $L_c = 0.00100$ agreement is practically perfect.

Formula (16) covers the case of unstaggered biplanes only. Munk states that stagger does not materially affect the value of the induction factor "k". This means that for equal lifts, the value of the drag is not materially affected by stagger. On examining data (Table 88) taken from curves för Göt. 387 staggered biplanes (Plate 10), we find that variation of drag with stagger is indeed immaterial, being usually within 2% (the experimental error) from $L_c = 0.00050$ (or from minimum drag) to 0.9 L_c max. The agreement is thus good throughout the whole useful range.

Table 88

Effect of stagger on drag ($D_c \times 10^6$) at equal lifts.

Göt. 387 Biplane, G/C = 1.00

C_L	$L_c \times 10^5$	Stagger					
		-40%	-20%	0%	20%	40%	60%
.0	0	100	121	106	104	123	110
.2	51	76	73	72	73	73	80
.4	102	90	90	90	87	85	92
.6	153	123	124	123	120	123	125
.8	205	178	180	180	176	180	180
1.0	256	250	253	251	246	250	250
1.2	307	346	347	338	332	337	338
1.4	358	542	481	453	443	453	445

As a further means of showing the negligible effect which stagger has on drag, we have calculated the biplane correction factors for D_c at equal L_c's for both U.S.A. 27 and Göt. 387 biplanes at G/C = 1.00, and stagger -40% to 60%. These factors are summarized in Tables 89 and 90 (Appendix C), respectively. They show at a glance the variation of the biplane D_c in terms of the D_c of the monoplane having the same L_c. The average values of the correction factors for the whole range of stagger are tabulated at the right side of each table. An inspection of the factors will show that these average values can be used from L_c = .00050 to 0.9 L_c max., and from stagger equal -40% to 60%, without incurring an average error > 2½%, for the Göt. 387, or 1½% for the U.S.A. 27. The average values are plotted in Plate 13, one curve being drawn.

We have also calculated the biplane correction factors at equal L_c for the U.S.A. 27 and Göt. 387 at zero stagger, and several gap/chord ratios (Tables 91 and 92, respectively). Since the effect of stagger is negligible, these may be used for all staggers as well. We have plotted them in Plate 13, drawing only one curve at each gap/chord ratio, to serve both the U.S.A. 27 and Göt. 387 at all staggers. The correction factors differ somewhat for all airfoils in general, depending on the profile drag of the sections. But we estimate that the curves in Plate 13 will give drags accurate to ± 1½% for all airfoils of maximum combination equal 10% to 16%. To avoid confusion the plotted points are not included on the plate. With the exception of three points, no deviations exceeded 0.015, while the average was not > 0.005. A separate curve (Plate 13) was plotted for the D_c min. correction factors (Table 93), since the minimum drags occur at somewhat different lifts. There is a definite decrease of D_c min. as the gap/chord ratio is increased, amounting to about 15% from G/C = 0.50 to 2.00. The effect of stagger is negligible when G/C is > 0.75.

Summary. The effect of stagger on the drag at equal lifts is neglible from 0.1 to 0.9 L max. Munk's formula therefore gives values of the drag accurate within ± 5% for all staggers and gap/chord ratios, but this accuracy holds only from L_c = 0.00050 to 0100200, or from about 0.1 to 0.5 L_c max. In Plate 13 we have plotted curves, showing the biplane correction factors for D_c, which we believe will give results accurate within ± 1½% from about 0.1 to 0.9 L_c max. These curves cover the case of all staggers and gap/chord ratios, but are applicable only to airfoils in the same general group as the U1S.A. 27 and Göt. 387 so far as profile drag is concerned.

3. Lift/Drag Ratios - These are tabulated in Tables 48 - 49 for the U.S.A. 27, and 68-70 for the Göt. 387 biplanes, and are plotted against angles of attack as ordinates in Plates 8 - 9, and 11 - 12, respectively. The plotted points are not shown, but in no case did the deviations exceed 0.1, expressed in terms of L/D.

We have calculated and plotted L/D's for only a relatively small range of biplane combinations, because these ratios are secondary characteristics, and can always be computed from the values of lift and drag to which we have given greater consideration.

A direct comparison between theoretical and experimental values of L/D are unnecessary, since we have previously made such comparisons for lift and drag separately. Since at equal lifts, L/D is inversely proportional to the drag, we can draw our conclusions as regards L/D directly from our previous ones concerning drag.

The effects of stagger at equal lifts will be negligible. But L/D max. occurs at unequal lifts for different biplane combinations, so we have calculated the biplane correction factors for L/D max. for both the U.S.A. 27 and Göt. 387 biplanes. These are tabulated in Tables 94 and 95 (Appendix C), respectively. They show beyond peradventure that the effect of stagger on L/D max. is negligible. The factors for the U.S.A. 27 and Göt. 387 biplanes agree excellently. Average values (Table 94) can be taken at each gap/chord ratio and applied to all staggers without involving an error $>$ ± 1%. These average values are plotted against gap/chord ratios in Plate 13. L/D max. shows a distinct improvement, about 25%, as the gap/chord ratio is increased from 0.50 to 2.00. Such an increase in efficiency is just what would be expected from the vortex theory.

The correction factors for L/D at equal lifts (Tables 96-97) are the reciprocals of the factors for D_c (Tables 91 - 92), and the same curves on Plate 13 serve for both, reciprocal scales being erected at the side. In general, the correction factors vary inversely as the lift, and directly as the gap/chord ratio.

4. Moment Coefficients - These are tabulated in Tables 50-55 for the U.S.A. 27, and 71-73 for the Göt. 387 biplanes, and are plotted

against L_c's as ordinates in Plates 8-9, and 11-12, respectively. The plotted points are not included on the plates, but the deviations in no case exceeded ±0.000D1lbs. ft,/sq. ft/mph/ft. of chord. For our biplane models this way equivalent to a moment of ±0.003 lbs. ft. about the leading edge.

A glance at the plates mentioned will show that the effect of stagger on M_c is much more potent than that of the gap/chord ratio. The effect of the latter, such as it is, is to increase M_c, * while the effect of positive stagger is just the opposite. The effect of negative stagger is negligible.

A simple theoretical formula for calculating the moment coefficient seems hard to attain. Munk states that the moment coefficient with respect to the center of the biplane (C_m), is increased both from induction and interference. Due to induction -

$$** \; \Delta C_m = 4\frac{s^2}{T^2}\cdot\frac{S}{b^2}\cdot\frac{T}{b}\left[b\cdot\frac{(1/k^2 - 0.5)}{R}\right]C_m, \qquad (17)$$

while due to interference -

$$** \; \Delta C''_m = C_m\left(.08 + \frac{.16s^2}{G^2}\right) + C_L\cdot\frac{.16s}{G^2} \quad . \qquad (18)$$

In these formulae C_m is the moment coefficient of the monoplane about its center point.

By means of (17) and (18) we have calculated C_m for both the U.S.A. 27 and Göt. 387 biplanes at G/C = 1.00, with positive stagger from 0% to 60%. As aforementioned, the effect of negative stagger

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* Disregarding the sign of M_c, an increase means an increase in diving moment about the L.E.

** Ref. 9, p. 28.

(1) Theoretical, and (2) Experimental Values of the Moment Coefficient with respect to the Center of the Biplane ($C_m \times 10^3$).

TABLE 98

U.S.A. 27 Biplane

G/C = 1.00

		STAGGER							
C_L	$L_c \times 10^5$	0%		20%		40%		60%	
		(1)	(2)	(1)	(2)	(1)	(2)	(2)	(1)
.2	51	-40	-41	-40	-27	-40	-17	-5	-42
.4	102	17	14	19	26	21	44	65	24
.6	153	74	67	78	85	83	113	132	90
.8	205	135	122	140	147	148	174	208	159
1.0	256	186	171	193	192	203	236	260	219
1.2	307	243	216	251	244	264	293	317	279

TABLE 99

Göt. 387 Biplane

G/C = 1.00

		STAGGER							
C_L	$L_c \times 10^5$	0%		20%		40%		60%	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
.2	51	-57	-42	-57	-34	-58	-24	-60	-19
.4	102	- 6	- 4	- 5	17	-4	29	- 2	43
.6	153	45	51	48	65	51	88	57	112
.8	205	93	104	97	113	104	133	113	171
1.0	256	142	147	148	162	157	177	170	230
1.2	307	186	195	193	202	204	237	220	284
1.4	358	241	232	250	246	264	277	284	318

appears negligible, and formulae (17) and (18) are not applicable to negative stagger anyway. The theoretical and experimental values of C_m are compared in Tables 98 and 99, ~~Appendix C~~. Values of C_m rather than of M_0 were calculated and compared, because the theoretical values of the former could not be converted into the latter without assuming center of pressure values. An inspection of Tables 98-99 shows that agreement between the theoretical and experimental values of C_m is very poor. The former are almost invariably too low, the average error being about -18%.

These large discrepancies led us to examine formula (17) and (18) with greater care. The only ready possibility for revision which we could find was the fact that the derivation of (18) involved the assumption that $\frac{1}{4} C_L/C_m = 1$. For (18) is evidently derived from the following equation on p. 23 (Ref. 9).

$$C^1_m = \frac{\pi\beta' s}{T}$$

$$= \frac{+2\ s^2}{b^2}\left[\frac{b}{R}\left(\frac{1}{k^2} - 0.5\right)\right]\cdot C_L \qquad (19)$$

Equation (18) reduces to

$$\Delta C_m = \frac{8\ s^2}{b^2}\left[\frac{b}{R}\left(\frac{1}{K^2} - 0.5\right)\right]\cdot C_m,$$

when we substitute $S/bT - 2$, which holds true for a biplane. Munk here uses C^1_m and ΔC_m to designate the same thing, viz., the additional moment due to induction, thus involving the assumption mentioned above. But for the U.S.A. 27 monoplane, the value of C_L / C_m varies from -1.35 to 6.41, as shown by the following figures:

C_L	0.2	0.4	0.6	0.8	1.0	1.2
$\frac{1}{4} C_L'/C_m$	-1.35	6.41	2.28	1.61	1.45	1.33

We therefore hoped that by applying corrections for this we could obtain better theoretical values for C_M. But the increase of moment due to induction constitutes only about 8% of the total increase, so that the final values of C_m averaged only about 3% higher than before, and were still quite inadequate.

Since the theoretical formulae are apparently not of much use in finding the moment coefficients for a given biplane combination, we have calculated the biplane correction factors for M_c at equal L_c, for both the U.S.A. 27 and Göt. 387 biplanes at G/C = 1.00, all staggers, and at stagger = 0, all G/C's (Tables 100-103, Appendix C). These factors are practically constant for all lifts < L_c max. This can be seen from Plates 8-9, 11-12, by the fact that the curves of M_c vs. L_c are practically straight lines radiating from a focus, which focus is approximately $L_c = 0$, $M_c \times 10^5 = -23 \pm 2$, for both U.S.A. 27 and Göt. 387 monoplanes and biplanes. We have struck an average for each stagger and gap/chord ratio, and plotted them (Plate 14). These averages for the U.S.A. 27 and Göt. 387 agree just about well enough to justify drawing only one smooth curve. Plotted points are not shown, but a comparison between plotted points and curve points is given in Tables 101 a and 103 a. Correction factors > 1.00 were reduced to 1.00, because theoretically it appears that the M_c about the leading edge can be reduced but not increased above the monoplane values. We have therefore considered that our M_c curve for G/C = 2.00, stagger = 0 (Plate 8), is notably in error. The corresponding C.P. curve is also in error.

Summary.

We have previously seen that the theoretically predicted values of the moment coefficient were hopelessly too low, the errors averaging about -18%. From our experimental data we have therefore attempted to derive some useful approximations. The results are incorporated in the two M_c correction factor curves in Plate 14. These are applicable from about $L_c = 0.00050$ to L_c max. The curve showing variation with stagger at G/C = 1.00 can be taken as accurate to within about ±0.01½, while the corresponding figure curve showing variation with Gap/chord ratio at zero stagger is about ± 0.02½. The difference is due to the fact that our experimental data for the former showed a more uniform variation than did that for the latter.

5. CENTER OF PRESSURE COEFFICIENTS.

These are tabulated in Tables 56-61 for the U.S.A. 27, and 73-76 for the Göt. 387. They were obtained by subtracting the following corrections from the original C.P.'s (Appendix B) obtained for the biplane subject to the interference of the discoid case.

α°	-4	-2	0	2	4	6	8	10	12	14	16	18	20	22
U.S.A.27	0	0	0	.01	.01½	.02	.02	.02	.02	.02	.01½	.01½	.01½	.01
Göt. 387	0	0	0	.00½	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01

These corrections constitute the difference between the C.P. curves for the monoplanes tested in the routine way, and the C.P. curves for the corresponding monoplane tested in the presence of the interference of the discoid case. (Plates 3-4). The assumption is made that the effect pf the discoid case interference was to move the C.P.'s forward by equal amounts on both monoplane and all biplanes incorporating the same wing section.

The C.P.'s (Tables 56-61, 73-76) were plotted against L_c's as ordinates (Plates 8-9, 11-12). The plotted points are not included, but they did not deviate from their respective curves by a fraction of the chord $> .005$, when $L_c > .00050$. A glance at the curves shows that in general the C.P. moves forward as the stagger is increased from -40% to 60%, and backward as G/C is increased from 0.50 to 2.00. The effect of positive stagger is much larger than that of G/C. The effect of negative stagger is negligible. Theory indicates that the biplane C.P. is never farther back from the leading edge than the monoplane C.P. for the same L_c. In general our curves bear this out, the principal exception being that for the U.S.A. 27 biplane G/C = 2.00, stagger = 0, the value for which we consider to be in error.

We shall now consider the theoretical calculation of the C.P.. The problem may be divided into two parts, (1) the variation with G/C, at stagger = 0, and (2) the variation with stagger, at G/c = 1.00.

In order to calculate the C.P.'s for unstaggered biplanes at various G/C's, we first made use of the method indicated by Munk, Part 1 of the Appendix (ref.9). The procedure is to calculate separately the lifts due to curvature and angle of attack, multiphy each by its C.P., add, and then divide by the sum of the two lifts. This gives the

C.P. for the total lift of the biplane. The formulae given by Munk apply to two-dimensional flow only, but the results obtained can be corrected to take account of the aerodynamical induction arising from the lateral dimensions. We calculated these corrections first, making use of the formula -

$$\Delta T = T \frac{S}{b^2}\left[\left(\frac{1}{k^2} - 0.5\right) \frac{b}{R}\right]\left(\frac{s}{T}\right)^2 \frac{T}{b} \quad * ,$$

where ΔT is the additional arm of moment about the center of the biplane produced by stagger and induction. Expressed as a fraction of the chord abaft the leading edge, and substituting S/bT=2 (for a biplane) this becomes -

$$\Delta C.P. = -\frac{\Delta T}{T} = -2 \left(\frac{s}{b}\right)^2 \cdot \left[\left(\frac{1}{k^2} - 0.5\right) \frac{b}{R}\right] \quad \ldots\ldots\ldots (17)$$

This expression involves the stagger (s). For an unstaggered biplane the value of the "effective stagger" is substituted, and (17) becomes -

$$\Delta C.P. = -\frac{1}{2} \left(\frac{C_L}{B} \; \frac{G}{b}\right)^2 \cdot \left[\left(\frac{1}{k^2} - 0.5\right) \frac{b}{R}\right] \ldots\ldots\ldots\ldots (18)$$

C_L (life coefficient), G (gap), and b (span), are known, while the values of B and $\left[\left(\frac{1}{k^2} - 0.5\right) \frac{b}{R}\right]$ can be obtained from Tables I and III, ref. 9. The corrections to take account of the lateral dimensions, calculated by equations (17) and (18), are listed in Table 104.

TABLE 104

ΔC.P.(fraction of chord abaft L.E.) due to lateral dimensions. G/C = 1.00. Applicable to all wing sections.

C_L	L_cx 10^6	STAGGER			
		0%	20%	40%	60%
.2	51	.000	-.002	-.006	-.014
.4	102	.000	-.002	-.006	-.014
.6	153	-.001	-.002	-.007	-.014
.8	205	-.001	-.002	-.007	-.015
1.0	256	-.001	-.003	-.007	-.015
1.2	307	-.002	-.003	-.008	-.016
1.4	358	-.003	-.004	-.008	-.016
Average		-.001	-.003	-.007	-.015

*Ref. 9, p. 32 Derived on p.23

It is seen that the corrections for zero stagger are entirely negligible. For biplanes without stagger, therefore, we can calculate the C.P. by the two-dimensional procedure previously mentioned (ref.9, p.31).

The C.P.'s calculated in this way averaged 4½% of the chord too low. But the theoretical values of lift, which this method involves, have previously been shown to be very much too high. The lift due to curvature ($2\pi \sin \beta_0 B_0$) seems to be about right, the discrepancy being in the values of lift due to the angle of attack ($2\pi \sin \beta B_g$). It therefore seemed apparent that the theoretical values of the lift due to curvature should be used, but that the differences between these values and the experimentally determined values of the total lift should be substituted for the theoretical lifts due to angle. This we did, at the same time incorporating the procedure in the following formulea -

$$C.P. = 0.50 - x + \frac{2\pi \sin \beta_0 \times B_0}{C_L}{}^{*}, \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (19)$$

in which C.P. is the fraction of the chord abaft the leading edge, x is the distance (fraction of chord) of the center of pressure from the center of the biplane for a wing section without curvature, $2\pi \sin \beta_0 B_0$ is the lift coefficient due to curvature, B_0 is a constant, and C_L is the total lift coefficient determined experimentally. Values of x and B_0 were obtained from Table I, Ref. 9.

A comparison between the theoretical C.P.'s, calculated by equation (19), and the corresponding experimentally determined values, ~~are~~ is given in Tables 105-106. Agreement is comparatively excellent, the average deviations of the theoretical from the experimental C.P.'s

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*Variation of Munk's formula, ref. 9, p. 14.

TABLE 105

Theoretical (Equation (19) and experimental values of the center of pressure coefficient (C.P.)

		STAGGER = 0.						
		GAP/ CHORD						
C_L	$L_c x 10^5$	0.50	0.75	1.00	1.33	1.67	2.00	Monoplane
		THEORETICAL						
.2	51	.62	.64	.65	.65½	.66	.66½	.67
.4	102	.42	.43	.44	.44½	.45	.45½	.46
.6	153	.35½	.36½	.37	.37½	.38	.38½	.39
.8	205	.32	.33	.33½	.34	.34½	.35	.35½
1.0	256	.30	.31	.31½	.32	.32½	.33	.33½
1.2	307	[illegible]	.29½	.30	.30½	.31	.31½	.32
		EXPERIMENTAL						
.2	51	.60½	.62	.69	.65	.67	.71	.68
.4	.02	.38	.40½	.46½	.42½	.45	.48½	.45½
.6	.53	.31½	.33	.39	.35	.37½	.40½	.38½
.8	205	.28½	.29	.35	.30½	.33	.36½	.34½
1.0	256	.27	.27	.33.	.28½	.31½	.34½	.32
1.2	307	-	.26	.32	.27½	.30½	.33½	.31

TABLE 106

(1) Theoretical, and (2) Experimental values of the center of pressure coefficient (C.P.)

Göt. 387 Biplane

STAGGER = 0.

C_L	$L_c \times 10^5$	GAP/CHORD							
		0.75		1.00		1.33		Monoplane	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
.2	51	.74½	.65	.75½	.68½	.76½	.68½	.78	.76
.4	102	.48½	.45½	.49½	.48½	.50	.48½	.51½	.51½
.6	153	.40	.39	.40½	.41	.41	.41	.42½	.43
.8	205	.35½	.35½	.36	.37	.37	.37	.38	.39
1.0	256	.33	.34	.33½	.35	.34	.35	.35½	.36½
1.2	307	.31	.31½	.32	.33½	.32½	.33½	.34	.34½
1.4	358	.30	.31½	.30½	.32	.31	.32	.32½	.33½

being as follows -

GAP/CHORD	0.50	0.75	1.00	1.33	1.67	2.00	MONOPLANE
U.S.A. 27 (C_L = .2 to 1.2) T	.03	.03	-.02	-.02	-.00½	-.02½	-.00½
Göt. 387 (C_L =.4 to 1.4)	...	.00	-.01	-.00	--	--	-.00½

From Tables 105-106 it is seen that the theoretical effect of G/C variation amounts to just about one half the experimental effect (apparent), and all of the theoretical biplane C.P.'s are < the monoplane C.P., which is not true of the experimental values. The range of variation between the C.P. curves for G/C = 0.50 and G/C = 2.00, amounts to .03 for the theoretical as compared to .07½ for the experimental curves. But we have no reason to doubt the experimental values as a whole, although the two curves for G/C = 1.00 and 2.00, Plate 8, seem to represent values about .02 too high. For the ordinary run of GAP/CHORD ratios -(0.75-1.33), it is considered that equation (19) will give results accurate within ± 0.01½, while a correlation of experimental results (Plate 14) will give values accurate within ± 0.01.

The foregoing applies only to unstaggered biplanes, equation (19) being applicable only to such. We performed similar calculations however, on a staggered biplane using the method indicated in Part II of Munk's Appendix (ref. 9, p. 32).

The lift due to angle of attack was again taken as the difference between the lift due to curvature, and the total lift determined experimentally. In addition, we took into account the fact that the center of pressure of the component of force parallel to the wing chord is somewhat above the mean chord of the biplane. Corrections (equa. (17)) were also applied to take into account the aerodynamical induction due to the lateral dimensions. C.P.'s for only one staggered biplane (U.S.A.27, G/C = 0.75, stagger = 40%) were calculated, because that was the only one for which the required constants could be obtained from Munk's table. * The results are given here.

TABLE 107.

(1) Theoretical, and (2) Experimental values of C.P.

U.S.A. 27 Biplane
G/C =0.75 , Stagger = 40%

$L_0 \times 10^5$	33	96	127	189	246	300	333
(1)	.78½	.40½	.34½	.28½	.25½	.23½	.23
(2)	.72	.38	.32½	.28½	.26½	.26	.26
Deviations	.06½	.02½	.02	.00	-.01	-.02½	-.03

The agreement shown between these values is not discouraging, but is not so good as was that for the unstaggered biplanes.

The variation of our experimental C.P.'s with stagger is very regular, and in addition covers a larger range than was the case for G/C variation (See Plates 11 and 9). We have calculated biplane corrections for C.P., showing the effect of stagger variation at G/C = 1.00, and the effect of G/C variation at stagger = 0. These corrections, expressed as fractions of the chord by which the C.P. is displaced towards the leading edge, applicable from 0.1 L_0 max. to L_0 max., are tabulated in Tables 108-109, Appendix C. Averages are taken of the Göt. 387 and U.S.A. 27 results and plotted in Plate 14. We consider

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*Table II, ref. 9.

the curves there given to be accurate within ± .01.

SUMMARY.

In this analysis of C.P.'s we have found that equation (19) can be used to calculate the C.P. for unstaggered biplanes, the accuracy being about ±0.01 from G/C = 0.75 to 1.33. The same method applied to staggered biplanes can be used with a lesser degree of accuracy. In each of these theoretical methods, accurate results require the assumption that -

(Lift due to angle) =
(Total lift, experimental)-(Curvature lift, theoretical).

The accuracy of the results thereby obtained indicates that the theoretical lift due to curvature is about right.

In Plate 14 we have plotted our experimental results in the form of corrections to be subtracted from the monoplane C.P. Values taken from the curves are accurate within about ± 0.01.

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THIS CONCLUDES THE ANALYSIS OF RESULTS. In connection with each part of the analysis a brief summary has been given. After we have made a REVIEW OF PREVIOUS EXPERIMENTAL WORK, SECTION VII, WE SHALL IN SECTION VIII GIVE A CONCISE GENERAL SUMMARY AND CONCLUSIONS.

SECTION VII.

REVIEW OF PREVIOUS EXPERIMENTAL WORK.

We are making this review to see if previous results check with ours for the variation with Stagger and G/C of the biplane correction factors for:

L_c max.
L_c at equal values of α, $0^\circ - 13^\circ$
D_c at equal L_c *
D_c min.
L/D at equal L_c *
L/D max.
M_c at equal L_c *
C.P. at equal L_c*

Our results are always given in column (2), ~~and~~ taken where possible from our two final charts (Plates 13-14), and those of the experimenter under consideration in column (1).

1. L. Bairstow, Tech. Report A.C.A., 1911-12, p.73-74.

Name of Section: Eiffel 13 bis (Bleriot 11a), maximum camber = 4.35%
Size of Model: 30"x 5".
Wind Velocity: 19 m.p.h.
Where Tested: N.P.L. 4 foot tunnel~~s~~.
Number of Tests: 6, 4 without stagger at G/C = 0.4, 0.8, 1.2, 1.6; and 2 at G/C = 1.00 and Stagger = 44% and -38%.

RESULTS: A table of L_c and L/D correction factors at equal α for 6°, 8°, and 10°; and small curves for L_c, D_c and L/D from -2° to 12°, from which results the following comparisons of correction factors is derived.

* Can only be computed from curves, and published curves are seldom accurate enough.

	L_c at equal α, 6°- 10°.		L/D	MAX.
	STAGGER = 0.			
G/C	(1)	(2)	(1)	(2)
0.4	.62	.73½	.75	.67
0.8	.77	.83	.79	.76½
1.0	.82	.86	.81	.78½
1.2	.86	.88½	.84	.80
1.6	.89	.91	.87½	.81½

2. J. R. Pannell, Tech. Report A.C.A., 1915-16, pp. 99-110.

Name of Section:	RAF 6c, maximum camber = 6.95%
Size of Model:	18" x 3"
Wind Velocity:	27.3 m.p.h.
Where Tested:	N.P.L. 3 foot tunnel.
Number of Tests:	8, 6 without Stagger at G/C = 0.67, 1.00, 1.33, 1.67, 2.00, and 2 at G/C = 0.9, with Stagger = 52% and -50%

RESULTS: Tables and curves showing the variation with G/C of L_c, D_c, L/D, M_c, and C.P., from -6^0 to 20^0; and showing the variations with Stagger of L_c, D_c, and L/D; and also loading of upper and lower planes for G/C = 1.03, Stagger = 0. From these we have derived corrections factors so as to make the following comparison. We have made as many comparisons as the author's data would permit.

VARIATION OF CORRECTION FACTORS WITH G/c. AT STAGGER = 0

G/C	Lc Max.		Dc Min.		L/D Max.	
	(1)	(2)	(1)	(2)	(1)	(2)
.67	.87½	.88½	.98	1.15½	.77½	.75
.90	.91½	.93½	-	-	.80½	.78
1.00	.93	.95	.99½	1.12½	.84	.78½
1.33	.94	.96½	.98	1.12	.88	.80½
1.67	.99	.96½	.98½	1.11	.88½	.82
2.00	.98½	.96½	.95½	1.05	.92	.88
STAG.	GAP/CHORD = 0.9					
+52%	.96½	.98½			.81½	.78
0	.91½	.93½			.80½	.78
-50%	.86½	.85			.82	.78

Correction factor for L_c at equal α, $0^\circ - 10^\circ$

G/C	(1)	(2)
1.00	.81	.86
1.33	.84½	.89½
1.67	.87½	.92
2.00	.90	.94

The correction factors for L_c at equal α show the same amount of variation, viz. 9% and 8% respectively, but (2) is always about 5% higher than (1). That this difference is considerable is shown by the fact that even at -40% stagger (2) does not become as low as (1). However, it is significant that the only two airfoils tested in the same tunnel at the same time by the same personnel and with conditions similar in every way, even though their camber differed by 4.16%, check within ½% for L_c correction factors at equal between $0^\circ - 13^\circ$.

D_c, L/D, Mc, and C.P. correction factors at equal value of L_c cannot be obtained from the author's data.

D and L loading factors for upper and lower wings fit in very well with our values.

A comparison is made in Section VI.

3. L. W. Bryant, Tech. Report A.C.A., 1917-18, Vol. 1, pp. 184-187.

Name of Section: RAF 15, maximum camber = 6.38%
Size of Model: 33".6 x 6", Rake = 21°03
Wind Velocity: 35.7 m.p.h. 50 foot section
Where Tested: N.P.L. 7 foot tunnel No. 1
Number of Tests: 1, at G/C = .884, Stagger = 23.°3 = 43%

RESULTS: L_c, D_c, L/D, and C.P. at 4° intervals, 0° - 16°.

From these we have deduced the following correction factors:

L_c Max. (1) .97½ (2) .95½
L_c at equal α, 4°-12° (1) .85½ (2) .87½
D_c Min. (1) .98½ (2) 1.13

4. W. L. Cowley, Tech. Report A.C.A., 1917-18, Vol. 1, p. 194

Name of Section: RAF 15.
Size of Model: 18" x 3".
Wind Velocity: 27.3 m.p.h. = 40 f~~ee~~t./sec~~tion~~.
Where Tested: N.P.L. 4 foot tunnel No. 1.
Number of Tests: 1 at G/C = 0.75, Stagger = 0.

RESULTS: The following comparison is made with correction factors deduced from Cowley's data:

	(1)	(2)
L_c Max.	.88½	.90½
L_c at equal α, 0°-12°	.77½	.82
D_c at equal L_c, L_c = (.00121	1.32	1.29½
(.00227	1.46½	1.40
D_c Min.	1.12	1.13½
L/D at equal L_c = (.00227)	.68	.71½
L/D Min.	.71½	.76

5. J. C. Hunsaker, Engineering, January 7, 1916, as reported by Alexander Klemin, Aviation, November 15, 1916.

Name of Section: RAF 6, Maximum camber = 6.82%
Size of Model: 18" x 13"
Wind Velocity: 30 m.p.h.
Where Tested: M.I.T.
Number of Tests: 1 at G/C = 1.2, Stagger = 0.

RESULTS: L_c Maximum (1) .95½ (2) .96
D_c and L/D correction factors for G/C = 1.00, Stagger = 0:—

Biplane Correction Factors

$L_0 \times 10^5$	L/D		D_0		
	(1)	(2)	(1)	(2)	
40	1.10	-	.90	-	
60	1.07	.94½	.93	1.06)	
80	.99	.86½	1.01	1.15½)	Very poor
120	.85	.80	1.15	1.25)	Agreement
160	.85	.77	1.15	1.29½)	
200	.75	.76	1.25	1.31½)	Good
240	.73	.75	1.27	1.33)	Agreement

These results attributed to Hunsaker by Klemin show very poor agreement with ours, (except for L_0 = .00200 to .00240), and are evidently in error, for on none of our 42 separate tests from G/C = 50, to 200, and Stagger = -40% to 60%, did we get an L/D correction factor greater than 1.00, or a D_0 correction factor less than 1.00, at equal values of L_0. At the same time it is evident that for equal L_0, the values of the L/D correction factors will be the reciprocals of the D_0 correction factors; whereas the inaccuracy of these results attributed to Hunsaker is shown by the fact that they do not even meet this simple test.

Alexander Klemin (ref. above) deduced from N.P.L. results the following correction factor for L_0, 4° - 8°; to which we compare our own:-

L_0 Correction Factors, 4° - 8°.

	GAP/CHORD			
	.80	1.00	1.20	1.60
(1)	.76	.81	.86	.89
(2)	.83	.86	.88½	.91

6. E. P. Warner, A. Klemin, G. C. Denkinger,
N.A.C.A. Report, 1917, pp. 289-292.

Name of Section: Eiffel 36, maximum camber = 6.88%
Size of Model: Complete model of JN-2 Biplane
18" x 2"65 wings.
Wind Velocity: 30 m.p.h.
Where Tested: M.I.T. 4 foot tunnel.
Number of Tests: 1 at G/c = 1.00, Stagger = 20%, Rake = about 20°.

RESULTS: L_c max. (1) .93½ (2) .96½
L_c for practical range of flight, average (1) .88,
(2) .88½

7. Lt. Col. Robert, International Air Congress, London, 1923,
pp. 357-367.

Name of Section: SC 56a (upper), SC 56c (lower). Joukowski profiles.
Size of Model: 706 x 118 mm. = 27"80 x 4"65
Wind Velocity: 40 m/s = 89.5 m.p.h.
Where Tested: Institute Aérodynamique St. Cyr, wind tunnel No. 1 (2 metres).
Number of Biplane Combinations Tested: 4, stagger = 0, G/C = 0.51, 0.74, 1.14, 1.59.
The upper and lower wings were separately tested.

RESULTS: L and D only were measured, and no data published on these, except small curves showing a fairly good agreement between the experimental and theoretical curves (from Prandtl's formulae) for L and D. This means that at equal values of L the theoretical values of D and α were in fair agreement with the experimental values.

Section VIII.

GENERAL SUMMARY AND CONCLUSIONS.

When this thesis was undertaken it appeared that the airplane designer could neither obtain from theory or experimental data an exact knowledge of the aerodynamic coefficients of biplanes. Certain formulae from the vortex theory showed good possibilities, but insufficient data, especially for staggered biplanes, existed to verify them.

We therefore proceeded to make a complete test in the wind tunnel of a large number of biplane combinations. Two U.S.A. 27 airfoil models were tested in 31 biplane combinations, from G/C equal 0.50 to 2.00, and stagger + 60% to -40%; while two Göttingen 387 airfoil models were tested in 12 combinations, from G/C equal 0.75 to 1.33, and stagger equal 60% to -40%. Each of the four airfoil models utilized was of course first tested thoroughly as a monoplane. The material of each was aluminum; the size 18" x 3", and all tests were conducted in the 4'00 M.I.T. wind tunnel at 40 m.p.h.

The following is an outline of the specific results obtained from the original data. In each case we refer the reader to specific tables or charts.

(1). Tabulated values of L_c, D_c, L/D, M_c, and C.P. at equal values of α for all tests. Tables 35 - 76. Curves for L_c, D_c, and L/D plotted against α, and for M_c, and C.P., plotted against L_c, for 63% of all tests. Plates 3-4, 5-12.

(2) Tabulated values of L_c, D_c, L/D, M_c, and C.P. for upper and lower wings tested separately, U.S.A. 27 biplane at G/C = 1.00 and 1.67, and stagger = 0. Fraction of total lift and drag on each wing. Table~~s~~ 34, 77-80 & pp. 104-109.

(3) Comparison at equal values of the L_c between the experimentally determined values and the values calculated by Munk's formulae, for the loading, L_c, D_c, L/D, M_c, C.P., and α. Tables 77-88, 98-99, 104-107.

(4) Biplane correction factors at equal values of α, for L_c, D_c, L/D, and M_c, for all tests. Tables 1-33.

(5) Biplane correction factors for L_c max., D_c min. and L/D max.; and for D_c, L/D, M_c and C.P., at equal values of the L_c. Plates 13-14, Tables 89-97, 100-103, 108-109.

All biplane correction factors mentioned in (5), as well as those for L_c at equal α ($0^\circ - 13^\circ$), have been plotted in Plates 13-14, in a form directly available for practical use. Correction factors taken from these curves have the following approximate degrees of accuracy:

±.01 for L_c max., L_c, at equal α (0°-13°), L/D max., and C.P.;
±.01½ for D_c, D_c min., L/D, and *M_c; and
±.02½ for **M_c.

A comparison with previously published data for the Eiffel 13 bis, Eiffel 36, R.A.F. 6, R.A.F. 6c, and R.A.F. 15, (Section VII), indicates that correction factors read from the our curves can be applied to this whole range of airfoils without incurring errors materially larger (±.00½) than those cited above. Agreement in specific cases did not usually come within this range of error, but the previous results, taken as a whole, bracket our correction factors. That is the significant fact, because these previous tests were performed at

---

* G/C = 1.00, stagger = -40% to 60%
** Stagger = 0, G/C = 0.50 to 2.00.

several different wind tunnels, wind speeds, and model sizes.

All of our results outlined in (1) to (5) above have been thoroughly analyzed in Section VI. The correction factors at equal α (4) were found to be of little significance, with the exception of those for L_c, which had practically the same values (±.01) from 0° to 13° for both the U.S.A. 27 and Göt. 387. These have been incorporated in Plate 13.

The lift loading can be found within ±.01 by the empirical equation (13): -

$$(\text{Frac. of lift on upper wing}) = 0.50 + K_1 L_c,$$

where $K_1 = 23.5$ for $G/C = 1.00$, and 16.1 for $G/C = 1.67$. This applies only to unstaggered biplanes from $L_c = .00125$ to L_c max, but it gives just as good results as Munk's more complicated theoretical formula (10). More experimental work is needed to determine the distribution for staggered biplanes, and for $\alpha < 4^\circ$. Drag loading can be found to ±.01 by the empirical equation : —

$$(\text{Frac. of drag on upper wing}) = K_2 + 33.3L_c, \qquad (14)$$

where $K_2 = 0.48$ for $G/C = 1.00$, and .46 for $G/C = 1.67$. This applies only to unstaggered biplanes, from $L_c = 0$ to L_c max. A relationship which gave just as good agreement so far as our results were concerned, was :-

$$(\%\ \text{Drag on upper}) = 50 + \frac{\alpha^\circ}{2} \, . \qquad (13)$$

The comparison of theoretical and experimental values of D_c, L/D, M_c, and C.P., at equal L_c (3), showed that: —

(a) L_c cannot be theoretically calculated for a given α , but that α for a given L_c can be calculated for unstaggered biplanes by Munk's equation:-

$$\alpha_2 = \alpha_1 - \frac{C_L}{\pi}\left[\left(\frac{S_1}{k_1^2 b_1^2} + I_1\right) - \left(\frac{S_2}{k_2^2 b_2^2} + I_2\right)\right] . \qquad (15)$$

This gives results accurate within 0°.4 (average) from 0.1 to 0.9 L_c max. Munk dismisses stagger as negligible. We found that the average amount by which α was decreased, when the stagger was increased from 0% to 60%, was 1°.2 at G/C = 1.00, and 2°.5 at G/C = 0.75. The effect of positive stagger was twice that of negative.

(b) D_c and L/D for a given L_c can be calculated by means of Munk's formula -

$$C_{D_2} = C_{D_1} - \frac{C_L^2}{\pi}\left[\frac{S_1}{b_1^2 k_1^2} - \frac{S_2}{b_2^2 k_2^2}\right] . \qquad (16)$$

This gives results accurate within ±5% from 0.1 to 0.5 L_c max., for biplanes both with and without stagger. The effect of stagger at equal lifts is negligible from 0.1 to 0.9 L_c max.

(c) The values of M_c calculated by Munk's formulae (17) and (18), were hoplessly too low, averaging -18%.

(d) C.P. can be calculated within ±.01 for unstaggered biplanes, G/C = 0.75 to 1.33, by Munk's formula -

$$\text{C.P.} = 0.50 - x + \frac{2\pi \sin\beta_0 \, x \, B_0}{C_L} \qquad (19)$$

Accurate results require the assumption that -

(Lift due to α) = (Total lift, experimental) — (Curvature lift, theoretical). The accuracy of the results thereby obtained indicates that the theoretical lift due to curvature is about correct. The theoretical lift due to α is entirely too high. If the assumption made above had been incorporated into the method for calculating M_c, results of greater accuracy might have been obtained.

Our analysis of results has disclosed in general that an increase in the gap/chord ratio of a biplane -

(1) equalizes the load on upper and lower wings,

(2) increases L_c max, and L/D for a given L_c,

(3) decreases D_c min., and α and D_c for a given L_c, and

(4) increases M_c and C.P. by small amounts.

While an increase in stagger -

(1) increases the load on the upper wing,

(2) decreases L_c max.,

(3) decreases α for a given L_c,

(4) increases M_c and C.P. by material amounts, and

(5) has a negligible effect on L/D and D_c for a given lift.

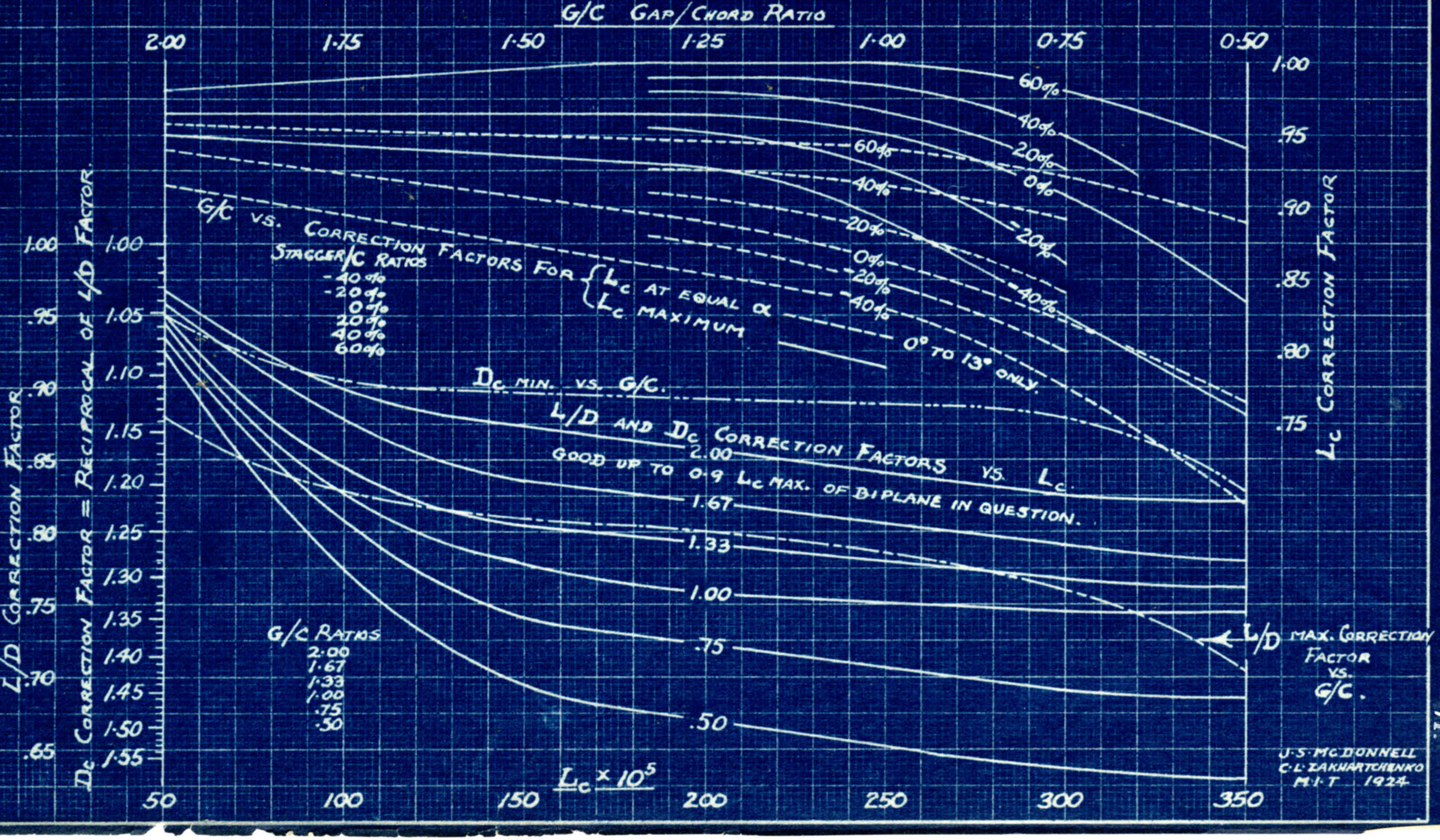
Plates 13 and 14 present a concise quantitative estimate of these various effects due to stagger and gap/chord variation; while Munk's formulae, specified above, can predict loading, α, D_c, L/D, and C.P. with rough accuracy over limited ranges.

CURVES SHOWING THE VARIATION WITH STAGGER AND G/C OF THE BIPLANE CORRECTION FACTORS FOR

PLATE 13

L/D AT EQUAL VALUES OF L_c; AND L/D MAX. } VARIATION WITH STAGGER IS NEGLIGIBLE
D_c " " " " "; AND D_c MIN. }
L_c AT EQUAL VALUES OF α; AND L_c MAX.

READ CORRECTION FACTORS ONLY TO THE NEAREST 1/2 %.



J.S. McDONNELL
C.L. ZAKHARTCHENKO
M.I.T 1924

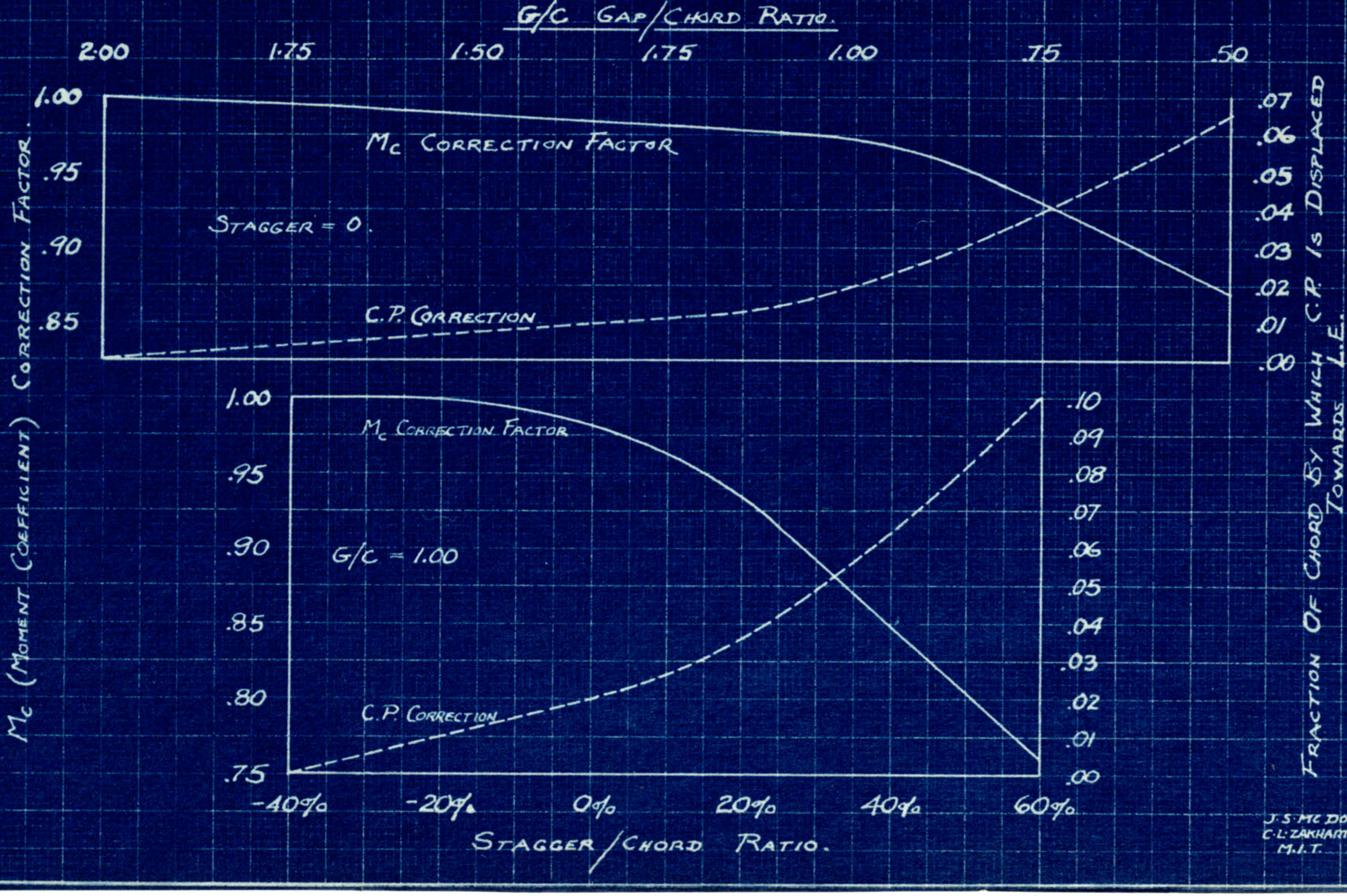
CURVES SHOWING THE VARIATION WITH STAGGER AND G/C OF THE BIPLANE CORRECTION FACTORS FOR

PLATE 14

M_c AT EQUAL VALUES OF L_c ————
C.P. " " " " " - - - - - -

} VARIATION OF THESE CORRECTION FACTORS WITH L_c IS NEGLIGIBLE FROM L_c = .00020 TO L_c MAXIMUM.

READ CORRECTION FACTORS ONLY TO THE NEAREST 1/2 %.



J.S. MC DONNELL
C.L. ZAKHARTCHENKO
M.I.T. 1924

SECTION IX.

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Appendix A.

NOTATION AND METHOD OF CALCULATIONS.

Symbol	Unit of Measure	Meaning of Symbol
Lo	Lbs.	Zero reading of lift arm on wind tunnel balance.
L_1	Lbs.	Reading in lbs. on lift arm with wind at 40 m.p.h.
L_s	Lbs.	Apparent lift due to spindle, or to spindle and balance crosshead combined. This only appeared when one airfoil was tested in the presence of another or when balance crosshead was not protected by the discoid case.
L	Lbs.	Equal to $L_1 - L_o$ or $L_1 - L_o - L_s$, gives the actual lift on the airfoil, except in the case of the test made with spindle 3"00 larger than standard where $L = (L_1 - L_o)/(.923)$.
D_o	Lbs.	Zero reading of balance drag arm.
D_1	Lbs.	Reading of balance drag arm with wind velocity 40 m.p.h.
D_s	Lbs.	Apparent drag due to spindle, or to spindle and balance crosshead combined when the latter was exposed.
D	Lbs.	Equal to $D_1 - D_o$ or $D_1 - D_o - D_s$ as the case may be, gives the drag on the airfoil.
L_c	(Lbs./ft.^{2}/mph)	The lift coefficient of the airfoil.
D_c	"	" drag " " " "
L/D		" lift/drag ratio " " "
M_o	Revolutions of moment wheel.	Zero position of moment wheel
M_1	"	Position of moment wheel, after pitching moment on the airfoil with wind velicity at 40 mph, has been counterbalanced by rotating the moment wheel, which operates a torsion wire.

Symbol	Unit of Measure	Meaning of Symbol
M_s	Revolutions of moment wheel.	Moment of spindle about balance axis, or of spindle and exposed balance crosshead about balance axis, as the case may be.
M	In.Lbs.	Equal to $(M_1 - M_0)/ 3.78$ or $(M_1-M_0-M_s)/ 3.78$ as the case may be, represents the pitching moment on the airfoil about the balance axis prolonged. 3.78 = torsion wire constant.
$M_{l.e.}$	In.Lbs.	For monoplane:- pitching moment of the airfoil about its leading edge, and equal to M - Za - Xh. For biplane:- pitching moment about leading edge of mean geometrical chord, and equal to M-Za and Xh, where H is taken as positive (+), whether measured above or below the M.G.C.
M_c	(Lbs. ft./Sq.ft/ M.P.H./ ft. of Chord)	For monoplane: moment coefficient of the airfoil about its leading edge, equal to $M_{l.e.}/(12\ c\ SV^2)$, where C = chord in ft, S = area in sq. ft., V = velocity of wind in m/p/h. For biplane: Moment coefficient about leading edge of geometrical mean chord, equal to $M_{l.e.}/12\ C\ SV^2$.
Z	Lbs.	Force parallel to the Z - axis. Equal to $L \cos\alpha - D \sin\alpha$.
X	Lbs.	Force parallel to the X - axis. Equal to $D \cos\alpha - L \sin\alpha$.
α	Degrees	Angle of attack, where $\alpha = 0$ means that the chord coinsides with the direction of the airflow.
C.P.	. . . .	Center of pressure coefficient expressed as a fraction of the Chord abaft the leading edge.
G	Ins.	Gap.
C	Ins.	Chord.
a	Ins.	Distance from the axis of rotation (= mean of upper and lower centers of rotation) to the leading edge, measured parallel to the X - axis. $a = 1.00 - \frac{d-(G/2-p) \tan\beta}{2}$ (Fig. 1).

Symbol	Unit of Measure	Meaning of Symbol
h	Ins.	Distance from mean axis of rotation to the chord of the airfoil (or to mean geometrical chord of biplane), measured parallel to the Z - axis. $h = G/4 - p/2$. (Fig. 1.).
p	Ins.	Distance from chord of lower wing (at upper end of biplane as mounted in wind tunnel) to upper center of rotation, measured parallel to Z - axis. (Fig. 1).
d	Ins.	Distance from upper center of rotation to center line of strut, measured parallel to the X - axis. (Fig. 1).
β	Degrees.	Angle between strut and line parallel to Z - Axis. This angle was recorded as negative (-) for positive stagger, and positive (-) for negative stagger. (Fig. 1).

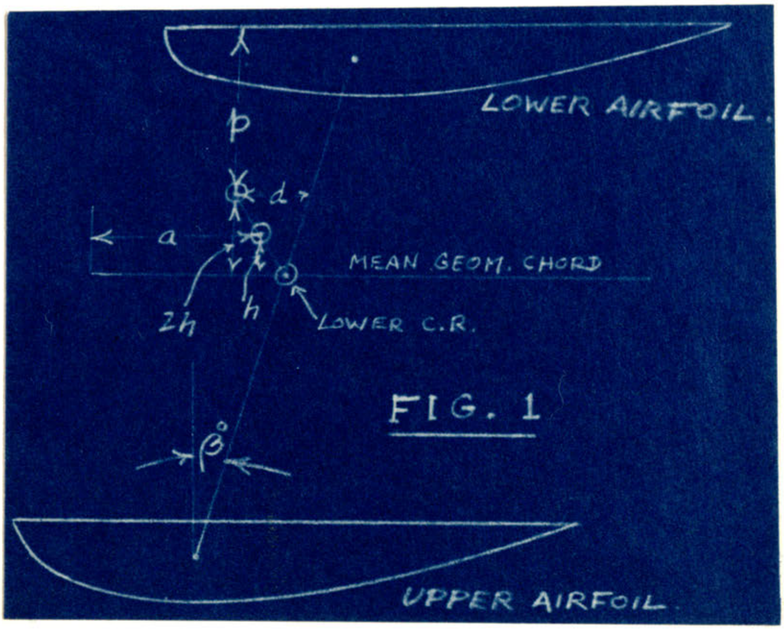


FIG. 1

Munk's (Ref. 9) nomenclature was used in the theoretical calculations involving his equations.

q	c.g.s.	Dynamic pressure, equal to $\frac{1}{2}\rho v^2$
β	Radians	Angle of attack, where $\beta = 0$ means that the moment aroundthe center of the wing is zero.

Symbol	Unit of Measure	Meaning of Symbol
β_0	Radians	The effect due to curvature, $=\frac{C_{L_0}}{2\pi}$, C_{L_0} being the lift coefficient for $\beta = 0$.
C_L	c.g.s.	Absolute lift coefficient = L/qS.
b	c.m.s.	Span.
T	c.m.s.	Chord.
s	c.m.s.	Stagger
x	. . . .	Center of pressure of airfoil without curvature effect, expressed as frac. of chord.
B, C, v,	. . . .	Constants for a given biplane combination.
B_0	. . . .	Equal $\sqrt{B}$
I	. . . .	Interference factor.
k	. . . . .	Induction factor (empirical).

Appendix B.

ORIGINAL DATA.

N.B. In all tabulations of data, negative signs (-) are inserted, but all positive signs (+) are omitted. The absence of a sign means that the value is positive (+).

U.S.A.-27 Monoplane #1

1st Test

D_s = .0450 a = 0"98 h = 0"10

α°	$L_o^{\#}$	$L_1^{\#}$	$L_1-L_o^{\#}$	D_o	D_1	$D_1-D_o-D_s$	M_o	M_1	M_1-M_o
-6	.368	.252	-.116	.0727	.1920	.0743	12.47	10.93	-1.54
-4	.366	.515	.149	.0728	.1586	.0408	12.47	11.13	-1.34
-2	.366	.746	.380	.0729	.1514	.0335	12.47	11.35	-1.12
0	.366	.945	.579	.0730	.1550	.0370	12.47	11.63	- .84
2	.366	1.196	.830	.0730	.1643	.0463	12.47	11.83	- .64
4	.364	1.427	1.063	.0730	.1811	.0631			
6	.364	1.628	1.264	.0730	.2001	.0821	12.47	12.36	- .11
8	.364	1.845	1.481	.0730	.2241	.1061			
10	.364	2.041	1.677	.0730	.2494	.1314	12.47	12.80	.33
12	.363	2.232	1.869	.0730	.2762	.1582			
14	.362	2.383	2.021	.0730	.3063	.1883	12.47	13.18	.71
16	.362	2.456	2.094	.0730	.3380	.2200			
18	.361	2.434	2.073	.0728	.4068	.2809	12.47	12.94	.47

2nd Test

D_s = .0450 a = 1"00 h = 0"11

α	L_o	L_1	L_1-L_o	D_o	D_1	$D_1-D_o-D_s$	M_o	M_1	M_1-M_o
-6	.290	.164	-.126	.1445	.2691	.0796	14.28	12.73	-1.55
-4	.291	.428	.137	.1446	.2324	.0429	14.28	12.91	-1.37
-2	.291	.651	.360	.1447	.2238	.0341	14.28	13.18	-1.20
0	.290	.853	.563	.1447	.2251	.0364	14.28	13.45	- .83
2	.290	1.102	.812	.1447	.2351	.0454	14.28	13.68	- .60
4	.289	1.320	1.031	.1447	.2507	.0610	14.28	13.91	- .37
6	.289	1.528	1.239	.1447	.2695	.0798	14.28	14.17	- .11
8	.288	1.733	1.445	.1447	.2932	.1035			
10	.288	1.927	1.639	.1447	.3181	.1284	14.28	14.71	.43
12	.287	2.122	1.835	.1448	.3449	.1551			
14	.287	2.276	1.989	.1448	.3766	.1868	14.28	15.17	.89
16	.286	2.359	2.073	.1448	.4066	.2168	14.28	15.31	1.03
18	.285	2.330	2.045	.1448	.4658	.2760	14.28	15.01	.76
20	.285	2.267	1.982	.1448	.5264	.3366			
22	.285	2.166	1.881	.1448	.5799	.3901	14.28	14.45	.17

U.S.A.-27 Monoplane #1

Mean Values of Two Tests

$a = 0''.99$ $h = 0''.11$

α	L_1-L_o	$D_1-D_o-D_s$	L/D	L_c	D_c	M_1-M_o	$\frac{M_1-M_o}{3.78}$
- 6	- .121	.0770	-1.57	-.00020	.000128	-1.55	-.410
- 4	.143	.0419	3.42	.00024	.000070	-1.36	-.360
- 2	.370	.0338	10.93	.00062	.000056	-1.16	-.307
0	.571	.0367	15.58	.00095	.000061	- .84	-.222
2	.821	.0459	17.90	.00137	.000077	- .62	-.164
4	1.047	.0620	16.89	.00175	.000103	- .38	-.101
6	1.251	.0810	15.46	.00209	.000135	- .11	-.029
8	1.463	.1048	13.98	.00244	.000175		
10	1.658	.1299	12.78	.00276	.000217	.37	.098
12	1.847	.1567	11.80	.00308	.000261		
14	2.005	.1876	10.70	.00334	.000313	.80	.212
16	2.084	.2184	9.55	.00347	.000364		
18	2.059	.2785	7.39	.00343	.000464	.62	.164
20	1.982	.3366	5.89	.00330	.000561		
22	1.881	.3901	4.82	.00314	.000650	.17	.045

α	X	Z	Za	Xh	$M_{l.e.}$	C.P.%	M_c
- 6	.064	- .129	- .128	.0070	- .275	- 71.1	-.00015
- 4	.051	.140	.139	.0056	- .493	117.2	-.00027
- 2	.047	.369	.365	.0052	- .667	60.3	-.00037
0	.038	.571	.566	.0042	- .784	45.7	-.00044
2	.018	.820	.811	.0020	- .973	39.5	-.00054
4	- .011	1.048	1.037	-.0012	-1.139	36.3	-.00063
6	- .050	1.251	1.240	-.0055	-1.275	33.9	-.00071
8	- .100	1.461	1.447	-.0110			
10	- .160	1.654	1.639	-.0176	-1.555	31.4	-.00086
12	- .231	1.838	1.819	-.0254			
14	- .303	1.989	1.969	-.0333	-1.790	30.0	-.00099
16	- .364	2.061	2.040	-.0400			
18	- .370	2.042	2.021	-.0407	-1.898	30.9	-.00105
20	- .360	1.977	1.957	-.0396			
22	- .344	1.890	1.871	-.0378	-1.865	32.9	-.00104

U.S.A.-27 Monoplane #2

1st Test

D_s =.0450, a = 0"97 h = 0"14

α°	L_1	L_o	L_1-L_o	D_1	D_o	$D_1-D_o-D_s$	M_1	M_o	M_1-M_o
- 6	.146	.288	- .142	.2596	.1439	.0707	14.48	16.00	-1.52
- 4	.447	.288	.159	.2342	.1439	.0453	14.58	16.00	-1.42
- 2	.646	.287	.359	.2241	.1440	.0351	14.79	16.00	-1.21
0	.863	.286	.577	.2255	.1440	.0365	15.02	16.00	- .98
2	1.105	.286	.819	.2354	.1440	.0464	15.28	16.00	- .72
4	1.327	.285	1.042	.2500	.1440	.0610	15.53	16.00	- .47
6	1.528	.285	1.243	.2694	.1439	.0805	15.77	16.00	- .23
8	1.735	.284	1.451	.2903	.1438	.1115			
10	1.932	.284	1.648	.3166	.1437	.1279	16.23	16.00	.23
12	2.122	.284	1.838	.3450	.1436	.1564			
14	2.282	.283	1.999	.3730	.1435	.1845	16.69	16.00	.69
16	2.385	.283	2.102	.4044	.1434	.2160	16.72	16.00	.72
18	2.371	.282	2.089	.4603	.1432	.2721	16.65	16.00	.65
20	2.287	.282	2.005	.5264	.1430	.3384			
22	2.186	.281	1.905	.5874	.1428	.3994	15.97	16.00	-.03

2nd Test

D_s = .0450 a = 0"99 h = 0"19

α°	L_o	L_1	L_1-L_o	D_o	D_1	$D_1-D_o-D_s$	M_o	M_1	M_1-M_o
- 6	.3650	.239	-.127	.0716	.1964	.0798	11.97	10.41	-1.56
- 4	.3653	.503	.138	.0719	.1585	.0416	11.97	10.52	-1.45
- 2	.3648	.738	.373	.0719	.1510	.0341	11.97	10.77	-1.20
0	.3643	.962	.598	.0719	.1540	.0371	11.97	10.92	-1.05
2	.3638	1.199	.835	.0719	.1630	.0461	11.97	11.27	- .70
4	.3631	1.419	1.055	.0719	.1795	.0626	11.97	11.47	- .50
6	.3624	1.628	1.266	.0718	.1990	.0822	11.97	11.75	- .22
8	.3628	1.830	1.468	.0718	.2200	.1032	11.97	12.02	.05
10	.3613	2.024	1.663	.0716	.2463	.1297	11.97	12.28	.31
12	.3614	2.225	1.864	.0714	.2750	.1586	11.97	12.46	.49
14	.3606	2.378	2.017	.0712	.3055	.1893	11.97	12.71	.74
16	.3601	2.477	2.116	.0711	.3355	.2194	11.97	12.92	.95
18	.3597	2.439	2.079	.0710	.3934	.2774	11.97	12.56	.59

U.S.A.-27 Monoplane #2

Mean Values of Two Tests

a = 0".98   h = 0".16

α	L_1-L_o	$D_1-D_o-D_s$	M_1-M_o	L_c	D_c	$\frac{L}{D}$	$\frac{M_1-M_o}{3.78}$
- 6	-.134	.0753	-1.54	-.00022	.000126	-1.78	- .407
- 4	.149	.0435	-1.44	.00025	.000073	3.42	- .381
- 2	.366	.0346	-1.21	.00061	.000058	10.59	- .320
0	.587	.0368	-1.02	.00098	.000061	15.98	- .270
2	.827	.0463	- .71	.00138	.000077	17.86	- .188
4	1.049	.0618	- .49	.00175	.000103	16.98	- .130
6	1.254	.0813	- .23	.00209	.000136	15.43	- .061
8	1.459	.1074		.00243	.000179	13.58	
10	1.656	.1288	.27	.00276	.000215	12.88	.071
12	1.851	.1575		.00309	.000263	11.77	
14	2.008	.1869	.72	.00335	.000312	10.75	.190
16	2.109	.2177	.84	.00352	.000363	9.70	.222
18	2.084	.2748	.62	.00347	.000458	7.48	.164
20	2.005	.3384		.00334	.000564	5.93	
22	1.905	.3994	- .03	.00318	.000666	4.77	- .008

α	X	Z	Za	Xh	$M_{l.e.}$	C.P.%	M_c
- 6	.060	- .140	- .137	.0096	- .260	- 62.0	-.00015
- 4	.053	.146	.143	.0085	- .515	+ 117.6	-.00028
- 2	.048	.364	.357	.0077	- .669	+ 61.2	-.00038
0	.037	.587	.575	.0059	- .839	+ 47.7	-.00046
2	.018	.828	.811	.0029	- .996	+ 40.3	-.00055
4	-.012	1.050	1.029	-.0019	-1.161	+ 36.9	-.00064
6	-.050	1.254	1.229	-.0080	-1.298	+ 34.4	-.00072
8	-.097	1.458	1.429	-.0155			
10	-.160	1.651	1.619	-.0256	-1.574	+ 31.8	-.00087
12	-.232	1.840	1.802	-.0371			
14	-.303	1.991	1.950	-.0485	-1.809	+ 30.2	-.00100
16	-.373	2.085	2.044	-.0596	-1.882	+ 30.1	-.00105
18	-.382	2.064	2.022	-.0611	-1.919	+ 30.9	-.00106
20	-.371	1.997	1.956	-.0594			
22	-.344	1.914	1.875	-.0550	-1.938	+ 33.7	-.00108

U.S.A.-27 Monoplane

Mean Values of Two Tests on #1 and Two Tests on #2

To be used as the standard to which to apply biplane correction factors.

α	$L_1 - L_o$	$D_1 - D_o - D_s$	L_c	D_c	L/D	C.P.%	M_c
- 6	- .128	.0762	.00021	.000127	- 1.68	-66.6	-.00015
- 4	.146	.0427	.00024	.000071	3.42	+117.4	-.00028
-2	.368	.0342	.00061	.000057	10.76	+60.8	-.00038
0	.579	.0368	.00097	.000061	15.71	+46.7	-.00045
2	.824	.0461	.00137	.000077	17.85	+39.9	-.00055
4	1.048	.0619	.00175	.000103	16.92	+36.6	-.00064
6	1.253	.0812	.00209	.000135	15.45	+34.2	-.00072
8	1.461	.1061	.00244	.000177	13.76		
10	1.651	.1294	.00276	.000216	12.70	+31.6	-.00087
12	1.849	.1571	.00309	.000262	11.78		
14	2.007	.1873	.00335	.000312	10.71	+30.1	-.00100
16	2.097	.2181	.00350	.000364	9.60		
18	2.072	.2767	.00345	.000461	7.49	+30.9	-.00105
20	1.994	.3375	.00332	.000563	5.91		
22	1.893	.3948	.00316	.000658	4.80	+33.3	-.00106

U.S.A.-27 As Upper
Plane of Bi-Plane Combination
G/C = 1.00, Stagger = 0

α	L_o	L_1	L_s	L	D_o	D_1	D_s	D
- 6	.332	.155	.002	- .175	.0687	.1880	.0365	.0828
- 4	.332	.371	.002	.037	.0687	.1569	.0366	.0516
- 2	.331	.573	.002	.239	.0687	.1471	.0368	.0416
0	.330	.759	.002	.427	.0687	.1443	.0370	.0386
2	.330	.943	.002	.611	.0687	.1503	.0372	.0444
4	.330	1.191	.002	.859	.0685	.1665	.0375	.0605
6	.329	1.358	.002	1.027	.0685	.1852	.0378	.0789
8	.329	1.543	.002	1.212	.0685	.2079	.0380	.1014
10	.329	1.718	.002	1.387	.0684	.2357	.0382	.1291
12	.328	1.905	.002	1.575	.0683	.2688	.0382	.1623
14	.328	2.075	.002	1.745	.0682	.3088	.0382	.2024
16	.327	2.246	.001	1.918	.0680	.3464	.0382	.2402
18	.327	2.401	.001	2.073	.0678	.3878	.0302	.2918
20	.326	2.469	.001	2.142	.0683	.4094	.0382	.3029
22	.323	2.409	0	2.086	.0683	.4805	.0382	.3740

α	L/D	L_c	D_c	M_o	M_1	M_1-M_o	$\frac{M_1-M_o}{3.78}$
- 6	-2.12	-.00029	.000138	11.56	10.12	-1.44	- .381
- 4	.72	.00006	.000086	11.56	10.19	-1.37	- .363
- 2	5.75	.00040	.000069	11.56	10.43	-1.13	- .299
0	11.07	.00071	.000064	11.56	10.63	- .93	- .246
2	13.79	.00102	.000074	11.56	10.79	- .77	- .204
4	14.20	.00143	.000101	11.56			
6	13.04	.00171	.000132	11.56	11.31	- .25	- .006
8	11.96	.00202	.000169	11.56			
10	10.74	.00231	.000215	11.56	11.68	.12	.032
12	9.70	.00263	.000271	11.56			
14	8.62	.00291	.000337	11.56	12.23	.67	.177
16	7.98	.00320	.000400	11.56			
18	7.10	.00344	.000486	11.56	12.91	1.35	.357
20	7.08	.00357	.000505				
22	5.58	.00347	.000623				

U.S.A.-27 As Upper Plane
of Biplane Combination
G/C = 1.00, Stagger = 0
- Continued -

a = 0".99 h = 0".19

α	X	Z	Za	Xh	M_{LE}	C.P.	M_c
- 6	.064	- .184	- .182	.012	- .187	- .339	-.00010
- 4	.053	.032	.0317	.010	- .385	4.010	-.00021
- 2	.050	.237	.235	.009	- .524	.736	-.00029
0	.039	.429	.425	.007	- .664	.515	-.00037
2	.023	.612	.606	.004	- .806	.439	-.00045
4	0	.860	.851	0			
6	-.039	1.028	1.018	-.007	-1.091	.356	-.00061
8	-.068	1.213	1.202	-.013			
10	-.113	1.387	1.372	-.022	-1.362	.328	-.00076
12	-.170	1.572	1.556	-.032			
14	-.225	1.740	1.721	-.043	-1.587	.304	-.00088
16	-.299	1.907	1.888	-.057			
18	-.363	2.060	2.040	-.069	-1.752	.283	-.00097

U.S.A.-27 As Lower Plane
of Biplane Combination
G/C = 1.00, Stagger = 0

α	L_0	L_1	L_s	L	D_0	D_1	D_s	D
-6	.332	.309	.002	.022	.0712	.1785	.0374	.0699
-4	.332	.495	.002	.165	.0712	.1482	.0374	.0396
-2	.332	.668	.002	.338	.0712	.1418	.0374	.0332
0	.331	.830	.002	.501	.0712	.1468	.0374	.0382
2	.330	1.006	.002	.678	.0712	.1556	.0373	.0471
4	.330	1.188	.002	.859	.0712	.1701	.0373	.0616
6	.329	1.333	.002	1.005	.0710	.1890	.0372	.0808
8	.329	1.501	.002	1.174	.0709	.2083	.0372	.1002
10	.328	1.664	.002	1.338	.0708	.2308	.0371	.1229
12	.327	1.813	.002	1.488	.0707	.2558	.0370	.1481
14	.327	1.961	.002	1.635	.0705	.2791	.0369	.1717
16	.327	2.079	.001	1.754	.0704	.3023	.0368	.1951
18	.327	2.168	.001	1.843	.0703	.3297	.0367	.2227
20	.326	2.129	.001	1.804	.0700	.3850	.0366	.2784
22	.325	2.110	.001	1.786	.0699	.4538	.0365	.3574

U.S.A.-27 As Lower
Plane of Bi-Plane Combination
G/C = 1.00, Stagger = 0

Continued

α	L/D	Lc	D_c	M_o	M_1	M_1-M_o	$\frac{M_1-M_o}{3.78}$
- 6	- .31	-.00004	.000116	14.45	12.67	-1.78	- .471
- 4	4.16	.00028	.000066	14.45	12.81	-1.64	- .434
- 2	10.18	.00056	.000055	14.45	13.06	-1.39	- .368
0	13.12	.00084	.000064	14.45	13.32	-1.13	- .299
2	14.39	.00113	.000079	14.45	13.45	-1.00	- .264
4	13.91	.00143	.000103	14.45			
6	12.45	.00168	.000135	14.45	13.82	- .63	- .169
8	11.70	.00195	.000167	14.45			
10	10.89	.00223	.000205	14.45	14.20	- .25	- .066
12	10.01	.00248	.000247	14.45			
14	9.53	.00273	.000286	14.45	14.69	.24	.064
16	9.00	.00292	.000325	14.45			
18	8.29	.00307	.000371	14.45	15.03	.58	.153
20	6.49	.00301	.000464	14.45	14.78	.33	.087
22	5.00	.00298	.000596	14.45	14.51	.06	.016

a = 0".93   h = 0".14

α	X	Z	Za	Xh	M_{LE}	C.P.	M_c
- 6	.068	-.029	-.028	.010	- .434	-1.496	-.00024
- 4	.050	.161	.150	.007	- .577	1.196	-.00032
- 2	.044	.337	.313	.006	- .675	.669	-.00038
0	.038	.501	.466	.005	- .760	.506	-.00042
2	.024	.679	.630	.003	- .895	.440	-.00050
4	.001	.860	.800	.000			
6	-.024	1.007	.937	-.003	-1.109	.368	-.00062
8	-.064	1.176	1.092	-.009			
10	-.111	1.338	1.241	-.016	-1.323	.330	-.00074
12	-.165	1.486	1.381	-.023			
14	-.229	1.626	1.511	-.032	-1.479	.304	-.00082
16	-.297	1.738	1.614	-.042			
18	-.358	1.820	1.692	-.050	-1.589	.291	-.00088
20	-.355	1.790	1.665	-.050	-1.628	.303	-.00091
22	-.340	1.790	1.665	-.048	-1.697	.315	-.00094

U.S.A.-27 As Upper Plane
of Biplane Combination
G/C = 1.67 Stagger = 0

α	L_s	L_o	L_1	L	D_s	D_o	D_1	D
-6	.002	.333	.178	-.157	.0373	.0687	.1694	.0634
-4	.002	.333	.520	.185	.0375	.0687	.1450	.0388
-2	.001	.333	.714	.380	.0377	.0687	.1417	.0353
0	.001	.332	.921	.587	.0379	.0687	.1453	.0387
2	.001	.331	1.140	.808	.0381	.0687	.1564	.0496
4	.001	.331	1.357	1.025	.0382	.0687	.1739	.0676
6	.001	.331	1.550	1.218	.0383	.0687	.1964	.0894
8	.001	.330	1.751	1.420	.0383	.0687	.2236	.1166
10	.001	.330	1.969	1.638	.0383	.0687	.2565	.1495
12	.001	.330	1.140	1.809	.0383	.0682	.2947	.1882
14	.001	.329	2.351	2.022	.0383	.0682	.3347	.2282
16	.000	.329	2.498	2.168	.0383	.0680	.3761	.3698
18	.000	.328	2.626	2.298	.0383	.0675	.4153	.3095
20	.000	.327	2.589	2.262	.0383	.0675	.4724	.3666

α	L/D	L_c	D_c	M_o	M_1	M_1-M_o	$\dfrac{M_1-M_o}{3.78}$
-6	-2.47	-.00026	.000106	12.51	10.90	-1.61	-.426
-4	4.78	.00031	.000065	12.51	11.10	-1.41	-.373
-2	10.76	.00063	.000059	12.51	11.31	-1.20	-.318
0	15.19	.00098	.000065	12.51	11.58	-.93	-.246
2	16.28	.00135	.000083	12.51	11.80	-.71	-.188
4	15.30	.00171	.000112	12.51			
6	13.61	.00203	.000149	12.51	12.28	-.23	-.061
8	12.22	.00237	.000194	12.51			
10	10.95	.00273	.000249	12.51	12.81	.30	.079
12	9.61	.00302	.000314	12.51			
14	8.86	.00337	.000380	12.51	13.40	.89	.236
16	8.05	.00361	.000450	12.51			
18	7.42	.00383	.000516	12.51			
20	6.18	.00377	.000611	12.51	13.69	1.18	.313

U.S.A.-27 As Upper Plane
of Biplane Combination
G/C = 1.67 Stagger = 0

- Continued -

a = 0".99 h = 0".19

α	X	Z	Za	Xh	M_{LE}	C.P.	M_c
- 6	.047	- .165	- .163	.009	- .254	- .514	-.00014
- 4	.050	.181	.178	.010	- .542	.999	-.00030
- 2	.048	.378	.374	.009	- .683	.601	-.00038
0	.039	.587	.581	.007	- .820	.470	-.00046
2	.022	.808	.800	.004	- .984	.406	-.00055
4	-.004	1.025	1.015	.001			
6	-.038	1.220	1.208	.007	-1.276	.348	-.00071
8	-.081	1.421	1.407	-.015			
10	-.136	1.638	1.622	-.026	-1.569	.319	-.00087
12	-.192	1.807	1.789	-.037			
14	-.267	2.014	1.994	-.051	-1.809	.299	-.00100
16	-.339	2.156	2.135	-.065			
18	-.416	2.279	2.256	-.079			
20	-.430	2.250	2.228	-.082	-1.997	.296	-.00111

U.S.A.-27 As Lower Plane
of Biplane Combination
G/C = 1.67 Stagger = 0

α	L_s	L_o	L_1	L	D_s	D_o	D_1	D
- 6	-.002	.338	.234	- .102	.0358	.0707	.1877	.0812
- 4	-.002	.337	.458	.123	.0358	.0707	.1517	.0452
- 2	-.002	.336	.653	.318	.0358	.0707	.1448	.0383
0	-.002	.336	.840	.506	.0358	.0707	.1465	.0400
2	-.002	.336	1.040	.706	.0358	.0706	.1560	.0496
4	-.002	.336	1.244	.910	.0358	.0706	.1702	.0638
6	-.002	.335	1.411	1.077	.0358	.0705	.1885	.0822
8	-.002	.335	1.590	1.257	.0359	.0705	.2055	.0991
10	-.002	.334	1.762	1.430	.0359	.0704	.2288	.1225
12	-.001	.334	1.936	1.604	.0360	.0701	.2540	.1479
14	-.001	.333	2.080	1.748	.0360	.0700	.2813	.1753
16	-.001	.333	2.204	1.872	.0361	.0700	.3069	.2008
18	-.001	.332	2.239	1.908	.0361	.0698	.3405	.2346
20	-.001	.332	2.188	1.956	.0362	.0696	.4057	.2999

U.S.A.-27 As Lower Plane
of Biplane
G/C = 1.67, Stagger = 0
- Continued -

α	L/D	L_c	D_c	M_o	M_1	M_1-M_o	$\frac{M_1-M_o}{3.78}$
- 6	- 1.25	-.00017	.000135	12.48	10.83	-1.65	.436
- 4	2.73	.00021	.000075	12.48	10.85	-1.63	.431
- 2	8.32	.00053	.000064	12.48	11.13	-1.35	.357
0	12.68	.00084	.000067	12.48	11.36	-1.12	.296
2	14.22	.00118	.000083	12.48	11.58	- .90	.238
4	14.28	.00152	.000106	12.48			
6	13.12	.00180	.000137	12.48	11.97	- .51	.135
8	12.69	.00210	.000165	12.48			
10	11.71	.00238	.000204	12.48	12.37	- .11	.029
12	10.85	.00267	.000246	12.48			
14	9.98	.00291	.000292	12.48	12.54	.06	.016
16	9.32	.00312	.000335	12.48			
18	8.13	.00318	.000391	12.48	12.97	.49	.130
20	6.19	.00309	.000500	12.48	12.60	.12	.032

a = 0".99 h = 0".19

α	X	Z	Za	Xh	$M_{1.e.}$	C.P.	M_c
- 6	.070	- .110	- .109	.013	- .314	- .95	-.00017
- 4	.053	.121	.112	.010	- .533	1.470	-.00030
- 2	.049	.316	.313	.009	- .661	.698	-.00037
0	.040	.506	.501	.008	- .789	.520	-.00044
2	.025	.708	.700	.005	- .933	.440	-.00052
4	.000	.911	.902	.000			
6	-.031	1.079	1.068	-.006	-1.262	.390	-.00070
8	-.078	1.257	1.244	-.015			
10	-.128	1.428	1.412	-.024	-1.465	.342	-.00081
12	-.189	1.599	1.581	-.036			
14	-.242	1.694	1.678	-.046	-1.708	.336	-.00095
16	-.322	1.853	1.835	-.061			
18	-.366	1.885	1.867	-.070	-1.806	.319	-.00100
20	-.352	1.845	1.827	-.067	-1.862	.337	-.00104

U.S.A.-27 Monoplane #1

Mounted on Balance Crosshead

α	L_1	L_0	D_1	D_0	$D_1-D_0-D_s$	$L_1-L_0-L_s$	L/D
-6	.118	.272	.2725	.0672	.0826	- .158	- 1.9
-4	.394	.271	.2335	.0665	.0447	.119	2.8
-2	.637	.271	.2240	.0657	.0360	.462	10.2
0	.865	.270	.2273	.0647	.0403	.696	14.6
2	1.099	.270	.2359	.0639	.0487	.826	17.0
4	1.328	.269	.2516	.0631	.0650	1.058	16.3
6	1.549	.269	.2741	.0619	.0885	1.279	14.4
8	1.751	.268	.2959	.0607	.1089	1.483	13.6
10	1.956	.268	.3216	.0595	.1364	1.688	12.4
12	2.149	.267	.3498	.0586	.1653	1.883	11.4
14	2.309	.267	.3826	.0575	.1992	2.044	10.3
16	2.408	.267	.4169	.0562	.2331	2.145	9.2
18	2.380	.266	.4732	.0554	.2954	2.119	7.2

Drag (D_s) Lift (L_s), of 5-7/8" spindle and balance crosshead on which spindle was mounted 3/4" from balance axis.

α	D_0	D_1	$D_s=D_1-D_0$	L_1	L_0	$L_s=L_1-L_0$
-6	.0451	.1678	.1227	.304	.300	.004
-4	.0451	.1674	.1223	.304	.300	.004
-2	.0449	.1672	.1223	.303	.299	.004
0	.0449	.1672	.1223	.302	.299	.003
2	.0447	.1680	.1233	.302	.299	.003
4	.0445	.1680	.1235	.301	.300	.001
6	.0443	.1680	.1237	.300	.299	.001
8	.0442	.1705	.1263	.299	.299	0
10	.0442	.1699	.1257	.299	.299	0
12	.0440	.1699	.1259	.299	.300	-.001
14	.0440	.1699	.1259	.298	.300	-.002
16	.0440	.1706	.1266	.296	.300	-.004
18	.0440	.1704	.1264	.295	.300	-.005

U.S.A.-27 Monoplane #1

Crosshead mounting protected by discoid case

1st Test

D_s = .0327 a = 0".79 h = 0".83

α	L_1	L_o	L_1-L_o	D_1	D_o	$D_1-D_o-D_s$	M_1	M_o	M_s	3.7[illegible] M
- 6	.170	.270	- .100	.1762	.0719	.0716	9.18	10.80	-.09	-1.53
- 4	.447	.270	.177	.1432	.0715	.0390	9.02	10.80	-.09	-1.69
- 2	.688	.270	.418	.1364	.0708	.0329	9.04	10.80	-.09	-1.67
0	.907	.269	.638	.1378	.0698	.0353	9.10	10.80	-.08	-1.62
2	1.159	.268	.891	.1484	.0683	.0474	9.15	10.81	-.08	-1.56
4	1.379	.268	1.111	.1634	.0671	.0636	9.21	10.81	-.08	-1.48
6	1.601	.267	1.334	.1821	.0661	.0833	9.38	10.81	-.08	-1.35
8	1.824	.267	1.557	.2067	.0649	.1091	9.55	10.81	-.08	-1.18
10	2.033	.266	1.767	.2343	.0635	.1381	9.75	10.81	-.08	- .98
12	2.241	.266	1.975	.2600	.0621	.1652	10.00	10.81	-.08	- .73
14	2.400	.265	2.135	.2940	.0613	.2000	10.33	10.82	-.08	- .41
16	2.469	.265	2.204	.3358	.0598	.2383	10.51	10.82	-.08	- .23
18	2.446	.265	2.181	.3979	.0590	.3062	10.38	10.82	-.09	- .35
20	2.364	.264	2.100	.4672	.0575	.3770	10.08	10.82	-.09	- .65
22	2.238	.264	1.974	.5300	.0562	.4411	9.83	10.82	-.09	- .90

2nd Test

D_s = .0327

α	L_1	L_o	L_1-L_o	D_1	D_o	$D_1-D_o-D_s$
- 6	.139	.270	- .131	.1775	.0677	.0771
- 4	.406	.269	.137	.1407	.0664	.0416
- 2	.650	.268	.382	.1314	.0655	.0332
0	.879	.268	.611	.1334	.0648	.0359
2	1.115	.267	.848	.1426	.0630	.0452
4	1.351	.267	1.084	.1574	.0622	.0625
6	1.558	.266	1.292	.1761	.0613	.0921
8	1.799	.266	1.533	.2000	.0598	.1075
10	2.009	.266	1.743	.2258	.0592	.1339
12	2.194	.266	1.928	.2530	.0579	.1624
14	2.352	.265	2.087	.2864	.0563	.1974
16	2.447	.264	2.183	.3215	.0553	.2435
18	2.418	.264	2.154	.3878	.0541	.3010

U.S.A.- 27 Monoplane #2

Crosshead mounting, protected by discoid case.

1st Test

D_s = .0301 a = 0".75 h = 0".87

α	L_1	L_0	L_1-L_0	D_1	D_0	$D_1-D_0-D_s$	M_1	M_0	M_s	3,78 M
- 6	.106	.254	- .148	.1934	.0839	.0794	9.65	11.31	-.09	-1.57
- 4	.384	.253	.131	.1556	.0879	.0436	9.49	11.31	-.09	-1.73
- 2	.634	.252	.382	.1460	.0818	.0341	9.53	11.31	-.09	-1.69
0	.858	.251	.607	.1482	.0808	.0373	9.58	11.30	-.08	-1.64
2	1.093	.250	.843	.1559	.0797	.0461	9.62	11.30	-.08	-1.60
4	1.337	.250	1.087	.1728	.0786	.0641	9.69	11.30	-.08	-1.53
6	1.560	.249	1.311	.1913	.0775	.0837	9.86	11.30	-.08	-1.36
8	1.777	.249	1.528	.2144	.0763	.1080	10.04	11.30	-.08	-1.18
10	1.972	.248	1.724	.2400	.0751	.1348	10.22	11.30	-.08	-1.00
12	2.150	.247	1.903	.2676	.0738	.1637	10.46	11.29	-.08	- .75
14	2.341	.246	2.095	.3008	.0725	.1982	10.76	11.29	-.08	- .45
16	2.447	.246	2.201	.3358	.0712	.2345	10.95	11.29	-.08	- .26
18	2.431	.245	2.186	.3975	.0699	.2975	10.85	11.29	-.09	- .45
20	2.357	.245	2.112	.4706	.0687	.3718	10.44	11.29	-.09	- .76
22	2.234	.244	1.990	.5300	.0674	.4325	10.19	11.29	-.09	-1.01

2nd Test

D_s = .0327

α	L_1	L_0	L_1-L_0	D_1	D_0	$D_1-D_0-D_s$
- 6	.201	.331	- .130	.1830	.0617	.0886
- 4	.479	.331	.148	.1446	.0633	.0486
- 2	.727	.330	.401	.1331	.0641	.0375
0	.958	.330	.628	.1392	.0659	.0406
2	1.194	.330	.871	.1475	.0666	.0502
4	1.427	.329	1.098	.1658	.0677	.0654
6	1.637	.328	1.309	.1870	.0686	.0857
8	1.843	.328	1.515	.2101	.0691	.1083
10	2.039	.327	1.712	.2376	.0698	.1351
12	2.229	.327	1.902	.2661	.0705	.1629
14	2.384	.326	2.058	.2981	.0716	.1938
16	2.470	.325	2.145	.3306	.0723	.2246
18	2.451	.325	2.126	.2851	.0736	.2788
20	2.387	.324	2.063	.4702	.0746	.3629
22	2.271	.323	1.948	.5395	.0758	.4310

U.S.A.-27 Monoplane

Mean of 4 tests for Lift and Drag and 2 Tests for Moments. Mounted on balance crosshead; crosshead protected from wind by discoid case.

To be used as standard to which to compare biplane results and thereby obtain biplane correction factors.

α	L	D	L_c	D_c	L/D	2 L	2 D	$2\,M_{LE}$
- 6	-. 127	.0791	-.00021	.000132	-1.63	- .254	.1582	- .500
- 4	.148	.0432	.00025	.000072	3.42	.296	.0864	-1.038
- 2	.396	.0343	.00066	.000057	11.54	.792	.0686	-1.416
0	.622	.0373	.00104	.000062	16.71	1.244	.0746	-1.758
2	.863	.0473	.00144	.000079	18.30	1.726	.0946	-2.136
4	1.095	.0639	.00183	.000106	17.20	2.190	.1278	-2.510
6	1.311	.0838	.00219	.000140	15.70	2.622	.1676	-2.830
8	1.533	.1082	.00256	.000180	14.20	3.066	.2164	-3.166
10	1.737	.1355	.00289	.000226	12.82	3.474	.2710	-3.486
12	1.927	.1636	.00321	.000273	11.79	3.854	.3272	-3.754
14	2.091	.1976	.00349	.000329	10.60	4.182	.3952	-3.960
16	2.183	.2329	.00364	.000388	9.38	4.366	.4658	-4.096
18	2.162	.2958	.00360	.000493	7.30	4.324	.5916	-4.172
20	2.092	.3707	.00349	.000618	5.64	4.184	.7414	-4.218
22	1.971	.4350	.00320	.000725	4.53	3.942	.8700	-4.142

a = 0".77   h = 0".85

α	M	X	Z	Za	Xh	$M_{l.e.}$	M_c	C.P.
- 6	-.410	.066	- .135	- .104	.056	- .250	-.00014	- .62
- 4	-.452	.053	.145	.112	.045	- .519	-.00029	1.19
- 2	-.445	.048	.394	.304	.041	- .708	-.00039	.60
0	-.431	.037	.622	.479	.031	- .879	-.00049	.47
2	-.418	.018	.864	.665	.015	-1.068	-.00059	.41
4	-.399	-.013	1.097	.845	-.011	-1.255	-.00070	.38
6	-.360	-.053	1.312	1.011	-.045	-1.415	-.00079	.36
8	-.312	-.105	1.535	1.182	-.089	-1.583	-.00088	.34 1/2
10	-.262	-.168	1.734	1.338	-.143	-1.743	-.00097	.33 1/2
12	-.196	-.241	1.917	1.476	-.205	-1.877	-.00104	.32 1/2
14	-.114	-.313	2.075	1.600	-.266	-1.980	-.00110	.32
16	-.066	-.370	2.162	1.667	-.315	-2.048	-.00114	.31 1/2
18	-.106	-.385	2.146	1.654	-.328	-2.086	-.00116	.32 1/2
20	-.188	-.366	2.092	1.610	-.311	-2.109	-.00117	.33 1/2
22	-.254	-.335	1.990	1.532	-.285	-2.071	-.00115	.34 1/2

U.S.A.-27 Monoplane #1

Crosshead mounting protected by discoid case.
Length of spindle = 8"00, i.e., 3"00 longer than standard length.

$D_s = .0547$

1st Test

α	L_0	L_1	L_1-L_0	D_0	D_1	$D_1-D_0-D_s$
- 6	.328	.148	- .180	.0570	.2130	.1013
- 4	.327	.445	.128	.0583	.1652	.0522
- 2	.327	.717	.391	.0598	.1563	.0418
0	.326	.968	.642	.0606	.1595	.0442
2	.326	1.205	.883	.0617	.1690	.0526
4	.326	1.462	1.136	.0626	.1866	.0693
6	.325	1.706	1.381	.0637	.2088	.0904
8	.325	1.925	1.600	.0651	.2372	.1174
10	.324	2.158	1.834	.0661	.2682	.1474
12	.324	2.352	2.028	.0670	.2971	.1754
14	.323	2.503	2.180	.0680	.3282	.2055
16	.322	2.645	2.323	.0690	.3679	.2442
18	.321	2.625	2.304	.0702	.4221	.2972

2nd Test

α	L_0	L_1	L_1-L_0	D_0	D_1	$D_1-D_0-D_s$
- 6	.267	.155	- .118	.0695	.2041	.0799
- 4	.266	.446	.180	.0693	.1684	.0444
- 2	.265	.7~~00~~08 ~~.706~~	.443	.0690	.1598 ~~.1598~~	.0361
0	.265	.946	.681	.0678	.1632	.0407
2	.265	1.217	.944	.0665	.1742	.0630
4	.264	1.459	1.195	.0655	.1914	.0812
6	.263	1.703	1.440	.0644	.2129	.0938
8	.263	1.932	1.669	.0630	.2383	.1206
10	.262	2.139	1.877	.0620	.2657	.1490
12	.262	2.362	2.100	.0610	.2983	.1826
14	.262	2.544	2.282	.0600	.3343	.2196
16	.261	2.604	2.343	.0590	.3741	.2604
18	.261	2.513	2.312	.0576	.4418	.3295

U.S.A.-27 Monoplane #2

Crosshead mounting protected by discoid case.
Length of spindle = 8"00, i.e., 3"00 longer than standard.

D_s = .0547

1st Test

α	L_0	L_1	L_1-L_0	D_0	D_1	$D_1-D_0-D_s$
- 6	.266	.188	- .078	.0706	.1980	.0727
- 4	.266	.473	.207	.0695	.1670	.0428
- 2	.265	.733	.468	.0680	.1600	.0373
0	.264	.973	.709	.0665	.1652	.0440
2	.264	1.244	.980	.0654	.1770	.0569
4	.263	1.491	1.228	.0642	.1945	.0756
6	.262	1.729	1.467	.0632	.2155	.0976
8	.261	1.955	1.694	.0622	.2405	.1236
10	.261	2.185	1.924	.0613	.2720	.1560
12	.261	2.404	2.143	.0603	.3048	.1898
14	.261	2.555	2.294	.0594	.3356	.2215
16	.260	2.616	2.356	.0584	.3749	.2618
18	.260	2.600	2.340	.0569	.4495	.3379

2nd Test

α	L_0	L_1	L_1-L_0	D_0	D_1	$D_1-D_0-D_s$
- 6	.268	.213	- .055	.0703	.1923	.0673
- 4	.267	.497	.230	.0695	.1656	.0514
- 2	.266	.754	.488	.0688	.1606 ~~06~~ ~~.1606~~	.0371
0	.265	1.006	.741	.0675	.1663	.0441
2	.265	1.273	1.008	.0668	.1787 ~~87~~ ~~.1791~~	.0568
4	.264	1.509	1.245	.0660	.1957	.0750
6	.264	1.737	1.473	.0650	.2184	.0987
8	.263	1.960	1.697	.0640	.2442	.1255
10	.263	2.200	1.937	.0627	.2744	.1570
12	.262	2.386	2.124	.0615	.3044	.1882
14	.262	2.538	2.276	.0603	.3396	.2246
16	.262	2.595	2.334	.0592	.3864 64 ~~.3854~~	.2735
18	.261	2.553	2.292	.0578	.4514	.0578

U.S.A.-27 Monoplane

Length of Spindle = 8"00, i.e., 3"00 longer than standard
Average of 2 tests on #1 and 2 tests on #2.

α	$L_1 - L_o$	$D_1 - D_o - D_s$	L_c	D_c	L/D
- 6	- .106	.0803	-.00016	.000125	- 1.3
- 4	.186	.0477	.00029	.000073	3.9
- 2	.448	.0381	.00069	.000059	11.8
0	.694	.0433	.00107	.000067	16.0
2	.954	.0573	.00147	.000088	16.7
4	1.201	.0752	.00185	.000116	16.0
6	1.440	.0951	.00222	.000146	15.1
8	1.665	.1218	.00256	.000187	13.7
10	1.893	.1524	.00292	.000235	12.4
12	2.099	.1840	.00323	.000283	11.4
14	2.258	.2178	.00347	.000335	10.4
16	2.339	.2600	.00360	.000400	9.0
18	2.312	.3259	.00356	.000502	7.1

U.S.A.-27 Biplane

G/C = .50 Stagger =-40%

D_s = .0556, a = 0°85, h = 0 Short Strut, β = 38°7

α	L_o	L_1	L	D_s'	D_o	D_1	D	L/D
- 6	.296	.051	- .245	.0056	.0969	.3431	.1950	-1.3
- 4	.294	.442	.148	.0054	.0976	.2733	.1147	1.3
- 2	.292	.797	.505	.0052	.0982	.2508	.0918	5.5
0	.290	1.126	.836	.0050	.0988	.2480	.0886	9.4
2	.288	1.455	1.167	.0047	.0994	.2595	.0998	11.7
4	.286	1.798	1.512	.0045	.0995	.2809	.1213	12.5
6	.285	2.102	1.817	.0043	.0996	.3108	.1513	12.0
8	.283	2.423	2.140	.0041	.0999	.3499	.1903	11.2
10	.281	2.727	2.446	.0039	.1002	.3928	.2331	10.5
12	.279	3.021	2.742	.0037	.1005	.4445	.2847	9.6
14	.277	3.302	3.025	.0035	.1007	.4945	.3347	9.0
16	.274	3.521	3.247	.0032	.1006	.5577	.3983	8.2
18	.272	3.579	3.307	.0030	.1005	.6296	.4705	7.0
20	.270	3.475	3.205	.0028	.1004	.7038	.5450	5.9

α	M_o	M_1	M	X	Z	Za	M_{LE}	C.P.
- 6	9.86	6.74	-.825	.165	- .267	- .227	- .598	- .74 1/2
- 4	9.86	6.57	-.870	.120	.143	.122	.992	2.32
- 2	9.86	6.76	-.820	.110	.500	.425	-1.245	.83
0	9.86	7.03	-.749	.089	.836	.711	-1.460	.58
2	9.86	7.23	-.695	.060	1.169	.994	-1.689	.48
4	9.86	7.49	-.627	.015	1.517	1.290	-1.917	.42
6	9.86	7.70	-.572	-.039	1.822	1.550	-2.122	.39
8	9.86	7.95	-.505	-.110	2.143	1.821	-2.326	.36
10	9.86	8.17	-.447	-.183	2.450	2.083	-2.530	.34 1/2
12	9.86	8.25	-.426	-.290	2.740	2.330	-2.756	.33 1/2
14	9.86	8.42	-.354	-.407	3.014	2.572	-2.926	.32 1/2
16	9.86	8.30	-.413	-.510	3.230	2.745	-3.158	.32 1/2
18	9.86	7.82	-.540	-.552	3.296	2.802	-3.342	.34
20	9.86	8.09	-.468	-.583	3.196	2.718	-3.186	.33

U.S.A.-27 Biplane

G/C = .50 Stagger = 0

D_s = .0571 a = 0"85 h = 0"12 Short Strut, β = 0°

α	L_o	L_1	L	D_s'	D_o	D_1	D	L/D
- 6	.296	.320	.024	.0083	.0837	.2635	.1144	.2
- 4	.296	.665	.369	.0085	.0843	.2364	.0865	4.3
- 2	.294	.968	.674	.0088	.0843	.2283	.0781	8.6
0	.293	1.287	.994	.0089	.0842	.2333	.0831	11.9
2	.291	1.617	1.326	.0088	.0840	.2535	.1036	12.8
4	.290	1.986	1.696	.0086	.0839	.2854	.1358	12.5
6	.295	2.304	2.009	.0084	.0838	.3204	.1711	11.7
8	.299	2.607	2.308	.0082	.0834	.3579	.2092	11.5
10	.298	2.923	2.625	.0080	.0831	.4058	.2576	10.2
12	.297	3.217	2.920	.0077	.0829	.4531	.3054	9.6
14	.296	3.470	3.174	.0075	.0827	.5086	.3613	8.8
16	.295	3.689	3.394	.0073	.0822	.5607	.4141	8.2
18	.294	3.836	3.542	.0071	.0820	.6130	.4668	7.6
20	.293	3.956	3.663	.0069	.0818	.6731	.5273	7.0
22	.292	3.859	3.567	.0067	.0816	.7980	.6526	5.5

α	M_o	M_1	M	X	Z	Za	Xh	M_{LE}	C.P.
- 6	9.98	7.07	-.770	.115	.012	.010	-.014	- .766	-21.77
- 4	9.98	7.27	-.716	.112	.361	.307	-.013	-1.010	.93 1/2
- 2	9.98	7.70	-.604	.100	.664	.564	-.012	-1.156	.58
0	9.98	8.07	-.505	.083	.994	.844	-.010	-1.339	.45
2	9.98	8.40	-.418	.057	1.328	1.129	-.007	-1.540	.38 1/2
4	9.98	8.61	-.352	.017	1.700	1.445	-.002	-1.795	.35
6	9.98	8.95	-.273	.040	2.015	1.712	.005	-1.990	.33
8	9.98	9.27	-.188	-.114	2.313	1.968	.014	-2.170	.31 1/2
10	9.97	9.50	-.124	-.200	2.628	2.235	.024	-2.383	.30
12	9.97	9.89	-.021	-.305	2.920	2.483	.037	-2.541	.29
14	9.97	10.13	.042	-.406	3.125	2.655	.049	-2.662	.29
16	9.97	10.52	.146	-.540	3.374	2.870	.065	-2.789	.27 1/2
18	9.96	11.17	.320	-.650	3.508	2.983	.078	-2.741	.26
20	9.96	11.01	.279	-.756	3.620	3.076	.091	-2.888	.26 1/2
22	9.95	10.87	.244	-.732	3.548	3.015	.088	-2.859	.27

U.S.A.-27 Biplane

G/C = .50 Stagger = 60%

D_s = .0556, a = 0".89, h = 0".16, Short Strut, β = 50°.2

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
- 6	.305	.321	.016	.0023	.0492	.2271	.1200	.1
- 4	.305	.697	.392	.0025	.0502	.1941	.0858	4.6
- 2	.304	1.078	.774	.0028	.0512	.1895	.0799	9.7
0	.304	1.451	1.147	.0030	.0527	.2017	.0904	12.7
2	.304	1.843	1.539	.0032	.0543	.2289	.1158	13.3
4	.303	2.228	1.925	.0035	.0547	.2644	.1506	12.7
6	.303	2.613	2.310	.0037	.0552	.3111	.1966	11.8
8	.303	3.006	2.703	.0040	.0563	.3693	.2534	10.7
10	.302	3.376	3.074	.0042	.0574	.4293	.3121	9.8
12	.302	3.730	3.428	.0044	.0584	.4980	.3796	9.0
14	.301	4.046	3.745	.0047	.0595	.5747	.4549	8.2
16	.301	4.297	3.996	.0049	.0604	.6937	.5728	7.0
18	.301	4.418	4.119	.0052	.0614	.8506	.7284	5.7
20	.300	4.433	4.133	.0054	.0622	1.0230	.8998	4.6
22	.300	4.289	3.989	.0056	.0630	1.2764	1.1512	3.5

α	M_o	M_1	M	X	Z	Za	Xh	M_{LE}	C.P.
- 6	10.11	8.41	- .450	.120	.003	.003	.0192	-.472	52.50
- 4	10.11	9.43	- .180	.112	.383	.343	.0179	-.541	.47
- 2	10.11	10.37	.069	.107	.770	.685	.0171	-.633	.27 1/2
0	10.11	11.29	.312	.090	1.147	1.021	.0144	-.723	.21
2	10.11	12.13	.535	.063	1.541	1.372	.0101	-.847	.18 1/2
4	10.11	12.93	.746	.016	1.930	1.720	.0026	-.977	.17
6	10.11	13.63	.931	-.046	2.317	9.062	-.0074	-1.123	.16
8	10.11	14.35	1.120	-.124	2.712	9.412	-.0199	-1.272	.15 1/2
10	10.11	14.98	1.289	-.225	3.080	2.741	-.0360	-1.416	.15 1/4
12	10.11	15.51	1.429	-.342	3.428	3.052	-.0546	-1.568	.15
14	10.11	15.80	1.503	-.455	3.745	3.335	-.0728	-1.759	.15 1/2
16	10.11	15.28	1.369	-.550	3.996	3.557	-.0870	-2.101	.17 1/2
18	10.11	14.04	1.040	-.580	4.140	3.680	-.0929	-2.647	.21 1/2
20	10.11	12.49	.630	-.564	4.190	3.722	-.0902	-3.002	.24
22	10.11	11.29	.312	-.428	4.134	3.676	-.0685	-3.295	.26 1/2

U.S.A.-27 Biplane

G/C = .75 Stagger = -40%

D_s = .0556, a = 0".86, h = 0".02, Short Strut, β= 28°.1

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
-6	.294	.062	- .232	.0067	.0926	.3189	.1640	- 1.4
-4	.292	.482	.190	.0065	.0935	.2520	.0964	1.9
-2	.291	.857	.566	.0063	.0943	.2357	.0795	7.1
0	.290	1.221	.931	.0061	.0947	.2376	.0812	11.5
2	.289	1.577	1.288	.0059	.0950	.2509	.0944	13.7
4	.287	1.928	1.641	.0056	.0957	.2795	.1226	13.4
6	.284	2.282	1.998	.0054	.0963	.3136	.1563	12.8
8	.282	2.648	2.366	.0052	.0967	.3573	.1998	11.8
10	.281	3.000	2.719	.0050	.0971	.4073	.2496	10.9
12	.279	3.311	3.032	.0048	.0972	.4632	.3056	9.9
14	.278	3.578	3.300	.0046	.0976	.5232	.3654	9.3
16	.276	3.791	3.515	.0044	.0977	.5874	.4297	8.2
18	.274	3.878	3.604	.0042	.0978	.6755	.5179	7.0
20	.272	3.859	3.587	.0040	.0978	.7579	.6005	6.0

α	M_o	M_1	M	X	Z	Za	Xh	M_{1e}	C.P.
-6	11.80	8.79	-.795	.138	- .250	- .215	.0028	- .583	- .775
-4	11.80	8.82	-.788	.108	.182	.156	.0022	- .946	1.735
-2	11.80	8.85	-.780	.099	.561	.483	.0020	-1.165	.695
0	11.80	9.20	-.687	.081	.931	.801	.0016	-1.490	.535
2	11.80	9.41	-.632	.048	1.289	1.109	.0010	-1.742	.45
4	11.80	9.60	-.582	.008	1.645	1.415	.0002	-1.997	.405
6	11.80	9.78	-.534	-.054	2.002	1.721	-.0011	-2.254	.375
8	11.80	9.75	-.542	-.132	2.370	2.040	-.0027	-2.579	.36
10	11.80	10.02	-.470	-.228	2.720	2.340	-.0046	-2.805	.345
12	11.80	10.20	-.423	-.330	3.028	2.605	-.0066	-3.021	.335
14	11.80	10.29	-.400	-.442	3.286	2.815	-.0088	-3.204	.325
16	11.80	9.99	-.479	-.558	3.496	3.005	-.0112	-3.472	.33
18	11.80	9.02	-.735	-.620	3.584	3.082	-.0124	-3.805	.355
20	11.80	8.41	-.896	-.660	3.575	3.075	-.0132	-3.958	.37

U.S.A.-27 Biplane

G/C = .75, Stagger = -20%

D_s = .0556, a = 0°87, h = 0°07 Short Strut, β= 14°9

α	L_o	L_1	L	D_s'	D_o	D_1	D	L/D
-6	.298	.131	-.167	.0080	.0870	.3010	.1504	-1.1
-4	.296	.518	.222	.0078	.0880	.2436	.0922	2.4
-2	.295	.876	.581	.0076	.0888	.2283	.0763	7.6
0	.293	1.230	.937	.0074	.0889	.2325	.0806	11.6
2	.292	1.581	1.289	.0072	.0900	.2477	.0949	13.6
4	.290	1.959	1.669	.0070	.0905	.2744	.1213	13.7
6	.289	2.361	2.072	.0068	.0909	.3155	.1622	12.8
8	.287	2.668	2.381	.0066	.0915	.3571	.2034	11.7
10	.286	2.986	2.700	.0064	.0920	.4060	.2520	10.7
12	.284	3.320	3.036	.0062	.0923	.4600	.3059	9.9
14	.282	3.636	3.354	.0060	.0925	.5200	.3659	9.2
16	.281	3.852	3.571	.0058	.0928	.5746	.4204	8.5
18	.280	4.017	3.737	.0056	.0931	.6419	.4876	7.7
20	.278	4.044	3.762	.0053	.0936	.7302	.5757	6.5
22	.277	3.878	3.601	.0051	.0940	.8513	.6966	5.2

α	M_o	M_1	M	X	Z	Za	Xh	M_{1e}	C.P.
-6	11.50	8.50	-.794	.130	-.180	-.157	.0091	- .646	-1.37
-4	11.50	8.53	-.785	.108	.215	.187	.0076	- .980	-1.52
-2	11.50	8.73	-.732	.096	.578	.503	.0067	-1.242	.715
0	11.50	8.88	-.693	.081	.937	.815	.0057	-1.514	.54
2	11.50	9.10	-.635	.048	1.290	1.122	.0034	-1.760	.455
4	11.50	9.10	-.635	.005	1.672	1.455	.0004	-2.090	.415
6	11.50	9.14	-.625	-.055	2.077	1.805	-.0039	-2.426	.39
8	11.50	9.36	-.566	-.130	2.384	2.074	-.0091	-2.631	.365
10	11.50	9.53	-.521	-.220	2.700	2.348	-.0154	-2.854	.35
12	11.50	10.04	-.386	-.330	3.032	2.638	-.0231	-3.001	.33
14	11.50	9.91	-.420	-.456	3.340	2.905	-.0319	-3.293	.33
16	11.50	9.90	-.423	-.580	3.544	3.084	-.0406	-3.466	.325
18	11.50	9.67	-.484	-.690	3.700	3.220	-.0483	-3.656	.33
20	11.50	9.14	-.624	-.774	3.726	3.240	-.0541	-3.840	.345
22	11.50	8.18	-.878	-.698	3.601	3.132	-.0489	-3.961	.365

U.S.A.-27 Biplane

$G/C = .75$ Stagger = 0

$D_s = .0571$ a = 0".87 h = 0".08 Short Strut, β= 0°

α	L_o	L_1	L	D_s'	D_o	D_1	D	L/D
-6	.313	.219	-.094	.0083	.0808	.2829	.1367	-.7
-4	.313	.598	.285	.0085	.0819	.2372	.0897	3.2
-2	.312	.956	.644	.0088	.0825	.2272	.0788	8.2
0	.311	1.327	1.116	.0089	.0832	.2339	.0847	13.2
2	.310	1.673	1.363	.0088	.0839	.2518	.1020	13.39
4	.309	2.142	1.832	.0086	.0846	.2872	.1369	13.40
6	.308	2.454	2.146	.0084	.0853	.3219	.1711	12.5
8	.307	2.768	2.461	.0082	.0858	.3637	.2126	11.6
10	.306	3.107	2.801	.0080	.0862	.4155	.2642	10.6
12	.306	3.438	3.132	.0077	.0866	.4720	.3206	9.8
14	.305	3.701	3.396	.0075	.0870	.5301	.3785	9.0
16	.303	4.007	3.704	.0073	.0875	.6017	.4498	8.2
18	.301	4.180	3.879	.0071	.0880	.6695	.5173	7.5
20	.300	4.285	3.985	.0069	.0880	.7494	.5974	6.7
22	.299	4.213	3.909	.0067	.0880	.8891	.7373	5.3

α	M_o	M_1	M	X	Z	Za	Xh	M_{le}	C.P.
-6	9.82	6.75	-.812	.126	-.108	-.094	.010	-.728	-2.24
-4	9.82	7.13	-.711	.110	.279	.243	.009	-.963	1.15
-2	9.82	7.46	-.624	.101	.640	.556	.008	-1.188	.62
0	9.82	7.92	-.502	.085	1.116	.971	.007	-1.480	.44
2	9.82	8.20	-.428	.054	1.366	1.189	.004	-1.621	.395
4	9.82	8.44	-.365	.008	1.836	1.598	.000	-1.963	.355
6	9.82	8.85	-.257	-.053	2.151	1.870	-.004	-2.123	.33
8	9.82	9.18	-.169	-.132	2.466	2.148	-.011	-2.306	.31
10	9.82	9.48	-.090	-.222	2.800	2.436	-.017	-2.509	.30
12	9.82	9.88	.016	-.334	3.129	2.722	-.027	-2.679	.285
14	9.82	10.15	.087	-.455	3.386	2.945	-.036	-2.822	.28
16	9.81	10.31	.132	-.586	3.682	3.203	-.047	-3.024	.275
18	9.81	10.34	.140	-.704	3.844	3.344	-.056	-3.148	.275
20	9.81	10.21	.106	-.800	3.943	3.432	-.064	-3.262	.275

U.S.A.-27 Biplane

G/C = .75, Stagger = 20%

D_s = .0556, a = 0".86, h = 0".09, Short Strut, β = -14°.9

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
-6	.300	.282	- .018	.0065	.0747	.2542	.1174	- .15
-4	.299	.664	.365	.0068	.0757	.2210	.0829	4.41
-2	.298	1.024	.726	.0070	.0766	.2145	.0753	9.65
0	.297	1.387	1.090	.0072	.0771	.2204	.0805	13.53
2	.296	1.818	1.522	.0075	.0777	.2461	.1053	14.43
4	.295	2.176	1.881	.0077	.0784	.2791	.1374	13.70
6	.294	2.545	2.251	.0080	.0791	.3218	.1791	12.57
8	.293	2.867	2.574	.0082	.0797	.3644	.2209	11.62
10	.292	3.182	2.890	.0084	.0803	.4197	.2754	10.54
12	.291	3.495	3.204	.0087	.0811	.4750	.3296	9.74
14	.290	3.799	3.509	.0089	.0818	.5409	.3946	8.90
16	.289	4.057	3.768	.0084	.0827	.6025	.4553	8.27
18	.287	4.278	3.991	.0087	.0835	.6711	.5233	7.64
20	.285	4.345	4.060	.0085	.0838	.7628	.6149	6.61
22	.284	4.276	3.992	.0083	.0840	.8869	.7390	5.40

α	M_o	M_1	M	X	Z	Z_a	X_h	M_{1e}	C.P.
-6	11.51	8.53	-.788	.114	- .029	- .025	.0103	- .773	-8.88
-4	11.51	9.02	-.659	.107	.360	.310	.0096	- .979	.905
-2	11.51	9.35	-.571	.100	.723	.621	.0090	-1.200	.555
0	11.51	9.65	-.490	.081	1.090	.937	.0073	-1.434	.44
2	11.51	9.94	-.415	.053	1.524	1.311	.0048	-1.731	.38
4	11.51	10.09	-.376	.005	1.893	1.629	.0005	-2.006	.355
6	11.51	10.38	-.299	-.046	2.257	1.940	-.0041	-2.235	.33
8	11.51	10.60	-.241	-.138	2.580	2.220	-.0124	-2.449	.315
10	11.51	10.84	-.177	-.210	2.886	2.482	-.0189	-2.640	.305
12	11.51	11.00	-.135	-.324	3.240	2.787	-.0292	-2.893	.295
14	11.51	11.08	-.114	-.560	3.470	2.985	-.0504	-3.049	.29
16	11.51	11.28	-.061	-.600	3.742	3.220	-.0540	-3.227	.285
18	11.51	11.33	-.048	-.736	3.952	3.400	-.0662	-3.382	.285
20	11.51	11.32	-.050	-.810	4.220	3.630	-.0729	-3.607	.285
22	11.51	10.86	-.172	-.814	3.970	3.415	-.0733	-3.514	.295

U.S.A.-27 Biplane

G/C = .75 Stagger = 40 %

D_s= .0556, a = .0".91, h = 0."12, Short strut, β= -28.°1

α	L_0	L_1	L	D_1	D_a	D_s^1	D	L/D
-6	.301	.380	.079	.2382	.0686	.0049	.1091	.72
-4	.300	.747	.447	.2100	.0700	.0052	.0792	5.65
-2	.299	1.130	.831	.2086	.0707	.0054	.0769	10.81
0	.298	1.519	1.221	.2214	.0714	.0057	.0887	13.78
2	.297	1.905	1.608	.2495	.0721	.0059	.1159	13.89
4	.296	2.288	1.992	.2856	.0731	.0061	.1508	13.21
6	.295	2.673	2.378	.3300	.0740	.0064	.1940	12.26
8	.294	3.004	2.710	.3841	.0747	.0066	.2472	10.97
10	.203	3.379	3.086	.4418	.0753	.0069	.3040	10.16
12	.292	3.706	3.414	.5021	.0760	.0071	.3633	9.40
14	.291	4.059	3.768	.5784	.0766	.0073	.4389	8.60
16	.291	4.326	4.035	.6525	.0771	.0076	.5122	7.88
18	.290	4.458	4.168	.7447	.0776	.0078	.6037	6.92
20	.288	4.483	4.195	.8610	.0782	.0081	.7191	5.84
22	.286	4.353	4.067	.9833	.0788	.0083	.8406	4.84

α	M_1	M_0	X	Z	Za	Xh	M_{LE}	C.P.	
-6	9.15	11.78	.118	.067	.061	.014	- .770	3.83	
-4	9.74	"	.108	.440	.400	.013	- .953	.72	
-2	10.25	"	.106	.826	.752	.013	-1.170	.47	
0	10.75	"	.089	1.221	1.102	.011	-1.386	.38	
2	11.20	"	.059	1.611	1.468	.007	-1.628	.33	1/2
4	11.48	"	-.023	1.996	1.817	-.003	-1.893	.31	1/2
6	11.83	11.78	-.057	2.384	2.170	-.007	-2.137	.30	
8	12.20	"	-.108	2.720	2.475	-.013	-2.351	.29	
10	12.39	"	-.223	3.050	2.775	-.027	-2.587	.28	
12	12.65	"	-.356	3.410	3.102	-.043	-2.829	.27	1/2
14	12.81	"	-.484	3.758	3.420	-.058	-3.089	.27	1/2
16	12.97	"	-.620	4.013	3.658	-.074	-3.269	.27	
18	12.54	"	-.715	4.145	3.770	-.086	-3.483	.28	
20	11.06	11.78	-.760	4.182	3.805	-.091	-3.524	.27	1/2

U.S.A.-27 Biplane

G/C = .75 Stagger = 60 %

D_s =.0556, a = 0."90, h = 0."07, Short strut, β = -38.°7

α	L_1	L_o	L	D_1	D_o	D_s^1	D	L/D
-6	.357	.304	.053	.2489	.0725	.0037	.1171	.5
-4	.764	.302	.462	.2166	.0743	.0039	.0828	5.6
-2	1.152	.302	.850	.2141	.0743	.0042	.0700	12.2
0	1.549	.302	1.247	.2276	.0752	.0044	.0924	13.5
2	1.953	.301	1.652	.2564	.0761	.0046	.1201	13.7
4	2.340	.301	2.039	.2944	.0770	.0049	.1569	13.0
6	2.747	.300	2.447	.3470	.0779	.0051	.2084	11.7
8	3.155	.300	2.855	.4038	.0787	.0053	.2642	10.8
10	3.508	.299	3.209	.4649	.0795	.0056	.3242	9.9
12	3.854	.298	3.556	.5380	.0799	.0058	.3967	9.0
14	4.199	.297	3.902	.6164	.0803	.0061	.4744	8.2
16	4.439	.296	4.143	.7177	.0810	.0063	.5748	7.2
18	4.588	.295	4.293	.8410	.0817	.0065	.6972	6.2
20	4.601	.295	4.306	.9777	.0827	.0068	.8326	5.2
22	4.525	.294	4.231	1.1906	.0838	.0070	1.0442	4.1

α	M_1	M_o	X	Z	Za	Xh	M_{LE}	C.P.
-6	9.74	11.68	.122	.039	.035	.009	- .560	-4.79
-4	10.41	11.68	.115	.456	.410	.008	- .754	.55
-2	11.11	11.67	.100	.847	.762	.007	- .917	.36
0	11.77	11.66	.092	1.247	1.122	.006	-1.099	.29 1/2
2	12.42	11.65	.062	1.656	1.490	.004	-1.290	.26
4	12.94	11.64	.018	2.044	1.840	.011	-1.497	.24 1/2
6	13.44	11.64	-.049	2.544	2.290	-.003	-1.811	.23 1/2
8	13.82	11.64	-.140	2.860	2.574	-.010	-1.978	.23
10	14.25	11.65	-.235	3.215	2.993	-.016	-2.289	.23 1/2
12	14.48	11.66	-.350	3.560	3.204	-.025	-2.434	.23
14	14.86	11.67	-.484	3.900	3.510	-.034	-2.632	.22 1/2
16	14.38	11.68	-.592	4.133	3.720	-.041	-2.965	.23
18	13.69	11.69	-.663	4.293	3.864	-.046	-3.289	.25 1/2
20	12.98	11.69	-.685	4.320	3.888	-.048	-3.499	.27

U.S.A.-27 Biplane

G/C = 1.00, Stagger = -40 %

D_s= .0556, a = 0."92, h = 0."05, Short strut, β = 21.°8

α	L_1	L_o	L	D_1	D_o	D_s^1	D	L/D
-6	.030	.302	-.272	.3156	.0873	.0073	.1654	-1.6
-4	.491	.301	.190	.2452	.0892	.0071	.0933	2.0
-2	.916	.300	.616	.2268	.0890	.0069	.0753	8.2
0	1.296	.298	.998	.2299	.0893	.0067	.0783	12.7
2	1.677	.296	1.381	.2493	.0905	.0065	.0967	14.3
4	2.078	.294	1.784	.2786	.0910	.0063	.1257	14.2
6	2.476	.293	2.183	.3200	.0915	.0061	.1668	13.1
8	2.807	.291	2.516	.3690	.0920	.0059	.2155	11.7
10	3.202	.290	2.912	.4238	.0926	.0057	.2699	10.8
12	3.503	.288	3.215	.4852	.0929	.0055	.3312	9.7
14	3.835	.287	3.548	.5505	.0931	.0052	.3966	9.0
16	4.091	.285	3.806	.6218	.0933	.0050	.4679	8.2
18	4.223	.283	3.940	.7111	.0935	.0048	.5572	7.1
20	4.207	.281	3.926	.8014	.0937	.0046	.6475	6.1

α	M_1	M_o	X	Z	Z_a	Xh	M_{LE}	C.P.
-6	4.59	7.56	.132	.289	.266	.007	-.526	-.61
-4	4.48	"	.106	.182	.167	.005	-.987	1.80
-2	4.60	"	.097	.613	.564	.005	-1.352	.73 1/2
0	4.87	"	.078	.998	.918	.004	-1.633	.54 1/2
2	5.09	"	.048	1.383	1.272	.002	-1.928	.46 1/2
4	5.26	"	.000	1.785	1.641	.000	-2.250	.42
6	5.29	7.56	-.062	2.187	2.013	-.003	-2.610	.40
8	5.53	"	-.138	2.515	2.313	-.007	-2.843	.38
10	5.79	"	-.238	2.913	2.680	-.012	-3.136	.36
12	5.95	"	-.345	3.210	2.962	-.017	-3.381	.35
14	5.97	"	-.474	3.535	3.252	-.024	-3.648	.34 1/2
16	5.74	"	-.600	3.780	3.478	-.030	-3.929	.34 1/2
18	4.74	"	-.685	3.918	3.601	-.034	-4.313	.37
20	3.72	7.56	-.543	3.974	3.656	-.027	-4.644	.39

U.S.A.-27 Biplane

G/C = 1.00, Stagger = -20 %

D_s=.0571, a =0."89, h = 0."21, Short strut, β = 11.°3

α	L_1	L_0	L	D_1	D_0	D_s^1	D	L/D
-6	.171	.315	-.144	.3123	.0966	.0085	.1501	-.9
-4	.597	.313	.284	.2562	.0979	.0082	.0930	3.1
-2	.995	.312	.683	.2438	.0983	.0080	.0804	8.5
0	1.398	.310	1.088	.2512	.0989	.0078	.0874	12.5
2	1.778	.309	1.469	.2695	.0994	.0076	.1054	13.9
4	2.206	.307	1.899	.3035	.1000	.0074	.1390	13.6
6	2.589	.306	2.283	.3466	.1005	.0072	.1818	12.6
8	2.949	.304	2.645	.3921	.1011	.0070	.2269	11.7
10	3.297	.303	2.994	.4473	.1016	.0068	.2818	10.6
12	3.649	.302	3.347	.5090	.1021	.0066	.3432	9.8
14	3.975	.300	3.675	.5733	.1025	.0064	.4073	9.0
16	4.226	.299	3.927	.6395	.1027	.0061	.4736	8.3
18	4.369	.298	4.071	.7269	.1028	.0059	.5611	7.2
20	4.345	.296	4.049	.8235	.1030	.0057	.6577	6.2

α	M_1	M_0	X	Z	Za	X h	M_{LE}	C.P.
-6	4.41	7.34	.146	-.160	-.142	.031	-.664	-1.38
-4	4.29	7.33	.115	.277	.247	.024	-1.076	1.29 1/2
-2	4.38	7.32	.107	.679	.604	.022	-1.404	.69
0	4.59	7.31	.087	1.088	.969	.018	-1.707	.52 1/2
2	4.75	7.31	.053	1.471	1.310	.011	-1.998	.45
4	4.72	7.30	.006	1.902	1.693	.001	-2.376	.41 1/2
6	4.82	7.30	-.059	2.288	2.038	-.012	-2.681	.39
8	4.96	7.30	-.145	2.647	2.358	-.030	-2.947	.37
10	5.12	7.31	-.239	2.996	2.663	-.050	-3.193	.35 1/2
12	5.25	7.31	-.360	3.341	2.974	-.076	-3.443	.34 1/2
14	5.38	7.32	-.493	3.655	3.252	-.104	-3.661	.33 1/2
16	5.42	7.33	-.629	3.900	3.471	-.132	-3.844	.33
18	4.83	7.33	-.740	4.032	3.585	-.155	-4.090	.34
20	4.02	7.34	-.920	4.448	3.959	-.193	-4.645	.35

U.S.A.-27 Biplane

G/C = 1.00 Stagger = 0

D_s=.0571, a=0."88, h = 0."08, Short strut, β = 0°

α	L_1	L_0	L	D_1	D_0	D_s^1	D	L/D
-6	.186	.320	-.134	.2998	.0934	.0083	.1406	-1.0
-4	.604	.319	.285	.2495	.0941	.0085	.0898	3.2
-2	1.011	.318	.793	.2381	.0949	.0088	.0773	10.3
0	1.382	.316	1.066	.2457	.0956	.0089	.0841	12.7
2	1.805	.314	1.491	.2651	.0964	.0088	.1028	14.5
4	2.214	.313	1.901	.3012	.0972	.0086	.1383	13.8
6	2.586	.311	2.275	.3431	.0975	.0084	.1801	12.6
8	2.932	.310	2.622	.3900	.0983	.0082	.2264	11.6
10	3.293	.309	2.984	.4456	.0990	.0080	.2815	10.6
12	3.637	.307	3.330	.5060	.0995	.0077	.3417	9.7
14	3.966	.305	3.661	.5750	.1000	.0075	.4104	8.9
16	4.238	.303	3.935	.6419	.1004	.0073	.4771	8.2
18	4.471	.302	4.169	.7161	.1007	.0071	.5512	7.6
20	4.459	.300	4.159	.8091	.1008	.0069	.6443	6.5

α	M_1	M_0	X	Z	Za	Xh	M_{LE}	C.P.
-6	4.64	7.63	.127	-.148	-.130	.010	-.671	-1.51
-4	4.45	"	.107	.279	.246	.009	-1.058	1.26
-2	4.77	"	.106	.790	.695	.008	-1.459	.61 1/2
0	4.99	"	.084	1.066	.939	.007	-1.644	.51 1/2
2	5.10	"	.051	1.492	1.313	.004	-1.986	.44 1/2
4	5.02	7.64	.004	1.901	1.673	.000	-2.366	.41 1/2
6	5.21	"	-.058	2.278	2.004	-.005	-2.642	.38 1/2
8	5.28	"	-.140	2.622	2.307	-.011	-2.918	.37
10	5.41	"	-.240	2.984	2.626	-.019	-3.197	.35 1/2
12	5.51	"	-.360	3.323	2.925	-.029	-3.460	.34 1/2
14	5.52	"	-.485	3.647	3.210	-.039	-3.731	.34
16	5.56	7.65	-.624	3.900	3.432	-.050	-3.935	.33 1/2
18	5.61	7.65	-.763	4.123	3.628	-.061	-4.107	.33
20	5.11	7.65	-.815	4.122	3.628	-.065	-4.235	.34

U.S.A.-27 Biplane

G/C = 1.00 Stagger = 20%

D_s=.0571, a = 0."87, h=0."06, Short strut, β= -11.°3

α	L_1	L_o	L	D_1	D_o	D_s^1	D	L/D
-6	.227	.323	-.096	.2865	.0856	.0070	.1368	-.7
-4	.638	.321	.317	.2385	.0863	.0072	.0879	3.6
-2	1.040	.320	.720	.2290	.0872	.0074	.0773	9.3
0	1.418	.319	1.099	.2337	.0879	.0077	.0810	13.6
2	1.858	.318	1.540	.2568	.0890	.0079	.1028	15.0
4	2.275	.317	1.958	.2945	.897	.0082	.1395	14.0
6	2.640	.315	2.325	.3391	.0902	.0084	.1834	12.7
8	3.008	.314	2.694	.3897	.0910	.0086	.2330	11.5
10	3.357	.313	3.044	.4454	.0919	.0088	.2867	10.6
12	3.690	.312	3.378	.5043	.0925	.0089	.3458	9.8
14	4.058	.310	3.748	.5714	.0931	.0087	.4225	8.9
16	4.362	.308	4.054	.6482	.0936	.0085	.4890	8.3
18	4.567	.307	4.260	.7163	.0944	.0083	.5565	7.7
20	4.568	.305	4.263	.8215	.0949	.0081	.6614	6.5
22	4.420	.304	4.116	.9680	.0959	.0079	.8071	5.1

α	M_1	M_o	X	Z	Za	Xh	M_{LE}	C.P.
-6	4.15	7.23	.127	-.108	-.094	.008	- .879	-2.71
-4	4.44	"	.105	.311	.271	.006	-1.015	1.09
-2	4.79	"	.102	.716	.624	.006	-1.275	.59 1/2
0	5.00	"	.081	1.099	.955	.005	-1.550	.47
2	5.19	"	.049	1.542	1.342	.003	-1.885	.41
4	5.43	7.24	.002	1.958	1.702	.000	-2.181	.37
6	5.65	"	-.060	2.330	2.027	-.004	-2.443	.35
8	5.82	"	-.144	2.700	2.368	-.009	-2.735	.33 1/2
10	5.94	"	-.244	3.042	2.648	-.015	-2.977	.32 1/2
12	6.09	"	-.364	3.373	2.935	-.022	-3.217	.31 1/2
14	6.19	"	-.495	3.738	3.250	-.030	-3.498	.31
16	6.27	"	-.647	4.028	3.504	-.039	-3.721	.30 1/2
18	6.38	"	-.785	4.220	3.675	-.047	-3.855	.30 1/2
20	6.04	7.24	-.833	4.223	3.677	-.050	-3.944	.31

U.S.A.-27 Biplane

G/C = 1.00, Stagger = 40%

D_s=.0556, a=0"86, h = 0"09½ ,Short strut, β = -.21°8

α	L_1	L_o	L	D_1	D_o	D'_s	D	L/D
-6	.247	.304	-.057	.2577	.0700	.0057	.1264	-.5
-4	.673	.302	.371	.2173	.0712	.0060	.0845	4.5
-2	1.068	.301	.767	.2110	.0724	.0062	.0768	10.0
0	1.454	.300	1.154	.2216	.0731	.0064	.0865	13.3
2	1.887	.299	1.588	.2468	.0738	.0066	.1108	14.3
4	2.230	.298	1.932	.2837	.0746	.0069	.1466	13.2
6	2.658	.298	2.360	.3256	.0754	.0071	.1875	12.6
8	3.028	.297	2.731	.3754	.0763	.0074	.2361	11.5
10	3.406	.296	3.110	.4362	.0772	.0076	.2958	10.5
12	3.759	.295	3.464	.5024	.0778	.0079	.3611	9.6
14	4.098	.294	3.804	.5736	.0783	.0081	.4317	8.8
16	4.379	.293	4.086	.6441	.0787	.0083	.5015	8.1
18	4.588	.292	4.296	.7256	.0791	.0086	.5823	7.4
20	4.569	.290	4.279	.8339	.0795	.0088	.6900	6.2

α	M_1	M_o	X	Z	Za	Xh	M_{1e}	C.P.
-6	6.71	9.74	.119	-.070	-.060	.011	-.753	-3.585
-4	7.21	9.74	.110	.364	.313	.011	-.994	.91
-2	7.69	9.74	.104	.763	.655	.010	-1.207	.525
0	8.15	9.74	.087	1.154	.993	.008	-1.413	.41
2	8.57	9.74	.055	1.590	1.369	.005	-1.683	.355
4	8.84	9.74	.012	1.937	1.664	.001	-1.903	.325
6	9.21	9.74	-.061	2.366	2.034	-.006	-2.219	.31
8	9.54	9.74	-.148	2.736	2.350	-.014	-2.389	.29
10	9.82	9.74	-.246	3.112	2.675	-.023	-2.631	.28
12	10.05	9.74	-.358	3.464	2.980	-.034	-2.864	.275
14	10.26	9.74	-.500	3.794	3.260	-.048	-3.074	.27
16	10.42	9.74	-.630	4.066	3.500	-.060	-3.260	.265
18	10.54	9.74	-.774	4.260	3.670	-.074	-3.384	.265
20	9.99	9.74	-.814	4.254	3.660	-.077	-3.517	.275

U.S.A.-27 Biplane

G/C = 1.00, Stagger = 60%

D_s = .0571, a = 0."81, h = 0."05, Short strut, β = -31.°0

α	L_0	L_1	L	D_1	D_0	D_s^1	D	L/D
-6	.328	.276	-.052	.2660	.0771	.0046	.1272	-.4
-4	.327	.672	.345	.2246	.0783	.0048	.0844	4.1
-2	.325	1.106	.781	.2150	.0795	.0051	.0733	10.7
0	.324	1.518	1.194	.2295	.0803	.0053	.0868	13.7
2	.323	1.927	1.604	.2550	.0810	.0056	.1113	14.4
4	.322	2.362	2.040	.2955	.0821	.0058	.1505	13.6
6	.321	2.759	2.438	.3433	.0832	.0060	.1970	12.4
8	.320	3.160	2.840	.4000	.0840	.0063	.2526	11.2
10	.319	3.542	3.223	.4623	.0847	.0065	.3140	10.3
12	.318	3.927	3.609	.5288	.0856	.0068	.3793	9.3
14	.317	4.238	3.921	.5979	.0865	.0070	.4473	8.8
16	.317	4.558	4.241	.6861	.0875	.0072	.5343	7.9
18	.315	4.725	4.410	.7900	.0882	.0075	.6372	6.9
20	.313	4.706	4.393	.9130	.0892	.0077	.7590	5.8

α	M_1	M_0	X	Z	Za	$X\ h$	M_{LE}	C.P.
-6	8.49	11.59	.110	-.064	-.052	.006	- .774	-4.96
-4	9.20	"	.108	.338	.274	.005	- .910	.90
-2	9.85	"	.100	.778	.630	.005	-1.095	.47
0	10.43	"	.087	1.194	.968	.004	-1.279	.35 1/2
2	11.06	"	.057	1.601	1.299	.003	-1.442	.30
4	11.38	"	.011	2.008	1.628	.001	-1.685	.28
6	11.81	"	-.060	2.443	1.980	-.003	-1.919	.26
8	12.16	"	-.126	2.886	2.336	-.006	-2.179	.25
10	12.44	11.60	-.250	3.224	2.612	-.013	-2.377	.24 1/2
12	12.68	"	-.382	3.602	2.918	-.019	-2.613	.24
14	12.85	"	-.515	3.908	3.166	-.026	-2.809	.24
16	12.78	"	-.659	4.220	3.420	-.033	-3.076	.24
18	12.38	"	-.755	4.380	3.548	-.038	-3.304	.25
20	11.97	11.61	-.788	4.380	3.548	-.039	-3.408	.26

U.S.A.-27 Biplane

G/C = 1.33, Stagger = -40 %

D_s= .0556, a = 0."92, h = 0."06, Medium strut, β= 16.°7

α	L_1	L_o	L	D_1	D_o	D_s^1	D	L/D
-6	.078	.301	-.223	.3249	.0983	.0089	.1621	-1.4
-4	.534	.300	.234	.2595	.0990	.0087	.0962	2.4
-2	.964	.299	.665	.2435	.0997	.0085	.0797	8.3
0	1.359	.298	1.061	.2490	.1004	.0082	.0848	12.5
2	1.778	.297	1.481	.2695	.1010	.0080	.1049	14.14
4	2.197	.295	1.902	.3001	.1016	.0077	.1352	14.07
6	2.592	.294	2.298	.3420	.1022	.0075	.1767	13.0
8	2.996	.292	2.704	.3935	.1028	.0073	.2278	11.9
10	3.366	.290	3.076	.4500	.1034	.0070	.2940	10.5
12	3.699	.289	3.410	.5095	.1040	.0068	.3431	10.0
14	3.975	.287	3.678	.5723	.1046	.0065	.4056	8.9
16	4.257	.285	3.972	.6497	.1046	.0063	.4832	8.2
18	4.377	.283	4.094	.7466	.1045	.0060	.5805	7.0
20	4.371	.281	4.090	.8495	.1046	.0058	.6835	6.0

α	M_1	M_o	X	Z	Za	Xh	M_{LE}	C.P.
-6	11.59	14.30	.136	-.238	-.219	.008	-.505	-.77
-4	11.58	14.30	.110	.227	.209	.007	- .935	1.37
-2	11.70	14.31	.103	.661	.609	.006	-1.305	.66
0	11.92	14.31	.085	1.061	.977	.005	-1.614	.50 1/2
2	12.16	14.32	.054	1.482	1.364	.003	-1.938	.43 1/2
4	12.24	14.32	.002	1.906	1.753	.000	-2.303	.40
6	12.35	14.32	-.065	2.302	2.119	-.004	-2.635	.38
8	12.41	14.32	-.150	2.706	2.490	-.009	-2.986	.35 1/2
10	12.82	14.32	-.239	3.076	2.830	-.014	-3.213	.34 1/2
12	12.83	14.32	-.371	3.402	3.130	-.022	-3.502	.34 1/2
14	12.84	14.32	-.494	3.661	3.368	-.030	-3.729	.34
16	12.51	14.32	-.630	3.946	3.631	-.038	-4.072	.34 1/2
18	10.73	14.33	-.710	4.068	3.745	-.043	-4.654	.38
20	9.51	14.33	-.755	4.072	3.748	-.045	-4.975	.40 1/2

U.S.A.-27 Biplane

G/C = 1.33, Stagger = -20%

D_s = .0556, a = 0".92, h = 0".04, medium strut, β = 8°.5

α	L_0	L_1	L	D'_s	D_0	D_1	D	L/D
-6	.302	.144	-.158	.0099	.0957	.3092	.1480	-1.1
-4	.301	.592	.293	.0097	.0967	.2526	.0906	3.2
-2	.300	1.002	.722	.0095	.0976	.2404	.0777	9.2
0	.299	1.410	1.111	.0092	.0983	.2459	.0828	13.4
2	.298	1.822	1.524	.0090	.0990	.2678	.1042	14.6
4	.296	2.277	1.981	.0087	.0996	.3045	.1406	14.1
6	.294	2.656	2.362	.0085	.0999	.3464	.1824	13.0
8	.292	3.024	2.732	.0082	.1002	.3955	.2315	11.8
10	.291	3.369	3.078	.0080	.1004	.4548	.2908	10.6
12	.290	3.734	3.444	.0077	.1006	.5159	.3502	9.8
14	.288	4.062	3.774	.0075	.1011	.5788	.4146	9.1
16	.286	4.298	4.012	.0073	.1016	.6535	.4890	8.2
18	.286	4.475	4.189	.0070	.1018	.7384	.5740	7.3
20	.284	4.458	4.174	.0068	.1018	.8519	.6877	6.1

α	M_0	M_1	M	X	Z	Za	Xh	M_{1e}	C.P.
-6	11.70	8.51	-.844	.128	-.173	-.159	.005	-.690	-1.33
-4	11.70	8.59	-.822	.111	.285	.262	.004	-1.088	1.27
-2	11.70	8.76	-.778	.105	.718	.660	.004	-1.442	.67
0	11.70	9.01	-.710	.083	1.111	1.022	.003	-1.735	.52
2	11.70	9.16	-.672	.051	1.526	1.403	.002	-2.077	.455
4	11.70	9.14	-.677	.003	1.985	1.827	.000	-2.504	.42
6	11.70	9.37	-.616	-.067	2.367	2.180	-.003	-2.799	.39
8	11.70	9.60	-.555	-.149	2.734	2.515	-.006	-3.064	.375
10	11.70	9.70	-.529	-.251	3.080	2.835	-.010	-3.354	.365
12	11.70	9.82	-.497	-.377	3.438	3.160	-.015	-3.642	.355
14	11.70	9.96	-.460	-.509	3.770	3.468	-.020	-3.908	.345
16	11.70	9.89	-.479	-.637	3.986	3.668	-.026	-4.121	.345
18	11.70	9.14	-.677	-.750	4.158	3.824	-.030	-4.471	.36
20	11.70	8.14	-.942	-.780	4.152	3.820	-.031	-4.731	.38

U.S.A. 27 Biplane

G/C = 1.33 Stagger = 0

D_s = .0571, a = 0"88, h = 0"06, Medium Strut, β = 0°

α	L_0	L_1	L	D_s'	D_0	D_1	D	L/D
-6	.311	.134	-.177	.0094	.0826	.3012	.1515	-1.2
-4	.311	.587	.276	.0097	.0835	.2408	.0905	3.1
-2	.310	1.000	.690	.0099	.0847	.2277	.0760	9.1
0	.309	1.387	1.078	.0100	.0849	.2329	.0809	13.3
2	.308	1.829	1.521	.0099	.0855	.2526	.1001	15.2
4	.308	2.272	1.964	.0097	.0861	.2897	.1368	14.4
6	.306	2.651	2.345	.0095	.0863	.3295	.1766	13.3
8	.302	3.025	2.723	.0093	.0873	.3791	.2254	12.1
10	.303	3.369	3.066	.0090	.0873	.4299	.2865	10.7
12	.302	3.706	3.404	.0088	.0873	.4957	.3425	9.9
14	.301	4.079	3.778	.0085	.0878	.5650	.4116	9.2
16	.300	4.328	4.028	.0083	.0878	.6510	.4978	8.1
18	.300	4.529	4.229	.0081	.0885	.7577	.6040	7.0
20	.299	4.478	4.179	.0078	.0880	.8246	.6717	6.2

α	Mo	M_1	M	X	Z	Z_0	Xh	M_{1e}	C.P.
-6	9.97	6.77	-.847	.130	-.194	-.171	.008	-.688	-1.18
-4	9.97	7.02	-.780	.110	.268	.236	.007	-1.023	1.27
-2	9.97	7.36	-.690	.100	.686	.604	.006	-1.300	.63
0	9.97	7.81	-.571	.081	1.078	.948	.005	-1.524	.47
2	9.97	8.21	-.466	.047	1.522	1.340	.003	-1.809	.395
4	9.97	8.44	-.405	-.001	1.968	1.731	.000	-2.136	.36
6	9.97	8.83	-.302	-.069	2.349	2.067	-.004	-2.366	.335
8	9.97	9.20	-.204	-.150	2.726	2.400	-.009	-2.595	.315
10	9.97	9.51	-.122	-.249	3.064	2.696	-.015	-2.803	.305
12	9.97	9.80	-.045	-.374	3.400	2.992	-.022	-3.015	.295
14	9.97	10.01	.011	-.512	3.760	3.308	-.031	-3.266	.29
16	9.96	10.15	.050	-.632	4.004	3.523	-.038	-3.485	.29
18	9.96	10.22	.069	-.732	4.202	3.700	-.044	-3.604	.285
20	9.96	10.12	.042	-.794	4.150	3.652	-.048	-3.562	.285

U.S.A.-27 Biplane

G/C = 1.33 Stagger = 20%

D_s = .0556, a = 0°88, h = 0°06, Medium Strut, β = -8°5

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
-6	.304	.258	- .046	.0083	.0894	.2824	.1291	- .4
-4	.303	.703	.400	.0085	.0898	.2377	.0838	4.8
-2	.302	1.113	.811	.0088	.0903	.2322	.0775	10.5
0	.300	1.519	1.219	.0091	.0911	.2435	.0877	13.9
2	.299	1.947	1.648	.0093	.0918	.2685	.1118	14.7
4	.298	2.368	2.070	.0096	.0926	.3026	.1448	14.2
6	.297	2.754	2.457	.0098	.0933	.0933	.1898	13.0
8	.295	3.136	2.841	.0100	.0940	.0940	.2416	11.8
10	.294	3.520	3.226	.0100	.0947	.0947	.3037	10.6
12	.293	3.907	3.614	.0098	.0951	.0951	.3691	9.8
14	.292	4.214	3.922	.0096	.0955	.0955	.4358	9.0
16	.291	4.507	4.216	.0093	.0958	.0958	.5033	8.4
18	.290	4.602	4.312	.0091	.0961	.0961	.5842	7.4
20	.288	4.547	4.259	.0088	.0962	.0962	.7174	6.0

α	M_o	M_1	M	X	Z	Za	Xh	M_{1e}	C.P.
-6	12.10	8.95	-.833	.123	- .060	- .053	.007	- .787	-4.37
-4	12.10	9.31	-.738	.112	.392	.345	.007	-1.090	.93
-2	12.10	9.56	-.672	.106	.807	.710	.006	-1.388	.575
0	12.10	9.91	-.580	.088	1.219	1.071	.005	-1.626	.445
2	12.10	10.09	-.531	.054	1.650	1.451	.003	-1.985	.40
4	12.10	10.28	-.481	-.000	2.074	1.824	.000	-2.305	.37
6	12.10	10.50	-.424	-.069	2.462	2.167	-.004	-2.587	.35
8	12.10	10.72	-.365	-.155	2.844	2.503	-.009	-2.859	.335
10	12.10	11.01	-.290	-.261	3.228	2.840	-.016	-3.149	.325
12	12.10	11.01	-.290	-.392	3.608	3.175	-.024	-3.441	.315
14	12.10	11.17	-.246	-.461	3.916	3.442	-.028	-3.660	.31
16	12.10	11.28	-.217	-.680	4.188	3.680	-.041	-3.856	.305
18	12.10	11.34	-.201	-.775	4.276	3.760	-.047	-3.914	.305
20	12.10	10.53	-.415	-.780	4.243	3.730	-.047	-4.098	.31

U.S.A.-27 Biplane

G/C = 1.33 Stagger = + 40%

D_s = .0556, a = 0"90, h = 0"08, Medium Strut, β = -16°7

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
-6	.305	.161	- .144	.0072	.0853	.2918	.1437	- 1.0
-4	.304	.600	.296	.0075	.0863	.2389	.0895	3.3
-2	.303	1.025	.722	.0077	.0872	.2278	.0773	9.3
0	.301	1.432	1.131	.0080	.0880	.2346	.0830	13.6
2	.300	1.861	1.561	.0082	.0888	.2566	.1040	15.0
4	.300	2.293	1.993	.0085	.0896	.2926	.1389	14.4
6	.299	2.706	2.407	.0087	.0904	.3364	.1817	13.2
8	.297	3.071	2.774	.0090	.0911	.3858	.2301	12.0
10	.296	3.462	3.166	.0093	.0917	.4439	.2873	11.0
12	.295	3.843	3.548	.0096	.0924	.5093	.3517	10.1
14	.294	4.198	3.904	.0098	.0930	.5786	.4202	9.3
16	.293	4.476	4.183	.0100	.0938	.6518	.4924	8.5
18	.291	4.621	4.330	.0100	.0946	.7269	.5667	7.6
20	.290	4.598	4.308	.0098	.0946	.8462	.6862	6.3

α	M_o	M_1	M	X	Z	Za	Xh	M_{1e}	C.P.
-6	12.11	8.91	-.846	.127	- .158	- .142	.010	- .714	-1.51
-4	12.11	9.26	-.754	.110	.290	.261	.009	-1.024	1.18
-2	12.11	9.60	-.664	.103	.718	.646	.008	-1.318	.61
0	12.11	9.96	-.569	.083	1.131	1.018	.007	-1.594	.47
2	12.11	10.44	-.442	.049	1.564	1.508	.004	-1.854	.395
4	12.11	10.63	-.392	.000	1.993	1.794	.000	-2.186	.365
6	12.11	11.04	-.281	-.072	2.412	2.171	-.006	-2.446	.34
8	12.11	11.25	-.227	-.157	2.776	2.598	-.013	-2.812	.34
10	12.10	11.62	-.127	-.280	3.163	2.847	-.022	-2.952	.31
12	12.10	11.75	-.093	-.394	3.541	3.187	-.032	-3.248	.305
14	12.10	12.02	-.021	-.536	3.886	3.497	-.043	-3.475	.30
16	12.10	12.12	+.005	-.680	4.152	3.737	-.055	-3.677	.295
18	12.10	12.25	+.015	-.798	4.290	3.861	-.064	-3.157	.29
20	12.10	11.81	-.077	-.828	4.280	3.852	-.066	-3.709	.29

U.S.A.-27 Biplane

G/C = 1.33 Stagger = 60%

D_s = .0571, a = 0".86, h = 0".17, Medium Strut, β=-24°.2

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
-6	.320	.099	- .221	.0062	.0802	.3000	.1565	- 1.4
-4	.320	.549	.229	.0065	.0814	.2393	.0943	2.4
-2	.319	.996	.677	.0067	.0826	.2250	.0796	8.5
0	.318	1.398	1.080	.0070	.0835	.2297	.0821	13.2
2	.317	1.831	1.514	.0073	.0844	.2520	.1032	14.7
4	.315	2.276	1.961	.0075	.0852	.2880	.1382	14.2
6	.314	2.638	2.324	.0078	.0860	.3267	.1758	13.2
8	.312	3.059	2.747	.0080	.0869	.3813	.2293	12.0
10	.311	3.418	3.107	.0083	.0877	.4402	.2971	10.5
12	.311	3.809	3.498	.0086	.0883	.5083	.3543	9.9
14	.310	4.200	3.890	.0089	.0888	.5821	.4273	9.1
16	.309	4.479	4.170	.0091	.0897	.6495	.4936	8.5
18	.308	4.698	4.390	.0094	.0906	.7307	.5736	7.2
20	.306	4.678	4.372	.0096	.0912	.8474	.6895	6.3

α	M_o	M_1	M	X	Z	Za	Xh	M_{1e}	C.P.
-6	13.44	10.37	-.811	.132	- .236	- .203	.022	- .630	- .89
-4	13.44	10.60	-.750	.110	.222	.191	.019	- .960	1.44
-2	13.44	11.08	-.624	.104	.672	.578	.018	-1.220	.605
0	13.44	11.52	-.508	.082	1.080	.930	.014	-1.452	.45
2	13.44	12.06	-.365	.051	1.516	1.303	.009	-1.677	.38
4	13.44	12.29	-.304	.001	1.961	1.689	.000	-1.993	.34
6	13.43	12.64	-.209	-.068	2.329	2.004	-.012	-2.201	.315
8	13.43	13.02	-.108	-.151	2.748	2.365	-.026	-2.447	.295
10	13.43	13.25	-.048	-.244	3.106	2.672	-.042	-2.678	.285
12	13.43	13.37	-.002	-.382	3.492	3.001	-.065	-2.938	.28
14	13.43	13.49	+.011	-.524	3.875	3.332	-.089	-3.232	.275
16	13.43	13.71	+.074	-.675	4.140	3.555	-.115	-3.366	.27
18	13.43	13.55	.032	-.808	4.346	3.735	-.137	-3.566	.275
20	13.43	13.33	.026	-.844	4.340	3.730	-.143	-3.661	.28

U.S.A.-27 Biplane

G/C = 1.67 Stagger = -40%

D_s = .0556, a = 0″.91, h = 0″.06, Medium Strut, β = 13°.5

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
-6	.302	.103	-.199	.0093	.0812	.2973	.1512	-1.3
-4	.301	.572	.271	.0091	.0822	.2331	.0862	3.1
-2	.300	1.003	.704	.0088	.0833	.2215	.0738	9.5
0	.298	1.401	1.103	.0086	.0843	.2270	.0785	14.1
2	.297	1.807	1.510	.0084	.0852	.2490	.0998	15.1
4	.295	2.223	1.928	.0081	.0856	.2811	.1318	14.6
6	.294	2.630	2.336	.0079	.0860	.3243	.1748	13.4
8	.293	2.996	2.703	.0076	.0868	.3758	.2258	12.0
10	.291	3.379	3.088	.0074	.0876	.4339	.2833	10.9
12	.290	3.714	3.424	.0071	.0880	.4909	.3402	10.1
14	.289	4.056	3.767	.0069	.0883	.5607	.4099	9.2
16	.288	4.280	3.992	.0067	.0885	.6358	.4835	8.3
18	.286	4.406	4.120	.0064	.0887	.7100	.5593	7.4
20	.285	4.398	4.113	.0062	.0889	.8261	.6754	6.1

α	M_o	M_1	M	X	Z	Za	Xh	M_{1e}	C.P.
-6	7.54	4.53	-.795	.128	- .214	- .195	.008	- .608	- .95
-4	7.54	4.46	-.815	.105	.263	.239	.006	-1.060	1.34
-2	7.54	4.78	-.730	.100	.700	.637	.006	-1.373	.655
0	7.54	5.08	-.650	.079	1.103	1.029	.005	-1.684	.51
2	7.54	5.35	-.580	.047	1.512	1.378	.003	-1.961	.43
4	7.54	5.45	-.553	-.003	1.928	1.753	-.000	-2.306	.40
6	7.54	5.75	-.473	-.071	2.342	2.135	-.004	-2.604	.37
8	7.54	5.99	-.410	-.150	2.708	2.465	-.009	-2.866	.355
10	7.54	6.12	-.376	-.257	3.090	2.812	-.015	-3.173	.345
12	7.54	6.23	-.347	-.378	3.420	3.112	-.023	-3.436	.335
14	7.54	6.32	-.323	-.514	3.752	3.413	-.031	-3.705	.33
16	7.54	5.98	-.413	-.638	3.968	3.610	-.038	-3.985	.335
18	7.54	5.08	-.650	-.740	4.089	3.715	-.044	-4.321	.355
20	7.54	3.74	-1.005	-.770	4.093	3.720	-.046	-4.679	.38

U.S.A.-27 Biplane

G/C = 1.67 Stagger = -33%

D_s = .0571 a = 0°93 h = 0°04 Medium Strut, β= 11°3

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
-6	.276	.129	- .147	.0096	.0895	.3000	.1438	- 1.0
-4	.275	.608	.333	.0093	.0892	.2440	.0874	3.8
-2	.274	1.038	.764	.0091	.0890	.2319	.0757	10.1
0	.272	1.453	1.181	.0089	.0889	.2395	.0854	13.8
2	.271	1.885	1.614	.0086	.0886	.2622	.1091	14.8
4	.270	2.308	2.038	.0084	.0884	.2966	.1445	14.1
6	.269	2.709	2.440	.0081	.0881	.3387	.1875	13.0
8	.268	3.099	2.831	.0079	.0079	.3905	.2404	11.8
10	.267	3.474	3.207	.0077	.0077	.4432	.2932	10.9
12	.266	3.820	3.554	.0074	.0074	.5104	.3686	9.6
14	.265	4.171	3.906	.0072	.0072	.5751	.4283	9.1
16	.264	4.405	4.141	.0069	.0069	.6395	.4940	8.4
18	.263	4.452	4.189	.0067	.0067	.7301	.5867	7.1
20	.261	4.376	4.105	.0065	.0065	.8495	.7065	5.8

α	M_o	M_1	M	X	Z	Za	Xh	M_{le}	C.P.
-6	7.54	4.45	-.817	.128	- .161	- .150	.005	- .672	- 1.49
-4	7.54	4.49	-.806	.109	.326	.303	.004	-1.113	1.14
-2	7.54	4.52	-.799	.102	.760	.707	.004	-1.510	..665
0	7.54	5.05	-.659	.085	1.181	1.100	.003	-1.762	.495
2	7.54	5.41	-.564	.052	1.616	1.502	.002	-2.068	.425
4	7.54	5.66	-.497	.002	2.043	1.900	.000	-2.397	.39
6	7.54	5.99	-.410	-.069	2.445	2.374	-.003	-2.781	.38
8	7.54	6.37	-.310	-.152	2.836	2.636	-.006	-2.940	.345
10	7.54	6.73	-.214	-.270	3.206	2.981	-.011	-3.184	.33
12	7.54	7.11	-.114	-.380	3.550	3.301	-.015	-3.400	.32
14	7.54	7.39	-.040	-.528	3.892	3.612	-.021	-3.621	.31
16	7.54	7.43	-.029	-.664	4.113	3.830	-.027	-3.832	.31
18	7.54	6.31	-.325	-.754	4.152	3.861	-.030	-4.156	.335
20	7.54	5.31	-.590	-.740	4.094	3.808	-.030	-4.368	.355

U.S.A.-27 Biplane

G/C = 1.67 Stagger = 0

D_s = .0556, a = 0."90, h = 0."06, Medium strut, β = 0°

α	L_1	L_o	L	D_1	D_o	D_s'	D	L/D
-6	.049	.303	-.254	.3040	.0770	.0094	.1620	-1.57
-4	.509	.302	.207	.2334	.0779	.0097	.0902	2.29
-2	.946	.301	.645	.2165	.0787	.0099	.0723	8.92
0	1.350	.300	1.050	.2205	.0793	.0100	.0756	13.89
2	1.740	.299	1.441	.2398	.0798	.0099	.0945	15.25
4	2.198	.298	1.900	.2716	.0806	.0097	.1257	15.12
6	2.557	.297	2.260	.3100	.0813	.0095	.1636	13.82
8	2.948	.295	2.653	.3590	.0821	.0093	.2120	12.50
10	3.328	.293	3.035	.4150	.0828	.0090	.2676	11.34
12	3.651	.291	3.360	.4750	.0834	.0088	.3272	10.3
14	3.998	.290	3.708	.5403	.0837	.0085	.3925	9.2
16	4.295	.289	4.006	.6098	.0840	.0083	.4619	8.8
18	4.479	.288	4.191	.6833	.0843	.0081	.5353	7.8
20	4.459	.287	4.172	.7985	.0847	.0078	.6504	6.3

α	M_1	M_o	X	Z	Z_a	Xh	$M_{L.E.}$	C.P.
-6	4.95	7.79	.134	-.270	-.243	.008	- .516	-0.71
-4	4.87	7.79	.106	.199	.179	.006	- .957	1.60
-2	5.06	7.79	.096	.642	.578	.006	-1.306	.68
0	5.32	7.79	.076	1.050	.945	.005	-1.604	.51
2	5.63	7.79	.045	1.443	1.299	.003	-1.873	.43 1/2
4	5.77	7.79	-.007	1.903	1.713	.000	-2.247	.39 1/2
6	6.09	7.79	-.074	2.264	2.038	-.004	-2.484	.36 1/2
8	6.32	7.79	-.176	2.655	2.389	-.011	-2.767	.34 1/2
10	6.57	7.79	-.262	3.032	2.729	-.016	-3.036	.33 1/2
12	6.75	7.79	-.378	3.353	3.018	-.023	-3.270	.32 1/2
14	6.86	7.79	-.515	3.690	3.321	-.031	-3.536	.32
16	6.99	7.79	-.660	3.977	3.579	-.040	-3.751	.31 1/2
18	6.78	7.79	-.790	4.146	3.731	-.047	-3.951	.31 1/2
20	5.99	7.79	-.812	4.140	3.726	-.049	-4.153	.33 1/2

U.S.A.-27 Biplane

G/C = 1.67 Stagger = 33%

D_s = .0571, a = 0".81, h = 0".07, Medium Strut, β = -11°.3

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
-6	.285	.150	-.135	.0079	.0981	.3033	.1402	-1.0
-4	.283	.616	.333	.0082	.0976	.2495	.0866	+3.8
-2	.282	1.036	.858	.0084	.0972	.2431	.0804	10.7
0	.280	1.425	1.145	.0087	.0968	.2443	.0817	14.0
2	.279	1.865	1.585	.0090	.0965	.2693	.1067	14.9
4	.277	2.294	2.017	.0092	.0960	.3006	.1383	14.6
6	.276	2.676	2.400	.0095	.0955	.3424	.1803	13.3
8	.274	3.069	2.795	.0098	.0948	.3922	.2305	12.1
10	.273	3.426	3.153	.0100	.0942	.4441	.2827	11.1
12	.272	3.812	3.530	.0100	.0937	.5072	.3464	10.2
14	.271	4.137	3.866	.0099	.0933	.5745	.4142	9.3
16	.270	4.428	4.158	.0096	.0923	.6488	.4898	8.5
18	.268	4.521	4.253	.0094	.0914	.7229	.5650	7.5
20	.266	4.353	4.087	.0091	.0907	.8446	.6877	5.9

α	M_o	M_1	M	X	Z	Za	Xh	M_{1e}	C.P
-6	10.40	7.24	-.836	.126	-.150	-.122	.009	-.723	-1.61
-4	10.38	7.15	-.855	.109	.325	.263	.008	-1.126	1.15
-2	10.37	7.50	-.759	.109	.854	.691	.008	-1.458	.57
0	10.36	7.70	-.704	.082	1.145	.928	.006	-1.638	.475
2	10.34	7.95	-.632	.050	1.588	1.385	.004	-2.021	.425
4	10.32	8.02	-.609	-.002	2.021	1.638	.000	-2.247	.37
6	10.30	8.32	-.524	-.073	2.406	1.949	-.005	-2.468	.34
8	10.31	8.38	-.510	-.158	2.798	2.265	-.011	-2.764	.33
10	10.32	8.61	-.453	-.270	3.152	2.552	-.019	-2.986	.315
12	10.33	8.77	-.413	-.398	3.521	2.855	-.028	-3.240	.305
14	10.34	8.93	-.373	-.531	3.848	3.118	-.037	-3.454	.30
16	10.35	9.24	-.294	-.678	4.130	3.341	-.048	-3.587	.29
18	10.35	9.44	-.241	-.775	4.214	3.419	-.054	-3.606	.285
20	10.35	8.91	-.381	-.750	4.072	3.300	-.052	-3.628	.29

U.S.A.-27 Biplane

G/C = 1.67 Stagger = 60%

D_s = .0571, a = 0"92, h = 0"06, Medium Strut, β=-19°8

α	L_0	L_1	L	D'_s	D_0	D_1	D	L/D
-6	.315	.232	-.083	.0068	.0812	.2802	.1351	-0.6
-4	.313	.698	.385	.0070	.0822	.2317	.0854	4.5
-2	.312	1.127	.815	.0073	.0832	.2255	.0779	10.5
0	.311	1.536	1.225	.0076	.0840	.2340	.0853	14.4
2	.310	1.988	1.679	.0078	.0847	.0847	.1118	15.0
4	.309	2.399	2.090	.0081	.0854	.0854	.1478	14.2
6	.308	2.779	2.471	.0083	.0861	.0861	.1895	13.1
8	.307	3.169	2.862	.0086	.0867	.0867	.2413	11.8
10	.306	3.548	3.242	.0089	.0872	.0872	.2978	10.9
12	.305	3.910	3.605	.0092	.0879	.0879	.3628	10.0
14	.303	4.264	3.961	.0094	.0886	.0886	.4349	9.1
16	.302	4.526	4.224	.0097	.0892	.0892	.4985	8.5
18	.301	4.605	4.304	.0099	.0898	.0898	.5769	7.4
20	.299	4.497	4.198	.0100	.0900	.0900	.7129	5.9

α	M_0	M_1	M	X	Z	Za	Xh	M_{1e}	C.P.
-6	11.91	8.36	-.940	.126	-.096	-.088	.008	-.860	-2.98
-4	11.91	8.69	-.851	.112	.378	.348	.007	-1.206	1.06
-2	11.91	9.10	-.743	.110	.811	.746	.007	-1.496	.615
0	11.91	9.59	-.610	.085	1.225	1.128	.005	-1.743	.475
2	11.91	9.83	-.550	.052	1.681	1.549	.003	-2.102	.415
4	11.91	10.21	-.450	.001	2.096	1.928	.000	-2.378	.38
6	11.91	10.58	-.352	-.080	2.478	2.280	-.005	-2.627	.355
8	11.91	10.88	-.272	-.155	2.870	2.640	-.09	-2.903	.335
10	11.91	11.11	-.212	-.268	3.242	2.983	-.016	-3.179	.325
12	11.91	11.28	-.167	-.395	3.600	3.312	-.024	-3.455	.32
14	11.92	11.53	-.103	-.536	3.945	3.630	-.032	-3.701	.315
16	11.92	11.83	-.024	-.688	4.193	3.855	-.041	-3.838	.305
18	11.92	11.76	-.042	-.780	4.268	3.930	-.047	-3.925	.305
20	11.92	11.04	-.233	-.762	4.186	3.848	-.046	-4.035	.32

U.S.A.-27 Biplane

G/C = 2.00 Stagger = - 40%

D_s = .0556, a = 0°92, h = 0°04 , Long Strut, β = 11°3

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
-6	.300	.138	- .162	.0134	.0966	.3144	.1458	- 1.1
-4	.298	.607	.309	.0131	.0975	.2505	.0843	3.7
-2	.296	1.046	.750	.0128	.0984	.2391	.0723	10.4
0	.295	1.458	1.163	.0124	.0989	.2462	.0793	14.7
2	.294	1.878	1.584	.0121	.0994	.2682	.1011	15.7
4	.293	2.301	2.008	.0118	.0999	.3005	.1332	15.1
6	.291	2.700	2.409	.0114	.1003	.3442	.1769	13.6
8	.290	3.093	2.803	.0111	.1005	.3932	.2260	12.4
10	.289	3.467	3.178	.0108	.1006	.4513	.2843	11.2
12	.288	3.836	3.548	.0105	.1011	.5119	.3447	10.3
14	.286	4.145	3.859	.0101	.1015	.5756	.4084	9.5
16	.284	4.383	4.099	.0098	.1017	.6454	.4783	8.6
18	.282	4.456	4.174	.0095	.1018	.7271	.5602	7.5
20	.281	4.317	4.036	.0091	.1020	.8591	.6924	5.8

α	M_o	M1	M	X	Z	Za	Xh	M_{1e}	C.P.
-6	14.33	11.30	-.801	.128	- .176	- .162	-.005	- .634	-1.20
-4	14.33	11.33	-.794	.106	.302	.278	-.004	-1.068	1.18
-2	14.33	11.51	-.746	.099	.746	.686	-.004	-1.428	.635
0	14.33	11.83	-.661	.079	1.163	1.070	-.003	-1.728	.495
2	14.33	12.03	-.608	.045	1.586	1.459	-.002	-2.065	.435
4	14.33	12.10	-.590	-.007	2.012	1.850	.000	-2.440	.405
6	14.34	12.38	-.518	-.075	2.412	2.220	.003	-2.741	.38
8	14.34	12.53	-.455	-.164	2.806	2.582	.007	-3.044	.36
10	14.34	12.74	-.423	-.270	3.178	2.922	.011	-3.356	.35
12	14.34	12.84	-.397	-.400	3.542	3.260	.016	-3.673	.345
14	14.34	12.94	-.370	-.537	3.837	3.528	.022	-3.920	.34
16	14.34	12.65	-.447	-.670	4.065	3.740	.027	-4.214	.345
18	14.34	11.43	-.770	-.756	4.140	3.800	.030	-4.600	.37
20	14.34	10.48	-1.020	-.725	4.030	3.705	.029	-4.754	.395

U.S.A.-27 Biplane

G/C = 2.00 Stagger = 0

D_s = .0571, a = 0".95, h = 0, Long strut, β = 0

α	L_0	L_1	L	D'_s	D_0	D_1	D	L/D
-6	.323	.190	-.233	.0132	.0892	.3028	.1433	-1.6
-4	.322	.670	.348	.0136	.0902	.2452	.0843	4.1
-2	.320	1.106	.786	.0140	.0911	.2357	.0735	10.7
0	.319	1.518	1.199	.0141	.0919	.2437	.0806	14.9
2	.318	1.932	1.614	.0140	.0930	.2639	.0998	16.2
4	.318	2.418	2.100	.0136	.0938	.3037	.1392	15.1
6	.315	2.775	2.460	.0133	.0941	.3450	.1805	13.6
8	.313	3.167	2.854	.0130	.0950	.3971	.2320	12.3
10	.312	3.548	3.236	.0127	.0958	.4501	.2845	11.4
12	.311	3.876	3.565	.0123	.0964	.5146	.3479	10.2
14	.310	4.230	3.920	.0120	.0969	.5805	.4145	9.5
16	.309	4.489	4.180	.0116	.0971	.6504	.4846	8.6
18	.307	4.555	4.248	.0113	.0978	.7313	.5651	7.5
20	.305	4.439	4.134	.0110	.0979	.8641	.6981	5.9

α	M_0	M_1	M	h=0 X Xh=0	Z	Za	M_{1e}	C.P.
-6	9.17	6.25	-.772	.117	-.247	-.235	-.537	-.725
-4	9.17	6.09	-.815	.110	.340	.323	-1.238	1.21
-2	9.17	6.37	-.741	.098	.783	.744	-1.485	.63
0	9.17	6.61	-.678	.081	1.199	1.139	-1.817	.505
2	9.17	6.77	-.635	.044	1.616	1.536	-2.171	.45
4	9.17	6.94	-.590	-.008	2.103	1.998	-2.588	.41
6	9.17	7.12	-.542	-.078	2.466	2.392	-2.884	.39
8	9.17	7.29	-.497	-.166	2.858	2.713	-3.210	.375
10	9.17	7.38	-.474	-.280	3.235	3.073	-3.547	.365
12	9.17	7.54	-.431	-.400	3.556	3.376	-3.807	.355

U.S.A.-27 Biplane

G/C = 2.00 Stagger = 60 %

D_s = .0571, a = 0"93, h = -.0"01, Long strut, β = -16°7

α	L_o	L_1	L	D'_s	D_o	D_1	D	L/D
-6	.316	.293	-.023	.0099	.0810	.2740	.1260	-.2
-4	.757	.757	.443	.0103	.0824	.2295	.0797	5.5
-2	.313	1.183	.870	.0107	.0839	.2230	.0713	12.2
0	.312	1.579	1.267	.0111	.0849	.2344	.0813	15.6
2	.311	2.032	1.721	.0115	.0859	.2596	.1051	16.4
4	.310	2.460	2.150	.0119	.0866	.2975	.1419	15.2
6	.309	2.838	2.529	.0122	.0874	.3410	.1843	13.7
8	.308	3.221	2.913	.0126	.0882	.3927	.2348	12.4
10	.306	3.609	3.303	.0130	.0890	.4520	.2929	11.3
12	.304	3.974	3.670	.0134	.0897	.5159	.3557	10.3
14	.303	4.283	3.980	.0138	.0904	.5826	.4213	9.4
16	.302	4.509	4.207	.0141	.0909	.6496	.4875	8.6
18	.301	4.605	4.304	.0141	.0914	.7396	.5770	7.5
20	.300	4.550	4.250	.0138	.0924	.8895	.7262	5.9

α	M_o	M_1	M	X	Z	Za	Xh	M_{1e}	C.P.
-6	11.87	8.93	-.778	.123	-.036	-.034	-.001	-.743	-.69
-4	11.87	9.35	-.666	.112	.436	.406	-.001	-1.071	.82
-2	11.88	9.70	-.576	.100	.867	.806	-.001	-1.381	.53
0	11.88	10.04	-.486	.081	1.267	1.178	-.001	-1.663	.44
2	11.89	10.42	-.389	.045	1.723	1.603	.000	-1.992	.385
4	11.89	10.61	-.338	-.008	2.153	2.002	.000	-2.340	.365
6	11.90	10.88	-.270	-.080	2.533	2.355	.001	-2.626	.345
8	11.89	11.07	-.217	-.174	2.916	2.714	.002	-2.933	.335
10	11.89	11.27	-.164	-.284	3.300	3.070	.003	-3.237	.325
12	11.88	11.35	-.140	-.414	3.660	3.405	.004	-3.549	.325
14	11.87	11.43	-.116	-.553	3.960	3.684	.006	-3.806	.32
16	11.86	11.75	-.029	-.692	4.173	3.880	.007	-3.916	.315
18	11.85	11.50	-.093	-.780	4.268	3.975	.008	-4.076	.32
20	11.85	10.90	-.251	-.771	4.236	3.932	.008	-4.191	.33

Gottingen 387 Monoplane

Test made by Aeronautical Department, M.I.T., Nov. 8, 1922.
To be used as standard to which to apply biplane correction factors

α	L	D	L/D	L_c	D_c	M_c	C.P.
- 8	- .093	.0860	-1.08	-.00016	.000143	-.00019	- 1.08
- 6	.121	.0457	2.65	.00020	.000076	-.00031	1.60
- 5	.229	.0412	5.56	.00038	.000069	-.00036	.95
- 4	.340	.0397	8.56	.00057	.000066	-.00040	.72
- 3	.452	.0411	11.00	.00075	.000068	-.00045	.60
- 2	.565	.0432	13.10	.00094	.000072	-.00050	.53
0	.796	.0522	15.24	.00133	.000087	-.00060	.45
2	1.028	.0648	15.86	.00171	.000108	-.00069	.40
4	1.258	.0832	15.13	.00209	.000139	-.00079	.37
6	1.477	.1068	13.82	.00246	.000178	-.00088	.36
8	1.699	.1337	12.72	.00283	.000223	-.00097	.34
10	1.920	.1645	11.67	.00320	.000274	-.00107	.33
12	2.097	.1961	10.70	.00349	.000327	-.00114	.33
14	2.235	.2282	9.79	.00372	.000380	-.00118	.32
16	2.312	.2630	8.79	.00385	.000438	-.00121	.32
18	2.363	.3060	7.72	.00394	.000501	-.00124	.32
20	2.368	.3582	6.62	.00395	.000597	-.00126	.31
22	2.314	.4284	5.40	.00386	.000714		

Göttingen 387   Monoplane #1

Crosshead Mounting Protected By Discoid Case

D_s=.0301, a = 0".74, h = 0".92

α	L_1	L_0	L	D_1
-8	.188	.251	-.063	.1880
-6	.401	.250	.151	.1525
-4	.614	.249	.365	.1465
-2	.816	.247	.569	.1490
0	1.076	.247	.829	.1567
2	1.310	.246	1.064	.1703
4	1.550	.245	1.305	.1895
6	1.779	.244	1.535	.2146
8	2.001	.243	1.758	.2402
10	2.205	.242	1.963	.2701
12	2.405	.242	2.163	.3031
14	2.519	.241	2.278	.3364
16	2.606	.241	2.365	.3747
18	2.610	.240	2.370	.4203
20	2.605	.240	2.365	.4757

α	D_0	D	X	Z
-8	.0793	.0786	.070	-.073
-6	.0776	.0448	.060	.147
-4	.0768	.0397	.065	.361
-2	.0760	.0429	.063	.567
0	.0750	.0516	.052	.829
2	.0740	.0662	.029	1.066
4	.0726	.0868	-.003	1.307
6	.0712	.1133	-.049	1.538
8	.0698	.1403	-.105	1.760
10	.0685	.1715	-.170	1.962
12	.0670	.2060	-.249	2.157
14	.0665	.2408	-.317	2.268
16	.0639	.2807	-.380	2.340
18	.0622	.3280	-.422	2.353
20	.0608	.3848	-.448	2.353

Göttingen 387 Monoplane #1(Cont.)

α	M_1	M_o	M_s	M
-8	8.84	10.72	-.09	-.474
-6	8.62	10.72	-.09	-.532
-4	8.60	10.72	-.09	-.537
-2	8.56	10.72	-.09	-.548
0	8.58	10.72	-.08	-.545
2	8.56	10.72	-.08	-.550
4	8.64	10.72	-.08	-.529
6	8.77	10.71	-.08	-.492
8	8.87	10.71	-.08	-.465
10	9.05	10.71	-.08	-.418
12	9.28	10.71	-.08	-.357
14	9.57	10.71	-.08	-.281
16	9.74	10.71	-.08	-.235
18	9.82	10.71	-.09	-.212
20	9.75	10.71	-.09	-.233

α	Za	Xh	M_{le}	C.P.
-8	-.055	.064	-.355	-1.62
-6	.109	.055	-.686	1.56
-4	.267	.060	-.744	.685
-2	.420	.058	-.910	.535
0	.613	.048	-1.110	.445
2	.789	.027	-1.312	.41
4	.967	-.003	-1.499	.385
6	1.139	-.045	-1.676	.365
8	1.302	-.097	-1.864	.355
10	1.452	-.156	-2.026	.345
12	1.597	-.229	-2.183	.335
14	1.680	-.292	-2.253	.33
16	1.731	-.350	-2.316	.33
18	1.740	-.388	-2.340	.33
20	1.740	-.412	-2.385	.335

Göttingen 387 Monoplane #2

Crosshead Mounting Protected By Discoid Case

$D_s = .0301$, a = 0".87, h = 0".82

α	L_1	L_o	L	D_1
-8	.217	.255	-.038	.1637
-6	.434	.254	.180	.1441
-4	.653	.253	.400	.1395
-2	.881	.252	.629	.1435
0	1.118	.251	.867	.1524
2	1.345	.250	1.095	.1662
4	1.588	.250	1.338	.1863
6	1.807	.250	1.557	.2000
8	2.020	.249	1.771	.2369
10	2.225	.249	1.976	.2680
12	2.419	.248	2.171	.3011
14	2.524	.248	2.276	.3341
16	2.603	.247	2.356	.3755
18	2.622	.246	2.376	.4177
20	2.617	.246	2.371	.4796

α	D_o	D	X	Z
-8	.0715	.0621	.057	-.047
-6	.0707	.0433	.062	.174
-4	.0699	.0395	.067	.395
-2	.0690	.0444	.068	.627
0	.0681	.0540	.054	.867
2	.0667	.0694	.031	1.097
4	.0649	.0913	-.003	1.340
6	.0639	.1060	-.058	1.558
8	.0629	.1439	-.103	1.774
10	.0619	.1760	-.170	1.976
12	.0609	.2101	-.246	2.166
14	.0598	.2442	-.313	2.267
16	.0583	.2871	-.373	2.342
18	.0568	.3308	-.442	2.353
20	.0555	.3940	-.442	2.363

Göttingen 387 Monoplane #2(Cont.)

α	M_1	M_0	M_s	M
-8	8.71	10.69	-.09	-.500
-6	8.74	10.69	-.09	-.492
-4	8.80	10.69	-.09	-.476
-2	8.87	10.69	-.09	-.458
0	9.000	10.69	-.08	-.426
2	9.12	10.69	-.08	-.394
4	9.28	10.69	-.08	-.352
6	9.47	10.69	-.08	-.302
8	9.72	10.68	-.08	-.233
10	9.96	10.68	-.08	-.169
12	10.23	10.68	-.08	-.098
14	10.56	10.68	-.08	-.011
16	10.73	10.68	-.08	.034
18	10.81	10.68	-.09	.058
20	10.72	10.68	-.09	.034

α	Za	Xh	M_{1e}	C.P.
-8	-.041	.047	-.412	-2.92
-6	.151	.051	-.592	1.13
-4	.344	.055	-.765	.645
-2	.545	.056	-.947	.505
0	.754	.044	-1.136	.435
2	.954	.025	-1.323	.405
4	1.167	-.002	-1.521	.38
6	1.356	-.048	-1.706	.365
8	1.543	-.085	-1.861	.35
10	1.719	-.139	-2.027	.34
12	1.884	-.202	-2.184	.335
14	1.972	-.257	-2.240	.33
16	2.039	-.306	-2.311	.33
18	2.047	-.363	-2.352	.335
20	2.057	-.363	12.386	.335

GÖTTINGEN 387 Monoplane

Crosshead Mounting Protected by Discoid Case
Mean of 1 Test on #1 and 1 Test on #2.

To be used as standard of comparison in obtaining biplane correction factors.

α	L	D	L/D	L_c	D_c	M_{1e}	M_c
-8	-.051	.0703	- 0.73	-.00009	.000117	- .384	-.00021
-6	.166	.0441	3.76	.00028	.000074	- .639	-.00035
-4	.383	.0396	9.69	.00064	.000066	- .755	-.00042
-2	.599	.0437	13.71	.00100	.000073	- .929	-.00052
0	.848	.0528	16.07	.00141	.000088	-1.123	-.00063
2	1.082	.0678	15.98	.00180	.000113	-1.318	-.00073
4	1.322	.0891	14.81	.00220	.000149	-1.510	-.00084
6	1.546	.1097	14.10	.00258	.000183	-1.691	-.00094
8	1.765	.1421	12.41	.00294	.000237	-1.863	-.00104
10	1.970	.1738	11.34	.00328	.000290	-2.097	-.00113
12	2.167	.2081	10.40	.00361	.000347	-2.184	-.00121
14	2.277	.2425	9.39	.00380	.000404	-2.247	-.00125
16	2.361	.2839	8.33	.00394	.000473	-2.314	-.00129
18	2.373	.3294	7.20	.00396	.000549	-2.346	-.00130
20	2.368	.3894	6.09	.00395	.000649	-2.386	-.00133

α	X	Z	2L	2D	$2M_{1e}$	C.P.
-8	.064	- .060	- .102	.1406	- .768	- 2.13
-6	.061	.061	.332	.0881	- 1.278	1.32
-4	.066	.378	.767	.0792	-1.510	.665
-2	.065	.597	1.198	.0874	-1.858	.52
0	.053	.848	1.696	.1056	-2.246	.44
2	.030	1.082	2.164	.1356	-2.636	.405
4	-.003	1.324	2.644	.1782	-3.020	.38
6	-.054	1.548	3.092	.2194	-3.382	.365
8	-.104	1.767	3.530	.2842	-3.726	.35
10	-.170	1.969	3.940	.3476	-4.054	.345
12	-.248	2.162	4.334	.4162	-4.368	.335
14	-.315	2.268	4.554	.4850	-4.494	.33
16	-.377	2.341	4.722	.5678	-4.628	.33
18	-.432	2.353	4.746	.6588	-4.692	.335
20	-.445	2.358	4.736	.7788	-4.772	.34

Göttingen 387 Biplane

G/C = .75, Stagger = -40 %

D_s = .0556, a = 0"90, h = -0"05, Short strut, β = 28°1

α	L_0	L_1	L	D_s'	D_0	D_1
-8	.286	.155	-.131	.0069	.0896	.3169
-4	.283	.862	.579	.0065	.0908	.2487
0	.280	1.595	1.315	.0061	.0918	.2709
2	.279	2.008	1.729	.0059	.0921	.3001
6	.276	2.693	2.417	.0054	.0926	.3708
10	.273	3.362	3.089	.0050	.0929	.4736
14	.270	3.990	3.720	.0046	.0928	.6038
18	.268	4.309	4.041	.0042	.0927	.7497
20	.267	3.950	3.683	.0040	.0925	.8943

α	D	L/D	M_0	M_1	M
-8	.1648	-0.80	10.61	6.85	-.995
-4	.0958	6.05	10.61	7.35	-.863
0	.1174	11.20	10.61	7.96	-.700
2	.1465	11.80	10.61	8.24	-.626
6	.2172	11.12	10.60	9.00	-.423
10	.3201	9.65	10.60	9.62	-.259
14	.4508	8.25	10.60	10.10	-.132
18	.5972	6.76	10.60	9.75	-.225
20	.7422	4.97			

α	X	Z	Za	Xh	$M_{L.E.}$	C.P.
-8	.182	-.107	-.096	-.009	-.890	-2.77
-4	.135	.570	.513	-.007	-1.369	.80
0	.117	1.315	1.183	-.006	-1.877	.475
2	.087	1.732	1.558	-.004	-2.180	.42
6	-.037	2.426	2.283	.002	-2.708	.37
10	-.219	3.096	2.786	.011	-3.056	.33
14	-.464	3.714	3.343	.023	-3.498	.315
18	-.681	4.020	3.618	.034	-3.877	.32

Göttingen 387 Biplane

G/C = .75, Stagger = 0

D_s = .0556, a = 0".90, h = 0".08, Short strut, β = 0

α	L_o	L_1	L	D_s'	D_o	D_1
-8	.304	.317	.013	.0081	.0829	.2687
-4	.301	.996	.695	.0085	.0855	.2382
0	.299	1.706	1.407	.0089	.0873	.2682
2	.299	2.059	1.760	.0088	.0887	.2953
6	.296	2.809	2.513	.0084	.0902	.3823
10	.293	3.500	3.207	.0080	.0916	.4950
14	.290	4.116	3.826	.0075	.0937	.6278
18	.287	4.555	4.268	.0071	.0947	.7684
20	.285	4.609	4.324	.0069	.0951	.8504
22	.284	4.670	4.386	.0067	.0955	.9463
24	.283	4.400	4.117	.0065	.0959	1.0700

α	D	L/D	M_1	M_o	M
-8	.1221	.11	7.62	10.86	-.856
-4	.0886	7.84	8.07	10.86	-.738
0	.1164	12.09	8.47	10.86	-.632
2	.1422	12.37	8.73	10.86	-.563
6	.2281	11.00	9.02	10.86	-.487
10	.3398	9.45	9.32	10.86	-.408
14	.4710	8.11	9.68	10.86	-.312
18	.6110	6.99	9.95	10.86	-.241
20	.6928	6.25			
22	.7886	5.56	9.66	10.86	-.317
24	.9120	4.51			

α	X	Z	Za	Xh	M_{1e}	C.P.
-8	.122	-.005	-.004	.010	- .862	-71.78
-4	.137	.686	.617	.011	-1.366	.665
0	.116	1.407	1.266	.009	-1.907	.45
2	.080	1.762	1.576	.006	-2.155	.405
6	-.035	2.521	2.269	-.003	-2.753	.365
10	-.220	3.216	2.894	-.018	-3.284	.34
14	-.466	3.824	3.442	-.037	-3.717	.325
18	-.732	4.242	3.818	-.058	-4.001	.315
22	-.915	4.356	3.920	-.073	-4.164	.32

Göttingen 387 Biplane

G/C = .75, Stagger = 60 %

D_s = .0556, a = 0".86, h = 0".04, Short strut, β = -38°.7

α	L_0	L_1	L	D_s'	D_0	D_1
-8	.301	.387	.086	.0037	.0695	.2433
-4	.299	1.107	.808	.0039	.0710	.2203
0	.297	1.873	1.576	.0044	.0727	.2585
2	.297	2.279	1.982	.0046	.0742	.2934
6	.295	3.049	2.754	.0051	.0757	.3984
10	.294	3.871	3.577	.0056	.0769	.5338
14	.292	4.568	4.276	.0061	.0790	.6982
18	.290	5.100	4.810	.0065	.0805	.9200
20	.289	5.150	4.861	.0068	.0808	1.0800
22	.288	4.900	4.612	.0072	.0810	1.3500

α	D	L/D	M_0	M_1	M
-8	.1135	.76	10.55	8.05	-.661
-4	.0898	9.00	10.55	9.32	-.325
0	.1258	12.52	10.55	10.52	-.008
2	.1590	12.48	10.55	11.12	.151
6	.2620	10.50	10.55	11.97	.376
10	.3957	9.05	10.56	12.69	.563
14	.5575	7.67	10.56	12.85	.605
18	.7774	6.20	10.56	12.24	.445
20	.9368	5.19	10.56	11.42	.228
22	1.2062	3.84			

α	X	Z	Za	$\dot{X}h$	M_{1e}	C.P.
-8	.125	-.070	-.060	.005	-.606	-2.88
-4	.146	.800	.688	.006	1.019	.425
0	.126	1.576	1.355	.005	1.368	.29
2	.089	1.985	1.700	.004	1.552	.26
6	-.028	2.762	2.376	-.001	1.999	.24
10	-.230	3.590	3.087	-.009	2.515	.235
14	-.492	4.279	3.680	-.020	3.055	.24
18	-.748	4.812	4.145	-.030	3.670	.255
20	-.786	4.883	4.200	-.032	3.940	.27

Göttingen 387 Biplane

G/C = 1.00, Stagger = - 40 %

D_s = .0556, a ≐ 0"94, h = 0"04, Short strut, β = 21°8

α	L_o	L_1	L	D_o	D_1	D_s'
-8	.313	.216	-.097	.0921	.3117	.0055
-4	.311	.957	.646	.0948	.2478	.0060
0	.308	1.758	1.450	.0965	.2788	.0064
2	.306	2.130	1.824	.0975	.3074	.0066
6	.302	2.934	2.632	.0990	.3959	.0071
10	.299	3.665	3.366	.1001	.5177	.0076
14	.296	4.309	4.013	.1005	.6592	.0081
18	.293	4.615	4.322	.1009	.8133	.0086
20	.291	4.600	4.309	.1014	.9333	.0088

α	D	L/D	M_1	M_o	M
-8	.1585	-0.61	7.19	10.79	-.953
-4	.0914	7.07	7.50	10.79	-.870
0	.1203	12.04	7.97	10.79	-.746
2	.1477	12.35	8.17	10.79	-.693
6	.2342	11.22	8.69	10.79	-.555
10	.3544	9.50	9.07	10.79	-.455
14	.4950	8.11	9.37	10.79	-.376
18	.6482	6.67	8.35	10.79	-.645
20	.7675	5.62	8.11	10.79	-.709

α	X	Z	Za	Xh	M_{1e}	C.P.
-8	.144	-.118	-.111	.006	-.848	-2.39
-4	.136	.638	.600	.005	1.475	.77
0	.120	1.450	1.361	.005	2.112	.485
2	.083	1.828	1.718	.003	2.414	.44
6	-.042	2.641	2.482	-.002	3.035	.385
10	-.235	3.378	3.175	-.009	3.621	.355
14	-.490	4.008	3.767	-.020	4.123	.345
18	-.718	4.304	4.046	-.029	4.662	.36
20	-.750	4.305	4.047	-.030	4.726	.365

Göttingen 387 Biplane

G/C = 1.00, Stagger = -20 %

D_s = .0556, a = 0".92, h = 0".05, Short strut, β = 11°.3

α	L_0	L_1	L	D_s'	D_0	D_1
-8	.310	.287	-.023	.0086	.0864	.2875
-4	.307	1.008	.701	.0082	.0896	.2412
0	.304	1.789	1.485	.0078	.0908	.2757
2	.303	2.177	1.874	.0076	.0916	.3044
6	.300	2.973	2.673	.0072	.0932	.3987
10	.298	3.707	3.409	.0068	.0944	.5195
14	.295	4.328	4.033	.0064	.0957	.6610
18	.292	4.694	4.402	.0059	.0970	.8074
20	.290	4.724	4.434	.0057	.0972	.9087
22	.288	4.200	3.912	.0055	.0974	1.1200

α	D	L/D	M_1	M_0	M
-8	.1369	-0.17	7.20	10.85	-.965
-4	.0878	7.99	7.65	10.85	-.846
0	.1215	12.21	8.22	10.85	-.695
2	.1496	12.53	8.38	10.85	-.654
6	.2427	11.00	8.82	10.85	-.537
10	.3627	9.40	9.21	10.85	-.434
14	.5033	8.02	9.51	10.85	-.355
18	.6489	6.80	9.48	10.85	-.362
20	.7502	5.91	8.96	10.85	-.500
22	.9615	4.11			

α	X	Z	Za	Xh	$M_{1.e.}$	C.P.
-8	.133	-.042	-.039	.007	-.933	-7.40
-4	.146	.693	.638	.007	-1.491	.72
0	.122	1.485	1.367	.006	-2.068	.465
2	.083	1.878	1.728	.004	-2.386	.425
6	-.070	2.981	2.843	-.004	-3.278	.365
10	-.234	3.419	3.141	-.012	-3.563	.345
14	-.488	4.032	3.710	-.024	-4.041	.335
18	-.745	4.380	4.029	-.037	-4.354	.33
20	-.811	4.418	4.066	-.041	-4.520	.34

Göttingen 387 Biplane

G/C = 1.00 Stagger = 0

D_s = .0556, a = 0".90, h = 0, Short strut, β = 0

α	L_0	L_1	L	D_s'	D_0	D_1
-8	.295	.247	-.048	.0081	.0853	.2889
-4	.293	.972	.679	.0085	.0874	.2397
0	.290	1.746	1.456	.0089	.0886	.2706
2	.290	2.129	1.839	.0088	.0896	.2989
6	.287	2.937	2.650	.0084	.0906	.3920
10	.284	3.700	3.416	.0080	.0914	.5113
14	.281	4.350	4.069	.0075	.0922	.6458
18	.278	4.759	4.481	.0071	.0931	.7900
20	.276	4.852	4.576	.0069	.0933	.8836
22	.275	4.830	4.555	.0067	.0935	1.0036

α	D	L/D	M_1	M_0	M
-8	.1399	-0.35	7.35	10.94	-.950
-4	.0882	7.70	7.75	10.94	-.844
0	.1175	12.40	8.20	10.94	-.725
2	.1449	12.70	8.43	10.94	-.664
6	.2376	11.17	8.84	10.94	-.555
10	.3563	9.59	9.22	10.94	-.455
14	.4905	8.30	9.56	10.94	-.365
18	.6342	7.07	9.90	10.94	-.275
20	.7278	6.30	9.75	10.94	-.315
22	.8478	5.38	9.29	10.94	-.436

h = 0, Xh = 0

α	X	Z	Za	$M_{1.e.}$	C.P.
-8	.131	-.136	-.122	-.828	-2.03
-4	.135	.670	.603	-1.447	.72
0	.118	1.456	1.310	-2.035	.465
2	.080	1.841	1.657	-2.321	.42
6	-.041	2.659	2.393	-2.948	.37
10	-.242	3.424	3.082	-3.537	.345
14	-.508	4.062	3.656	-4.021	.33
18	-.780	4.450	4.005	-4.280	.32
20	-.880	4.544	4.090	-4.405	.325
22	-.922	4.536	4.082	-4.528	.335

Göttingen 387 Biplane

G/C = 1.00, Stagger = 20 %

D_s = .0556, a = 0"92, h = 0"08, Short strut, β = -11°3

α	L_o	L_1	L	D_s'	D_o	D_1
-8	.306	.200	-.106	.0067	.0774	.3000
-4	.303	.921	.618	.0072	.0800	.2302
0	.301	1.701	1.400	.0077	.0816	.2576
2	.300	2.114	1.814	.0079	.0824	.2870
6	.298	2.912	2.614	.0084	.0842	.3758
10	.296	3.692	3.396	.0088	.0868	.4971
14	.293	4.377	4.084	.0087	.0880	.6432
18	.290	4.905	4.615	.0083	.0895	.8019
20	.289	4.992	4.703	.0081	.0902	.8800
22	.288	5.046	4.758	.0079	.0905	.9895
24	.287	4.941	4.654	.0077	.0910	1.1518

α	D	L/D	M_1	M_o	M
-8	.1603	-0.66	7.64	10.87	-.855
-4	.0874	7.08	8.05	10.87	-.745
0	.1127	12.42	8.71	10.87	-.571
2	.1411	12.86	8.98	10.87	-.500
6	.2276	11.50	9.45	10.87	-.376
10	.3459	9.82	9.87	10.88	-.267
14	.4909	8.32	10.18	10.88	-.185
18	.6485	7.13	10.51	10.88	-.098
20	.7261	6.49	10.47	10.88	-.108
22	.8355	5.70	10.25	10.88	-.167
24	.9975	4.67	9.85	10.88	-.273

α	X	Z	Za	Xh	$M_{1,e.}$	C.P.
-8	.144	-.129	-.119	.012	-.748	-1.93
-4	.129	.610	.561	.010	-1.316	.72
0	.113	1.400	1.289	.009	-1.869	.445
2	.078	1.817	1.671	.006	-2.177	.40
6	-.046	2.620	2.410	-.004	-2.782	.355
10	-.247	3.401	3.128	-.020	-3.375	.33
14	-.510	4.078	3.752	-.041	-3.896	.32
18	-.810	4.584	4.210	-.065	-4.243	.31
20	-.926	4.664	4.296	-.074	-4.340	.31
22	-1.012	4.718	4.345	-.079	-4.433	.315
24	.983	4.654	4.281	-.081	-4.473	.32

Göttingen 387 Biplane

G/C = 1.00 Stagger = 40 %

D_s = .0556, a = 0".91, h = 0".08, Short strut, β = -21°.8

α	L_o	L_1	L	D_o	D_1	D'_s
-8	.317	.300	-.017	.0747	.2692	.0075
-4	.315	1.042	.727	.0766	.2254	.0071
0	.313	1.848	1.535	.0788	.2602	.0067
2	.312	2.250	1.938	.0800	.2959	.0065
6	.311	3.079	2.768	.0818	.3961	.0061
10	.309	3.859	3.550	.0836	.5238	.0057
14	.307	4.576	4.269	.0856	.6815	.0052
18	.305	5.059	4.754	.0868	.8501	.0048
20	.304	5.130	4.826	.0881	.9460	.0046
22	.303	5.191	4.888	.0892	1.0631	.0044
24	.302	4.850	4.548	.0897	1.3500	.0042

α	D	L/D	M_1	M_o	M
-8	.1314	-0.13	7.66	10.94	-.867
-4	.0861	8.44	8.51	10.94	-.643
0	.1191	12.89	9.34	10.94	-.424
2	.1538	12.60	9.78	10.94	-.307
6	.2526	10.96	10.43	10.94	-.135
10	.3789	9.37	10.84	10.94	-.026
14	.5351	7.97	11.11	10.94	.045
18	.7029	6.77	11.21	10.94	.071
20	.7977	6.05	11.06	10.94	.032
22	.9139	5.35	10.70	10.94	-.063
24	1.2005	3.78			

α	X	Z	Za	Xh	M_{1e}	C.P.
-8	.127	-.037	-.034	.010	-.843	-7.59
-4	.136	.720	.655	.011	1.309	.605
0	.119	1.535	1.398	.010	1.832	.40
2	.086	1.941	1.768	.007	2.082	.355
6	-.036	2.773	2.523	-.003	2.655	.325
10	-.245	3.560	3.240	-.020	3.246	.305
14	-.510	4.270	3.887	-.041	3.801	.295
18	-.800	4.732	4.300	-.064	4.165	.295
20	-.900	4.800	4.362	-.072	4.258	.295
22	-.986	4.868	4.436	-.079	4.420	.305

Göttingen 387 Biplane

G/C = 1.00, Stagger = 60 %

D_s = .0556, a = 0".86, h = 0".06, Short strut, β = -31°.0

α	L_o	L_1	L	D'_s	D_o	D_1
-8	.300	.365	-.065	.0043	.0725	.2553
-4	.299	1.130	.831	.0048	.0749	.2284
0	.297	1.954	1.657	.0053	.0772	.2702
2	.296	2.369	2.073	.0055	.0779	.3041
6	.294	3.186	2.892	.0060	.0796	.4103
10	.292	3.982	3.690	.0065	.0815	.5490
14	.290	4.708	4.418	.0070	.0826	.7114
18	.288	5.169	4.881	.0075	.0841	.9005
20	.287	5.281	4.994	.0077	.0845	1.0300
22	.286	5.142	4.856	.0080	.0849	1.1600

α	D	L/D	M_1	M_o	M
-8	.1229	-0.53	7.82	10.83	-.796
-4	.0931	6.77	8.80	10.83	-.537
0	.1321	12.52	9.80	10.83	-.273
2	.1651	12.55	10.36	10.83	-.124
6	.2691	11.75	11.12	10.83	.077
10	.4054	9.10	11.62	10.83	.209
14	.5662	7.80	11.87	10.83	.275
18	.7533	6.48	11.69	10.83	.228
20	.8822	5.66	11.29	10.83	.122
22	1.0115	4.80	10.48	10.83	-.093

α	X	Z	Za	Xh	M_{1e}	C.P.
-8	.114	-.081	-.070	.007	-.733	-3.02
-4	.149	.822	.707	.009	-1.353	.55
0	.132	1.657	1.425	.008	-1.706	.345
2	.094	2.077	1.786	.006	-1.916	.305
6	-.035	2.901	2.498	-.002	-2.419	.275
10	-.257	3.798	3.265	-.015	-3.041	.265
14	-.518	4.420	3.804	-.031	-3.498	.265
18	-.790	4.870	4.191	-.047	-3.916	.27
20	-.878	4.990	4.290	-.053	-4.115	.275
22	-.883	4.880	4.200	-.053	-4.240	.29

Göttingen 387 Biplane

G/C = 1.33 Stagger = -40 %

D_s = .0556, a = $0.^{\prime\prime}95$, h = 0, Medium strut, $\beta = 16.^{\circ}7$

α	L_0	L_1	L	D_s'	D_0	D_1
-8	.300	.118	-.182	.0092	.0860	.3271
-4	.298	.877	.581	.0087	.0874	.2406
0	.296	1.680	1.384	.0082	.0886	.2660
2	.294	2.086	1.792	.0080	.0891	.2939
6	.291	2.909	2.618	.0075	.0900	.3843
10	.289	3.726	3.435	.0070	.0905	.5079
14	.286	4.366	4.080	.0065	.0915	.6440
18	.283	4.779	4.496	.0060	.0917	.8002
20	.282	4.799	4.517	.0058	.0919	.8932
22	.281	4.460	4.179	.0055	.0921	1.0980

α	D	L/D	M_0	M_1	M
-8	.1763	-1.03	10.59	7.99	-.688
-4	.0889	6.55	10.59	7.45	-.830
0	.1136	12.20	10.59	8.19	-.635
2	.1412	12.70	10.58	8.34	-.592
6	.2312	11.31	10.58	8.84	-.460
10	.3548	9.68	10.58	9.34	-.328
14	.4904	8.31	10.57	9.67	-.238
18	.6469	6.95	10.57	9.25	-.349
20	.7399	6.11	10.57	8.71	-.492
22	.9448	4.43			

h=0, Xh = 0

α	X	Z	Za	M_{1e}	C.P.
-8	.200	-.155	-.147	-.541	-1.16
-4	.130	.573	.545	1.375	.80
0	.114	1.384	1.315	1.950	.47
2	.078	1.795	1.705	2.297	.425
6	.001	2.624	2.494	2.954	.375
10	-.247	3.440	3.268	3.596	.35
14	-.510	4.074	3.872	4.110	.345
18	-.776	4.472	4.250	4.599	.345
20	-.850	4.494	4.270	4.762	.355

Göttingen 387 Biplane

G/C = 1.33 Stagger = 0

$D_s' = .0556$, a = 0".93, h = 0".04, medium strut, $\beta = 0$

α	L_0	L_1	L	D_s'	D_0	D_1
-8	.299	.260	-.039	.0095	.0815	.2754
-4	.296	1.009	.713	.0097	.0829	.2359
0	.294	1.829	1.535	.0100	.0844	.2708
2	.293	2.233	1.940	.0099	.0856	.3024
6	.290	3.047	2.757	.0095	.0870	.3967
10	.288	3.828	3.540	.0090	.0884	.5251
14	.285	4.503	4.218	.0085	.0898	.6683
18	.282	4.891	4.609	.0081	.0910	.8180
20	.281	4.929	4.648	.0078	.0908	.9100
22	.280	4.872	4.592	.0075	.0916	1.0260

α	D	L/D	M_0	M_1	M
-8	.1288	-0.30	10.58	7.05	-.934
-4	.0877	8.13	10.58	7.65	-.775
0	.1208	12.70	10.58	8.10	-.656
2	.1513	12.81	10.59	8.44	-.569
6	.2446	11.28	10.59	8.94	-.436
10	.3721	9.51	10.59	9.37	-.323
14	.5144	8.21	10.59	9.73	-.227
18	.6633	6.95	10.60	9.87	-.196
20	.7558	6.14	10.60	9.57	-.275
22	.8713	5.15	10.60	9.02	-.418

α	X	Z	Z_a	X_h	$M_{L.E.}$	C.P.
-8	.132	-.020	-.019	.005	-.920	-15.32
-4	.137	.705	.656	.005	-1.436	.68
0	.121	1.535	1.429	.005	-2.090	.455
2	.083	1.942	1.808	.003	-2.380	.41
6	-.041	2.766	2.573	-.002	-3.007	.36
10	-.249	3.548	3.301	-.010	-3.614	.34
14	-.520	4.212	3.925	-.021	-4.131	.325
18	-.792	4.584	4.262	-.032	-4.426	.32
20	-.879	4.619	4.300	-.035	-4.540	.325
22	-.916	4.578	4.257	-.037	-4.638	.335

Göttingen 387 Biplane

G/C = 1.33 Stagger = 60 %

D_s = .0556, a = 0".92, h = 0".10, Medium Strut, β = -24°.2

α	L_0	L_1	L	$D_s^{\frac{1}{2}}$	D_0	D_1
-8	.305	.221	-.084	.0059	.0728	.2813
-4	.303	.996	.693	.0065	.0744	.2250
0	.301	1.826	1.523	.0070	.0768	.2580
2	.300	2.245	1.945	.0072	.0780	.2886
6	.299	3.074	2.775	.0078	.0800	.3867
10	.297	3.879	3.582	.0083	.0816	.3165
14	.295	4.609	4.314	.0089	.0834	.6742
18	.293	5.075	4.782	.0094	.0848	.8394
20	.291	5.182	4.891	.0096	.0854	.9394
22	.290	5.092	4.802	.0099	.0859	1.0800

α	D	L/D	M_0	M_1	M
-8	.1470	-.57	10.63	7.31	-.878
-4	.0885	7.83	10.63	8.14	-.659
0	.1186	12.86	10.63	9.02	-.426
2	.1478	13.17	10.63	9.55	-.286
6	.2433	11.40	10.63	10.35	-.071
10	.3710	9.66	10.64	10.98	.090
14	.5253	8.22	10.64	11.38	.196
18	.6896	6.94	10.64	11.49	.225
20	.7888	6.20	10.64	11.35	.188
22	.9286	5.18	10.64	10.94	.079

α	X	Z	Z_a	Xh	$M_{1.e.}$	C.P.
-8	.157	-.062	-.057	.016	-.837	-4.50
-4	.136	.686	.631	.014	-1.304	.635
0	.119	1.523	1.401	.012	-1.839	.40
2	.078	1.945	1.790	.008	-2.084	.355
6	-.042	2.782	2.560	-.004	-2.627	.315
10	-.274	3.588	3.300	-.027	-3.183	.295
14	-.530	4.308	3.960	-.053	-3.711	.285
18	-.822	4.756	4.378	-.082	-4.071	.285
20	-.932	4.860	4.475	-.093	-4.194	.285
22	-.945	4.796	4.410	-.095	-4.236	.295

APPENDIX C.

TABULATED RESULTS

N.B. In all tabulations of data, negative signs (-) are inserted, but positive signs (+) are omitted. The absence of a sign means that the value is positive (+).

BIPLANE CORRECTION FACTORS FOR L_c AT EQUAL α.

Table 1
U.S.A. 27 Biplane
Stagger = 0

	G/C					
$\alpha°$	.50	.75	1.00	1.33	1.67	2.00
-6	-.105	.412	.588	.776	1.113	1.021
-4	1.280	.990	.990	.959	.718	1.208
-2	.864	.825	1.016	.885	.826	1.010
0	.786	.895	.855	.872	.842	.961
2	.766	.789	.864	.880	.835	.933
4	.775	.835	.870	.899	.870	.962
6	.764	.817	.866	.892	.859	.936
8	.755	.805	.857	.890	.866	.933
10	.759	.810	.864	.887	.878	.936
12	.760	.815	.867	.887	.876	.929
14	.759	.812	.876	.904	.887	.938
16	.776	.848	.899	.922	.916	.956
18	.820	.896	.965	.978	.970	.981
20	.876	.953	.996	.999	.998	.989
22	.905	.992				

Table 2.
U.S.A. 27 Biplane
G/C = 0.50

	Stagger.		
$\alpha°$	-40%	0%	60%
-6	-1.074	-.105	.072
-4	.514	1.280	1.362
-2	.648	.864	.992
0	.669	.786	.918
2	.675	.766	.890
4	.692	.775	.880
6	.691	.764	.879
8	.700	.775	.892
10	.708	.759	.887
12	.715	.760	.893
14	.723	.759	.894
16	.744	.776	.915
18	.765	.820	.952
20	.766	.876	.985
22	———	.905	1.011

BIPLANE CORRECTION FACTORS FOR L_c AT EQUAL α.

Table 3
U.S.A. 27 Biplane
G/C = 0.75
Stagger.

$\alpha°$	-40%	-20%	0	20%	40%	60%
-6	-1.018	-.732	.412	-.079	.346	.232
-4	.660	.771	.990	1.268	1.551	1.602
-2	.726	.745	.825	.930	1.065	1.089
0	.704	.708	.895	.873	.979	.999
2	.745	.746	.789	.882	.930	.856
4	.751	.763	.835	.860	.912	.932
6	.760	.788	.817	.856	.904	.932
8	.773	.778	.805	.841	.885	.933
10	.786	.781	.810	.836	.893	.928
12	.789	.790	.815	.787	.889	.926
14	.788	.801	.812	.838	.900	.908
16	.805	.818	.848	.863	.923	.949
18	.834	.864	.896	.923	.964	.991
20	.858	.900	.953	.971	1.002	1.029
22	____	.913	.992	1.011	1.031	1.071

Table 4.
Göt. 387 Biplane
G/C = 0.75
Stagger.

$\alpha°$	-40%	0	60%
-8	1.364	-.135	-.896
-4	.710	.851	.990
0	.766	.820	.919
2	.796	.811	.914
6	.783	.815	.892
10	.778	.808	.900
14	.814	.836	.935
18	.845	.893	1.007
20	.776	.913	1.027
22		.946	.997

BIPLANE CORRECTION FACTORS FOR L_c AT EQUAL α

Table 5
U.S.A. 27 Biplane
G/C = 1.00

Stagger

$\alpha°$	-40%	-20%	0%	20%	40%	60%
-6	1.191	.631	.588	.421	.250	.228
-4	.660	.986	.990	1.101	1.289	1.199
-2	.790	.875	1.016	.924	.984	1.002
0	.800	.872	.855	.881	.925	.958
2	.800	.848	.864	.890	.917	.928
4	.817	.869	.870	.894	.884	.933
6	.818	.860	.866	.877	.888	.928
8	.822	.864	.857	. 881	.892	.927
10	.842	.866	.864	.880	.899	.932
12	.837	.872	.867	.879	.902	.939
14	.849	.879	.876	.896	.910	.938
16	.871	.899	.899	.928	.934	.970
18	.910	.941	.965	.985	.993	1.020
20	.939	.968	.995	1.020	1.023	1.050
22				1.045		

Table 6
Göt. 387 Bipland
G/C = 1.00

Stagger

$\alpha°$	-40%	-20%	0	20%	40%	60%
-8	1.010	.243	.477	1.104	.178	.077
-4	.792	.859	.831	.758	.891	1.019
0	.845	.866	.849	.816	.895	.965
2	.840	.864	.846	.836	.892	.955
6	.854	.866	.860	.849	.894	.934
10	.848	.859	.860	.855	.896	.933
14	.879	.882	.890	.894	.934	.967
18	.905	.921	.938	.967	.995	1.021
20	.910	.935	.966	.993	1.019	1.053
22			.983	1.028	1.054	1.050

BIPLANE CORRECTION FACTORS FOR L_0 AT EQUAL α

Table 7
U.S.A. 27 Biplane
G/C = 1.33

Stagger

$\alpha°$	-40%	-20%	0%	20%	40%	60%
-6	.978	-.693	.776	-.496	-.632	-.969
-4	.813	1.017	.959	1.380	1.027	.795
-2	.852	.925	.885	1.040	.925	.867
0	.850	.891	.872	.976	.907	.865
2	.858	.883	.880	.953	.905	.877
4	.869	.906	.899	.947	.912	.897
6	.874	.899	.892	.934	.917	.885
8	.884	.893	.890	.929	.906	.898
10	.890	.890	.887	.934	.916	.900
12	.888	.897	.887	.941	.924	.911
14	.878	.902	.904	.937	.933	.929
16	.910	.919	.922	.965	.957	.954
18	.945	.968	.978	.998	1.001	1.015
20	.978	.997	.999	1.018	1.030	1.045
22	[illegible]	—	—	—	—	—

Table 8
Göt. 387 Bipland
G/C = 1.33

Stagger

$\alpha°$	-40%	0	60%
-8	1.898	.407	.875
-4	.712	.874	.849
0	.807	.895	.889
2	.826	.894	.896
6	.849	.894	.900
10	.865	.891	.902
14	.892	.923	.944
18	.941	.965	1.000
20	.954	.981	1.030
22	.902	.991	1.037

BIPLANE CORRECTION FACTORS FOR L_c AT EQUAL α

Table 9
U.S.A. 27 Biplane
$G/C = 1.67$

Stagger

$\alpha°$	-40%	-33%	0	33%	60%
-6	-.873	-.645	1.113	-.592	-.364
-4	.941	1.156	.718	1.156	1.336
-2	.902	.979	.826	1.100	1.045
0	.885	.866	.842	.915	.981
2	.874	.935	.835	.918	.971
4	.882	.940	.870	.922	.956
6	.888	.928	.859	.913	.940
8	.884	.925	.866	.913	.936
10	.894	.928	.878	.913	.938
12	.893	.926	.876	.919	.939
14	.900	.933	.887	.924	.947
16	.913	.948	.916	.954	.968
18	.953	.969	.970	.977	1.002
20	.933	.881	.998	.978	.997
22	———	———	———	———	———

Table 10
U.S.A. 27 Biplane
$G/C = 2.00$

Stagger

$\alpha°$	-40%	0%	60%
-6	.711	1.021	-.101
-4	1.072	1.208	1.540
-2	.961	1.010	1.115
0	.932	.961	1.015
2	.977	.933	1.003
4	.919	.962	.922
6	.917	.936	.963
8	.917	.933	.952
10	.919	.936	.956
12	.924	.929	.956
14	.922	.938	.950
16	.938	.956	.964
18	.966	.981	.995
20	.964	.989	.985
22	———	———	———

BIPLANE CORRECTION FACTORS FOR D_c AT EQUAL α

Table 11
U.S.A. 27 Biplane
G/C = 0.50

Stagger

$\alpha°$	-40%	0	60%
-6	1.230	.722	.758
-4	1.346	1.015	1.006
-2	1.341	1.141	1.168
0	1.210	1.137	1.233
2	1.065	1.107	1.236
4	.963	1.077	1.195
6	.901	1.019	1.170
8	.876	.963	1.166
10	.894	.954	1.156
12	.869	.931	1.159
14	.861	.929	1.170
16	.854	.886	1.228
18	.800	.795	1.239
20	.747	.723	1.232
22	____	.747	1.320

Table 12
Göt. 387
G/C = 0.75

Stagger

$\alpha°$	-40%	0	60%
-8	1.17	.871	.809
-4	1.21	1.11	1.13
0	1.10	1.08	1.18
2	1.07	1.04	1.16
6	.957	1.01	1.16
10	.924	.979	1.14
14	.940	.982	1.16
18	.915	.935	1.19
20	.951	.889	1.20
22	____	.846	1.29

Table 13
U.S.A. 27 Biplane
G/C - 0.75

Stagger

$\alpha°$	-40%	-20%	0	20%	40%	60%
-6	1.035	.950	.862	.741	.690	.740
-4	1.130	1.081	1.052	.972	.930	.971
-2	1.161	1.114	1.151	1.100	1.121	1.023
0	1.109	1.101	1.157	1.100	1.211	1.260
2	1.007	1.012	1.090	1.127	1.238	1.283
4	.972	.963	1.085	1.090	1.197	1.243
6	.930	.965	1.019	1.068	1.153	1.240
8	.919	.936	.979	1.018	1.138	1.218
10	.924	.933	.979	1.020	1.127	1.200
12	.933	.934	.979	1.006	1.109	1.211
14	.940	.941	.974	1.014	1.129	1.220
16	.920	.901	.964	.976	1.097	1.230
18	.880	.830	.880	.889	1.027	1.185
20	.823	.790	.819	.843	.985	1.141
22	____	.799	.845	.846	.964	1.198

BIPLANE CORRECTION FACTORS FOR D_c AT EQUAL α

Table 14
U.S.A. 27 - Biplane
G/C - 1.00

Stagger

α	-40%	-20%	0	20%	40%	60%
-6	1.044	.948	.887	.864	.798	.804
-4	1.093	1.091	1.052	1.031	.992	.991
-2	1.100	1.174	1.129	1.129	1.121	1.071
0	1.069	1.191	1.150	1.107	1.181	1.184
2	1.032	1.128	1.098	1.098	1.182	1.190
4	1.997	1.102	1.099	1.107	1.161	1.193
6	.992	1.080	1.071	1.091	1.116	1.171
8	.992	1.044	1.041	1.071	1.089	1.161
10	1.000	1.043	1.042	1.061	1.095	1.161
12	1.010	1.048	1.042	1.056	1.101	1.158
14	1.020	1.049	1.057	1.088	1.110	1.150
16	1.001	1.013	1.022	1.048	1.074	1.143
18	.948	.955	.940	.947	.990	1.082
20	.888	.901	.883	.908	.946	1.040
22	——	——	——	.925	——	——

Table 15
Göt. 387
G/C - 1.00

Stagger

α	-40%	-20%	0	20%	40%	60%
-8	1.13	.975	.997	1.14	.937	.876
-4	1.15	1.11	1.11	1.10	1.09	1.18
0	1.13	1.14	1.10	1.05	1.02	1.24
2	1.08	1.09	1.06	1.03	1.12	1.21
6	1.03	1.07	1.05	1.00	1.11	1.19
10	1.02	1.05	1.03	.997	1.09	1.17
14	1.03	1.05	1.02	1.02	1.12	1.18
18	.993	.994	.920	.993	1.08	1.15
20	.984	.962	.933	.931	1.02	1.07
22	——	——	.910	.897	.980	1.09

BIPLANE CORRECTION FACTORS FOR D_c AT EQUAL

Table 16
U.S.A. 27 Biplane
G/C - 1.33

Stagger

α	-40%	-20%	0	20%	40%	60%
-6	1.02	.935	.956	.816	.906	.989
-4	1.13	1.06	1.06	.984	1.05	1.11
-2	1.17	1.14	1.11	1.13	1.13	1.16
0	1.16	1.13	1.10	1.20	1.15	1.12
2	1.12	1.12	1.07	1.19	1.11	1.10
4	1.07	1.12	1.08	1.15	1.10	1.10
6	1.05	1.09	1.05	1.13	1.07	1.05
8	1.05	1.07	1.04	1.11	1.06	1.06
10	1.09	1.08	1.06	1.12	1.06	1.10
12	1.05	1.07	1.05	1.13	1.07	1.08
14	1.04	1.07	1.06	1.12	1.08	.925
16	1.03	1.07	1.06	1.07	1.05	1.06
18	.988	.975	1.03	.992	.965	.975
20	.935	.941	.920	.984	.940	.944

Table 17
Göt. 387 Biplane
G/C - 1.33

Stagger

α	-40%	0	60%
-8	1.26	.917	1.05
-4	1.12	1.11	1.12
0	1.06	1.13	1.11
2	1.03	1.11	1.08
6	1.02	1.08	1.07
10	1.02	1.07	1.07
14	1.02	1.07	1.10
18	.991	1.02	1.06
20	.947	.969	1.01
22	1.01	.935	.996

BIPLANE CORRECTION FACTORS FOR D_c AT EQUAL α

Table 18
U.S.A. 27 Biplane
G/C - 1.67

Stagger

α	-40%	-33%	0	33%	60%
-6	.955	.908	1.02	.886	.854
-4	1.01	1.03	1.06	1.02	1.00
-2	1.06	1.11	1.06	1.17	1.14
0	1.07	1.17	1.03	1.12	1.17
2	1.07	1.17	1.01	1.14	1.19
4	1.05	1.15	.996	.910	1.17
6	1.04	1.12	.974	1.07	1.13
8	1.04	1.11	.976	1.06	1.11
10	1.05	1.09	.990	1.05	1.10
12	1.04	1.13	1.00	1.06	1.11
14	1.10	1.05	1.01	1.06	1.12
16	1.03	1.06	.990	1.05	1.07
18	.950	.999	.910	.960	.981
20	.921	.969	.891	.941	.976

Table 19
U.S.A. 27 Biplane
G/C - 2.00

Stagger

α	-40%	0%	60%
-6	.920	.905	.796
-4	.990	.990	.936
-2	1.06	1.07	1.04
0	1.08	1.10	1.11
2	1.08	1.07	1.12
4	1.06	1.11	1.12
6	1.05	1.07	1.10
8	1.04	1.07	1.08
10	1.05	1.05	1.08
12	1.05	1.06	1.09
14	1.05	1.07	1.08
16	1.02	1.04	1.04
18	.954	.961	.980
20	.949	.955	.995

BIPLANE CORRECTION FACTORS FOR L/D at EQUAL α

Table 20
U.S.A. 27 Biplane
G/C - 0

Stagger

α	.50	.75	1.00	1.33	1.67	2.00
-6	.131	.440	.589	1.33	1.67	2.00
-4	1.10	.819	.819	.751	.585	1.11
-2	.757	.704	.901	.796	.775	.976
0	.709	.789	.763	.815	.837	.880
2	.692	.720	.777	.827	.820	.825
4	.718	.765	.791	.824	.764	.852
6	.756	.809	.809	.848	.884	.855
8	.796	.843	.839	.873	.904	.882
10	.799	.831	.829	.839	.882	.867
12	.809	.828	.824	.837	.868	.847
14	.812	.830	.826	.850	.874	.860
16	.868	.871	.870	.858	.918	.908
18	1.03	1.02	1.02	.950	1.06	.995
20	1.22	1.17	1.12	1.09	1.12	1.00
22	1.21	1.17	———	———	———	———

Table 21
U.S.A. 27 Biplane
G/C - 1.00

Stagger

α	-40%	-20%	0%	20%	40%	60%
-6	1.04	.649	.589	.440	.298	.238
-4	.524	.787	.819	.921	1.13	1.04
-2	.709	.735	.901	.814	.872	.960
0	.763	.740	.763	.804	.804	.830
2	.770	.747	.777	.804	.775	.774
4	.816	.790	.791	.810	.759	.780
6	.825	.797	.804	.805	.797	.795
8	.846	.844	.839	.841	.845	.814
10	.845	.834	.829	.832	.820	.804
12	.820	.825	.824	.825	.811	.803
14	.831	.837	.826	.821	.815	.812
16	.861	.877	.870	.877	.859	.837
18	.956	.984	1.02	1.04	1.01	.935
20	1.06	1.08	1.12	1.12	1.08	1.01
22	———	———	———	1.13	———	———

BIPLANE CORRECTION FACTORS FOR L/D AT EQUAL α

Table 23
Göt. 387 Biplane
G/C - 1.00

Stagger

α	-40%	-20%	0%	20%	40%	60%
-8	.916	.324	.518	.629	.204	.814
-4	.691	.785	.754	.690	.828	.880
0	.743	.755	.793	.770	.799	.779
2	.776	.790	.795	.805	.792	.785
6	.825	.806	.820	.847	.803	.784
10	.830	.819	.836	.860	.821	.799
14	.852	.843	.871	.872	.834	.820
18	.921	.936	.979	.987	.936	.896
20	.924	.960	1.03	1.07	.997	.930
22			1.08	1.15	1.08	.965

Table 22
Göt. 387 Biplane
G/C - .75

Stagger

α	-40%	0%	60%
-8	1.60	-.148	-1.12
-4	.597	.774	.874
0	.690	.754	.770
2	.739	.782	.782
6	.818	.807	.768
10	.845	.825	.793
14	.842	.853	.805
18	.934	.966	.856
20	.815	1.03	.855
22		1.12	.774

Table 24
Göt. 387 Biplane
G/C - 1.33

Stagger

α	-40%	0%	60%
-8	1.55	.491	.860
-4	.646	.800	.758
0	.756	.790	.766
2	.794	.799	.824
6	.832	.828	.837
10	.849	.831	.841
14	.873	.861	.860
18	.963	.961	.959
20	1.01	.997	1.02
22	.965	.981	1.04

Biplane Correction Factors for M_c at Equal α

TABLE 25

U.S.A. 27 Biplane

CAD/CHORD = .50

	STAGGER		
α	-40%	0%	60%
-6	1.19	1.53	.945
-4	.955	.975	.523
-2	.880	.816	.447
0	.831	.761	.411
2	.790	.721	.396
4	.764	.715	.389
6	.750	.704	.397
8	.735	.685	.402
10	.725	.683	.406
12	.734	.677	.417
14	.739	.673	.444
16	.770	.681	.514
18	.801	.681	.635
20	.754	.684	.711
22	--	.690	.795

TABLE 26

Göt. 387 Biplane

G/c = .75

	STAGGER		
α	-40%	0%	60%
-8	1.16	1.12	.790
-4	.905	.904	.788
0	.836	.850	.609
2	.827	.818	.589
6	.800	.813	.589
10	.754	.810	.620
14	.778	.826	.680
18	.825	.853	.781
20	--	.873	.825

TABLE 27

U.S.A. 27 Biplane

GAP/CHORD = .75

α	-40%	-20%	0%	20%	40%	60%
-6	1.17	1.29	1.45	1.54	1.54	1.12
-4	.913	.945	.929	.944	.919	.726
-2	.823	.879	.839	.848	.826	.648
0	.848	.862	.843	.816	.789	.625
2	.816	.824	.760	.811	.758	.604
4	.795	.833	.783	.800	.755	.596
6	.797	.858	.750	.790	.755	.641
8	.814	.830	.728	.774	.741	.625
10	.805	.817	.720	.757	.742	.656
12	.805	.800	.714	.770	.754	.649
14	.810	.831	.713	.770	.780	.664
16	.848	.846	.739	.788	.798	.724
18	.911	.875	.755	.810	.835	.789
20	.936	.909	.772	.854	.835	.828
22	--	.957	--	.849	--	--

Biplane Correction Factors for M_c at Equal α

TABLE 28

U.S.A. 27 Biplane

G/C = 1.00

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-6	1.05	1.33	1.34	1.76	1.51	1.55
-4	.951	1.04	1.02	.979	.958	.878
-1	.956	.992	1.03	.900	.852	.774
0	.930	.971	.936	.882	.805	.728
2	.901	.935	.929	.882	.788	.675
4	.896	.947	.943	.870	.759	.671
6	.923	.948	.935	.864	.784	.678
8	.899	.931	.920	.864	.755	.688
10	.899	.915	.916	.853	.754	.681
12	.900	.918	.921	.856	.764	.696
14	.921	.925	.942	.883	.776	.710
16	.960	.939	.961	.909	.795	.751
18	1.03	.980	.985	.924	.811	.792
20	1.10	1.10	1.00	.934	.832	.807

TABLE 29

Göt. 387 Biplane

G/C = 1.00

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-8	1.103	1.215	1.07	.975	1.10	.955
-4	.977	1.01	.958	.871	.866	.896
0	.941	.922	.905	.834	.816	.760
2	.915	.905	.880	.825	.790	.726
6	.895	.968	.870	.821	.784	.714
10	.893	.879	.871	.832	.800	.750
14	.917	.898	.895	.866	.846	.778
18	.974	.928	.911	.904	.889	.834
20	.990	.948	.923	.908	.893	.863

Biplane Correction Factors for M_c at Equal α

TABLE 30

U.S.A. 27 Biplane

G/C = 1.33

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-6	1.01	1.38	1.37	1.57	1.43	1.26
-4	.902	1.05	.987	1.05	.988	.925
-2	.921	1.02	.918	.980	.930	.862
0	.920	.988	.868	.925	.908	.827
2	.906	.972	.845	.929	.868	.785
4	.919	.998	.851	.919	.871	.795
6	.931	.989	.836	.915	.865	.778
8	.944	.968	.820	.903	.888	.773
10	.921	.961	.804	.903	.846	.767
12	.934	.970	.804	.918	.865	.780
14	.941	.987	.800	.924	.878	.816
16	.994	1.01	.851	.940	.897	.822
18	1.12	1.07	.864	.938	.899	.855
20	1.18	1.12	.843	.970	.878	.867

TABLE 31

Göt. 387 Biplane

G/C = 1.33

	STAGGER		
[illegible]	-40%	0%	60%
-8	.706	1.20	1.09
-4	.911	.950	.864
0	.809	.931	.818
2	.871	.903	.790
6	.871	.888	.775
10	.886	.891	.785
14	.915	.919	.847
18	.980	.943	.867
20	.998	.950	.879

Biplane Correction Factors for M_c at Equal

TABLE 32
U.S.A. 27 Biplane
$G/C = 1.67$

	STAGGER				
α	-40%	-33%	0%	33%	60%
-6	1.22	1.34	1.03	1.44	1.72
-4	1.02	1.07	.924	1.08	1.16
-2	.970	1.07	.922	1.03	1.06
0	.959	1.00	.914	.932	.994
2	.919	.969	.878	.946	.985
4	.919	.955	.895	.895	.948
6	.920	.984	.879	.873	.930
8	.905	.929	.875	.874	.917
10	.910	.913	.870	.855	.911
12	.915	.906	.871	.864	.920
14	.936	.916	.893	.871	.935
16	.973	.935	.915	.876	.936
18	1.03	.996	.947	.864	.940
20	1.11	1.03	.983	.859	.955

TABLE 33
U.S.A.27 Biplane
$G/C = 2.00$

	STAGGER		
α	-40%	0%	60%
-6	1.26	1.07	1.48
-4	1.03	1.19	1.03
-2	1.01	1.05	.976
0	.984	1.03	.947
2	.966	1.02	.934
4	.973	1.03	.933
6	.970	1.02	.929
8	.961	1.02	.926
10	.961	1.02	.927
12	.979	1.01	.946
14	.990		.961
16	1.03		.956
18	1.10		.976
20	1.13		.993

TABLE 34
(2 pages)

U.S.A. 27 Biplane

Combination of results obtained by testing each plane separately in the presence of the other.

G/C = 1.00 STAGGER = 0

α	L/D	$L_C \times 10^5$	$D_C \times 10^5$	C.P.	$M_C \times 10^5$	Loading on Upper and Lower Planes Lift		Drag	
						Upper	Lower	Upper	Lower
-6	-1.26	.016	.127	-.496	-.017	-.888	-.112	.543	.457
-4	2.24	.017	.076	1.662	-.027	.183	.817	.566	.434
-2	7.74	.048	.062	.708	-.034	.414	.586	.557	.443
0	12.02	.077	.064	.510	-.040	.460	.540	.500	.500
2	13.90	.107	.077	.440	-.048	.475	.525	.424	.516
4	14.01	.143	.102			.500	.500	.495	.505
6	12.61	.169	.134	.361	-.062	.505	.495	.495	.505
8	11.83	.199	.168			.508	.492	.503	.497
10	10.77	.226	.210	.329	-.075	.510	.490	.512	.488
12	9.85	.255	.259			.515	.485	.514	.486
14	9.04	.282	.312	.304	-.085	.516	.484	.541	.459
16	8.44	.306	.363			.523	.477	.552	.448
18	7.58	.325	.429	.287	-.093	.529	.471	.568	.432
20	6.78	.329	.485			.542	.458	.522	.478

-continued on next page -

TABLE 34
(concluded from previous page)

U.S.A. 27 Biplane

Combination of results obtained by testing each plane separately in the presence of the other.

G/C = 1.67 STAGGER = 0

α	L/D	$L_0 \times 10^5$	$D_0 \times 10^5$	C.P.	$M_0 \times 10^5$	Loading on Upper and Lower Planes Lift		Drag	
						Upper	Lower	Upper	Lower
-6	-1.82	-.022	.121	-.776	-.016	-.607	-.393	.440	.560
-4	3.71	.026	.070	1.188	-.030	.602	.398	.465	.535
-2	9.36	.058	.062	.645	-.038	.544	.456	.480	.520
0	13.79	.091	.066	.493	-.045	.536	.464	.493	.507
2	15.18	.126	.083	.422	-.054	.533	.467	.500	.500
4	14.86	.162	.109			.530	.470	.514	.486
6	13.36	.191	.143	.368	-.071	.530	.470	.521	.479
8	12.40	.223	.180	.		.530	.470	.540	.460
10	11.29	.256	.227	.330	-.084	.534	.466	.550	.450
12	10.15	.284	.280			.530	.470	.560	.440
14	9.35	.314	.336	.316	-.098	.536	.464	.566	.434
16	8.57	.337	.393			.537	.463	.573	.427
18	7.74	.351	.454			.546	.454	.570	.430
20	6.16	.343	.556	.315	-.108	.550	.450	.550	.450

Lift Coefficients (L_cx 10^5) for U.S.A. 27 Biplanes

TABLE 35

G/C = 0.50

α	STAGGER -40%	0%	60%
-6	24	2	1
-4	11	27	29
-2	40	53	61
0	65	77	90
2	93	105	122
4	120	134	152
6	145	160	184
8	170	183	216
10	195	209	244
12	219	233	274
14	241	253	298
16	260	272	320
18	264	283	328
20	252	293	327
22	--	286	320

TABLE 36

G/C = 0.75

α	STAGGER -40%	-20%	0%	20%	40%	60%
-6	- 19	-14	-8	- 2	7	4
-4	14	16	21	27	33	34
-2	44	45	50	57	65	67
0	69	69	88	86	96	98
2	102	102	108	121	127	117
4	130	132	144	149	158	161
6	159	165	171	179	189	195
8	188	189	196	204	215	227
10	216	215	223	230	246	255
12	242	242	250	241	273	284
14	263	267	271	280	300	303
16	281	286	297	302	323	332
18	287	298	309	318	332	342
20	285	299	318	322	333	341
22	--	289	314	320	326	339

Lift Coefficients ($L_c \times 10^5$) for U.S.A. 27 Biplane

TABLE 37
G/C = 1.00

			STAGGER			
α	-40%T	-20%	0%	20%	40%	60%
-6	-23	-12	-11	-8	-5	-4
-4	14	21	21	23	27	25
-2	48	53	62	56	60	61
0	78	85	84	86	91	94
2	110	116	118	122	126	127
4	141	150	150	155	153	161
6	171	180	181	183	186	194
8	200	219	208	214	217	225
10	232	238	237	242	247	256
12	257	268	266	270	277	288
14	284	294	293	299	304	313
16	305	314	314	325	327	339
18	314	325	333	340	345	351
20	312	322	--	339	340	349

TABLE 38
G/C = 1.33

	~~-40%~~	~~-20~~	STAGGER			
α	-40%	-20%	0%	20%	40%	60%
-6	-19	-13	-15	-4	-12	-18
-4	17	21	20	29	22	17
-2	52	56	54	63	56	53
0	83	87	85	96	89	85
2	118	121	121	130	124	120
4	150	157	155	164	158	155
6	183	188	186	195	192	185
8	215	217	216	225	220	218
10	245	245	244	257	252	247
12	272	275	273	289	283	279
14	293	301	302	313	311	310
16	318	321	323	337	334	333
18	326	334	337	344	345	351
20	325	331	333	338	342	347

Lift Coefficients ($L_c \times 10^5$) for U.S.A. 27 Biplane

TABLE 39

G/C = 1.67

	STAGGER				
α	-40%	-33%	0%	33%	60%
-6	-17	-12	-21	-11	-7
-4	20	24	15	24	28
-2	55	60	50	67	64
0	87	85	83	90	96
2	120	128	114	126	133
4	153	163	151	159	165
6	186	194	179	191	196
8	215	224	210	222	227
10	246	255	241	251	258
12	274	284	269	282	288
14	300	311	296	308	316
16	319	331	321	333	338
18	329	334	335	337	346
20	309	326	333	324	331

TABLE 40

G/C = 2.00

	STAGGER		
α	-40%	0%	60%
-6	-14	-19	-2
-4	23	25	32
-2	59	62	68
0	91	94	99
2	126	128	138
4	159	166	160
6	197	196	201
8	223	227	231
10	252	258	263
12	274	285	293
14	308	313	317
16	328	335	337
18	333	338	343
20	320	331	327

Lift Coefficients ($L_c \times 10^5$) for U.S.A. 27 Biplane

TABLE 41

			STAGGER = 0			
			GAP/CHORD			
α	.50	.75	1.00	1.33	1.67	2.00
-6	2	-8	-11	-15	-21	-19
-4	27	21	21	20	15	25
-2	53	50	62	54	50	62
0	77	88	84	85	83	94
2	105	108	118	121	114	128
4	134	144	150	155	151	166
6	160	171	181	186	179	196
8	183	196	208	216	210	227
10	209	223	237	244	240	258
12	233	250	266	273	269	285
14	253	271	293	302	296	313
16	272	297	314	323	321	335
18	283	309	333	337	335	338
20	293	318	330	333	333	331

Drag Coefficients ($D_c \times 10^6$) for U.S.A. 27 Biplane

TABLE 42

G/C = 0.50

	STAGGER		
α	-40%	0%	60%
-6	155	91	96
-4	96	72	71
-2	76	65	67
0	74	69	75
2	82	85	95
4	98	110	122
6	122	137	158
8	152	167	202
10	187	206	250
12	228	245	305
14	270	291	367
16	314	326	451
18	370	368	572
20	420	406	693
22		492	870

TABLE 43

G/C = 0.75

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-6	130	119	108	93	87	93
-4	80	77	75	69	66	69
-2	66	64	66	63	64	58
0	68	67	71	67	74	77
2	78	78	84	87	95	99
4	99	98	111	111	122	127
6	126	130	137	144	156	167
8	159	162	169	176	197	211
10	199	202	211	220	243	259
12	246	246	257	265	292	319
14	294	295	305	318	353	382
16	339	332	355	359	404	453
18	407	384	407	411	475	548
20	462	444	460	474	554	641
22		526	557	557	635	789

Drag Coefficients ($D_c \times 10^6$) for U.S.A. 27 Biplane

TABLE 44

G/C = 1.00

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-6	132	119	111	108	100	100
-4	78	78	75	73	70	70
-2	63	67	64	64	64	61
0	65	73	70	68	72	72
2	80	87	85	85	91	92
4	102	112	112	113	119	122
6	134	146	145	147	151	158
8	172	181	180	185	188	201
10	216	225	225	229	237	251
12	266	276	274	278	290	305
14	319	328	331	340	348	360
16	369	373	376	386	396	421
18	438	491	435	438	458	501
20	499	506	496	510	532	584

TABLE 45

G/C - 1.33

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-6	129	118	120	103	114	124
-4	80	76	75	70	75	79
-2	66	65	63	65	65	66
0	71	69	67	73	69	69
2	86	86	82	92	86	85
4	109	114	111	117	112	112
6	142	147	142	152	146	141
8	182	184	180	192	183	183
10	235	233	229	243	230	238
12	275	281	277	296	282	285
14	327	334	332	351	338	344
16	380	385	392	396	388	389
18	456	451	474	459	445	450
20	525	529	517	551	529	530

Drag Coefficients ($D_c \times 10^5$) for U.S.A. 27 Biplane

TABLE 46

G/C = 1.67

	STAGGER				
α	-40%	-33%	0%	33%	60%
-6	120	114	129	112	107
-4	72	73	75	72	71
-2	62	63	60	67	65
0	65	71	63	68	71
2	82	90	78	88	92
4	107	117	102	112	119
6	140	151	131	145	152
8	180	192	169	184	192
10	227	234	214	226	238
12	273	296	263	278	291
14	330	345	316	333	350
16	381	389	364	386	393
18	439	461	421	444	454
20	520	544	503	529	549

TABLE 47

G/C = 2.00

	STAGGER		
α	-40%	0%	60%
-6	116	114	100
-4	70	70	66
-2	60	61	59
0	66	67	68
2	83	82	87
4	108	113	115
6	142	145	148
8	180	185	187
10	228	228	234
12	277	279	286
14	329	334	340
16	377	382	384
18	440	444	454
20	533	537	559

Lift Drag Ratios for U.S.A. 27 Biplane

TABLE 48

			STAGGER=0%			
			GAP/CHORD			
α	.50	.75	1.00	1.33	1.67	2.00
-6	.22	-.74	-.99	-1.25	-1.63	-1.90
-4	3.75	2.80	2.80	2.67	2.00	3.79
-2	8.15	7.58	9.70	8.56	8.34	10.50
0	11.15	12.40	12.00	12.70	13.17	13.81
2	12.35	12.85	13.89	14.76	14.61	14.71
4	12.17	12.98	13.40	13.96	14.80	14.42
6	11.69	12.49	12.48	13.10	13.67	13.21
8	10.95	11.59	11.53	12.00	12.41	12.13
10	10.14	10.56	10.52	10.65	11.20	11.01
12	9.51	9.74	9.70	9.86	10.21	9.97
14	8.70	8.89	8.85	9.10	9.36	9.21
16	8.34	8.36	8.35	8.24	8.81	8.73
18	7.69	7.60	7.65	7.11	7.95	7.45
20	7.21	6.90	6.65	6.44	6.62	5.93
22	5.81	5.64				

TABLE 49

			G/C = 1.00			
			STAGGER			
α	-40%	-20%	0%	20%	40%	60%
-6	-1.74	-1.09	-.99	-.74	-.50	-.40
-4	1.79	2.69	2.80	3.15	3.86	3.57
-2	7.62	7.91	9.70	8.75	9.38	10.00
0	12.00	11.64	12.00	12.63	12.63	13.04
2	13.74	13.32	13.89	14.35	13.84	13.80
4	13.81	13.39	13.40	13.71	12.85	13.20
6	12.76	12.31	12.49	12.43	12.31	12.28
8	11.62	11.60	11.53	11.57	11.51	11.20
10	10.72	10.59	10.52	10.57	10.41	10.20
12	9.65	9.71	9.70	9.71	9.55	9.46
14	8.90	8.96	8.85	8.80	8.74	8.70
16	8.26	8.42	8.35	8.41	8.25	8.04
18	7.16	7.36	7.65	7.76	7.53	7.00
20	6.26	6.36	6.65	6.65	6.39	5.98
22				5.42		

Moment Coefficients (M_c x 10^5) for U.S.A.27 Biplanes

All of the following values denote diving moments, and should be prefixed by a minus sign.

TABLE 50

G/C = 0.50

	STAGGER		
α	-40%	0%	60%
-6	18	23	14
-4	27	27	15
-2	33	31	17
0	37	34	19
2	43	40	22
4	49	46	25
6	54	51	29
8	59	55	32
10	63	69	35
12	69	64	39
14	74	67	44
16	79	70	53
18	84	72	67
20	80	73	75
22		73	84

TABLE 51

G/C = 0.75

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-6	17	19	22	23	23	17
-4	26	26	26	26	26	20
-2	31	33	32	32	31	25
0	38	39	38	37	35	28
2	45	45	42	45	42	33
4	51	53	50	51	48	38
6	57	62	54	57	54	46
8	65	66	57	62	59	50
10	70	71	63	66	65	57
12	76	75	67	72	71	61
14	81	83	71	77	78	66
16	87	87	76	81	82	75
18	96	92	79	85	88	83
20	99	96	82	91	89	88
22		101		90		

Moment Coefficients ($M_c \times 10^5$) for U.S.A. 27 Biplane

All of the following values denote diving moments, and should be prefixed by a minus sign.

TABLE 52

G/C = 1.00

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-6	16	20	20	26	23	23
-4	27	29	29	27	27	25
-2	36	38	39	34	32	29
0	42	44	42	40	36	33
2	50	51	51	49	43	37
4	57	61	60	56	49	43
6	66	68	67	62	56	49
8	72	75	74	69	60	55
10	78	80	80	74	56	59
12	85	86	87	80	72	65
14	92	93	94	88	78	71
16	99	97	99	94	82	78
18	109	103	103	97	85	83
20	117	117	106	99	88	86

TABLE 53

G/C = 1.33

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-6	15	21	21	24	21	19
-4	25	29	28	29	28	26
-2	35	39	35	37	35	33
0	41	44	39	42	41	37
2	50	53	47	51	48	43
4	59	64	54	59	56	51
6	67	71	60	66	62	56
8	75	77	66	72	71	62
10	80	84	70	79	74	67
12	88	91	76	86	81	73
14	94	99	80	92	88	82
16	99	104	88	97	93	85
18	117	112	91	98	94	90
20	125	119	89	103	93	92

Moment Coefficients ($M_c \times 10^5$) for U.S.A. 27 Biplane

All of the following values denote diving moments, and should be prefixed by a minus sign.

TABLE 54

G/C=1.67

	STAGGER				
α	-40%	-33%	0%	33%	60%
-6	18	20	15	22	26
-4	29	30	26	30	33
-2	37	40	35	39	40
0	43	45	41	42	45
2	51	53	48	52	54
4	59	61	57	57	61
6	66	71	63	63	67
8	72	74	70	70	73
10	79	79	76	74	79
12	86	85	82	81	87
14	94	92	89	87	94
16	100	96	94	90	97
18	109	105	100	91	99
20	117	110	104	91	101

TABLE 55

G/C = 2.00

	STAGGER		
α	-40%	0%	60%
-6	19	16	22
-4	29	33	29
-2	38	40	37
0	44	47	43
2	53	56	51
4	62	66	60
6	70	73	67
8	77	81	74
10	84	89	81
12	92	95	89
14	99		96
16	106		99
18	116		102
20	119		105

Center of Pressure Coefficients for U.S.A. 27 Biplanes

TABLE 56

G/C = 0.50

	STAGGER		
α	-40%	0%	60%
-4	2.32	.93½	.47
-2	.83	.58	.27½
0	.58	.45	.21
2	.47	.37½	.17½
4	.40½	.33½	.15½
6	.37	.31	.14
8	.34	.29½	.13½
10	.32½	.28	.13½
12	.31½	.27	.13½
14	.30½	.27	.14½
16	.31	.26	.15
18	.32½	.24½	.20
20	.31½	.25	.22½

TABLE 57

G/C - 0.75

			STAGGER			
α	-40%	-20%	0%	20%	40%	60%
-4	1.73½	1.52	1.15	.90½	.72	.55
-2	.69½	.71½	.62	.55½	.47	.36
0	.53½	.54	.44	.44	.38	.29½
2	.44	.44½	.38½	.37	.32½	.25
4	.39	.40	.34½	.34	.30½	.23½
6	.35½	.37½	.31½	.31½	.28½	.22½
8	.34	.35	.29½	.30	.27½	.22
10	.32½	.34	.28½	.29	.26½	.22½
12	.31½	.32	.27	.28	.26	.22
14	.30½	.32	.26½	.27½	.26	.21½
16	.31½	.31½	.26	.27	.25½	.22
18	.34	.32	.26	.27	.26½	.24
20	.35½	.33½	.26	.27	.26	.25½

Center of Pressure Coefficients for U.S.A. 27 Biplane

TABLE 58

G/C = 1.00

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-4	1.80	1.29½	1.25	1.09	.91	.90
-2	73½	69	.61½	.59½	.52½	.47
0	54½	52½	.51½	.47	.41	.35½
2	45½	44	.43½	.40	.34½	.29
4	40½	40	.40	.35½	.31½	.27
6	38	37	.36½	.33	.29½	.24½
8	36	35	.35	.32	.27½	.24
10	34	34	.33½	.31	.26½	.23½
12	33½	33	.33	.30	.26	.23
14	33	32	.32½	.29½	.25½	.23
16	33	31½	.32	.29	.25	.23
18	35	32½	.31	.29	.25	.24
20	37	33½	.32½	.29½	.26	.24½

TABLE 59

G/C = 1.33

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-4	1.37	1.27	1.27	.93	1.18	1.44
-2	.66	.67	.63	.57½	.61	.60½
0	.50½	.52	.47	.44½	.47	.45
2	.42½	.44½	.38½	.39	.38½	.37
4	.38½	.40½	.35	.36	.35½	.33
6	.36	.37	.32	.33	.32	.29½
8	.33½	.35½	.30	.32	.32	.28
10	.32½	.34½	.29	.31	.29½	.27
12	.32½	.33½	.28	.30	.29	.26½
14	.32	.32½	.27½	.29½	.28½	.26
16	.32½	.32½	.27½	.29	.28	.25½
18	.36	.34	.27	.29½	.27½	.26
20	.38½	.36	.27	.29½	.27½	.26½

Center of Pressure Coefficients for U.S.A. 27 Biplane

TABLE 60

G/C = 1.67

	STAGGER				
α	-40%	-33%	0%	33%	60%
-4	1.34	1.14	1.60	1.15	1.06
-2	.65½	.66½	.68	.57	.61½
0	.51	.49½	.51	.47½	.47½
2	.42	.41½	.42½	.31½	.40½
4	.38½	.37½	.38	.36	.36½
6	.35	.36	.34½	.32½	.33½
8	.34	.33	.33	.31½	.32
10	.33	.31½	.32	.30	.31
12	.32	.39½	.31	.29	.30½
14	.31½	.29½	.30½	.28½	.30
16	.32	.29½	.30	.27½	.29
18	.34	.32	.30	.27	.29

TABLE 61

G/C = 2.00

	STAGGER		
α	-40%	0%	60%
-4	1.18	1.21	.82
-2	.63½	.63	.53
0	.49½	.50½	.44
2	.42½	.44	.37½
4	.39	.39½	.35
6	.36	.37	.33
8	.34	.35½	.32
10	.33½	.34½	.31
12	.33	.34	.31
14	.32½	.33½	.30½
16	.33	.34	.30
18	.35	.36	.30½

Lift Coefficients ($L_c \times 10^5$) for Göt. 387 Biplane

TABLE 62

Göt. 387 Biplane
G/C = .75

	STAGGER		
α	-40%	0%	60%
-8	-29	2	14
-4	41	49	56
0	101	108	121
2	136	139	156
6	192	200	219
10	249	258	288
14	302	311	348
18	333	352	397
20	306	361	406
22	--	365	385

TABLE 64

Göt. 387 Biplane
G/C = 1.33

	STAGGER		
α	-40%	0%	60%
-8	-30	-7	-14
-4	41	50	48
0	106	118	112
2	141	152	153
6	208	220	221
10	277	285	288
14	332	343	351
18	371	380	394
20	377	387	407
22	348	383	400

TABLE 63

Göt. 387 Biplane
G/C = 1.00

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-8	-16	-4	-8	-17	-3	-11
-4	45	49	47	43	51	58
0	111	114	116	108	118	127
2	144	148	145	143	152	163
6	210	213	211	208	220	229
10	271	274	275	274	287	298
14	327	328	331	332	347	359
18	356	363	370	381	392	403
20	359	365	381	392	403	416
22			379	397	407	405

Drag Coefficients ($D_c \times 10^6$) for Göt. 387 Biplanes.

TABLE 65

G/C = .75

	STAGGER		
α	-40%	0%	60%
-8	168	124	116
-4	80	74	75
0	96	94	103
2	116	112	126
6	170	179	206
10	253	268	312
14	367	373	442
18	461	471	600
20	566	530	716
22	-	604	921

TABLE 67

G/C = 1.33

	STAGGER		
α	-40%	0%	60%
-8	180	131	150
-4	74	73	74
0	92	98	96
2	112	120	117
6	181	192	191
10	280	294	294
14	389	407	417
18	499	512	532
20	565	577	603
22	668	724	711

TABLE 66

G/C = 1.00

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-8	162	139	143	163	134	125
-4	76	73	73	73	72	78
0	98	99	96	97	89	107
2	117	118	115	112	121	131
6	184	191	186	178	198	211
10	280	287	282	273	300	320
14	392	398	388	389	425	448
18	500	501	489	500	542	581
20	586	574	556	555	610	675
22			650	640	700	778

Lift Drag Ratios for Göt. 387 Biplanes

TABLE 69

			G/C = 1.00			
			STAGGER			
α	-40%	-20%	0%	20%	40%	60%
-8	−.99	−.35	−.56	−.68	−.22	−.88
-4	5.92	6.71	6.45	5.90	7.09	7.53
0	11.31	11.50	12.09	11.74	13.27	11.88
2	12.30	12.53	12.61	12.77	12.57	12.43
6	11.40	11.16	11.33	11.70	11.10	10.84
10	9.69	9.55	9.75	10.02	9.57	9.31
14	8.34	8.25	8.53	8.54	8.16	8.02
18	7.11	7.24	7.56	7.62	7.24	6.93
20	6.12	6.36	6.85	7.06	6.60	6.16
22	-	-	5.83	6.20	5.81	5.21

TABLE 68

		G/C = .75	
		STAGGER	
α	-40%	0%	60%
-8	-1.73	.16	1.21
-4	5.11	6.62	7.47
0	10.51	11.49	11.72
2	11.71	12.40	12.39
6	11.30	11.18	10.61
10	9.85	9.63	9.24
14	8.24	8.35	7.88
18	7.21	7.46	6.61
20	5.40	6.81	5.67
22	-	6.05	4.18

TABLE 70

		G/C = 1.33	
		STAGGER	
α	-40%	0%	60%
-8	-1.67	-.53	-.93
-4	5.54	6.85	6.49
0	11.52	12.03	11.69
2	12.59	12.68	13.08
6	11.50	11.45	11.58
10	9.90	9.70	9.80
14	8.54	8.43	8.41
18	7.44	7.42	7.40
20	6.68	6.60	6.76
22	5.21	5.30	5.62

Moment Coefficients ($M_c \times 10^5$) for Göt. 387 Biplanes.

All the following values denote diving moments
and should be prefixed by a minus sign.

TABLE 72

	G/C = 1.00					
	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-8	21	23	20	19	21	18
-4	39	40	38	35	35	36
0	57	55	54	50	49	96
2	63	62	61	57	55	50
6	79	85	77	72	69	63
10	96	94	93	89	86	80
14	108	106	106	102	100	92
18	121	115	113	112	110	103
20	125	119	116	114	113	108

TABLE 71

	G/C = .75		
	STAGGER		
α	-40%	0%	60%
-8	22	21	15
-4	36	36	32
0	50	51	37
2	57	56	41
6	70	71	52
10	81	87	66
14	92	98	80
18	102	106	97
20	--	110	104

TABLE 73

	G/C = 1.33		
	STAGGER		
α	-40%	0%	60%
-8	14	23	21
-4	36	38	35
0	52	56	49
2	60	62	55
6	77	78	68
10	95	95	89
14	108	108	100
18	121	117	107
20	126	120	111

Center of Pressure Coefficients for Göt. 387 Biplanes.

TABLE 74

G/C = 0.75

	STAGGER		
α	-40%	0%	60%
-8	-2.77	-71.78	-2.88
-4	.80	.66½	.42½
0	.47½	.45	.29
2	.41½	.40	.25½
6	.36	.35½	.23
10	.32	.33	.22½
14	.30½	.31	.23
18	.31	.30½	.24½
20	-	-	.26
22	-	.32	-

TABLE 76

G/C = 1.33

	STAGGER		
α	-40%	0%	60%
-8	-1.16	-15.32	-4.50
-4	.80	.68	.63½
0	.47	.45½	.40
2	.42	.40½	.35
6	.36½	.35	.30½
10	.34	.33	.28½
14	.33½	.31½	.27½
18	.33½	.31	.27½
20	.34½	.31½	.27½
22	-	.32½	.28½

TABLE 75

G/C = 1.00

	STAGGER					
α	-40%	-20%	0%	20%	40%	60%
-8	-2.39	-7.40	-2.03	-1.93	-7.59	-3.02
-4	.77	.72	.72	.72	.60½	.55
0	.48½	.46½	.46½	.44½	.40	.34½
2	.43½	.42	.41½	.39½	.35	.30
6	.37½	.35½	.36	.34½	.31½	.26½
10	.34½	.33½	.33½	.32	.29½	.25½
14	.33½	.32½	.32	.31	.29½	.25½
18	.35	.32	.31	.30	.29½	.26
20	.35½	.33	.31½	.30	.28½	.26½
22	-	-	.32½	.30½	.29½	.28

Biplane Correction Factors for D_0 at Equal L_0.

TABLE 89

U.S.A.27 Biplane

G/C = 1.00

		STAGGER						
C_L	$L_0 \times 10^5$	-40%	-20%	0%	20%	40%	60%	Average
.2	.051	1.07	1.12	1.12	1.12	1.15½	1.12	1.12
.4	.102	1.21	1.22½	1.21	1.24	1.21	1.21	1.22
.6	.153	1.25	1.30½	1.30½	1.27½	1.30	1.26	1.28
.8	.205	1.32	1.33½	1.32	1.30	1.30	1.30	1.31
1.0	.256	1.37	1.32½	1.31½	1.29	1.30½	1.30½	1.32
1.2	.307	-	1.36	1.34	1.30	1.32	1.32	1.33
1.3	.333	-	-	1.35½	1.31	1.32½	1.31	1.32½

TABLE 90

Göt. 387 Biplane

G/C = 1.00

		STAGGER						
C_L	$L_0 \times 10^5$	-40%	-20%	0%	20%	40%	60%	Average
.2	.051	1.31	1.26	1.24	1.26	1.26	1.38	1.26½
.4	.102	1.50	1.50	1.50	1.45	1.42	1.53	1.48½
.6	.153	1.43	1.44	1.43	1.40	1.43	1.45	1.43
.8	.205	1.35	1.37	1.37	1.34½	1.37	1.37	1.36½
1.0	.256	1.33	1.34½	1.33½	1.31	1.33	1.33	1.33
1.2	.307	1.31½	1.32	1.28½	1.26½	1.28	1.28½	1.29
1.4	.358	-	-	1.45	1.41½	1.45	1.42	1.43½

Biplant Correction Factors for D_c at Equal L_c.

TABLE 91

U.S.A. 27 Biplane

Stagger = 0

		GAP/CHORD					
C_L	$L_c \times 10^5$	.50	.75	1.00	1.33	1.67	2.00
0	0	1.14	1.03½	1.03½	1.06½	1.03½	1.01
.2	.051	1.12	1.08½	1.08½	1.08½	1.03½	1.12
.4	.102	1.30	1.25	1.25	1.17	1.17	1.12
.6	.153	1.45½	1.37	1.30	1.22	1.21	1.14
.8	.205	1.49	1.38	1.31	1.24½	1.22	1.17
1.0	.256	1.54	1.41½	1.27½	1.27	1.25	1.21
1.2	.307	-	1.50	1.35	1.29	1.27	1.21
1.3	.333	-	-	1.78	1.32½	1.32½	1.21½

TABLE 92

Göt. 387 Biplane

Stagger = 0

		GAP/CHORD		
C_L	$L_c \times 10^5$	0.75	1.00	1.33
.2	.051	1.12	1.08½	1.08½
.4	.102	1.20	1.20	1.20
.6	.153	1.31	1.26½	1.26½
.8	.205	1.40	1.32½	1.29
1.0	.256	1.41	1.32½	1.31
1.2	.307	1.44	1.33½	1.31½
1.4	.358	1.45	1.31½	1.30

Biplane Correction Factors for D_C Minimum

TABLE 93

U.S.A. 27 Biplane

	GAP/CHORD					
Stagger	**0.50**	**0.75**	**1.00**	**1.33**	**1.67**	**2.00**
60%	1.17½	1.02	1.07	1.10½	1.14	1.03½
40%		1.12	1.12	1.14		
20%		1.10½	1.12	1.14		
0%	1.14	1.16	1.12	1.10½	1.05	1.07
-20%		1.12½	1.17½	1.14		
-40%	1.30	1.16	1.10½	1.16	1.09	1.05
Average of Tables 93 and 94	1.20½	1.12½	1.12	1.13	1.11	1.05

TABLE 94

Göt. 387 Biplane

	GAP/CHORD		
Stagger	**0.75**	**1.00**	**1.33**
60%	1.13½	1.18	1.12
40%		1.09	
20%		1.10½	
0%	1.12	1.10½	1.10½
-20%		1.10½	
-40%	1.21	1.15	1.12

Biplane Correction Factors for L/D max.

TABLE 94

U.S.A. 27 Biplane

	GAP/CHORD					
Stagger	0.50	0.75	1.00	1.33	1.67	2.00
60%	.72½	.75	.78½	.80½	.82	.89½
40%		.76	.78	.82		
20%		.79	.82	.80½	.81½	
0%	.70	.73½	.79½	.83	.83½	.88½
-20%		.75	.78	.80	.81	
-40%	.68½	.75	.78	.77½	.82½	.86
Average for U.S.A. 27 & Göt. 387	.70½	.76	.78½	.80½	.82	.88

TABLE 95

Göt. 387 Biplane

Stagger	0.75	1.00	1.33
60%	.78	.78	.82
40%		.80	
20%		.80	
0%	.77	.79	.80
-20%		.78	
-40%	.73½	.77	.79

Table 95a

Biplane Correction Factors for L_c max.

	Gap/Chord					
Stagger	0.50	0.75	1.00	1.33	1.67	2.00
		U.S.A. 27 Biplane				
60%	.94	.98	1.00	1.00	.99	.98
40%		.95	.98½	.98½		
20%		.92	.97	.98½		
0%	.83½	.91	.95	.96½	.96	.97½
-20%		.85½	.93	.95½		
-40%	.75½	.82	.89½	.93	.94	.95
		Göt. 387 Biplanes				
60%		1.03	1.05½	1.03		
40%			1.03			
20%			1.00½			
0%		.92½	.96½	.98		
-20%			.92½			
-40%		.84½	.91	.95½		

Biplane Correction Factors for L/D at Equal L_c.

TABLE 96

U.S.A. 27 Biplane

		STAGGER = 0					
		GAP/CHORD					
C_L	L_cx 10^5	0.50	0.75	1.00	1.33	1.67	2.00
.2	51	.92	.93½	.95	.95	.96½	.96½
.4	102	.77	.79	.81	.84½	.88	.89½
.6	153	.69	.73	.77	.82	.83	.87½
.8	205	.67	.72½	.76	.80½	.82	.85½
1.0	256	.65	.70	.74½	.78½	.80	.83
1.2	307		.66½	.74	.77½	.79	.82½
1.3	333				.75½	.75½	.82½

TABLE 97

Göt. 387 Biplane

		STAGGER = 0		
		GAP/CHORD		
C_L	L_cx 10^5	0.75	1.00	1.33
.2	51	.89½	.92	.92
.4	102	.83½	.83½	.83½
.6	153	.76½	.79	.79
.8	205	.71½	.75½	.77½
1.0	256	.71	.75½	.76½
1.2	307	.69½	.75	.76
1.4	358	.69	.76	.77

Biplane Correction Factors for M_c at Equal L_c.

TABLE 100

U.S.A.27 Biplane
G/C = 1.00

C_L	$L_c \times 10^5$	Stagger 0%	20%	40%	60%
.2	51	1.02½	.91½	.83½	.78
.4	102	1.00	.95½	.82½	.74
.6	153	1.03½	.95	.83	.69½
.8	205	1.03	.94½	.83	.72
1.0	256	1.03½	.94	.83	.72
1.2	307	1.04	.96	.83	.73½
Average		1.02½	.94½	.83	.73

TABLE 101

Göt. 387 Biplane
G/C = 1.00

C_L	$L_c \times 10^5$	Stagger 0%	20%	40%	60%
.2	51	1.00	.95	.90	.87
.4	102	.98	.94½	.88½	.84½
.6	153	.97	.91	.84½	.75½
.8	205	.97½	.91	.84½	.74½
1.0	256	.97	.92½	.84½	.76
1.2	307	.98	.93	.88½	.79½
1.4	358	.95	.92½	.88	.79½
Average		.97½	.93	.85½	.79½

Correction Factors for negative stagger: For U.S.A. 27, these practically coincide with the values for zero stagger; for Göt. 387, they are practically equal to 1.00.

TABLE 101a

(1) Average for U.S.A. 27 & Göt. 387, combined.
(2) Corresponding values taken from a smooth curve (Plate 14)

Stagger	-40%	-20%	0%	20%	40%	60%
(1)	1.00	1.00	1.00	.93½	.84	.76
(2)	1.00	1.00	.98	.93½	.84	.76

Biplane Correction Factors for M_o at Equal L_o.

TABLE 102

U.S.A. 27 Biplane
G/C = 1.00

C_L	L_ox 100^5	GAP/CHORD .50	.75	1.00	1.33	1.67	2.00
.2	51	.86	.90	1.02½	.97½	1.00	1.07
.4	102	.85	.89	1.00	.92½	.98	1.06½
.6	153	.84½	.88	1.03½	.91½	.97½	1.07½
.8	205	.82½	.84½	1.03	.90	.97½	1.06½
1.0	256	.81½	.83	1.03½	.88	.96	1.07½
1.2	307	-	.84	1.04	.88½	.97½	-
Average		.84	.86½	1.02½	.91½	.98	1.07

TABLE 103

Got. 387, Biplane
G/C = 1.00

C_L	L_ox 10^5	GAP/CHORD .75	1.00	1.33
.2	51	.96	1.00	.98
.4	102	.95½	.98	1.00
.6	153	.91	.97	.96
.8	205	.93	.97½	.95
1.0	256	.95½	.97	.97
1.2	307	.94	.98	.98
1.4	358	.93½	.95	.96
Average		.94	.97½	.97

TABLE 103a

(1) Averages for U.S.A. 27 & Göt. 387 combined.
(2) Corresponding Values taken from a smooth curve(Plate 14)

G/C	0.50	0.75	1.00	1.33	1.67	2.00
(1)	.84	.90½	1.00	.94½	.98	1.07
(2)	.87	.93	.97½	.98½	.99½	1.00

Biplane corrections for C.P., expressed as fractions of chord by which C.P. is displaced towards leading edge, applicable from 0.1 L_c max. to L_c max.

TABLE 108

G/C = 1.00

(1) Average of Göt. 387 and U.S.A. 27.
(2) Average taken from curve (Plate 14).

Stagger	Göt. 387	U.S.A. 27	(1)	(2)
-40%	.00	-.01¼	-.00½	.00
-20%	.01½	-.01¼	-.00	.01
0%	.02	-.00¾	.00½	.02
20%	.03½	.02½	.03	.03½
40%	.06½	.06½	.06½	.06½
60%	.10	.10	.10	.10

TABLE 109

STAGGER = 0.

(1) Average of Göt. 387 and U.S.A. 27.
(2) Average from curve (Plate 14).

G/C	Göt. 387	U.S.A.27	(1)	(2)
0.50	-	.06½	.06½	.06½
0.75	.03½	.05½	.04½	.04
1.00	.02	-.00¾	.00¾	.02
1.33	.02	.03½	.02½	.01
1.67	-	.01	.01	.00½
2.00	-	-.02½	-.02½	.00

Appendix D.

CURVES

Plate 5.	L_c, and D_c vs. α for 6 U.S.A. 27 biplanes, stagger = 0; G/C = 0.50 to 0.75
Plate 6.	L_c and D_c vs. α for 16 U.S.A. 27 biplanes, stagger = -40% to 60%, G/C = 0.50 to 1.00.
Plate 7.	L_c and D_c vs. α for 8 U.S.A. 27 biplanes, stagger = -40% to 60%, G/C = 1.67 and 2.00.
Plate 8.	L/D vs. α, M_c and C.P. v. L_c, for 6 U.S.A. 27 biplanes. Stagger = 0, G/C = 0.50 to 2.00.
Plate 9.	L/D vs. α, M_c and C.P. vs. L_c, for 6 U.S.A. 27 biplanes. G/C = 1.00. Stagger = -40% to 60%.
Plate 10.	L_c and D_c vs. α for 6 Göt. 387 biplanes. G/C = 1.00, Stagger = -40% to 60%.
Plate 11.	L/D vs. α, M_c and C.P. vs. L_c, for 6 Göt. 387 biplanes. G/C = 1.00. Stagger = -40% to 60%.
Plate 12.	(L_c, D_c, L/D) vs. α, (M_c, C.P.) vs. L_c, for 3 Göt. 387 biplanes. Stagger = 0, G/C = 0.75 to 1.33.

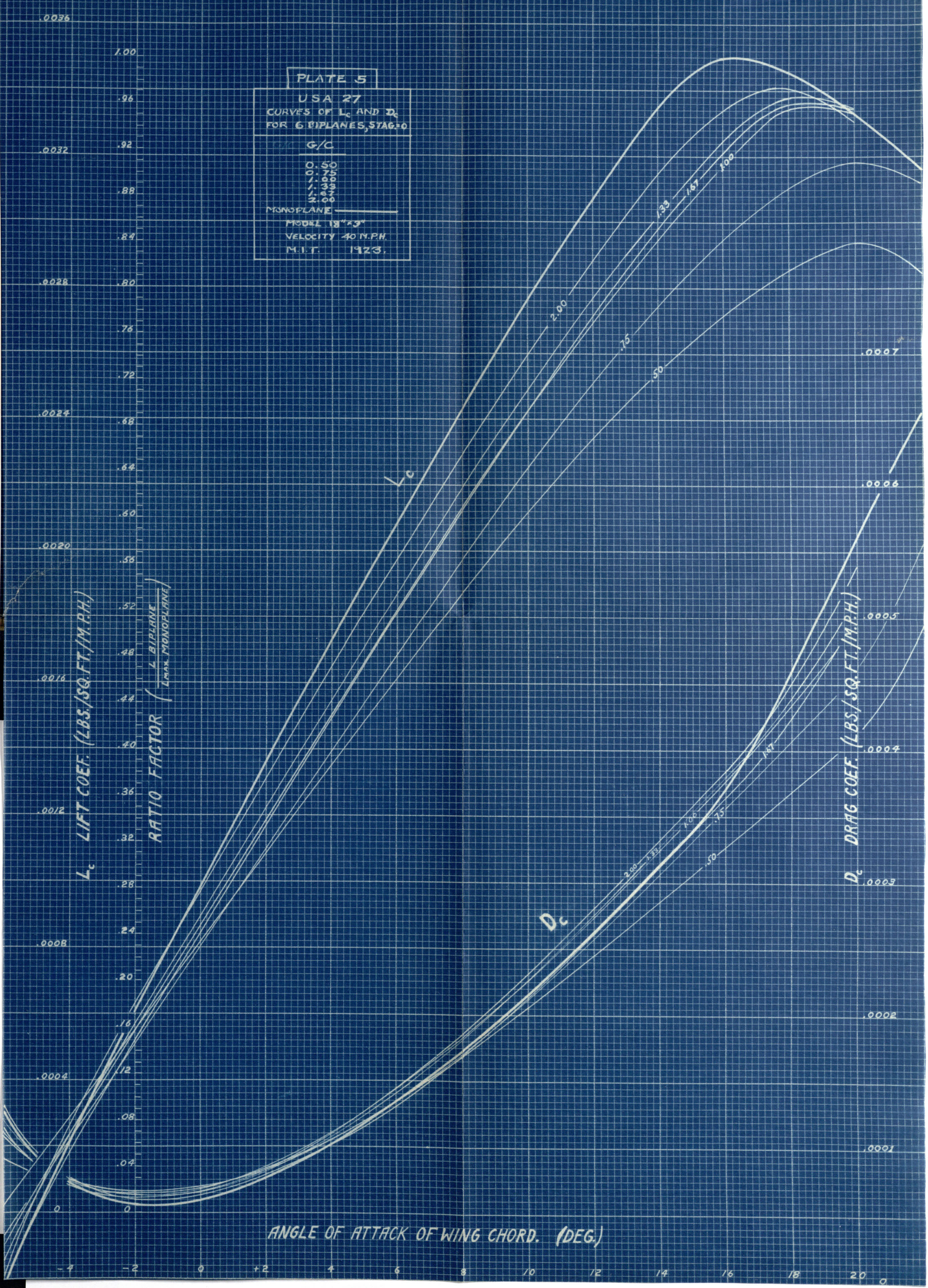


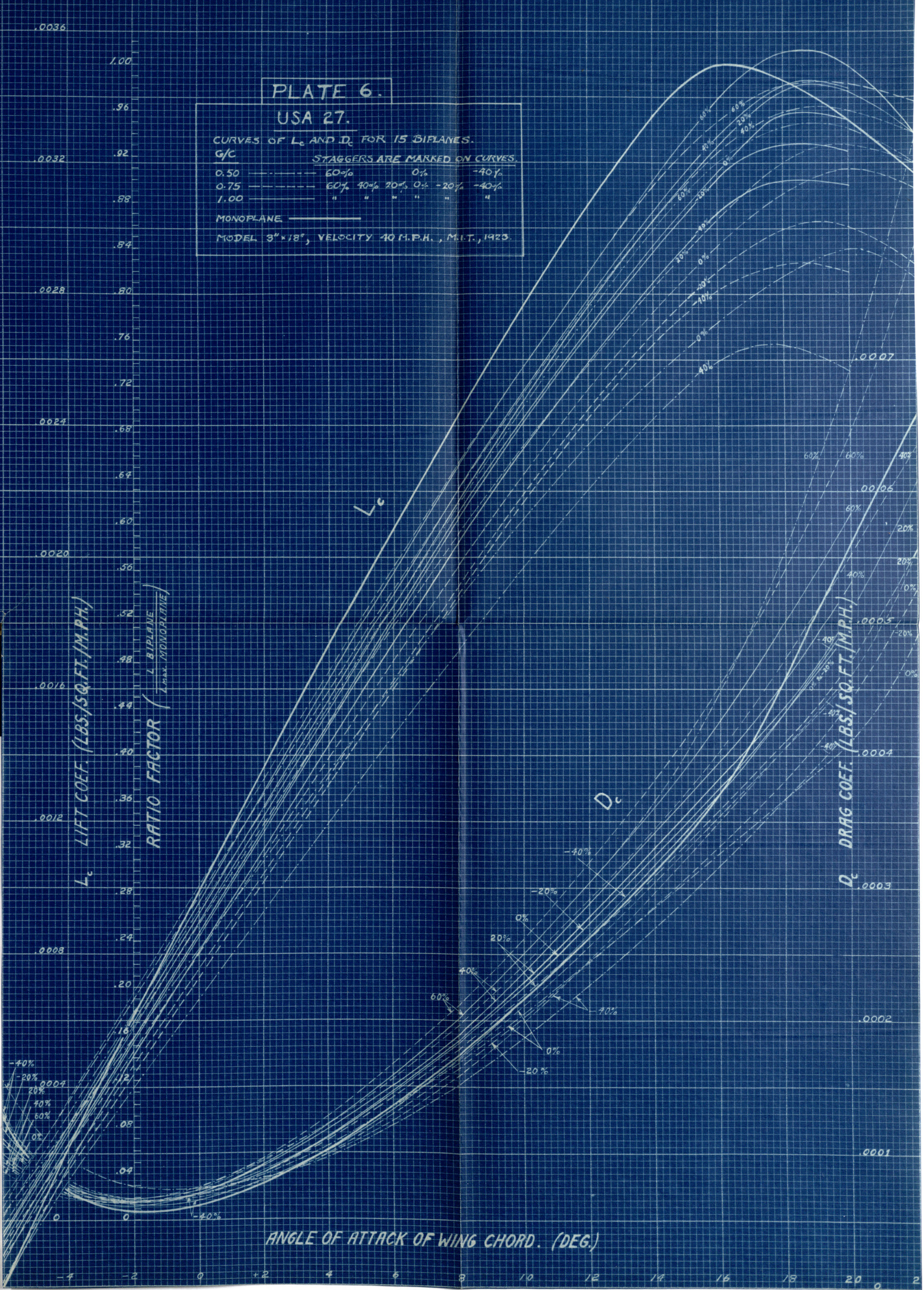
PLATE 5

USA 27
CURVES OF L_c AND D_c
FOR 6 BIPLANES, STAG.=0

G/C

0.50
0.75
1.00
1.33
1.67
2.00
MONOPLANE

MODEL 18"×3"
VELOCITY 40 M.P.H.
M.I.T. 1923.



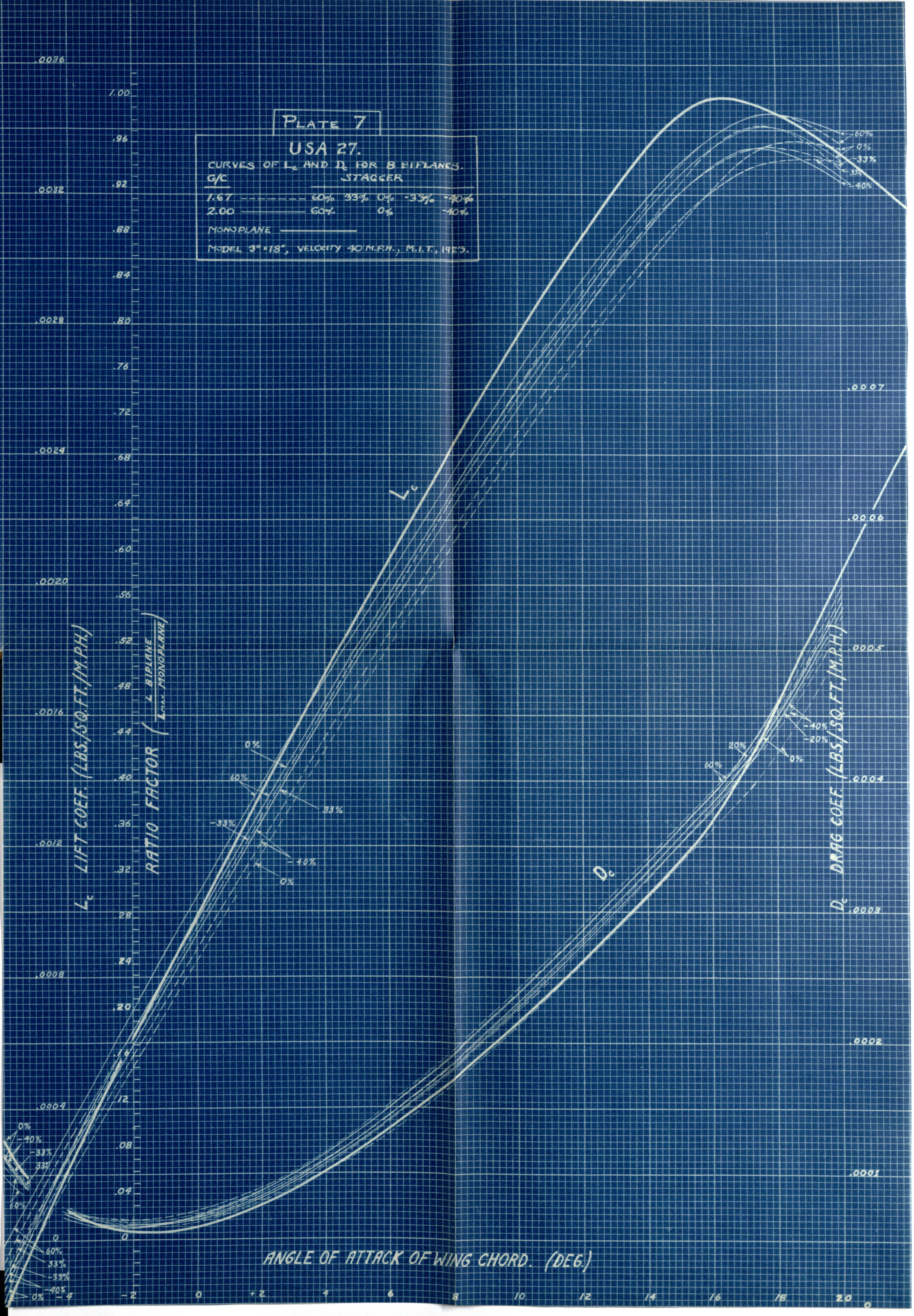


PLATE 7
USA 27.
CURVES OF L_c AND D_c FOR 8 BIPLANES.
G/C STAGGER
1.67 - - - - - - - - 60% 33% 0% -33% -40%
2.00 ———— 60% 0% -40%
MONOPLANE ————
MODEL 3"×18", VELOCITY 40 M.P.H., M.I.T., 1923.
L_c LIFT COEF. (LBS./SQ.FT./M.P.H.)
RATIO FACTOR (L BIPLANE / L MAX. MONOPLANE)
D_c DRAG COEF. (LBS./SQ.FT./M.P.H.)
ANGLE OF ATTACK OF WING CHORD. (DEG.)
L_c
D_c
.0036
.0032
.0028
.0024
.0020
.0016
.0012
.0008
.0004
0
1.00
.96
.92
.88
.84
.80
.76
.72
.68
.64
.60
.56
.52
.48
.44
.40
.36
.32
.28
.24
.20
.16
.12
.08
.04
0
.0007
.0006
.0005
.0004
.0003
.0002
.0001
0
-4
-2
0
+2
4
6
8
10
12
14
16
18
20
60%
0%
-33%
33%
-40%
0%
60%
33%
-33%
-40%
0%
-40%
-20%
20%
0%
60%
0%
-40%
-33%
33%
60%
0%
60%
33%
-33%
-40%
0%

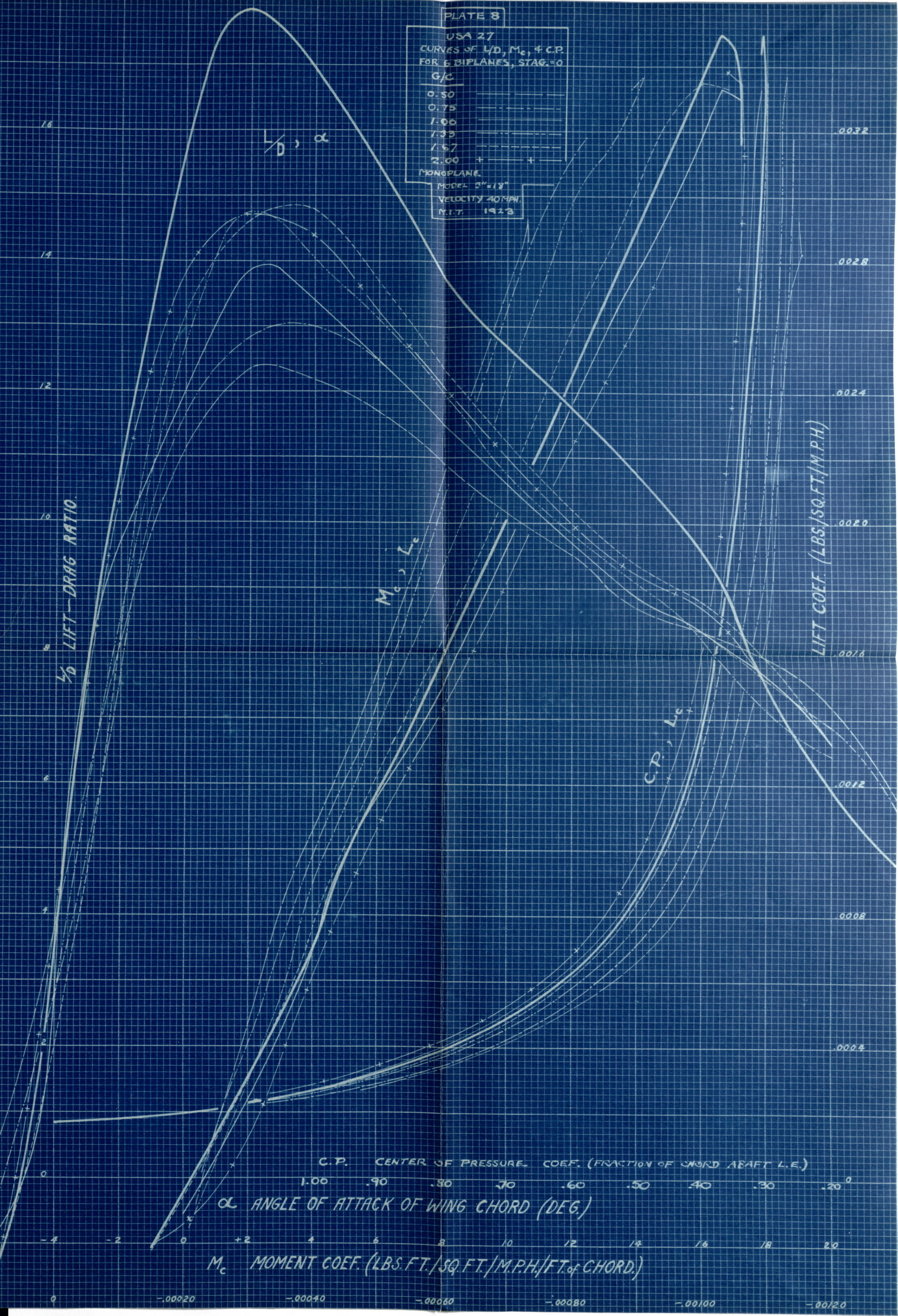


PLATE 8
USA 27
CURVES OF L/D, M_c, & C.P.
FOR 6 BIPLANES, STAG.=0
G/C
0.50
0.75
1.00
1.33
1.67
2.00
MONOPLANE
MODEL 3"×18"
VELOCITY 40 MPH.
M.I.T. 1923
L/D, α
M_c, L_c
C.P., L_c
L/D LIFT-DRAG RATIO
16
14
12
10
8
6
4
2
0
LIFT COEF. (LBS./SQ.FT./M.P.H.)
.0032
.0028
.0024
.0020
.0016
.0012
.0008
.0004
0
C.P. CENTER OF PRESSURE COEF. (FRACTION OF CHORD ABAFT L.E.)
1.00
.90
.80
.70
.60
.50
.40
.30
.20
α ANGLE OF ATTACK OF WING CHORD (DEG.)
-4
-2
0
+2
4
6
8
10
12
14
16
18
20
M_c MOMENT COEF. (LBS.FT./SQ.FT./M.P.H./FT. of CHORD)
0
-.00020
-.00040
-.00060
-.00080
-.00100
-.00120

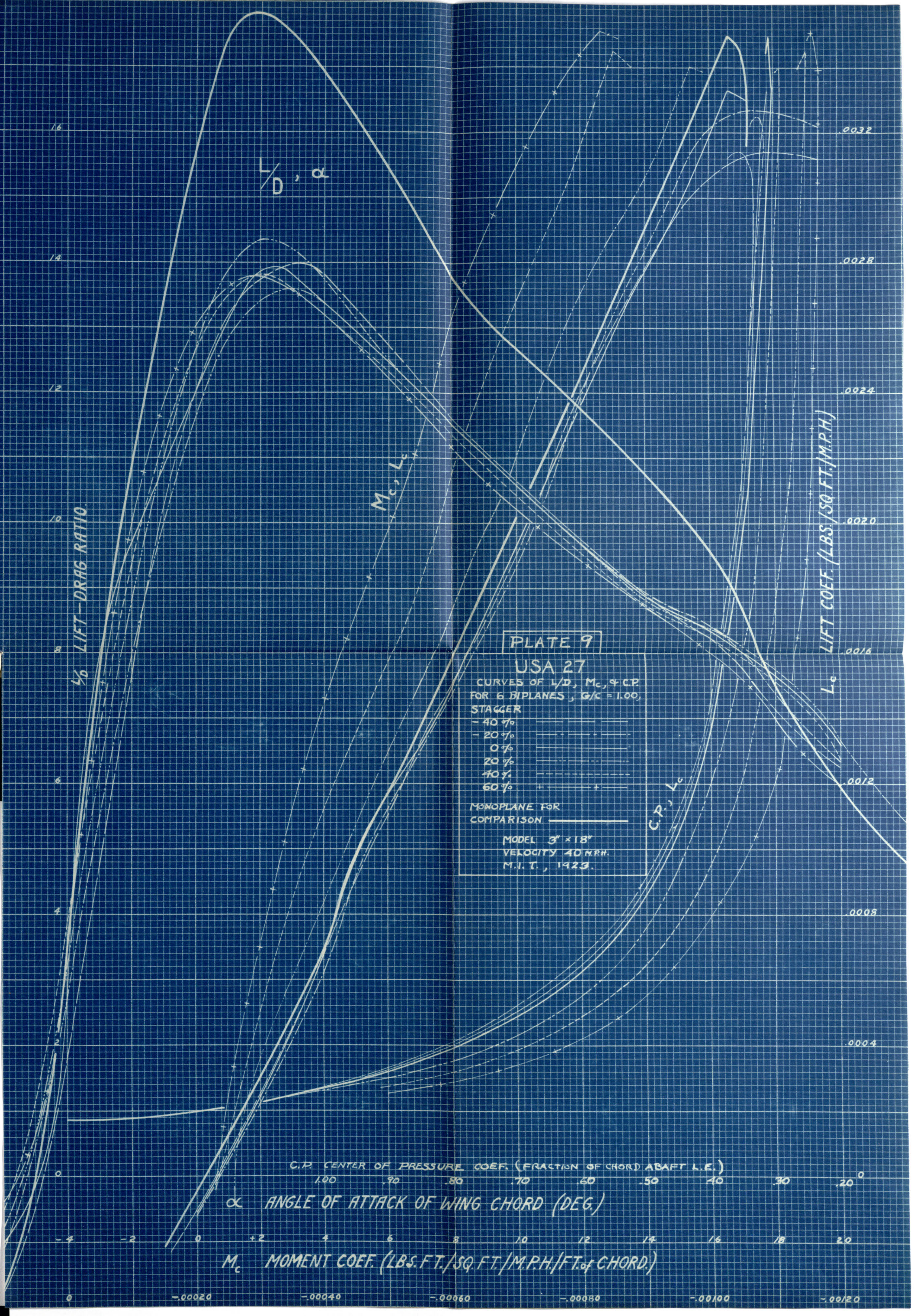


PLATE 9
USA 27
CURVES OF L/D, Mc, & C.P.
FOR 6 BIPLANES, G/C = 1.00,
STAGGER
- 40 %
- 20 %
0 %
20 %
40 %
60 %
MONOPLANE FOR
COMPARISON
MODEL 3" × 18"
VELOCITY 40 M.P.H.
M.I.T., 1923.
L/D, α
Mc, Lc
C.P., Lc
L/D LIFT-DRAG RATIO.
Lc LIFT COEF. (LBS./SQ.FT./M.P.H.)
16
14
12
10
8
6
4
2
0
.0032
.0028
.0024
.0020
.0016
.0012
.0008
.0004
0
C.P. CENTER OF PRESSURE COEF. (FRACTION OF CHORD ABAFT L.E.)
1.00
.90
.80
.70
.60
.50
.40
.30
.20
α ANGLE OF ATTACK OF WING CHORD (DEG.)
-4
-2
0
+2
4
6
8
10
12
14
16
18
20
Mc MOMENT COEF. (LBS.FT./SQ.FT./M.P.H./FT. of CHORD.)
0
-.00020
-.00040
-.00060
-.00080
-.00100
-.00120

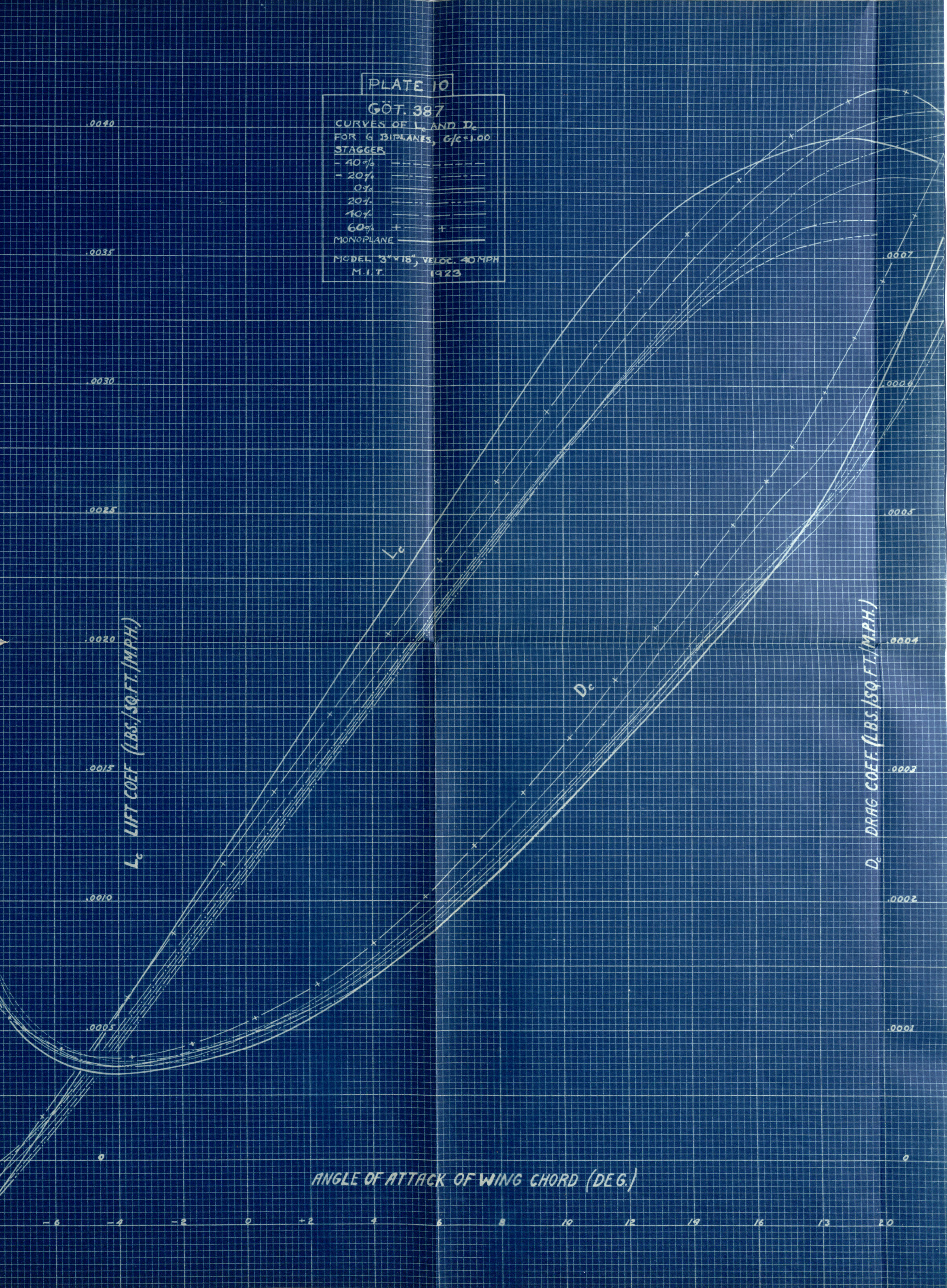


PLATE 10
GÖT. 387
CURVES OF L_c AND D_c
FOR 6 BIPLANES, G/C=1.00
STAGGER
- 40%
- 20%
0%
20%
40%
60%
MONOPLANE
MODEL 3"×18", VELOC. 40 MPH
M.I.T. 1923
L_c
D_c
L_c LIFT COEF (LBS./SQ.FT./MPH.)
D_c DRAG COEF. (LBS./SQ.FT./M.P.H.)
ANGLE OF ATTACK OF WING CHORD (DEG.)
.0040
.0035
.0030
.0025
.0020
.0015
.0010
.0005
0
.0007
.0006
.0005
.0004
.0003
.0002
.0001
0
-6
-4
-2
0
+2
4
6
8
10
12
14
16
13
20

PLATE 11

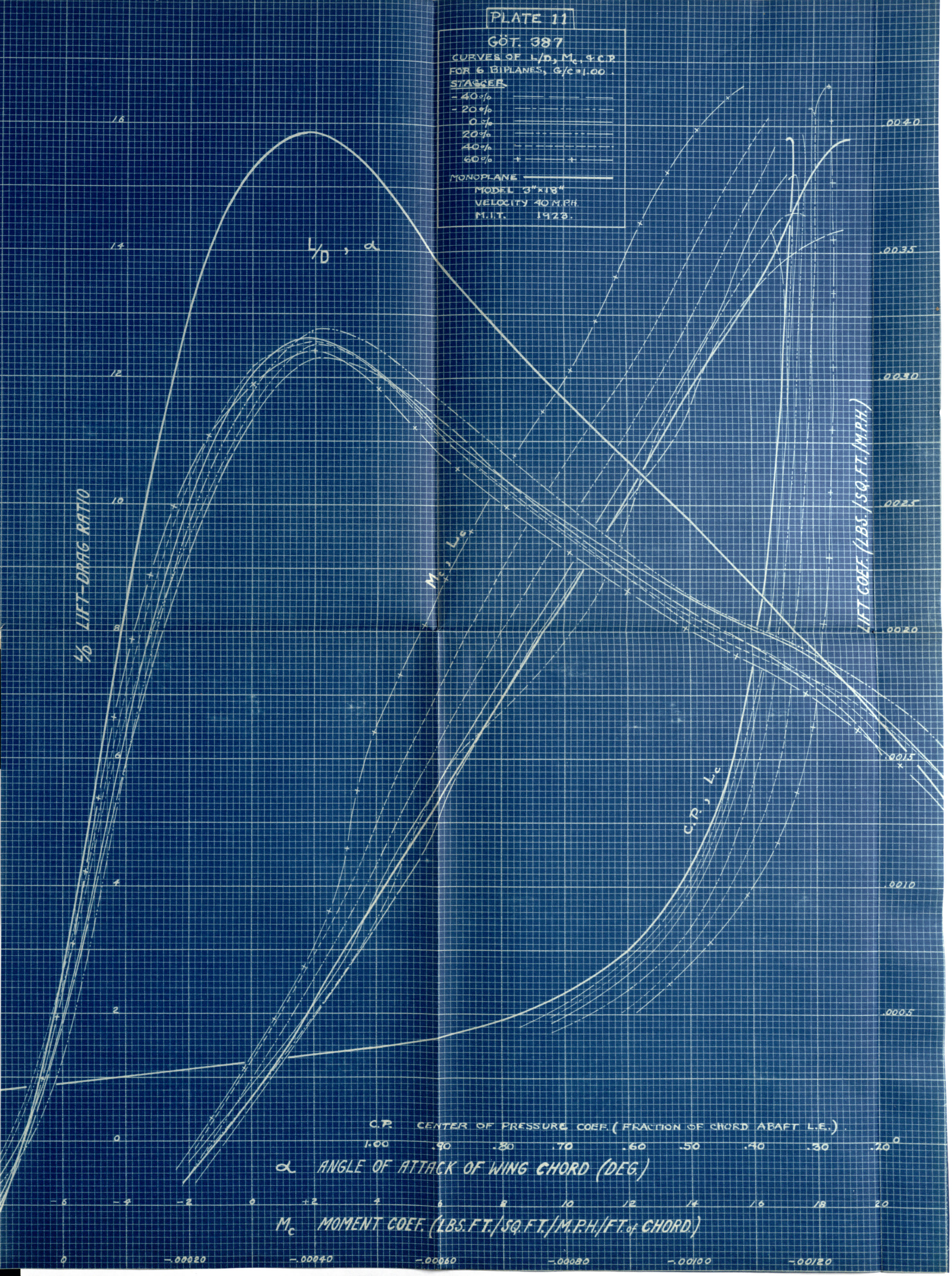
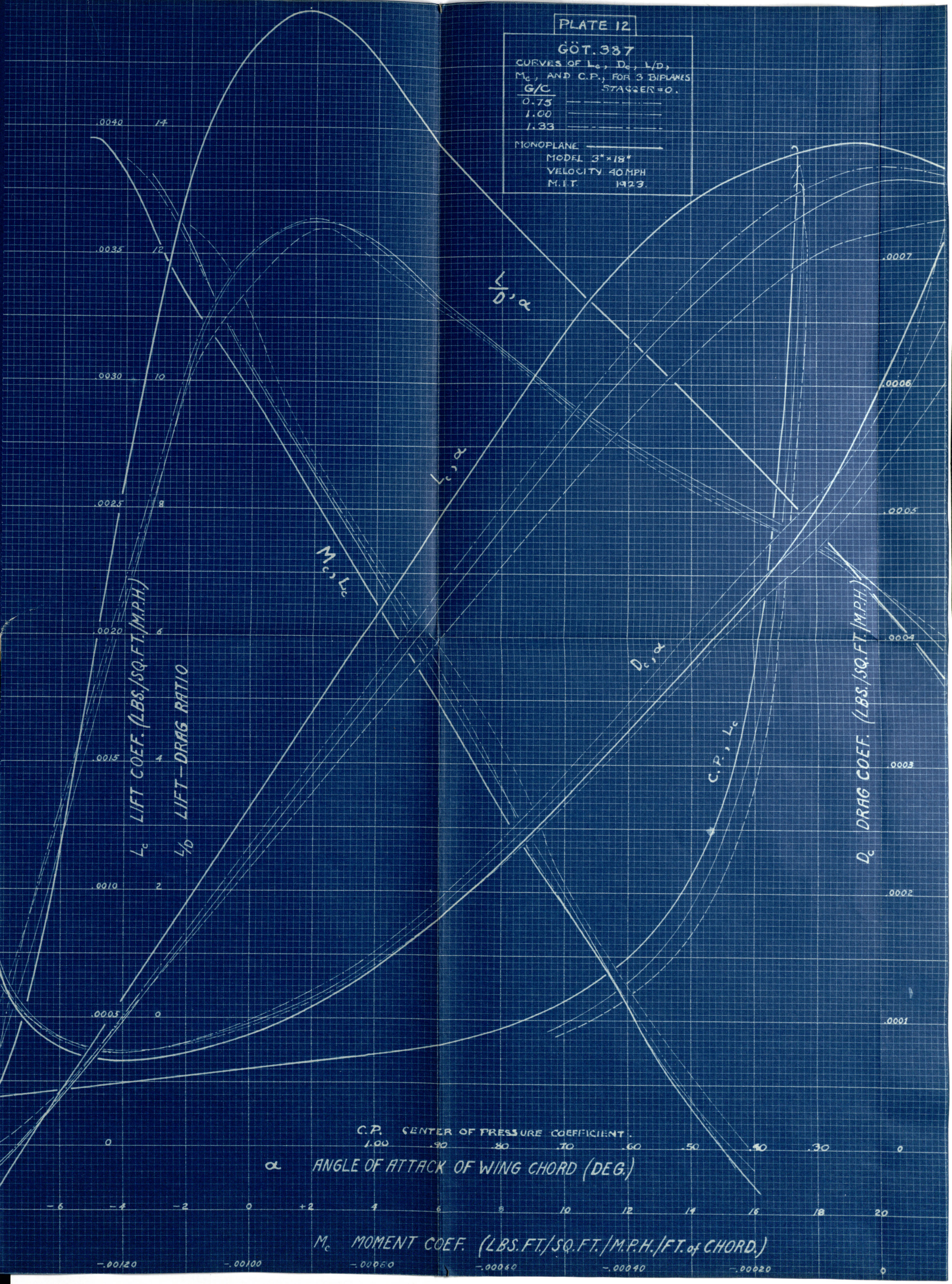

GÖT. 387
CURVES OF L/D, M_c, & C.P.
FOR 6 BIPLANES, G/C=1.00.
STAGGER
-40%
-20%
0%
20%
40%
60%
MONOPLANE
MODEL 3"×18"
VELOCITY 40 M.P.H.
M.I.T. 1923.
L/D , α
M_c , L_c
C.P. , L_c
L/D LIFT-DRAG RATIO
LIFT COEF. (LBS./SQ.FT./M.P.H.)
C.P. CENTER OF PRESSURE COEF. (FRACTION OF CHORD ABAFT L.E.)
α ANGLE OF ATTACK OF WING CHORD (DEG.)
M_c MOMENT COEF. (LBS.FT./SQ.FT./M.P.H./FT.of CHORD)
16
14
12
10
8
6
4
2
0
.0040
.0035
.0030
.0025
.0020
.0015
.0010
.0005
0
1.00
.90
.80
.70
.60
.50
.40
.30
.20
-6
-4
-2
0
+2
4
6
8
10
12
14
16
18
20
0
-.00020
-.00040
-.00060
-.00080
-.00100
-.00120

PLATE 12



GÖT. 387

CURVES OF L_c, D_c, L/D, M_c, AND C.P., FOR 3 BIPLANES STAGGER = 0.