NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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INTERFERENCE OF WING AND FUSELAGE FROM TESTS OF 209 COMBINATIONS IN THE N. A. C. A. VARIABLE-DENSITY TUNNEL

By Eastman N. Jacobs and Kenneth E. Ward

SUMMARY

Tests of 209 simple wing-fuselage combinations were made in the N. A. C. A. variable-density wind tunnel to provide information regarding the effects of aerodynamic interference between wings and fuselages at a large value of the Reynolds Number. This investigation is part of a basic investigation of aerodynamic interference now in progress at the Committee's laboratory and considers the interference as affected by the more important variables of a combined wing and fuselage.

Most of the tests were made with a round fuselage in combination with a rectangular wing of symmetrical section. Variations of the vertical position, longitudinal position, and angular position were covered. A sufficient number of tests of other variables, such as the wing and fuselage shape, were made to give a general understanding of the effects of these variables. For some of the combinations in which the wing and fuselage were not connected, the air forces on the wing and fuselage were determined separately in order to investigate the mutual interference.

The principal results are given in tabular form and summarized by presenting the important characteristics for all the combinations by means of parameters in a single table so that the relative merits of the various combinations may be readily compared. The results are discussed in relation to the character, cause, and significance of the interference effects encountered under various conditions.

INTRODUCTION

The continual improvement in the aerodynamic efficiency of airplanes may be ascribed to a gradually increasing knowledge of the flow about single bodies and the interference between them. As the units making up a combination have been improved, the residual drag arising from the interference has become an increasingly important factor in relation to the total drag. Many experimental data have now been secured on which to base the design of efficient component parts but adequate data concerning the interference between them are still lacking. Although the need for reliable information concerning aerodynamic interference has been appreciated for several years, the Committee considers that only recently the design of component parts has reached a point of refinement such that further improvements of airplanes demand more knowledge concerning the aerodynamic interference.

For several years the Committee has had in progress a basic investigation of aerodynamic interference in the variable-density tunnel. Such an investigation is necessarily based upon existing information about simple combinations and a knowledge of the flow about the simple bodies forming the combinations. Two bodies are considered as being of primary importance: the airfoil and an elongated streamline body representing the fuselage. The results of numerous investigations of the flow about airfoils and airship hulls, the potential-flow theory, and the various boundary-layer theories furnish a reasonably complete picture of the flow about the two simple basic forms. The first phase of the current interference investigation dealt with the flow about such bodies as affected by slight disturbances such as those produced by different types of small protuberances variously located on airfoils and streamline bodies. (See references 1, 2, and 3.) The second phase of the problem, the interference of wing-fuselage combinations, is reported herein.

PREVIOUS WING-FUSELAGE INTERFERENCE INVESTIGATIONS

One of the earliest wing-fuselage interference investigations was made by Prandtl, the results of which have been available in an English translation since 1921. (See reference 4.) Five wing-fuselage combinations were tested to determine the influence of the relative vertical position of wing and fuselage on the efficiency of the wing. Prandtl concluded that with a normal fuselage shape the drag differences are small for various vertical positions of the wing except for the combination having the wing a little below the fuselage, which showed an aerodynamic change for the worse in comparison with the other combinations. He also pointed out that the drag of the mid-wing combination noticeably increased at an angle of attack of about 12°.

The simplest wing-fuselage combination may be considered to be a wing having a thin flat plate inserted in the plane of the midspan cross section.

In an investigation of wing-fuselage interference, Muttray (reference 5) tested a wing-plate combination to show that the wing polar is unfavorably affected even by this "ideal fuselage." He tested a large number of low-wing combinations having different fuselage shapes and different wing shapes. Several of the combinations were also tested with fillets. From the results of this investigation Muttray found that the relative fore-and-aft position of the wing and fuselage greatly affected the magnitude of the additional (induced) drag, a result that he attributed to changes of the span load distribution resulting from the different positions of the center of pressure for wing and fuselage. For some positions separation occurred at moderately high values of the lift as indicated by the abnormal drag increase. Muttray attributed this separation to the sharp nose of the fuselage. A study of the effects of variation of the angle between the wing and the side of the fuselage showed that the smaller the angle the greater the additional induced drag, indicating an early separation of the air flow at the wing roots. Muttray devised the tapered, or expanding, fillets to improve the characteristics of the poor combinations. His investigations of the effects of wings having the trailing edge cut away at the root indicated that the separation at the root was not prevented by cutting away the trailing edge and that increasing the size of the cutaway portion increased the drag in the usual lift range but decreased the severity of the break in the polar curve.

Parkin and Klein (reference 6) tested combinations of 3 wings, varying in thickness, with 3 fuselages: streamline, cabin, and open cockpit. A number of typical monoplane and biplane combinations were tested, a few with fillets. The authors concluded that the interference effects were dependent on the shape of the fuselage, the airfoil section, and the relative position of the fuselage and the airfoil. The better the aerodynamic form of the fuselage and the thicker the airfoil section, the greater were shown to be the interference effects and the more marked the influence of the vertical wing position on the interference. The interference tended to lower the angle of attack corresponding to maximum lift and to increase the drag compared with those of the individual components. From aerodynamic considerations, the best position for the wing was found to be at the top of the fuselage and the worst at the bottom. Fillets and fairings improved combinations having poor characteristics but had little effect on arrangements already fairly satisfactory. Many other tests have been made using small models, and the general conclusions agree in most respects with those of the investigations mentioned.

In a comprehensive report on interference (reference 7), Ower describes an investigation in which large models with stub wings were used to obtain results for much larger values of the Reynolds Number than had been previously obtained. These Reynolds Numbers, however, were still well below those corresponding to flight and the fact that stub wings were used makes the application of the results somewhat questionable.

Among the investigations of wing-fuselage interference made at high values of the Reynolds Number was an investigation made in the N. A. C. A. variable-density tunnel in 1930 (unpublished) to compare high-wing, mid-wing, and low-wing monoplanes. The effects of expanding fillets were also studied. Although some conclusions were reached that confirmed previous results from tests at low values of the Reynolds Number, the results suggested a need for a more complete investigation at high Reynolds Numbers. A series of investigations were therefore started, the first of which considered a wing having a thin flat plate inserted in the midspan cross section (reference 8) to study the interference effects on this basic combination.

Other interference investigations have been made at relatively large values of the Reynolds Number. Short investigations, each of one particular type of low-wing monoplane, have been made at the California Institute of Technology (reference 9) and in the N. A. C. A. full-scale tunnel (reference 10) to study interference and buffeting. Both investigations confirmed Muttray's conclusions that expanding fillets improve the aerodynamic characteristics of low-wing monoplanes.

THE BASIC WING-FUSELAGE INTERFERENCE PROGRAM

Because the previous wing-fuselage interference investigations were incomplete in many respects, it was desired to consider in formulating this program all of the important variables. Once the important variables were listed, it became apparent that a complete investigation of all the possible combinations would be impracticable. This difficulty was partly overcome by classifiying the possible variables as "major" and "minor", so that the program could be formulated to include complete investigations of the major variables and to include only incidental investigations of the effects of the minor variables. The following tabulation presents the classification adopted:

Wing:
- Major variables:
  - Plan form.
  - Airfoil section.
- Minor variables:
  - Fillets.
  - Plan-form variations near fuselage, e. g., plan-form fillets or wing cut-outs.
  - Bends near fuselage, e. g., gull-wing types.
  - Incidence changes near fuselage.
  - High-lift and air-brake devices.
  - Size.
  - Aspect ratio.

Fuselage:
- Major variable:
  - Cross-sectional shape.
- Minor variables:
  - Longitudinal form.
  - Size.
  - Air-cooled engine in nose, cowled or uncowled.
  - Unusual form changes to accommodate wing and windshield.

Combinations:
- Major variable:
  - Vertical position of the wing with respect to the fuselage.
- Minor variables:
  - Longitudinal position of the wing with respect to the fuselage.
  - Angular relation of the wing and fuselage.
  - Fillets and strut attachments.

It will be noted that the major variables of the wing are taken as the airfoil plan form and section. Airfoil plan-form variations are probably covered sufficiently by the inclusion, in the program, of two plan forms: rectangular and 2:1 taper. The variations in airfoil section are likewise covered by the inclusion of two airfoil sections, a symmetrical N. A. C. A. 0012 representing slightly cambered sections and an N. A. C. A. 4412 representing moderately highly cambered sections. An incidental variation in section thickness is also obtained by considering the thick section at the root of the tapered wing as a variation of the N. A. C. A. 0012.

The major variable of the fuselage is the cross-sectional shape, the variation of which is included in the program by means of two fuselages, one having round and the other rectangular sections.

The major variable of the combination is the vertical position of the wing with respect to the fuselage. It appears to be necessary to include as many as 21 vertical positions to make the investigation reasonably complete in this respect.

The complete program is intended finally to include all possible combinations of major variables and all such combinations of minor variables as may appear to be of particular importance.

THE INVESTIGATION COVERED BY THIS REPORT

This report is not intended to present the results of the complete wing-fuselage interference investigation but mainly to consider the variations of a round fuselage in combination with a rectangular wing of symmetrical section. These combinations were tested for various vertical, longitudinal, and angular positions in order to determine which of the possible variables were of sufficient importance to include in the remainder of the program. Some of the minor variables, such as fillets and cut-outs, were also investigated, particularly with reference to the low-wing combinations, because of the present demand for data on such arrangements. Other minor fuselage variables, such as an air-cooled engine at the nose of the fuselage, were also included for the same reason and to determine the importance of these minor fuselage variables in respect to the remainder of the program. A sufficient number of combinations of the major variables to give some understanding of the effects of each were included to complete the main body of the investigation covered by this report. The scope of the present investigation is clearly indicated by reference to table V, the diagrams of which represent all the combinations tested.

MODELS

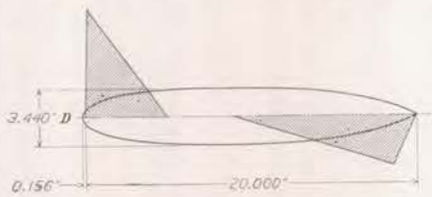
The wing models used for this investigation are a rectangular N. A. C. A. 0012, a rectangular N. A. C. A. 4412 (reference 11), a rectangular N. A. C. A. 0012 having a cut-out center section (reference 12), and a tapered wing having a root-to-tip chord ratio of 2 and sections tapering from the N. A. C. A. 0018 to the N. A. C. A. 0009 (fig. 18 and reference 11). Each rectangular wing has a chord of 5 inches and a span of 30 inches and was constructed of duralumin in the manner described in reference 13. The tapered wing is also of duralumin with an area of 150 square inches and a span of 30 inches.

Two fuselage models were used, one having circular and one rectangular cross sections. Both models are

FUSELAGE DIMENSIONS (INCHES)

Station	Round fuselage	Rectangular fuselage	
	Diameter	Height	Width
−0.156	0.000	0.000 diameter.	
.000	.772	.772 diameter.	
.250	1.242	1.242 diameter.	
.500	1.572	1.572 diameter.	
.719		1.795 diameter.	
1.000	2.044		
1.500		2.380	2.240
2.000	2.650		
2.312		2.790	2.370
3.406		3.090	2.470
4.000	3.238	3.238	2.543
6.000	3.410	3.410	2.678
8.000	3.440	3.440	2.702
10.000	3.406	3.406	2.675
12.000	3.268	3.268	2.567
14.000	2.990	2.990	2.348
16.000	2.516	2.516	1.976
17.000	2.170	2.175	1.704
18.000	1.698		1.334
19.000	1.000		.785
19.500	.548		.430
20.000	.000	1.125	.000

Source-sink distribution for round fuselage.



of duralumin with carefully polished surfaces and have lengths of 20.156 inches and maximum cross-sectional areas of 9.29 square inches. The circular-section fuselage was derived from a source-sink distribution to give a form approximating that of an airship of fineness ratio 5.86. The rectangular-section fuselage was derived from the circular one to obtain a related form having the same cross-sectional area. The fuselages were constructed to the dimensions on page 3.

The fuselage shape was further altered by the addition in the nose of a model engine with an N. A. C. A. cowling. The engine, 3.42 inches in diameter, was carefully modeled to scale to represent a 9-cylinder radial air-cooled engine. The cowling, 3.47 inches outside diameter, was constructed of a single thickness of metal arranged to slip over the engine. For tests with the rectangular fuselage the shape of the rear portion of the cowling was altered somewhat to provide an approximately constant-area slot permitting the free flow of air through the cowling around the edges of the fuselage. (See fig. 36.)

The juncture of the wing and fuselage of several of the combinations was altered by means of fillets. Most of the fillets were molded from plaster of paris and carefully finished to a smooth surface.

Other combinations of the wing and fuselage employed connecting struts. One connecting strut consisted of a thin steel plate, $\frac{1}{16}$ inch thick by 2 inches long, streamlined and polished. Other connecting struts were formed by building up this plate with wood and plaster of paris to form the desired sections.

The wings and fuselages were combined in different ways to give variations of vertical position, fore-and-aft position, and wing setting. A diagram of the various vertical and fore-and-aft positions of the rectangular wing of symmetrical section in combination with the round fuselage is shown in figure 1. Diagrams representing all the combinations are shown in table V and photographs of some typical wing-fuselage combinations, particularly those having fillets and attachments, are shown in figures 24 to 36.

TESTS

All the tests were made in the variable-density tunnel at a Reynolds Number of approximately 3,100,000. In addition, the maximum lift of most of the combinations was determined at a reduced speed corresponding to a Reynolds Number of approximately 1,400,000. A description of the tunnel and of the method of testing is given in reference 13.

The tests were of two distinct types, one type in which the forces on the wing and fuselage as a unit were determined, and the other type in which the forces on the wing and on the fuselage were each determined separately in the presence of the other.

The first tests were those in which the fuselage was attached to the wing and the combinations were mounted on the model supports in the usual manner (fig. 2). The method of testing and the accuracy of

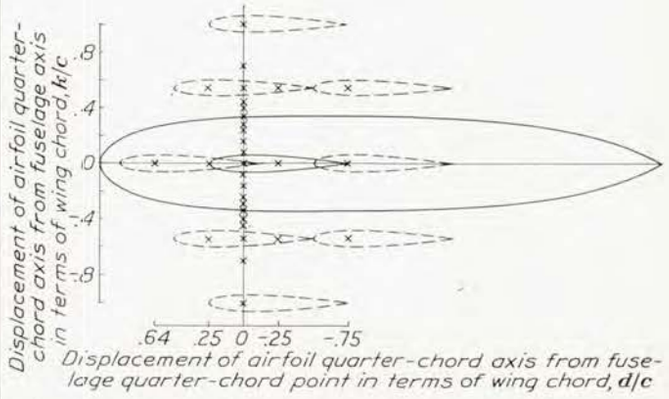


FIGURE 1.—A diagram of the various wing positions with respect to the fuselage.

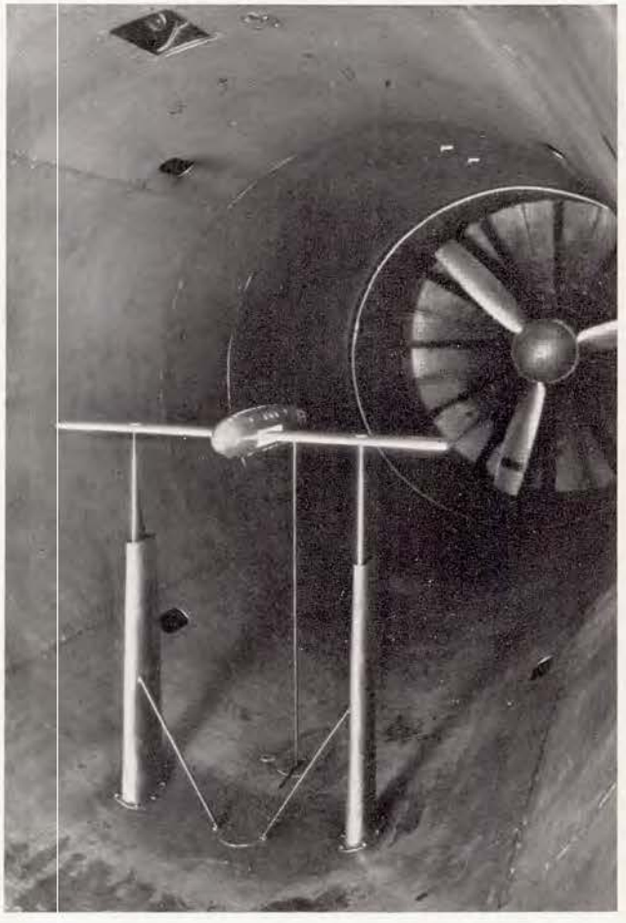


FIGURE 2.—A wind-tunnel set-up of a connected wing-fuselage combination.

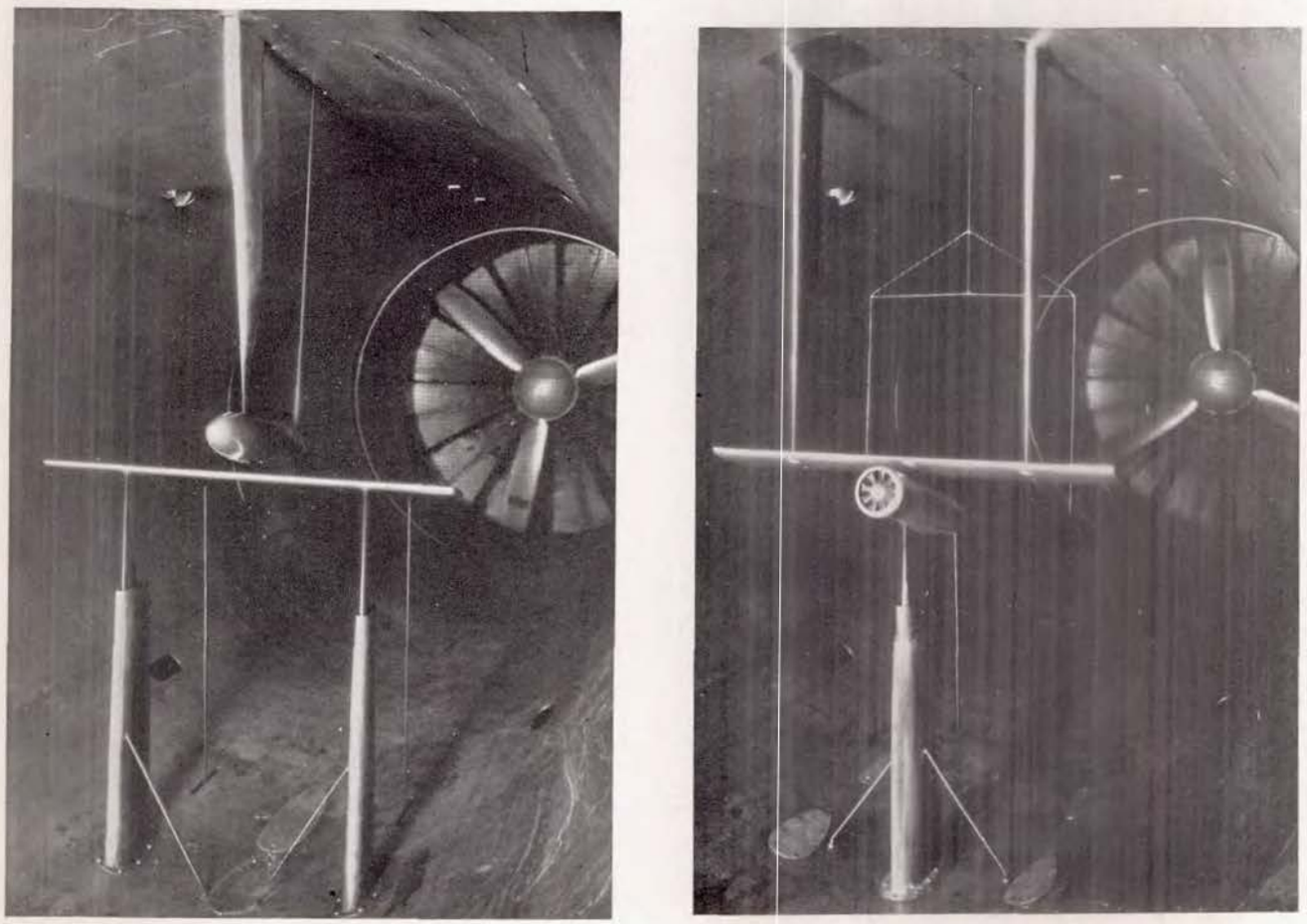
the tests were the same as those of the usual airfoil tests (references 11 and 13). The characteristics of both a high-wing and a low-wing combination having a symmetrical-section wing were determined with

one set-up by testing the combination through the complete range of positive and negative angles of attack.

The disconnected combinations were tested in such a manner that the forces on one body while in the presence of the other were independently determined. Only those combinations in which the wing was entirely outside the fuselage were tested in this way. For these tests the wing was first mounted on the balance in the usual manner and the fuselage was supported from the roof of the tunnel on a single strut and independent of the balance (fig. 3 (a)). The forces on the fuselage in the presence of the wing were similarly determined by supporting the fuselage on the balance and the wing independently from the tunnel structure (fig. 3 (b)). The angles of attack of the wing and of the fuselage could be varied separately.

The characteristics of high-wing and low-wing combinations having wings of symmetrical section were obtained by testing the combinations through positive and negative angles of attack. The wing always remained in the center of the tunnel and the gap between the wing and fuselage was varied by varying the position of the fuselage. Variations of the fore-and-aft position of the wing with respect to the fuselage were effected by varying the position of the fuselage support. As the gap and the fore-and-aft position changed slightly with the angle of attack, most of the tests required a small change in the set-up at high angles of attack. Consequently, the position was corrected at angles of attack of 16° and −16° to give the correct gap and fore-and-aft position and the angle-of-attack and wing-setting range for each set-up suitably chosen to give the least position error. The gap for each set-up was checked while the tunnel was under pressure by varying the angle of wing setting until the models were in contact (as shown by an electric fouling signal) and reading the angles of attack of each model. As the relative positions of the models at contact were known, the actual distance between the pivot points of the wing and the fuselage supports could be determined.

The test results of the disconnected combinations are relatively inaccurate as compared with the test results of the connected combinations. Because of



(a) The wing on the balance.

(b) The fuselage on the balance.

FIGURE 3.—Set-ups in the tunnel for two typical disconnected combinations.

the many different set-ups necessary, the final results for a combination are subject to accumulative errors. Also, because of the limitations of the set-up, corrections for position errors were necessary, which introduced errors into the final results. The net interference was determined from the small difference between relatively large interacting forces with resulting limitations of the accuracy. The interference of the supports on the models also introduced a small source of error. A comparison between the test results of a connected combination having a moderate gap and having the fuselage attached to the wing by means of a small thin plate and those of a similar disconnected combination indicates that, at minimum drag, the disconnected combination gives a value of the drag coefficient about 6.7 percent low and, at a moderately high lift, gives a value of the lift coefficient about 1.7 percent low.

Tests of the wings alone were made in the standard manner. In addition, the wings were tested alone with double stings placed directly behind the support struts for use with the results from tests of the disconnected combinations. The fuselages were tested alone with several different mountings. The accuracy of these test results is believed to be the same as that of the standard wing tests (reference 11).

RESULTS

METHODS OF ANALYSIS AND PRESENTATION

Some discussion of the presentation and analysis of the data is advisable owing to the somewhat unusual methods employed. Entirely satisfactory methods are very difficult, if not impossible, for such extensive test results involving so many aspects of the data to be considered. In the discussion, a part of the data is presented graphically in order to bring out the effects of some of the factors that influence the interference but a more compact tabular form has been adopted for the bulk of the data. Such data are presented in tables III and IV for all the combinations investigated.

Table V summarizes the principal characteristics of all the combinations and together with table II, which gives the characteristics of the fuselages alone, includes the most important results and all the data necessary to supplement those presented graphically with the discussion. Unless detailed applications of some of the data are contemplated, the reader may disregard the following paragraphs explaining the presentation of the tabular data and continue with the later section: Principal Characteristics of Combinations.

Various methods of presentation for the bulk of the tabular data were considered using either the lift or the angle of attack as the independent variable. Several methods of tabulating the interference values were also considered. The method finally adopted does not indicate the interference directly but rather the amounts by which the characteristics of the wing are altered by the presence of the fuselage in the combination.

Unless comparisons are made in such a manner that the total lifts of the combinations are equal, drag differences may be misleading owing to the inclusion of unequal components of unavoidable induced drag. For example, two combinations might be compared at equal angles of attack but the interference might increase the lift of one combination and decrease that of the other. As the result of a finite span, a larger unavoidable induced-drag component is included in the total drag of the combination having the higher lift so that it may show the higher drag even though the actual drag associated with the interference may be less than that of the other combination.

In order to avoid misleading comparisons owing to the inclusion of different unavoidable components of induced drag, drag values for comparison are given by means of an effective profile-drag coefficient C_{D_e}. The effective profile-drag coefficient is the difference between the total drag coefficient and the minimum induced-drag coefficient associated with the lift and span of the airfoil, i. e., the induced-drag coefficient $C_L^2/\pi A$ corresponding to the elliptical load distribution. Effective profile-drag coefficients thus eliminate, for purposes of comparison, any necessary induced-drag differences but include drag components due to changes in induced drag as the result of interference.

The use of the effective profile-drag coefficient thus permits the use of the angle of attack as the independent variable.

The character of the interference is then indicated most clearly by considering changes in the lift, drag, and pitching moment while the attitude remains unchanged. Characteristics of the wings alone, the fuselages alone, and the combinations (or data from which the characteristics of the combinations can be obtained) are consequently presented at certain angles of attack. Interference values for the combinations are, in general, not directly tabulated but may be readily obtained from the data given. Considering, for example, only the single characteristic, drag, the bulk of the data for the combinations is presented by giving the "drag and interference" of the fuselage. The values thus give directly any increase in the drag over that of the wing alone due to the presence of the fuselage in the combination. From these values the interference drag is found by deducting the drag of the fuselage alone, or the drag of the combination is found by adding the drag of the wing alone.

TABULAR PRESENTATION

Experimental Data.—Table I gives the lift and drag coefficients and the pitching-moment coefficient measured about the quarter-chord axis for the four airfoils used in this investigation. The characteristics of the symmetrical airfoils are given at angles of attack of 0°, 4°, and 12° and those of the cambered airfoil, which has an angle of zero lift of approximately −4°, are given at −4°, 0°, and 8°. The first two angles of attack represent the high-speed range and the third represents a high-angle-of-attack condition. The coefficients are based on a wing area of 150 square inches for all the wings, including those for the cut-out airfoil.

Table II gives the aerodynamic characteristics of the fuselage models. The coefficients are all based on the original wing area and chord; the pitching moment coefficient C_{m_F} is taken about a point on the fuselage axis one-quarter of the distance from the zero station to the tail; i. e., the quarter-chord point of the fuselage. The characteristics are given for angles of attack from 0° to 16° at intervals of 4°. As the fuselage models are symmetrical, the results for the negative-angle range may be obtained by changing the signs of the lift and pitching-moment coefficients.

Table III gives the "lift and interference" ΔC_L, "drag and interference" ΔC_{D_e}, and "pitching moment and interference" $\Delta C_{m_{c/4}}$ of the fuselage in the wing-fuselage combinations; that is, the differences between the characteristics of the combination and the characteristics of the wing alone. These results are given for two angles of attack representing the high-speed range and for one representing a high-angle-of-attack condition. This table includes the data from the tests of the disconnected combinations, which are discussed and presented in a more complete form in the following paragraphs.

Table IV gives the results of tests of the disconnected combinations in which the forces on the wing and on the fuselage were each measured. In order to eliminate tare tests and to obtain more consistent results than was believed possible otherwise, a unique method of deriving the final results was employed. From the test results of the wing in the presence of the independently supported fuselage were deducted the test results of the wing alone for the same set-up without the fuselage in place. (See section describing tests.) These differences of the lift, pitching moment, and total drag were then added, after correction for the change of the relative position with angle of attack, to the standard characteristics of the wing. The results obtained in this manner represent the characteristics of the wing in the presence of the fuselage. In order to obtain the desired drag values, the induced drag was deducted from the drag of the wing in the presence of the fuselage. The values thus obtained give polar curves, which in figures 11 and 12 are designated "wing in presence of fuselage." The values given in table IV for the interference on the wing in presence of the fuselage (δC_L, δC_{D_e}, and $\delta C_{m_{c/4}}$) were obtained as the differences between the characteristics of the wing in the presence of the fuselage and the characteristics of the wing alone after the induced drag had been deducted. These values are represented for the lift and the drag by the dashed lines of figures 11 and 12 joining test points at equal angles of attack of the "wing alone" curves and the "wing in presence of fuselage" curves.

The characteristics of the fuselage in the presence of the wing were obtained by adding to the standard fuselage characteristics the differences between the characteristics of the fuselage measured with and without the wing in place after correcting for position errors. The characteristics so obtained were added to the lift, moment, and the total drag of the wing in the presence of the fuselage. The total drag was then reduced by deducting the induced drag corresponding to the sum of the lift values. The resulting values are the characteristics of the wing-fuselage combination. These values are represented for typical combinations in figures 11 and 12 as the curves designated "wing-fuselage combination." The values given in table IV for the characteristics of the fuselage in presence of the wing (C_L, C_{D_e}, and $C_{m_{c/4}}$) were obtained as the differences between the characteristics of the wing-fuselage combination and the characteristics of the wing in the presence of the fuselage after deducting the induced drag from the corresponding total drags. These values are represented for the lift and drag by the dashed lines of figures 11 and 12 joining test points at equal angles of attack of the "wing-fuselage combination" curves and the "wing in presence of fuselage" curves.

Principal Characteristics of Combinations.—Table V gives the principal aerodynamic characteristics of all the combinations tested. The characteristics of the wings alone are also included. The geometric characteristics are given in diagrams that, together with the tabular data and the photographs of certain combinations (figs. 24 to 36, following the table), give all the information usually required. Those combinations differing only in respect to the angle of wing setting are represented by a single diagram in which the wing positions for the maximum incidence range are indicated by dashed lines. The first three columns of the table give the diagrams representing the combinations, the combination numbers, and pertinent remarks. The next three columns give the geometric relations of the wing and fuselage. The values d/c and k/c represent the longitudinal and vertical displacements, respectively, of the wing quarter-chord axis measured positive ahead of and

above the quarter-chord point of the fuselage, and i_w is the angle of wing setting.

The following important characteristics are presented by the last nine columns employing standard nondimensional coefficients based on the original wing areas of 150 square inches:

Lift-curve slope, a.

Airplane efficiency factor, e.

Minimum effective profile-drag coefficient, $C_{D_{e_{min}}}$.

Optimum lift coefficient, $C_{L_{opt}}$.

Aerodynamic center position, n_0.

Pitching-moment coefficient at zero lift, C_{m_0}.

Lift coefficient at the interference burble, $C_{L_{tb}}$.

Maximum lift coefficient, $C_{L_{max}}$ for an effective R. N. of 7,500,000.

Maximum lift coefficient, $C_{L_{max}}$ for an effective R. N. of 3,400,000.

The lift-curve slope a was determined in the high-speed, or low-lift-coefficient, range. The values represent change in lift coefficient per degree for an airplane having a wing of aspect ratio 6.86. This value of the aspect ratio differs from the actual value for the models used because the lift results are not otherwise corrected for tunnel-wall interference.

The airplane, or span, efficiency factor e is an empirical factor introduced by Oswald (reference 14). The reciprocal of the number represents a factor by which the minimum induced-drag coefficient $C_L^2/\pi A$ is increased to leave a reasonably constant residual drag coefficient over the normal working range of the lift coefficient. The factor was determined from the portion of the drag curve between $C_L=0.2$ and $C_L=1.0$ unless the interference burble occurred in this lift-coefficient range, in which case only the portion of the curve below the interference burble was considered. The method should therefore be used only for the approximate determination of drag coefficients corresponding to lift coefficients below the interference burble unless the interference burble is of the type designated "type C" in the $C_{L_{tb}}$ column of table V.

The minimum value of the effective profile-drag coefficient C_{D_e} represents the drag remaining after deducting the minimum induced drag, that is, the minimum induced drag that may be associated with the given lift and span. The effective profile drag therefore provides an ideal means of comparison as it includes with the actual profile drag and parasite drag any unnecessary induced drag associated with interference or a departure from the ideal span load distribution but, at the same time, eliminates from the comparison the unavoidable effects of the lift on the drag.

The optimum lift coefficient $C_{L_{opt}}$ is the lift coefficient corresponding to the minimum effective profile-drag coefficient.

The aerodynamic-center position is represented by values n_0 indicating approximately its fore-and-aft position expressed as a fraction of the wing chord forward of the quarter-chord axis of the wing. Each value is actually the slope of the curve of pitching-moment coefficient against lift coefficient at zero lift.

The pitching-moment coefficient at zero lift C_{m_0} is measured about the quarter-chord axis of the wing and is based on the original wing area and chord.

The lift cofficient at the interference burble $C_{L_{tb}}$ is the value of the lift coefficient beyond which the air flow has a tendency to break down as indicated by an abnormal increase in the drag.

The maximum lift coefficient $C_{L_{max}}$ is given for two different values of the effective Reynolds Number. The effective Reynolds Number is obtained from the actual test Reynolds Number by the application of a factor to allow for the effects of turbulence present in the tunnel. Comparative tests indicate that at the effective Reynolds Number, maximum-lift results from the tunnel tend to agree with those in flight. (See references 15 and 16.) The value of the turbulence factor used throughout this report was taken from reference 15 as 2.4.

DISCUSSION

For many applications of these results, a direct examination of the tabular data will undoubtedly yield more useful information than the following general discussion. The data presented in table V are particularly valuable in this connection because significant parameters representing the important characteristics as single values are tabulated for all the combinations investigated, thus affording a means of comparing various combinations. In the following discussion, however, the general variations are considered and discussed in relation to the cause of the interference and the significance of the results. Some of the data are presented graphically to supplement the discussion.

The interference is first considered in relation to all the characteristics of certain typical wing-fuselage combinations in order to point out in a general way the nature of the various interference effects that may be present in all the combinations. The discussion that follows is then subdivided considering: First, the drag as affected by the interference when the various geometric characteristics of the combinations are changed; second, the moment as affected by the interference; and finally, the maximum-lift characteristics as affected by the interference.

GENERAL CHARACTER OF INTERFERENCE FOR TYPICAL COMBINATIONS

Mid Wing.—The simplest combination investigated, the symmetrical-section wing combined at zero incidence in the midposition with the round-section fuselage, will be first considered. The characteristics of this combination are presented in figure 4 as coefficients plotted against the angle of attack. The lift and pitching moment of the combination are, of course, zero at zero angle of attack because the whole combination is symmetrical about the plane of the airfoil chords. The difference between the drag curves indicates the "drag and interference" of the fuselage.

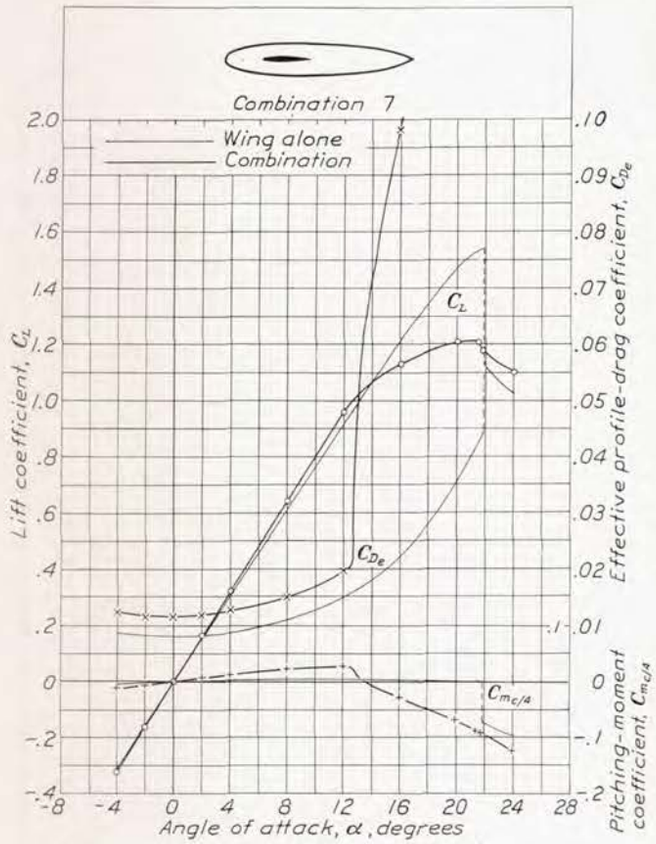


FIGURE 4.—Aerodynamic characteristics of a typical mid-wing combination.

Expressed as a coefficient the drag and interference of the fuselage under these conditions may be taken directly from figure 4 as being 0.0035. The drag of the fuselage when tested alone is found from table II to be 0.0041. A comparison of this value with the drag and interference indicates that the interference is favorable and is represented by the coefficient 0.0006. The favorable interference in this case is the result of eliminating the drag of that portion of the wing enclosed within the fuselage which, expressed as a coefficient, would amount to approximately 0.0009. After allowing for this interference effect, a small (0.0003) residual adverse interference remains that may be attributed to "boundary interference." Boundary interference applies to that part of the interference associated with the combination of the wing and fuselage boundary layers near the wing-fuselage junctures. The boundary interference for the type of juncture here considered is of the same nature as that for a perpendicular flat plate at the midspan section as investigated earlier (reference 8), the wing in both cases projecting perpendicularly from a surface along which only small pressure gradients exist when the wing is absent. As might be expected, the boundary-interference drag coefficient is about the same in either case.

In regard to the favorable interference drag coefficient shown as resulting from the enclosure of a part of the wing in the fuselage, it might be argued that the favorable drag increment results from the use of too large a wing area in deriving the drag coefficient of the combination rather than from any real favorable interference and that no favorable interference drag would have been indicated if the actual exposed wing area had been employed. The wing area consistently employed throughout this report is, however, the N. A. C. A. standard wing area which includes, and properly so, the area of the part of the wing that should be considered as enclosed by the fuselage. The favorable interference drag that results, although easily explained, is none the less real. As indicated by the subsequent discussion, a consideration of the interference on the basis of exposed wing area leads to difficulties in relation to the lift and induced drag and may lead to an analysis, such as that of reference 7, charging the mid-wing position with adverse interference.

Consider now the characteristics of the combination as the angle of attack is increased, remembering that the coefficients are based on an area including the area of that part of the wing inside the fuselage. If this portion of the wing were considered as ineffective in producing lift as it is in producing drag, a lift coefficient from the wing, at 12° for example, of only 0.816 or less would be expected. This lift coefficient added to the value of 0.011, the lift coefficient of the fuselage at 12°, gives 0.827 as the sum of the wing and fuselage lift coefficients; whereas the lift coefficient of the combination is actually 0.960. A comparison of the lift-curve slope of the combination with that of the wing alone indicates that the portion of the wing replaced by the fuselage may be even more effective than the original portion of the wing in producing lift. A comparison of the corresponding effective profile-drag curves shows, moreover, that the drag of the combination varies with angle of attack in much the same way as that of the wing alone except that the results indicate the presence of a small boundary-interference drag increasing with angle of attack, as would be expected from the results of

reference 8. Thus, with respect to the lift and induced drag, the combination behaves as though the entire wing were exposed to the air stream with the addition of lift and drag components due to the presence of the fuselage. This behavior continues until the conditions of the "interference burble" are reached.

For the combination under consideration, the interference burble occurs at an angle of attack of just above 12°, as indicated by an abrupt reduction in lift-curve slope and an increase of the effective profile-drag coefficient. These conditions must correspond to an incomplete flow breakdown occurring before the more complete breakdown that determines the maximum lift. The nature of the flow breakdown associated with the interference burble is not well understood and the subject deserves further investigation. It must, however, correspond to the failure of the lift distribution to be maintained across the central-span portion occupied by the fuselage as it was maintained, substantially the same as for the normal wing, before the onset of the flow breakdown.

Although, as previously stated, the mechanism of the flow breakdown is not well understood, some light is shed on the subject by studying the behavior of the aerodynamic characteristics for various combinations with different wings in different positions with and without juncture fillets and with other fuselage shapes. For example, the occurrence of the present type of interference burble is abrupt; the lift continues to increase beyond the burble point but with a reduced slope; the burble point is not markedly affected by filleting this juncture, or by changing the incidence, but is affected by changing the wing section, the fuselage shape, or the fore-and-aft position of the wing on the fuselage. From these and other considerations, a reasonably satisfactory picture of the mechanism of the flow breakdown may be inferred.

For the combination here considered, the initial flow breakdown probably originates near the leading edge of the wing on either side of the fuselage. With the type of airfoil section used with this combination, typical of slightly cambered sections showing an abrupt change of flow at maximum lift, the flow breakdown is associated with a separation of the flow near the leading edge as the result of an accumulation of dead air just behind the separation point. Where the wing enters the fuselage this accumulation of reduced-energy air in the low-pressure region on the wing surface is undoubtedly augmented by the proximity of the fuselage surface. Reduced-energy air from the fuselage boundary layer is drawn in by the low pressures prevailing on the upper surface of the wing in this region. These conditions obviously tend to produce a premature stall of the sections adjacent to the fuselage but such a stall of so limited a portion of the wing is not sufficient, in itself, to produce the abrupt and drastic changes in the net aerodynamic characteristics actually observed in figure 4. The flow breakdown once started, however, tends to aggravate itself and probably is further aggravated by the presence of the fuselage so that it rapidly increases in extent until it covers the entire central portion of the wing. In order to form an adequate picture of this subsequent spreading of the initial flow breakdown, it is necessary to consider the lift distribution across the span.

Consider the spanwise lift distribution as affected by a discontinuity in the plan form of the wing as, for example, a sudden increase in the chord. Such a discontinuity occurring in the plan form does not produce a corresponding discontinuity in the load-grading curve, although the lift does increase over the portion of the wing having the increased chord. The interference between the various sections of the wing acts so to modify the angle of attack of the sections that abrupt changes in the lift grading do not occur, the short-chord portions building up angle of attack and lift toward the discontinuity and the long-chord portions losing angle of attack and lift toward the discontinuity. These effects may be considered as the result of the vortices that are shed between sections when the lift changes between the sections. (See references 2 and 12.)

For the present purpose it is sufficient to note that the interference between sections acts so to affect the angle-of-attack distribution that variations in the spanwise lift distribution tend to be equalized. Hence, when a wing is combined with a fuselage as in the mid-wing combination under consideration, the lift grading across the portion of the span occupied by the fuselage will tend to be maintained. Although the fuselage when tested alone is found to be incapable of maintaining much lift, owing to its very low aspect ratio, when combined with the wing it is able to do so. The general regions of low and high pressures above and below the wing carry across above and below the fuselage. Although these pressures acting on the fuselage are less than those acting on the wing surface, the increased chord of the fuselage as compared with that of the wing allows a lift to be developed over the portion of the span occupied by the fuselage. In fact, the high lift-curve slope of the combination indicates that the fuselage is carrying an excess of lift as compared with the portion of the wing which it replaces. The interference consequently acts to increase the angle of attack of adjoining sections of the wing in order to equalize the load grading, thus tending further to overload the airfoil sections adjacent to the fuselage. Their premature stall owing to boundary interference is thus hastened and, when it occurs, the resulting loss of lift tends further to increase the angle of attack. In this way the condition aggravates itself and spreads until the low-pressure region no longer exists over the

fuselage. The fuselage and the adjoining sections of the wing have then lost most of their lift and the rest of the wing behaves much like two wings of reduced aspect ratio with a gap between.

The maximum lift of the combination is, of course, lower than that of the wing alone as the result of the interference burble and the resulting loss of lift over the central portion of the wing. The maximum-lift burble, however, occurs independently of the interference burble and at a higher angle of attack corresponding approximately to the angle of maximum lift for the wing alone.

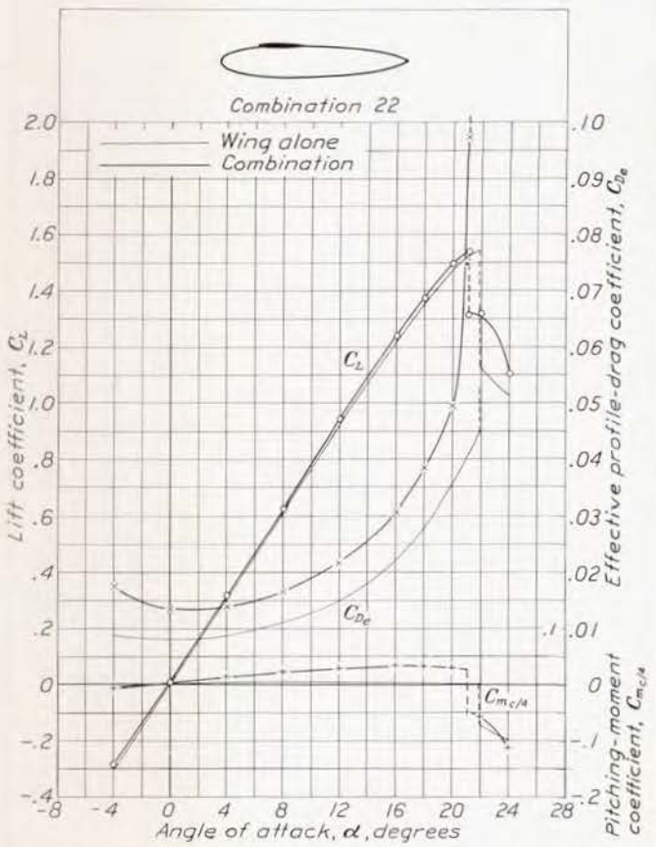


FIGURE 5.—Aerodynamic characteristics of a typical high-wing combination.

In regard to the pitching moment, the curves of $C_{m_{c/4}}$ in figure 4 indicate that the aerodynamic center of the combination tends to be farther forward than that of the wing alone. The fore-and-aft position of the wing in this instance is such that the quarter-chord points of the wing and fuselage coincide. A streamline body of revolution, such as the round fuselage, does not have an approximately constant aerodynamic center position as does a wing. The effect of combining such a body with a wing, aside from any interference effect, is to cause the pitching-moment curve to become sloped. Even though the combination cannot strictly be regarded as having an aerodynamic center, the position indicated by the moment-curve slope at zero lift is about 3 percent of the chord farther forward than for the wing alone. At lift coefficients below that of the interference burble the pitching-moment interference is usually small so that effects like those just discussed may be approximately predicted by adding the fuselage and wing moments. The changes of the pitching-moment coefficient that accompany the occurrence of the interference burble are of the same nature as those that accompany the maximum-lift burble of the plain airfoil but are more or less marked depending on the character of the interference burble.

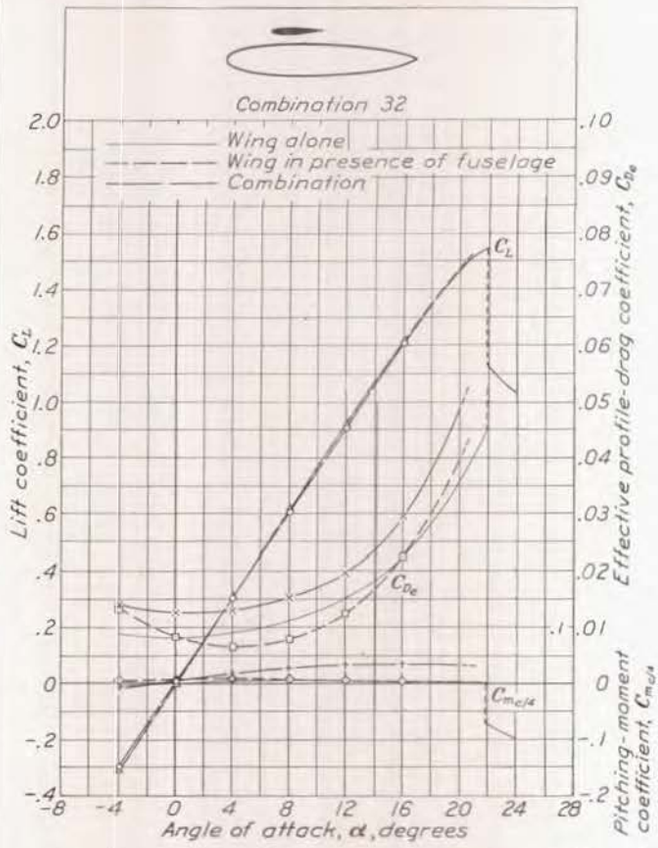


FIGURE 6.—Aerodynamic characteristics of a typical disconnected high-wing (parasol) combination.

High Wing.—The high-wing combination, the characteristics of which are shown in figure 5, will next be considered. It will be noted that the values of the lift and pitching-moment coefficients are still nearly zero at zero angle of attack and that the lift-curve slope, while remaining higher than that of the wing alone, is lower than that of the mid-wing combination. The minimum coefficient representing the drag and interference of the fuselage is 0.0050, indicating an adverse interference drag that is smallest at a small positive angle of attack. The interference drag increases slowly as the angle of attack is increased but none of the characteristic curves show indications of an interference burble. The maximum lift is approximately the same as that of the wing alone. At very low and at negative angles of attack the drag and

interference increases so rapidly toward larger negative angles that the condition might be referred to as a "negative interference burble." For certain high-wing combinations having very unsatisfactory forms of the wing-fuselage juncture this drag increase, or negative interference burble, may begin well to the right on the plot. In such cases the drag coefficient may be adversely affected within the high-speed range of the lift coefficient.

Disconnected High Wing.—The results for a disconnected high-wing, or parasol, combination are presented in figure 6. The characteristics of this combination are much like those of the connected high-wing

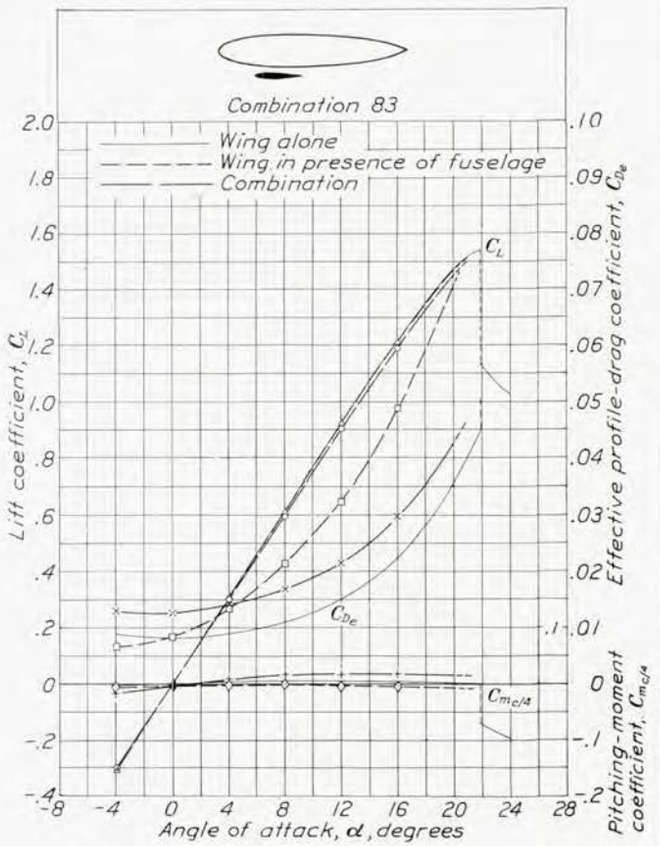


FIGURE 7.—Aerodynamic characteristics of a typical disconnected low-wing combination.

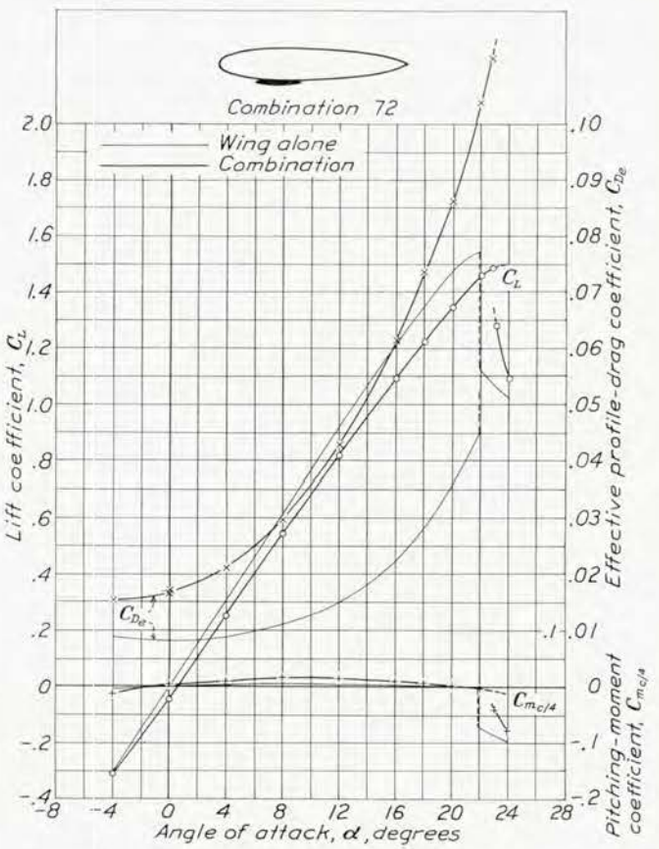


FIGURE 8.—Aerodynamic characteristics of a typical unsatisfactory low-wing combination.

combinations, except that the drag and interference of the fuselage is less. In figure 6 it has been possible, however, to indicate the characteristics of the wing in the presence of the fuselage because tests of the wing and fuselage were each made separately in the presence of the other for the separated positions. The wing in the presence of the fuselage is shown to have much lower effective profile-drag coefficients than the wing alone. This result has an important bearing on investigations of airfoil characteristics in flight by means of force-measuring devices in the fuselage, in which case such interference effects are so large that the measured drags are of little value. An examination of the test results for the disconnected combinations indicates that, in general, such mutual interference effects, although large, are of the nature of an interacting force between the wing and fuselage such as would result from a reduced pressure region between them. As the increments on the wing and fuselage therefore tend to be equal and opposite, the net interference is little affected. Such mutual interference is of importance in regard to the structural design of the components and their connecting members, however, because it affects the air loads and their distribution on each part.

Disconnected Low Wing.—The effects just considered are further brought out by the characteristics of the disconnected low-wing combination presented in figure 7. The effects of the low-pressure region between the wing and fuselage are evidenced by the increased lift of the wing in the presence of the fuselage as compared with the lift of the combination and the increased drag of the wing in the presence of the fuselage. In this instance, however, the net drag and interference is excessive, indicating the presence of some adverse interference drag, although there are no evidences of an interference burble.

Unsatisfactory Low Wing.—The characteristics of a very unsatisfactory type of low-wing combination are represented in figure 8. Here the interference burble occurs before zero lift although it is not of the abrupt

type occurring with the mid-wing combination. This type of interference burble is particularly objectionable because the drag is increased in the high-speed range of the lift coefficient. The drag continues to increase at higher lift coefficients as represented by the low value of the airplane, or span, efficiency factor for this combination (e=0.50 from table V). The low value of e indicates a reduced effective span and an increased induced drag associated with a loss of lift over the central portion in the neighborhood of the fuselage.

The character of this type of flow breakdown, having been discussed elsewhere (reference 5), will not be considered in detail. It is associated with the poor

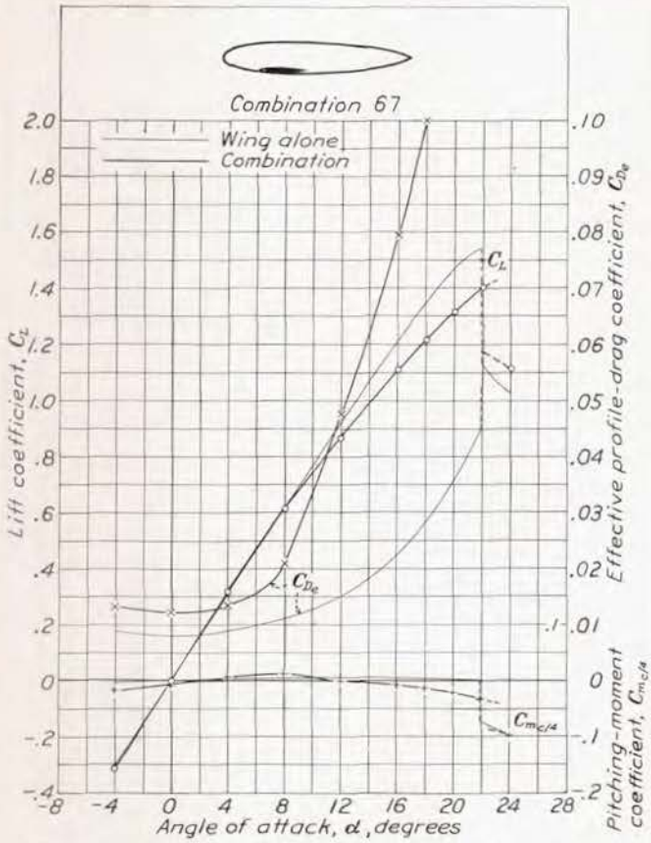


FIGURE 9.—Aerodynamic characteristics of a typical low-wing combination.

form of the air spaces at the wing-fuselage juncture and can be avoided by improving the juncture by fillets, or by other means. A separation or a thickening of the turbulent boundary layer occurs as the air spaces at the juncture expand toward the trailing edge of the wing. The maximum lift coefficient is little affected, probably because the maximum lift for this type of airfoil section is determined largely by the air-flow conditions near the leading rather than the trailing edge.

Typical Low Wing.—A more nearly representative low-wing combination than the one just considered is represented by combination 67 (fig. 9) in which the wing is internally tangent to the fuselage. As might be expected, the characteristics are intermediate between those of combination 72 (fig. 8) and those of the mid-wing combination. The drag at very low lift coefficients is not excessive. The interference burble is less abrupt than that of the mid-wing combination but occurs at a much lower lift coefficient. The maximum lift is adversely affected. The extent to which this type of interference burble is objectionable depends on how it affects the maximum lift, how early the interference burble occurs, and sometimes on secondary considerations, such as any tail buffeting or stability difficulties attributable to it.

DRAG AND INTERFERENCE

The results of tests of a large number of combinations having the rectangular wing of symmetrical section and the round fuselage are discussed with respect to the effects of the position variables, particularly the vertical position of the wing and the effects of fillets and strut attachments. The results of a few tests of other combinations having different variables, such as wing and fuselage shape, indicate the effects of these variables on the characteristics of combinations having the wing in a limited number of positions.

Rectangular Wing of Symmetrical Section with Round Fuselage—Vertical position.—The variation of the vertical position of the wing with respect to the fuselage is the most important of the position variables. It affects the wing-fuselage juncture and gap and also the shielding of the central portion of the wing by the fuselage. A cross plot of the effective profile-drag coefficient of the combination against the vertical position of the wing is shown in figure 10. The results are given for three values of the lift coefficient, two representing the high-speed range and the third a high-angle-of-attack condition. Reference to the figure shows that for the high-wing disconnected combinations the drag and interference of the fuselage is approximately equal to the drag of the fuselage alone. If the wing is lowered the drag and interference increases greatly and then, as the wing approaches the midposition, decreases to values that may be less than the drag of the fuselage alone. In the low-wing positions, the drag and interference becomes very large as the wing approaches the lower surface of the fuselage then rapidly decreases for the low-wing separated positions in which the interference is again small.

The largest contributing factor to adverse interference is probably the form of the wing-fuselage juncture. Whenever the angle between the wing and the fuselage surfaces at the juncture is acute, the interference is large and unfavorable, particularly when the juncture is on the upper surface of the wing. This unfavorable interference may be noted in figure 10, which shows large increases in drag when the wing passes the surfaces of the round fuselage. The detrimental effect may be attributed to the geometrical

divergence between the bodies, which may exceed the critical divergence for the air flow.

For the wing positions through the central portion of the fuselage, the wing-fuselage combinations of the type under consideration have the lowest drags. The position giving the least drag appears to be with the wing slightly above the center line of the fuselage. In the high-speed range the drag and interference of the fuselage for this combination is approximately 88 percent of the minimum fuselage drag and is still less at moderately high lift coefficients. For the mid-wing position and for positions immediately below, the combinations show an abrupt interference burble. The interference burble is absent for the high-wing combinations (table V).

The separated positions represent other regions in which the drag and interference is small. Reference to figure 10 shows that, with the exception of the disconnected high-wing positions at the high value of the lift, the wing may almost touch the fuselage (a clearance of approximately $0.02c$) before the drag and interference becomes large. The disconnected low-wing combinations have generally higher drags than the disconnected high-wing combinations, but no evidence of an interference burble is apparent for any of the disconnected combinations except those low-wing combinations having the wing very close to the fuselage. An important result shown by the interference tests of arrangements with wing and fuselage disconnected is the large interference on each body due to the presence of the other. The results of tests of typical high-wing and low-wing combinations with moderate clearances between wing and fuselage are shown in figures 11 and 12. In these figures the magnitude of the interference on both the lift and the drag is indicated by dotted lines connecting test points at the same angles of attack. Table IV gives the numerical values at representative angles of attack for all the disconnected combinations. It will be noted that, although the mutual interference is large, the net interference of a combination is relatively small.

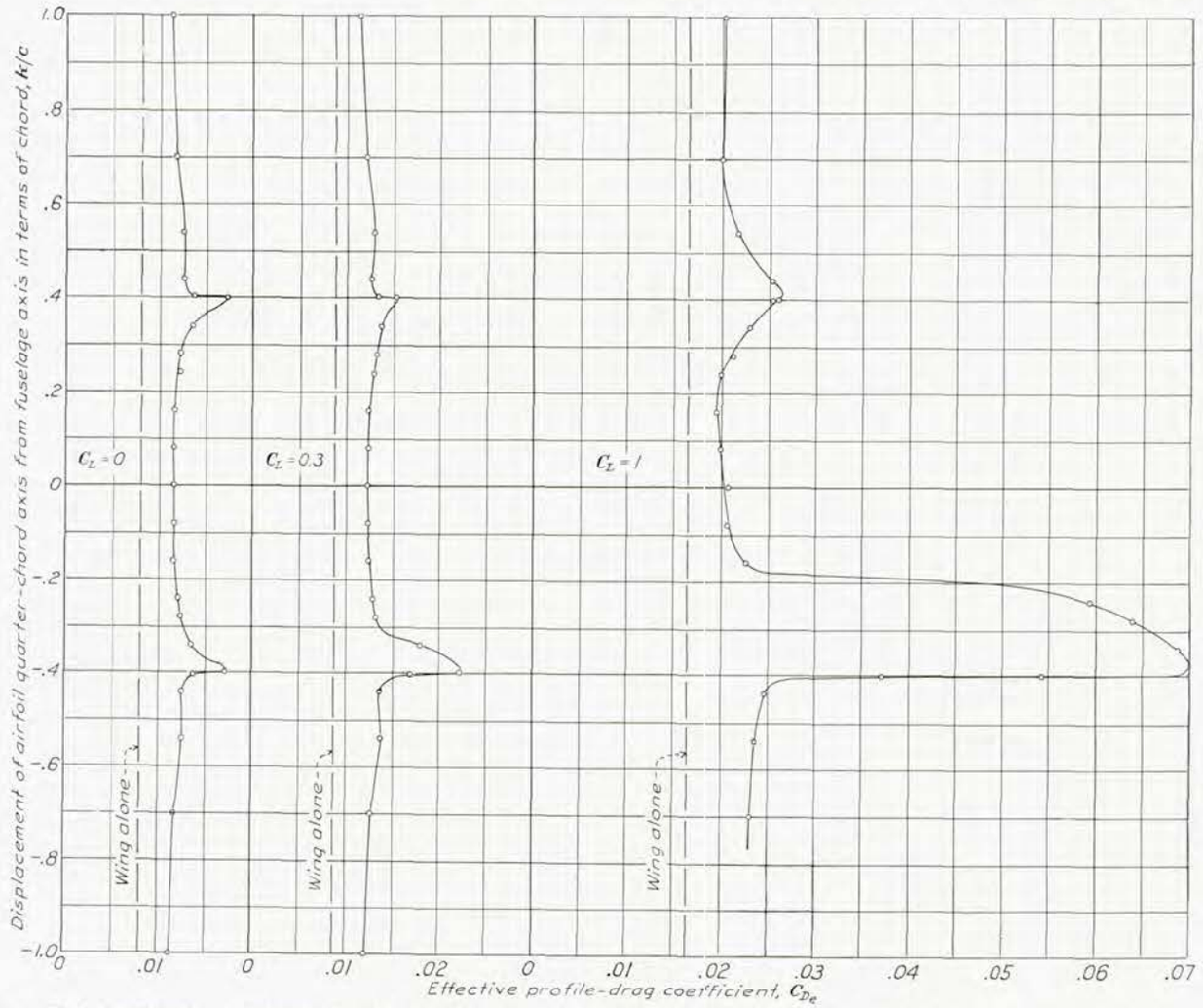


FIGURE 10.—Variation of effective profile-drag coefficient with vertical wing position. Rectangular wing of N. A. C. A. 0012 airfoil section and round fuselage; $d/c = 0$; $i_w = 0°$.

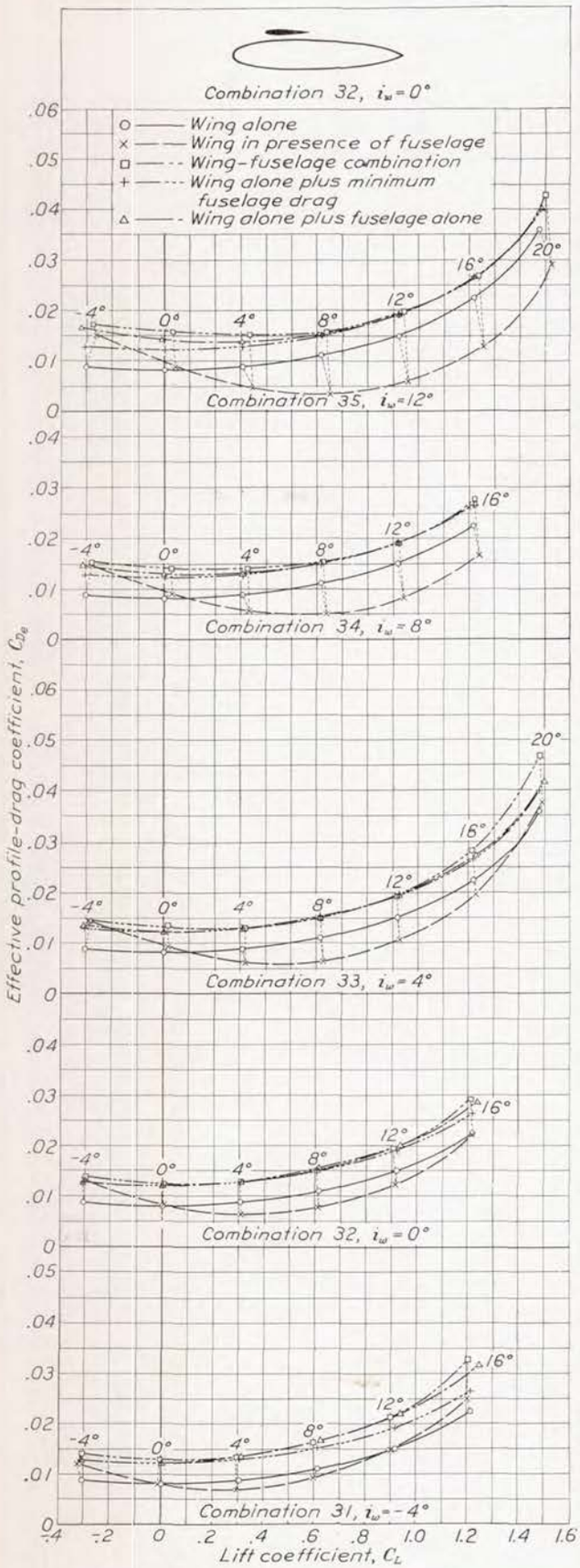


FIGURE 11.—Effect of mutual interference of wing and fuselage on disconnected high-wing combinations.

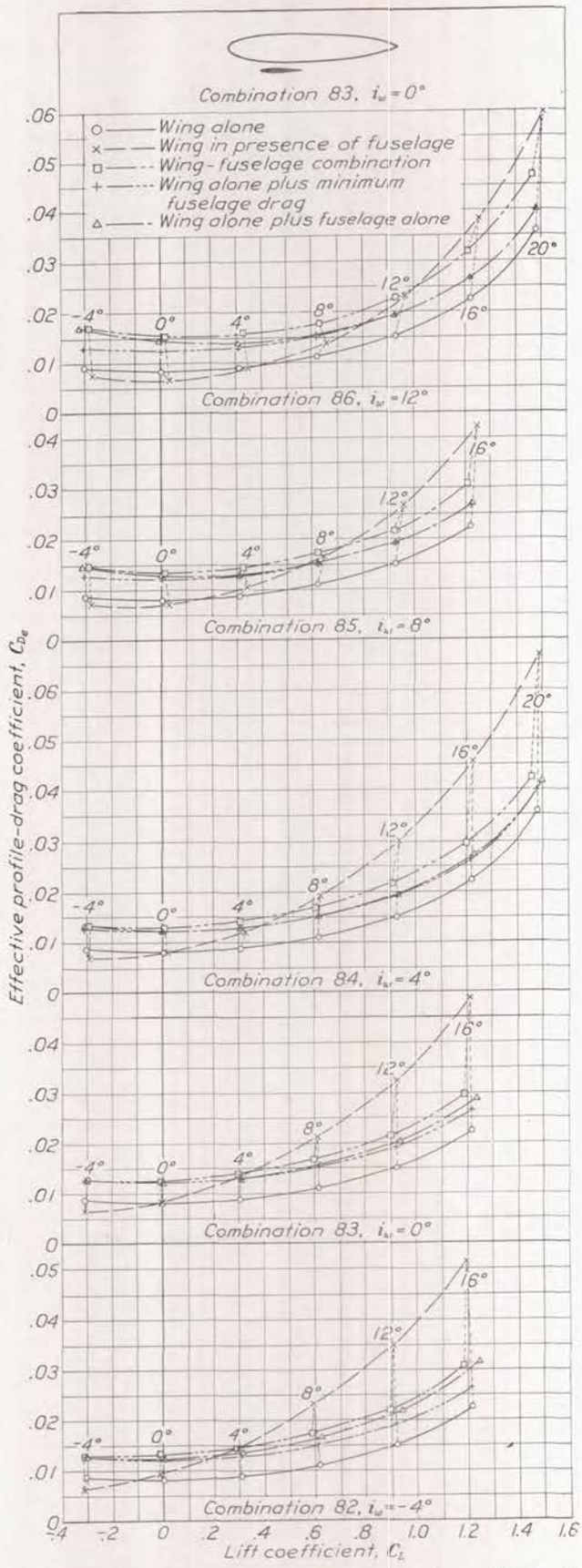


FIGURE 12.—Effect of mutual interference of wing and fuselage on disconnected low-wing combinations.

The results of tests of the high-wing connected combinations indicate an increase in the drag and interference of the fuselage as the wing approaches the fuselage surface and the angle at the juncture becomes acute. The highest drags result from the combination in which the lower surface of the wing is tangent to the surface of the fuselage. At zero lift the drag and interference of the fuselage for this combination is 224 percent of the minimum fuselage drag and at a moderately high lift is slightly higher. None of the high-wing combinations tested show an interference burble.

The low-wing connected combinations have the largest drags of any of the combinations tested.

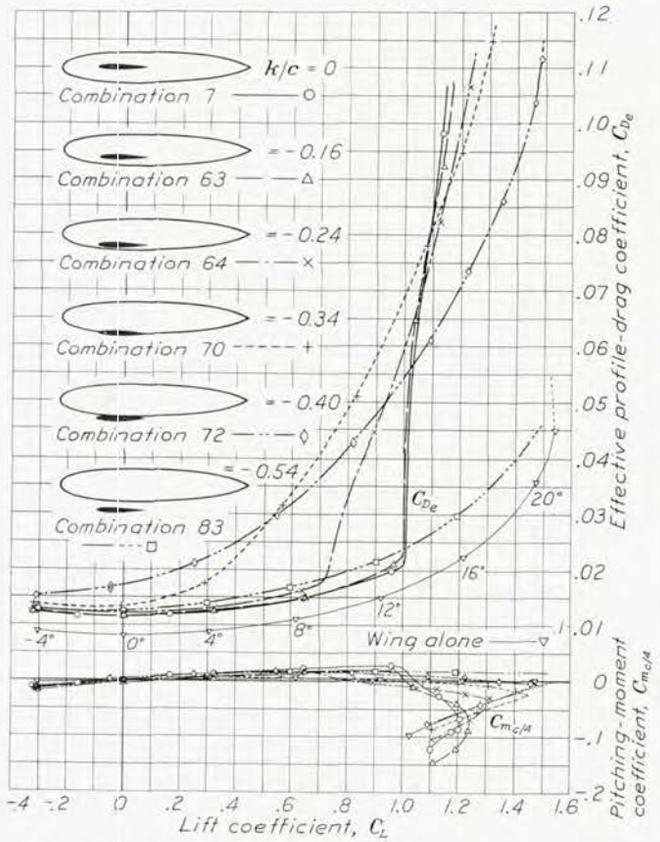


FIGURE 13.—Characteristics for various vertical wing positions. Rectangular wing of N. A. C. A. 0012 airfoil section and round fuselage.

With the wing in the low-wing positions the angle between the fuselage and the upper surface of the wing is acute and the geometrical divergence rapid. The adverse effects resulting from placing the wing on the lower portion of the fuselage are shown more completely in figure 13 by the graphical presentation of the results of tests of some typical combinations. It may be seen that lowering the wing increases the drag in the high-speed range and results in an earlier occurrence of the interference burble. As the wing approaches the externally tangent position the drags of the combinations become very large, even in the high-speed range. The most unfavorable position is with the wing partly contained in the fuselage (figs. 10 and 13). For this combination the drag and interference of the fuselage at zero lift is the same as that of the corresponding high-wing combination, but at a lift coefficient of 1 the drag and interference of the fuselage is 1,300 percent of the minimum drag of the fuselage alone. Those combinations having junctures that result in large drags and adverse interference effects require filleting to improve the aerodynamic characteristics.

Fore-and-aft position.—A complete analysis of the effects of a variation of the wing fore-and-aft position cannot be made from the available data. The data for the midposition and two disconnected vertical

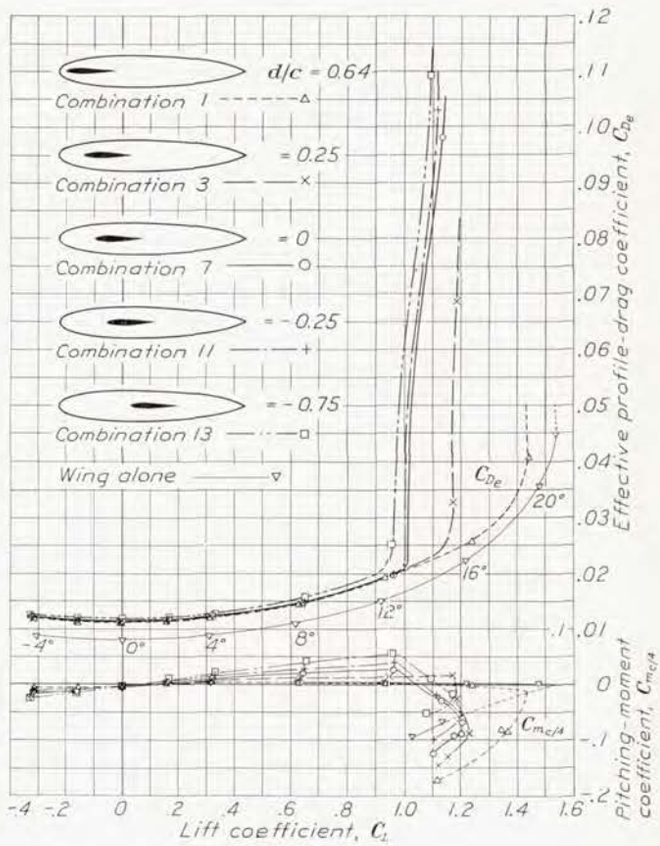


FIGURE 14.—Characteristics for various fore-and-aft wing positions. Rectangular wing of N. A. C. A. 0012 airfoil section and round fuselage.

positions indicate, however, that the variation of the fore-and-aft position of the wing has very little effect on the drag and interference of the fuselage except as it affects the occurrence of the interference burble of the mid-wing combinations. The effect of the fore-and-aft position is illustrated by the results of tests of combinations having the rectangular wing of symmetrical section in various mid-wing fore-and-aft positions (fig. 14). The drag tends to increase slightly as the wing is moved backward, the drag and interference of the fuselage at zero lift varying from 76 percent of the minimum fuselage drag with the wing in the most forward position to 93 percent in the

rear position. The chief effect of varying the fore-and-aft position of the wing is on the occurrence of the interference burble. The interference burble does not appear when the wing is in the most forward mid-wing position but is present for the second position back and occurs progressively earlier as the wing is moved backward from this latter position (fig. 14). In the region of the maximum diameter of the fuselage large changes in the fore-and-aft position of the wing apparently have little effect. The interference burble is probably affected principally by the amount of the leading edge of the wing contained within the fuselage. The most advantageous position aerodynamically is

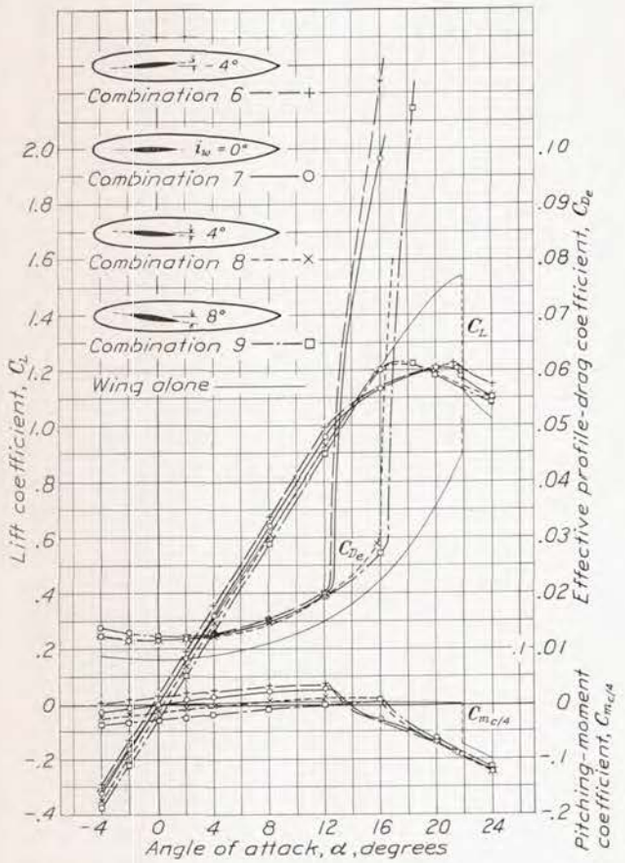


FIGURE 15.—Characteristics for various angles of wing setting. Rectangular wing of N. A. C. A. 0012 airfoil section and round fuselage.

well forward. This advantageous position gives the lowest drags and a small moment-curve slope but is impracticable because of the center-of-gravity location.

Tests of the combinations having the wing in the separated low-wing and high-wing positions show no definite tendencies with variations of the fore-and-aft position.

Wing setting.—The variation of the angle of wing setting affects the drag and interference of the fuselage chiefly by varying the attitude of the fuselage with respect to the relative wind for any given angle of attack of the combination. The angle of wing setting may also affect the wing-fuselage juncture, particularly for the combinations having the wing near the upper or lower surface of the fuselage, with resultant interference effects.

The effect of the variation of the wing setting is shown for a typical mid-wing position in figure 15. The chief effect is on the lift and pitching moment; the effect on the drag of the combination is small except as an increase in the wing setting delays the interference burble.

The variation of the wing setting with other vertical positions is most important for the high-wing and low-wing connected combinations where the wing is near the upper or lower surfaces of the fuselage.

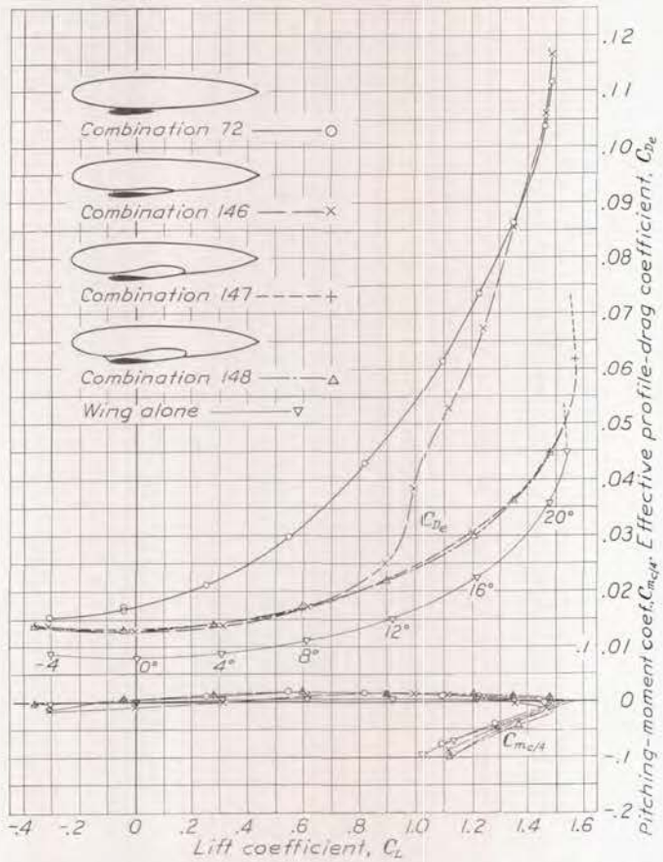


FIGURE 16.—Characteristics for various fillets on an unsatisfactory low-wing combination. Rectangular wing of N. A. C. A. 0012 airfoil section and round fuselage.

For such combinations small changes of the wing setting result in critical changes of the wing-fuselage junctures. The effects of variations of the angle of wing setting are not, however, large for any of the positions.

With variation of incidence other fore-and-aft mid-wing positions generally exhibit the same results as those of the normal mid-wing position. In the ranges of high speed and moderately high lift the wing setting has slight effect. Increasing the angle is chiefly effective in delaying the interference burble.

Fillets.—The addition of fillets to an unsatisfactory juncture reduces the drag and adverse interference of the fuselage by reducing the divergence and the combined adverse pressure gradients of the two bodies at the juncture. Fillets may also reduce the skin friction by reducing the wetted area at the juncture. An extensive investigation of various fillets is impracticable because specific applications will usually require individual designs. The favorable use of fillets, however, is typically illustrated for an unsatisfactory combination in figure 16, which shows that even small fillets give a marked improvement. The importance of completely filleting the rear portion of the juncture may be noted by comparing the curves of the combinations having small fillets with those having large ones. The interference burble, which still appears with the small fillets, is eliminated by increasing the size of the fillets to the rear. For some combinations small fillets may be more desirable than large fillets from considerations of steep glide characteristics because of the large increase in drag at lift coefficients above the climbing regime with only a small decrease in maximum lift.

For the high-wing combinations the chief effect of filleting is to reduce the drag and interference of the fuselage in the high-speed range where a high drag of the unfilleted combination may indicate serious interference.

An attempt was made to delay or eliminate the occurrence of the interference burble of the mid-wing combinations by changing the form of the juncture between the wing and fuselage. This change was effected by means of 3 sizes of normal fillets, which increased the root thickness and chord, and 3 sets of plan-form fillets, which increased the root chord and which varied the effective angle of attack of the root section when the trailing edge of the fillet was moved downward (washed-in fillets) and when moved upward (washed-out fillets) from the trailing edge of the wing. The results of tests of the combinations having normal fillets show that neither the interference burble nor drag is appreciably different from those of the unfilleted combination. These results agree with the results reported in reference 5: that for this type of juncture fillets have little effect on the drag. An increase in the root chord, obtained by means of a straight plan-form fillet, delays the burble to somewhat higher values of the lift coefficient and slightly increases the drag in the high-speed range. Washed-in and washed-out plan-form fillets increase the drag and interference but only slightly delay the occurrence of the interference burble. The chief effect of these fillets is on the lift and pitching moment.

Strut attachments.—Several combinations were tested in which disconnected wings and fuselages were joined by single struts, representing one means of connecting the body and the wing. For the high-wing combinations investigated the thickness or position of the strut has no large effect on the drag and interference. A combination having a moderately thick strut has characteristics comparable with those of the combination having a thin-plate connection or no connection at all. The thick strut increases the drag of the combination slightly. Tests of the combinations having a thick strut indicate that the forward position is slightly more favorable than the rear position. The drag differences due to the strut connections, however, are not large.

In the low-wing combinations the thick strut causes marked interference effects, which are absent for the combinations having the moderately thick strut and the thin plate. All three thick-strut combinations show an early interference burble. With the strut in the rear position, a discontinuity appears in the polar curve just beyond the interference burble. When the strut is moved forward, the drag is slightly improved in the high-speed range and the discontinuity is not so marked. Filleting the junctures between a thick strut and the wing and fuselage tends to increase the interference drag of the combination. The moderately thick strut is comparable with the thin-plate connection, both combinations having lower drags than the thick-strut combination and showing a normal drag increase over the entire range of lift coefficients.

Wing Shape.—At high values of the lift coefficient the stability of the air flow over the central portion of the wing varies for different wings. This stability may be expected to be critically affected by the presence of a fuselage and by the character of the root juncture.

Polar curves giving the results of tests of four mid-wing combinations having different wing shapes are compared in figure 17. The critical effect of the wing shape in the high-lift region is readily apparent from the curves. The interference burble, which occurs at a moderately high lift coefficient for the combination having the rectangular wing of symmetrical section, does not occur for the combinations having the cambered and tapered wings. Also, the drag for the combinations having the cambered and the tapered wings increases less rapidly than for the wings alone in the high-lift region. (See figs. 18 and 19.) In the high-speed range and up to moderately high lift coefficients the effect of the wing shape on the drag and interference of the fuselage is small except for the combination having the cut-out wing. For this combination the drag and interference decreases with increasing lift nearly up to the normal interference burble of the cut-out wing alone; whereas the drag and interference of the fuselage for combinations having the other wings remains reasonably constant. The drag and interference of the fuselage in the high-speed range for the

combination having the tapered wing is only 54 percent of the minimum drag of the fuselage, which is the lowest of the four combinations considered. The favorable drag characteristics of the tapered-wing combination may be attributed to the fact that the thick, high-drag portion of the wing is largely shielded within the fuselage. The minimum drag of this combination is equal to that of the combinations with the rectangular wing of symmetrical section and, aside from structural considerations, has the advantage of a high maximum lift and no interference burble.

The shape of the wing makes very little difference in the drag and interference of the fuselage as affected by the wing setting. The greatest differences are shown

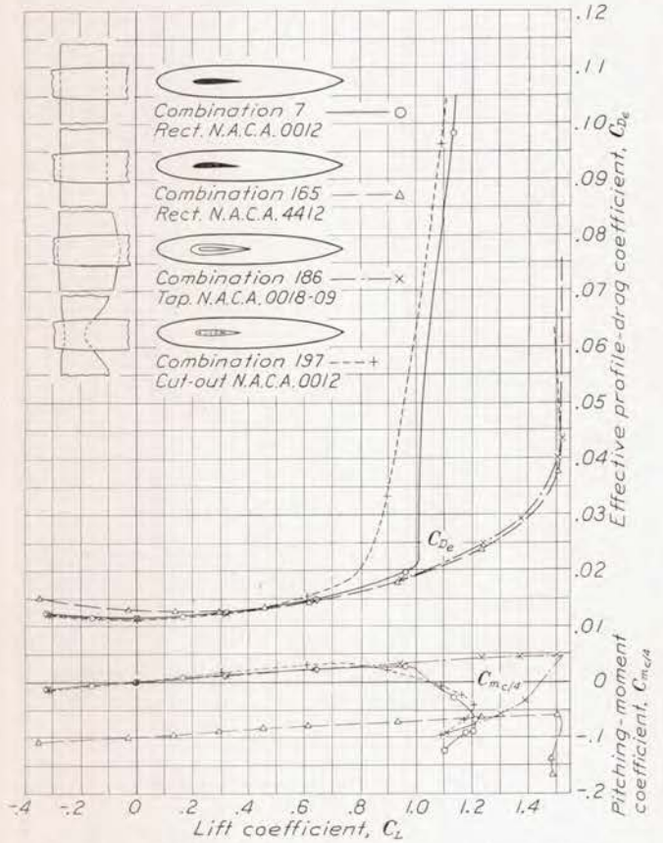


FIGURE 17.—Characteristics for various wing shapes. Round fuselage, mid-wing position.

by the combinations having the cut-out wing in the high-wing and low-wing separated positions for which the lowest drags are obtained with relatively large angles of wing setting. The cambered-wing combinations tend to have the lowest drags at higher negative angles of wing setting than the combinations with the rectangular wing of symmetrical section. This result may be accounted for by the negative angle of zero lift of the cambered wing.

Other vertical positions affect the combinations having the various wing shapes in a manner similar to their effect on the combinations with the rectangular wing of symmetrical section, as indicated in figures 18 and 19. They all show a large drag and interference where the juncture is unsatisfactory. The thick root of the tapered wing results in a more satisfactory form of juncture than those resulting from the other wing roots as evidenced by the fact that the drag increases less rapidly for the low-wing combination (fig. 18) than for the corresponding combination with the rectangular wing of symmetrical section. The interference burble is also delayed.

Fuselage Shape.—The variations of the fuselage shape are the cross-sectional form and the presence of an uncowled or a cowled engine. Variations of the cross-sectional form chiefly affect the form of wing-

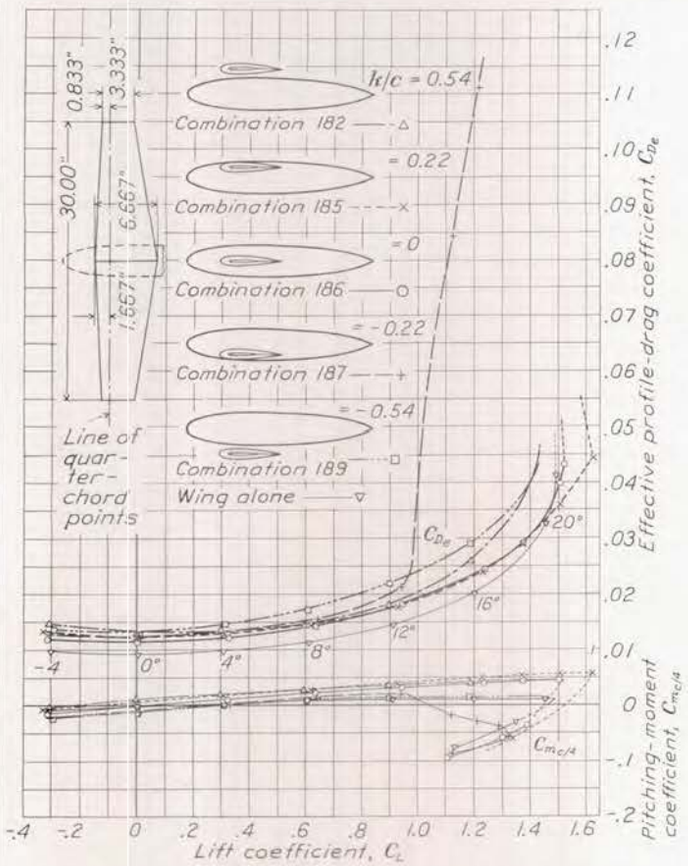


FIGURE 18.—Characteristics for various vertical wing positions. Tapered N. A. C. A. 0018-09 airfoil and round fuselage.

fuselage juncture. The addition of an engine introduces an interfering body at the nose of the fuselage, with resulting turbulence and variation of the air flow over the fuselage and the wing roots.

Uncowled and cowled engine.—The effects of adding either an uncowled or a cowled engine to typical mid-wing combinations are shown in figure 20. The addition of an uncowled engine to the round-fuselage combination increases the drag and interference of the fuselage at zero lift of the combination to 434 percent of the minimum drag of the fuselage alone without the

engine and delays the occurrence of the interference burble. If the difference in drag is based on the fuselage alone with the uncowled engine, the interference is slightly favorable. The addition of a cowled engine increases the drag and interference of the fuselage at zero lift of the combination to 149 percent of the minimum drag of the fuselage alone without the cowled engine, with favorable interference when based on the fuselage alone with the cowled engine. The interference burble is entirely absent for the cowled-engine combination. The drag and interference of the fuselage, which is substantially constant over a considerable lift range for the no-engine combination, increases with

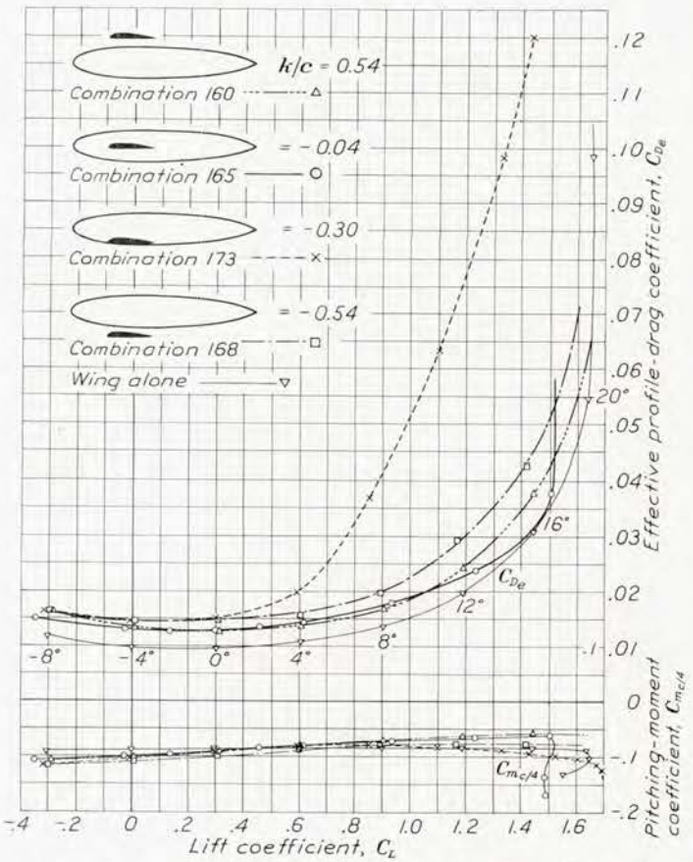


FIGURE 19.—Characteristics for various vertical wing positions. Cambered wing of N. A. C. A. 4412 airfoil section and round fuselage.

increasing lift when either the uncowled or cowled engine is added. The addition of the uncowled or cowled engine to the filleted mid-wing combination has no effects appreciably different from those of the unfilleted combination.

Tests of combinations of the rectangular wing of symmetrical section having the wing in a separated low-wing position indicate that the drag and interference of the fuselage with an uncowled or a cowled engine is somewhat higher than for corresponding combinations having the wing in the mid-wing position. Also, the drag and interference increases rapidly with increasing lift.

With the wing in the parasol or separated high-wing position, the drag and interference is approximately the same in the high-speed range as with the wing in the mid-wing position for corresponding combinations. An early interference burble occurs, however, for both the uncowled and cowled engine combinations at the approximate attitude at which the wing probably enters the turbulent wake from the engine. The interference burble becomes more abrupt with an increase in the angle of wing setting and the drag increase beyond the interference burble is more rapid for the uncowled-engine combinations than for the cowled-engine combinations.

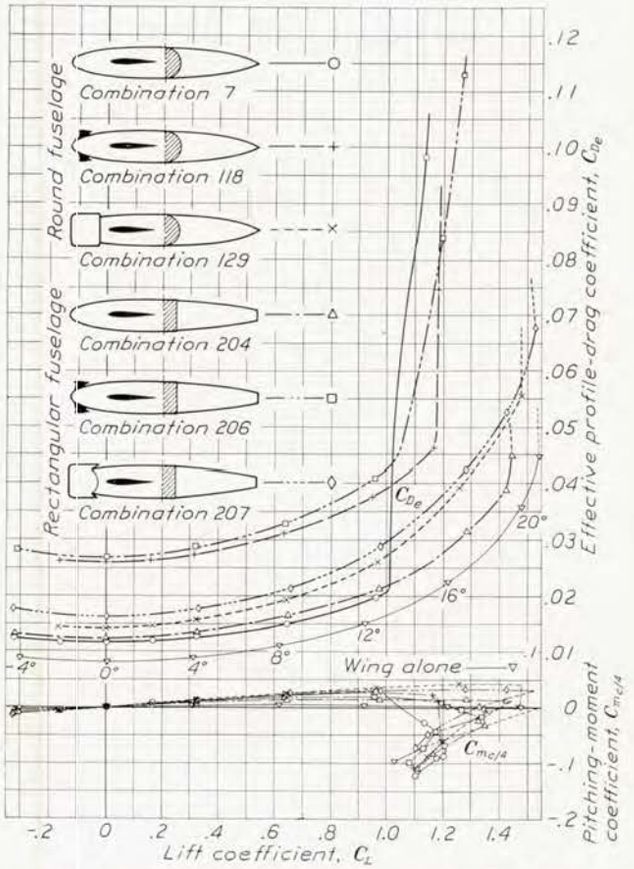


FIGURE 20.—Characteristics for various fuselage shapes. Mid-wing combinations with rectangular wing of N. A. C. A. 0012 airfoil section.

One mid-wing combination having the cowled engine and the cambered wing was tested to obtain information about the effect of the wing shape on this type of combination. At zero lift the drag and interference of the fuselage is the same as for the corresponding combination having the rectangular wing of symmetrical section but the increase in drag with increase in lift is much less and, in the high-speed range, is reasonably constant; whereas the drag of the combination having the rectangular wing of symmetrical section increases with an increase in lift.

The connected low-wing combination having the cambered wing and the round fuselage was chosen as

representing a typically unsatisfactory combination. Variations of the fuselage shape from this basic combination are shown in figure 21. Neither the uncowled nor the cowled engines affect the interference burble or the rapid drag increase that appears in the combinations with no engine in the fuselage.

Filleting the junctures of these typical low-wing combinations eliminates the interference burble and the rapid drag increase. Flow changes over the fuselage and wing roots due to the presence of an uncowled or a cowled engine do not greatly affect the action of the fillets.

Fuselage section.—Typical results for variations of the cross-sectional shape of the fuselage and the nose form resulting from the presence of an uncowled and cowled engine are illustrated in figure 20, which compares the results of tests of the rectangular fuselage and the round fuselage in combinations with the rectangular wing of symmetrical section in the mid-wing position. The principal result is the absence of the interference burble for the rectangular fuselage combination with no engine. Otherwise the rectangular fuselage combinations have generally higher drags over the entire lift range; the differences in drag of the no-engine fuselage combinations and the combinations having an uncowled engine approximately equal the differences between the corresponding round and rectangular fuselages alone. The results also show that the rectangular-fuselage combination having the uncowled engine has an early interference burble; no interference burble is present for the no-engine fuselage combination. The differences in drag between the round and the rectangular fuselage combinations having a cowled engine are greater than between either the combinations having the no-engine fuselage or the combinations having an uncowled engine, probably because of the peculiar shape of the cowling on the rectangular fuselage.

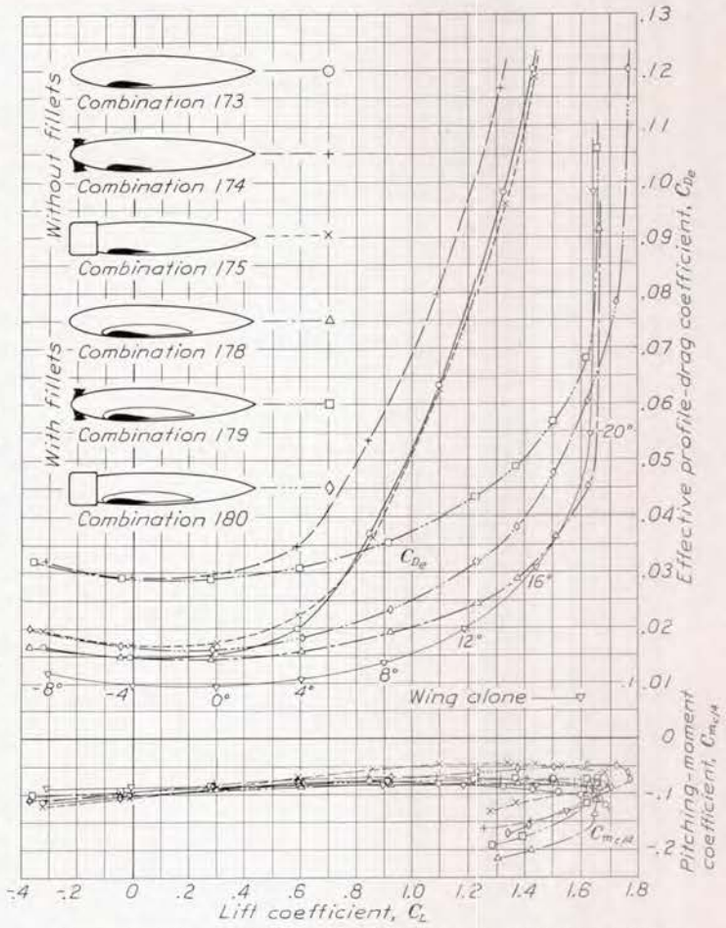


FIGURE 21.—Characteristics for various fuselage shapes. Typical unsatisfactory low-wing combinations, N. A. C. A. 4412 airfoil section with round fuselage.

A comparison of the results of tests of the rectangular-fuselage combinations having different wings with those of corresponding round-fuselage combinations indicates that, regardless of the wing shape, the characteristics of a mid-wing combination are not appreciably affected by the cross-sectional shape of the fuselage. An exception is noted for the combination with the rectangular wing of symmetrical section in which the interference burble is absent when the rectangular fuselage is used.

The importance of the combined action of the fuselage and the wing pressure gradients and air flow is illustrated by the sudden interference burble of the mid-wing combination of the rectangular wing of symmetrical section and the round fuselage. With other wings and with the rectangular fuselage, this early breakdown of the air flow is not evident. The introduction of turbulence and the probable change of the pressure gradient due to the addition of an uncowled engine apparently has no appreciable effect; whereas the addition of a cowled engine eliminates the interference burble of the mid-wing combination. This effect on the interference burble indicates that for wings having sections of the type similar to that of the N. A. C. A. 0012, i. e., those sections having a critical degree of stability of the air flow near maximum lift as indicated by a sudden loss of lift at the burble, the stability of the air flow over the wing roots is critically affected by the fuselage shape.

PITCHING MOMENT OF THE COMBINATIONS

As the interference effects on the pitching moment are usually small in the lift range below the interference burble, the approximate pitching moment of a wing-fuselage combination may usually be obtained by adding the moments of the wing and the fuselage. The pitching moments of fuselages of the type used in these tests are not constant about any one point as indicated by the variation of the pitching moment for the fuselages alone (see table II.) The slope of the

pitching-moment curve measured at zero lift n_0 shows that the aerodynamic center of the fuselage at the attitude of zero lift is well forward. When the moments of the fuselage are added to those of the wing, the resulting moments of the wing-fuselage combination indicate a position of the aerodynamic center (at zero lift) well forward of the quarter-chord point of the wing for the usual wing positions. The values of the slopes of the pitching-moment curves at zero lift, which represent the fore-and-aft positions of the aerodynamic center as fractions of the chord ahead of the quarter-chord point of the airfoil, are given for all the combinations in table V. The variable of most influence on the position of the aerodynamic center is the fore-and-aft position of the wing. As the wing moves aft from the most forward (mid-wing) position (fig. 14), the value of n_0 increases from 0.012 in the forward position to 0.067 in the rear position (table V). This increase represents a change in the fore-and-aft position of the aerodynamic center from 1.2 to 6.7 percent of the wing chord ahead of the quarter-chord point.

The effect on the aerodynamic center of adding fillets to a combination may also be of interest. The relatively large changes in the position of the aerodynamic center when fillets are added (table V) indicate that filleting the junctures of existing airplanes may affect the longitudinal stability to a serious extent unless compensating changes are made. Because the pitching moments of a combination are not constant about any one point, no actual aerodynamic center exists for a combination. Nevertheless, the value given representing the aerodynamic center as determined at zero lift, together with the pitching-moment coefficient at zero lift, provides information about the moment in the high-speed range of a combination.

The effects of the variables considered in this investigation on the pitching moment of the combinations are best studied by considering only the moment at zero lift. Values of the pitching-moment coefficient at zero lift C_{m_0} are given in table V for all the combinations tested. The chief effects are those caused by variations of the angle of wing setting (fig. 15) and variations in camber of the wing section (fig. 17). The angle of wing setting affects the relative attitude of the fuselage with respect to the attitude of the wing and the effect of wing setting on the pitching moment of the combination may be considered as being due almost entirely to the displacement of the pitching-moment curve of the fuselage alone. Increasing the wing setting 4° (near zero incidence) increases the diving moment at zero lift in the order of 13 to 19 percent of the moment of a moderately cambered wing. Other variables have small effects on the moment at zero lift. Figure 22 shows the variation of $C_{mc/4}$ with the vertical position of the rectangular N. A. C. A. 0012 wing set at 0° with respect to the round fuselage for values of the lift coefficient of 0, 0.3, and 1.

After the appearance of the interference burble the effect of the interference on the pitching moment increases. The effect of the interference burble is similar to the effect of the normal burble of an airfoil as the diving moment increases rapidly with an increase in the angle of attack beyond the burble. The large pitching-moment variations with variations of the vertical position of the wing, shown in figure 22 for lift coefficients of 0.3 and 1, are mainly because the air flow has already broken down at the interference

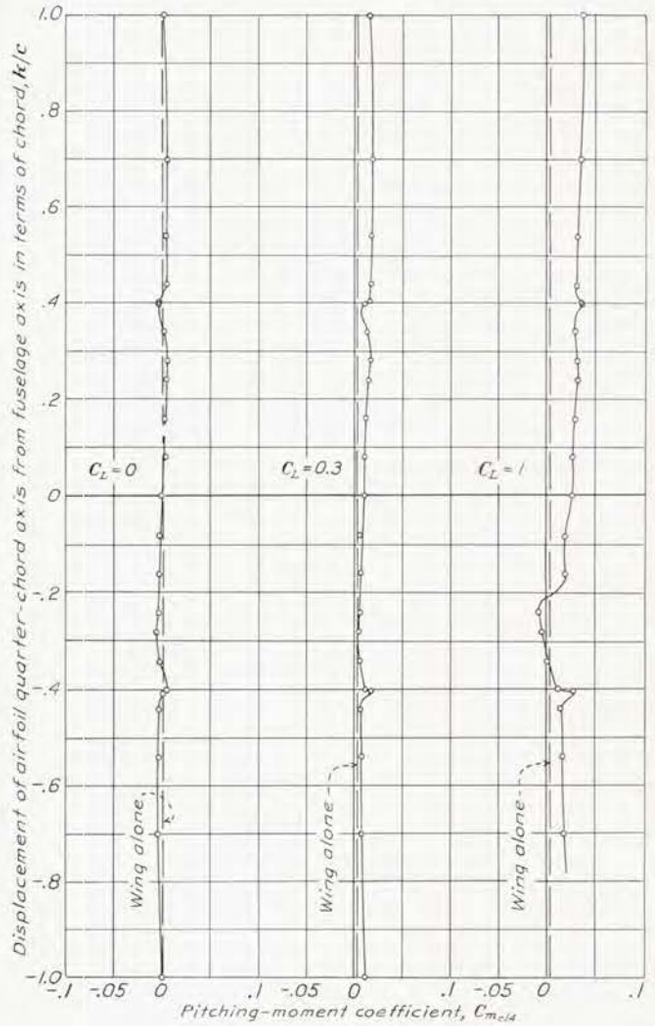


FIGURE 22.—Variation of pitching-moment coefficient with vertical wing position. Rectangular wing of N. A. C. A. 0012 airfoil section and round fuselage; $d/c = 0$; $i_w = 0°$.

burble for combinations having the wing in the positions corresponding to the large pitching-moment variations.

MAXIMUM LIFT OF THE COMBINATIONS

Considerations of the maximum lift coefficient of the wing as affected by the presence of the fuselage may be as important as considerations of the drag. The maximum lift is considered separately, however,

because the results show that the flow breakdown determining the maximum lift coefficient is almost unrelated to and independent of the earlier flow breakdown (interference burble) that causes marked drag increases. For considerations of maximum lift coefficients, variations with the Reynolds Number must be taken into account; whereas for comparisons of the drag the high-scale results may be compared without regard to scale effect, any scale effect on the drag coefficients being small at the high Reynolds Numbers associated with high-speed flight where considerations of the drag are of greatest importance.

Data on the scale effect for the maximum lift are given in table V by giving the maximum lift coefficients of the combinations at two values of the "effective Reynolds Number." The effective Reynolds Number is obtained from the actual test Reynolds Number by the application of a factor to allow for the effects of turbulence present in the tunnel. (See references 15 and 16.) Comparative tests indicate that, at this effective value of the Reynolds Number, maximum lift coefficients from the tunnel tend to agree with those in flight. The maximum lift coefficients presented should therefore be applied to flight at Reynolds Numbers of 3,400,000 and 7,500,000. The values given for the higher Reynolds Number are approximately correct for modern two-engine transport airplanes (7,500,000 corresponds to an airplane having a wing with an 11-foot mean chord and landing at 73 miles per hour) and the maximum lift coefficients given for 3,400,000 are approximately correct for popular single-engine four-place types (having a wing with a 6-foot mean chord and landing at 60 miles per hour).

As an aid in extending the maximum lift results to other values of the Reynolds Number, the variations of the coefficients for the wings alone are shown in figure 23 for a wider range of the Reynolds Number. For the extension of the results, it will be helpful to note that the scale effect for the wing-fuselage combination is either much like the scale effect for the wing alone when the adverse interference is small or the scale effect is small when the combination shows marked adverse interference. In other words, the results may usually be either corrected for scale effect paralleling the curve for the wing alone in figure 23 or used uncorrected, depending on the character of the interference.

Wing Position.—Consider first the effect of varying the wing position of the combinations having the rectangular wing of symmetrical section and round fuselage. A variation of the vertical position of the wing indicates marked reductions of the maximum lift coefficient when the wing is in the center and in the low positions. The greatest reductions occur for some of the mid-wing combinations. For some of the combinations, the maximum lift tends to be slightly higher than that of the wing alone. The interference effects on the maximum lift are apparently independent of the effects on the drag.

A variation of the fore-and-aft mid-wing positions shows a steady reduction in the maximum lift coefficient from a value approaching that of the wing alone at the most forward position to a value below that for the normal fore-and-aft position when the wing is well back along the fuselage. For the disconnected combinations a variation of the fore-and-aft position shows very little effect.

The angular position for a normal range of wing setting does not appreciably affect the maximum lift coefficients of the combinations. Although the differences over the full ranges of wing setting tested are sometimes rather large, there do not appear to be any noticeable general trends.

The effect on the maximum lift coefficients of the position variables appears to be governed mainly by the amount of the leading edge and upper surface of the wing exposed.

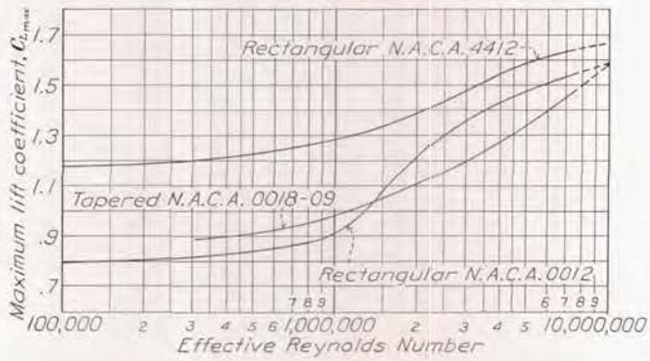


FIGURE 23.—Scale effect on the maximum lift coefficient of three wings.

Wing Shape.—The maximum lift coefficients of the combinations having the cambered wing are apparently much less affected by the different variables than are the maximum lift coefficients of the combinations having the rectangular wing of symmetrical section. The combinations having the tapered wing show generally favorable effects, except for the low-wing connected combinations, in which the effect is somewhat unfavorable over a small range of vertical positions. The maximum lift coefficients of the cut-out wing combinations are all low when compared with the uncut wing combinations but are somewhat higher than the maximum lift coefficients of the cut-out wing alone. In general, the conclusion is that low-cambered moderately thick wing sections like the N. A. C. A. 0012 having critical flow conditions at maximum lift are more susceptible than other sections to adverse interference from the fuselage and, on the other hand, that tapered wings having thick root sections may show favorable interference effects on the maximum lift coefficient as the result of enclosing the thickest part of the wing in the fuselage.

Fuselage Shape.—The rectangular fuselage mid-wing combination having the rectangular wing of symmetrical section has a more favorable maximum lift coefficient than the round-fuselage combination. With other wings there are smaller differences between the maximum lift coefficients of the round and rectangular-fuselage mid-wing combinations. Addition of the uncowled engine tends to decrease the maximum lift coefficient from that of the corresponding no-engine fuselage combination. Addition of the cowling, however, tends to eliminate the adverse effect of the engine and sometimes increases the maximum lift coefficient above that of the corresponding no-engine fuselage combination.

Fillets and Strut Attachments.—Fillets have a slight effect on the maximum lift coefficient except for certain well-shaped fillets that increase the maximum lift slightly with increase in size of the fillet, probably owing to an increase in the effective wing area. Differences appear to be surprisingly small between the maximum lift coefficients of the filleted and unfilleted combinations having very high-drag junctures. Straight plan-form fillets improve the maximum lift coefficients over the unfilleted mid-wing combination owing to the increase in area due to the fillets. The washed-in and washed-out fillets affect the maximum lift coefficients of the combinations in a manner similar to that to be expected with corresponding changes of camber of the section.

The combinations having thick and moderately thick connecting struts show some loss of maximum lift from that of the wing alone. The maximum lift coefficients of the combinations having a thin connecting plate are approximately the same as that of the wing alone and agree fairly well with the similar unconnected combinations.

CONCLUSION

As regards the general aerodynamic efficiency of the various combinations investigated, the most satisfactory criterion is probably the ratio $C_{L_{max}}/C_{D_e}$, where C_{D_e} is taken at a lift coefficient corresponding to either high-speed or cruising flight. On the basis of this so-called "speed-range index" the order of merit of the combinations may change with the Reynolds Number as the result of the rather large variation of $C_{L_{max}}$ with Reynolds Number for some of the combinations. A comparison of the various combinations on the basis of the speed-range index indicates that some of the parasol arrangements with the round fuselage and the N. A. C. A. 4412 airfoil would be among the best if the drag of the necessary wing-supporting members were eliminated as in the tests. If these combinations are eliminated because of the unavoidable drag of a wing-support system, the most favorable combinations seem to be those of the tapered wing or the rectangular N. A. C. A. 4412 wing in positions somewhat above the mid-wing position. The usual high-wing positions may be made nearly as favorable as the high mid-wing positions by the use of suitable fillets. Forward positions of the wing with respect to the fuselage appear to be favorable. Low-wing positions are unfavorable, but, by adequately filleting the wing-fuselage juncture, the aerodynamic efficiency of the low-wing combinations can be made to approach that of the better high-wing combinations.

In general, it may be noted that important favorable interference effects are usually the result of drag saved by enclosing a considerable part of the wing surface within the fuselage. Marked adverse interference effects are associated with a breakdown of the flow near the wing-fuselage juncture. This phenomenon, referred to as the "interference burble", is a complicated one dependent on the stability of the flow over the airfoil, the conditions at the wing-fuselage juncture, and the geometrical form of the air spaces at the juncture. Efficient airfoils of moderate thickness and low camber are most susceptible to such adverse interference. The interference burble does not necessarily affect the maximum lift coefficient.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., *March 8, 1935.*

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TABLE I.—AIRFOIL CHARACTERISTICS

Airfoil	C_L	C_{D_s}	$C_{m_{c/4}}$	C_L	C_{D_s}	$C_{m_{c/4}}$	C_L	C_{D_s}	$C_{m_{c/4}}$
	$\alpha=0°$			$\alpha=4°$			$\alpha=12°$		
Rectangular N. A. C. A. 0012	0.000	0.0080	0.000	0.307	0.0087	0.003	0.920	0.0150	0.004
Tapered N. A. C. A. 0018-09	.000	.0093	.000	.305	.0099	.006	.910	.0146	.013
Cut-out N. A. C. A. 0012	.000	.0074	.000	.266	.0085	.007	.788	.0186	.018
	$\alpha=-4°$			$\alpha=0°$			$\alpha=8°$		
Rectangular N. A. C. A. 4412	−0.006	0.0097	−0.089	0.298	0.0095	−0.087	0.899	0.0136	−0.084

TABLE II.—FUSELAGE CHARACTERISTICS

Fuselage	Engine	C_L	C_D	[1] C_{m_F}	C_L	C_D	[1] C_{m_F}	C_L	C_D	[1] C_{m_F}	C_L	C_D	[1] C_{m_F}	C_L	C_D	[1] C_{m_F}
		$\alpha=0°$			$\alpha=4°$			$\alpha=8°$			$\alpha=12°$			$\alpha=16°$		
Round	None	0.000	0.0041	0.000	0.001	0.0042	0.016	0.005	0.0049	0.028	0.011	0.0062	0.035	0.019	0.0085	0.038
Do	Uncowled	.000	.0189	.000	.001	.0191	.015	.004	.0200	.027	.008	.0216	.037	.015	.0244	.041
Do	Cowled	.0000	.0069	.000	.008	.0073	.013	.017	.0088	.025	.028	.0115	.035	.040	.0165	.044
Rectangular	None	.00	.0049	.000	.005	.0054	.009	.014	.0068	.015	.026	.0097	.018	.040	.0151	.015

[1] Pitching-moment coefficient about the quarter-chord point of the fuselage.

TABLE III.—LIFT AND INTERFERENCE, DRAG AND INTERFERENCE, AND PITCHING MOMENT AND INTERFERENCE OF FUSELAGE IN WING-FUSELAGE COMBINATIONS

Combination	ΔC_L	ΔC_{D_a}	$\Delta C_{m_{c/4}}$	ΔC_L	ΔC_{D_a}	$\Delta C_{m_{c/4}}$	ΔC_L	ΔC_{D_a}	$\Delta C_{m_{c/4}}$	Combination	ΔC_L	ΔC_{D_a}	$\Delta C_{m_{c/4}}$	ΔC_L	ΔC_{D_a}	$\Delta C_{m_{c/4}}$	ΔC_L	ΔC_{D_a}	$\Delta C_{m_{c/4}}$
	$\alpha=0°$			$\alpha=4°$			$\alpha=12°$				$\alpha=0°$			$\alpha=4°$			$\alpha=12°$		
1	0.000	0.0031	0.000	0.007	0.0035	0.002	0.016	0.0042	−0.002	80	0.015	0.0060	−0.029	0.018	0.0064	−0.023	−0.013	0.0107	−0.008
2	.062	.0042	.026	.071	.0050	.029	.092	.0067	.029	81	.020	.0080	−.030	.021	.0084	−.032	−.014	.0136	−.015
3	.000	.0032	.000	.008	.0037	.005	.026	.0046	.012	82	−.017	.0054	.015	−.018	.0057	.018	−.027	.0070	.021
4	−.062	.0042	−.026	−.050	.0039	−.023	−.028	.0044	−.014	83	−.006	.0045	−.003	−.008	.0053	.004	−.018	.0065	.012
5	.063	.0044	.027	.068	.0053	.033	.094	.0071	.042	84	.005	.0049	−.019	.001	.0056	−.012	−.015	.0069	.004
6	.028	.0036	.014	.044	.0038	.021	.071	.0053	.032	85	.012	.0054	−.030	.013	.0059	−.025	−.003	.0067	−.009
7	.000	.0035	.000	.013	.0039	.009	.040	.0047	.024	86	.017	.0071	−.034	.017	.0071	−.032	.002	.0076	−.023
8	−.028	.0036	−.014	−.015	.0036	−.005	.006	.0045	.008	87	−.021	.0040	.011	−.024	.0048	.017	−.033	.0059	.020
9	−.063	.0044	−.027	−.047	.0041	−.019	−.020	.0042	−.004	88	−.010	.0038	−.006	−.014	.0040	.003	−.034	.0056	.014
10	.058	.0044	.032	.069	.0057	.042	.070	.0300	.037	89	.001	.0038	−.023	−.005	.0041	−.014	−.019	.0052	.003
11	.000	.0035	.000	.022	.0038	.014	.044	.0051	.036	90	.007	.0046	−.033	.006	.0045	−.026	−.010	.0052	−.007
12	−.058	.0044	−.032	−.041	.0041	−.019	−.009	.0039	.003	91	.012	.0064	−.037	.012	.0059	−.034	−.007	.0074	−.022
13	.000	.0038	.000	.023	.0041	.019	.038	.0102	.052	92	−.021	.0038	.014	−.024	.0045	.022	-------	-------	-------
14	.000	.0036	.003	.016	.0038	.010	.049	.0042	.023	93	−.013	.0035	−.002	−.015	.0033	.008	-------	-------	-------
15	.000	.0036	.003	.011	.0038	.011	.047	.0040	.026	94	−.003	.0037	−.018	−.007	.0035	−.007	-------	-------	-------
16	−.002	.0041	.004	.012	.0043	.013	.039	.0042	.028	95	.001	.0040	−.029	.000	.0039	−.020	-------	-------	-------
17	−.003	.0053	.034	.022	.0063	.039	.041	.0089	.048	96	.004	.0056	−.034	.005	.0052	−.032	-------	-------	-------
18	.011	.0047	.021	.016	.0051	.029	-------	-------	-------	97	−.041	.0052	.023	−.040	.0061	.022	−.051	.0084	.009
19	−.001	.0042	.006	.008	.0046	.015	.030	.0051	.029	98	−.034	.0045	.011	−.035	.0052	.014	−.044	.0062	.010
20	−.017	.0037	−.009	−.008	.0041	−.002	.013	.0046	.012	99	−.023	.0052	−.007	−.026	.0046	−.001	−.035	.0052	.004
21	−.046	.0043	−.021	−.034	.0039	−.015	−.013	.0037	−.003	100	−.010	.0052	−.022	−.015	.0050	−.017	−.030	.0056	−.008
22	.010	.0054	.003	.012	.0052	.011	.021	.0067	.025	101	−.002	.0058	−.032	−.004	.0056	−.029	−.019	.0055	−.020
23	.022	.0114	.008	.001	.0077	.024	-------	-------	-------	102	.002	.0071	−.033	.004	.0067	−.035	−.011	.0064	−.032
24	.045	.0088	−.004	.004	.0066	.010	.000	.0083	.030	103	−.006	.0048	.013	−.005	.0057	.020	−.011	.0068	.026
25	.041	.0068	−.016	.031	.0053	−.007	.020	.0057	.013	104	.004	.0046	−.003	.006	.0050	.006	−.004	.0059	.017
26	−.006	.0058	.021	−.014	.0058	.028	−.022	.0089	.038	105	.017	.0047	−.018	.014	.0051	−.009	−.002	.0065	.009
27	.011	.0056	−.002	−.004	.0047	.013	−.020	.0082	.030	106	.023	.0053	−.029	.024	.0055	−.022	.007	.0067	−.003
28	−.008	.0049	.019	−.012	.0047	.028	−.019	.0077	.035	107	.025	.0073	−.034	.026	.0071	−.031	.010	.0074	−.016
29	.002	.0045	.004	.000	.0039	.015	−.014	.0062	.027	108	.016	.0049	.016	.018	.0056	.027	.011	.0080	.045
30	.014	.0045	−.012	.010	.0040	−.001	−.002	.0046	.014	109	.024	.0049	.000	.024	.0052	.013	.014	.0075	.036
31	−.005	.0049	.019	−.012	.0047	.028	−.019	.0063	.037	110	.034	.0052	−.017	.034	.0057	−.001	.018	.0070	.025
32	.006	.0045	.003	−.005	.0042	.015	−.014	.0046	.028	111	.040	.0063	−.029	.040	.0060	−.014	.023	.0072	.012
33	.017	.0054	−.015	.007	.0043	.000	−.005	.0044	.014	112	.043	.0077	−.037	.045	.0073	−.026	.026	.0087	.001
34	.026	.0050	−.028	.016	.0053	−.019	.005	.0043	−.002	113	.002	.0193	−.008	−.009	.0191	.013	−.069	.0289	.027
35	.030	.0078	−.033	.025	.0065	−.032	.018	.0047	−.021	114	.010	.0188	−.005	.001	.0183	−.001	−.064	.0265	.015
36	−.001	.0038	.023	−.012	.0035	.028	−.021	.0053	.038	115	.020	.0194	−.019	.012	.0182	−.011	−.047	.0230	.003
37	.010	.0038	.006	−.006	.0034	.016	−.011	.0029	.031	116	.030	.0204	−.033	.020	.0187	−.029	−.024	.0202	−.011
38	.021	.0040	−.011	.006	.0036	−.001	−.007	.0030	.020	117	.034	.0222	−.043	.031	.0202	−.042	−.003	.0192	−.025
39	.028	.0050	−.023	.017	.0041	−.018	.001	.0029	.002	118	.000	.0178	.000	.007	.0185	.010	.029	.0225	.024
40	.034	.0062	−.031	.025	.0051	−.030	.020	.0030	−.016	119	−.020	.0194	.019	−.024	.0210	.026	−.035	.0269	.031
41	.003	.0037	.018	−.007	.0029	.026	−.021	.0045	.041	120	−.010	.0188	−.005	−.012	.0204	.012	−.027	.0246	.023
42	.013	.0035	.002	−.001	.0028	.011	−.016	.0031	.032	121	−.002	.0193	−.008	−.003	.0197	−.001	−.012	.0238	.012
43	.021	.0038	−.014	.006	.0030	−.004	−.013	.0029	.021	122	.003	.0200	−.020	.004	.0204	−.012	−.007	.0237	.001
44	.027	.0045	−.027	.013	.0031	−.020	−.006	.0031	.003	123	.003	.0216	−.027	.011	.0212	−.023	−.002	.0233	−.010
45	.033	.0063	−.033	.021	.0041	−.032	.018	.0023	−.014	124	−.003	.0076	.015	−.004	.0088	.020	−.016	.0211	.035
46	.002	.0058	.032	−.006	.0066	.029	−.013	.0110	.030	125	.002	.0069	.002	.001	.0076	.008	−.006	.0132	.026
47	.010	.0052	.022	.001	.0055	.024	−.011	.0076	.029	126	.008	.0077	−.012	.006	.0070	−.006	.001	.0077	.011
48	.023	.0052	.007	.009	.0051	.012	−.005	.0057	.022	127	.013	.0093	−.028	.012	.0077	−.020	.010	.0062	−.006
49	.034	.0045	−.011	.019	.0055	−.007	.006	.0055	.009	128	.011	.0124	−.039	.016	.0094	−.035	.019	.0060	−.024
50	.041	.0052	−.023	.031	.0056	−.026	.017	.0050	−.007	129	.000	.0061	.000	.015	.0071	.009	.047	.0110	.032
51	.047	.0070	−.028	.038	.0065	−.035	.031	.0054	−.028	130	−.008	.0077	.012	−.005	.0095	.019	−.007	.0169	.030
52	−.017	.0047	.018	−.023	.0056	.028	−.025	.0073	.041	131	−.002	.0069	−.002	−.001	.0080	.006	−.003	.0131	.019
53	−.004	.0046	.003	−.014	.0048	.012	−.020	.0053	.030	132	.003	.0076	−.015	.004	.0082	−.008	−.005	.0114	.012
54	.006	.0048	−.013	−.005	.0049	−.005	−.013	.0049	.019	133	.004	.0093	−.025	.009	.0089	−.020	−.005	.0110	.000
55	.013	.0053	−.028	.005	.0053	−.021	−.007	.0049	.002	134	.007	.0125	−.034	.010	.0103	−.030	−.009	.0107	−.013
56	.018	.0071	−.036	.016	.0059	−.036	.006	.0052	−.017	135	.000	.0032	.000	.016	.0037	.009	.043	.0043	.024
57	−.034	.0052	.017	−.043	.0054	.033	−.038	.0079	.061	136	.000	.0034	.000	.012	.0040	.008	.044	.0047	.025
58	−.024	.0049	.000	−.038	.0045	.019	−.035	.0054	.045	137	.000	.0035	.000	.013	.0042	.007	.045	.0046	.020
59	−.016	.0049	−.016	−.025	.0044	.001	−.034	.0051	.030	138	.000	.0176	.000	.012	.0183	.008	.039	.0218	.021
60	−.006	.0054	−.031	−.016	.0047	−.017	−.024	.0044	.014	139	.000	.0058	.000	.019	.0064	.008	.059	.0110	.024
61	.000	.0068	−.043	−.007	.0053	−.033	−.013	.0049	−.006	140	−.056	.0055	.032	−.014	.0051	.030	.062	.0052	.027
62	.000	.0036	−.003	.015	.0038	.004	.044	.0048	.016	141	.000	.0040	.000	.040	.0041	.000	.111	.0055	.001
63	.000	.0036	−.003	.021	.0039	.005	.045	.0060	.016	142	.056	.0055	−.032	.090	.0056	−.032	.160	.0065	−.035
64	.002	.0041	−.004	.015	.0043	.003	−.028	.0295	−.007	143	.004	.0048	.009	.007	.0050	.015	.021	.0076	.027
65	.046	.0043	.021	.061	.0057	.021	.012	.0373	−.006	144	.048	.0051	−.005	.056	.0052	−.001	.077	.0076	.007
66	.017	.0037	.009	.028	.0044	.014	-------	-------	-------	145	.045	.0049	−.005	.056	.0050	.000	.076	.0069	.009
67	.001	.0042	−.006	.011	.0047	.003	−.054	.0327	−.004	146	−.004	.0048	−.009	.004	.0050	−.004	−.029	.0098	.010
68	−.011	.0047	−.021	−.001	.0053	−.012	−.078	.0325	−.012	147	−.048	.0051	.005	−.030	.0054	.008	−.022	.0070	.009
69	.003	.0053	−.034	−.014	.0053	−.025	−.080	.0268	−.015	148	−.045	.0049	.005	−.032	.0055	.009	−.021	.0069	.010
70	−.010	.0054	−.003	−.019	.0088	.003	−.092	.0359	.000	149	.006	.0054	.006	.007	.0051	.014	.005	.0060	.027
71	−.041	.0068	.016	−.047	.0092	.020	−.064	.0185	.020	150	−.004	.0051	.009	−.001	.0051	.017	−.002	.0062	.030
72	−.045	.0088	.004	−.056	.0124	.007	−.101	.0277	.011	151	−.001	.0062	.009	−.009	.0060	.020	−.006	.0073	.026
73	−.022	.0114	−.008	−.069	.0176	.001	−.155	.0353	.011	152	−.009	.0061	.008	−.010	.0058	.016	−.007	.0067	.028
74	−.011	.0056	.002	−.045	.0078	.014	−.088	.0155	.023	153	−.009	.0063	.008	−.013	.0064	.017	−.011	.0080	.029
75	.006	.0058	−.021	−.003	.0065	−.010	−.113	.0172	.017	154	−.006	.0054	−.006	−.002	.0059	.002	−.004	.0074	.012
76	.014	.0080	−.029	.002	.0109	−.019	−.157	.0318	.004	155	.004	.0051	−.009	.003	.0058	−.001	.000	.0073	.007
77	−.014	.0045	.012	−.010	.0056	.015	−.024	.0083	.020	156	.001	.0062	−.009	−.008	.0082	.002	−.050	.0188	.016
78	−.002	.0045	−.004	−.004	.0052	.003	−.017	.0074	.010	157	.009	.0061	−.008	.004	.0074	−.001	−.071	.0232	.013
79	.008	.0049	−.019	.005	.0060	−.013	−.013	.0084	.001	158	.009	.0063	−.008	−.001	.0083	.003	−.070	.0240	.015

TABLE III.—LIFT AND INTERFERENCE, DRAG AND INTERFERENCE, AND PITCHING MOMENT AND INTERFERENCE OF FUSELAGE IN WING-FUSELAGE COMBINATIONS—Continued

Combination	ΔC_L	ΔC_{D_s}	$\Delta C_{m_{c/4}}$	ΔC_L	ΔC_{D_s}	$\Delta C_{m_{c/4}}$	ΔC_L	ΔC_{D_s}	$\Delta C_{m_{c/4}}$
	$\alpha=-4°$			$\alpha=0°$			$\alpha=8°$		
159	0.001	0.0037	0.007	−0.003	0.0033	0.014	−0.009	0.0043	0.027
160	.010	.0037	−.012	.012	.0032	−.004	.003	.0033	.013
161	.022	.0044	−.027	.023	.0035	−.021	.013	.0032	−.005
162	.029	.0058	−.034	.031	.0047	−.035	.024	.0037	−.022
163	.030	.0091	−.032	.034	.0071	−.037	.034	.0043	−.038
164	.003	.0036	.004	.024	.0035	.013	.062	.0043	.026
165	−.024	.0033	−.011	−.002	.0033	−.003	.033	.0044	.011
166	−.056	.0045	−.025	−.035	.0039	−.017	.005	.0041	−.002
167	−.003	.0046	−.007	−.002	.0052	.004	−.016	.0067	.014
168	.009	.0048	−.020	.007	.0051	−.013	−.009	.0063	.006
169	.015	.0055	−.030	.018	.0054	−.026	−.002	.0063	−.006
170	.021	.0073	−.035	.021	.0063	−.032	.004	.0067	−.019
171	.023	.0098	−.039	.027	.0083	−.035	.011	.0078	−.027
172	−.031	.0064	−.011	−.004	.0060	.000	.036	.0088	.022
173	−.005	.0049	−.015	.001	.0056	−.005	−.049	.0231	.006
174	.000	.0193	−.011	−.006	.0201	.004	−.053	.0397	.014
175	−.003	.0072	−.017	.004	.0077	−.002	−.037	.0226	.028
176	.08	.0045	−.018	.025	.0043	−.007	.047	.0058	.010
177	−.026	.0038	−.013	−.006	.0043	−.004	.035	.0048	.007
178	−.040	.0049	−.013	−.019	.0048	−.007	.024	.0054	.001
179	−.036	.0192	−.007	−.020	.0191	−.001	.018	.0217	.007
180	−.038	.0069	−.012	−.014	.0064	−.004	.027	.0095	.013
	$\alpha=0°$			$\alpha=4°$			$\alpha=12°$		
181	−0.014	0.0041	0.022	−0.017	0.0045	0.026	−0.023	0.0055	0.034
182	−.004	.0038	.012	−.010	.0039	.015	−.017	.0037	.025
183	.006	.0038	−.004	.001	.0036	.001	−.006	.0030	.015
184	.015	.0044	−.016	.010	.0037	−.015	.003	.0032	.000
185	−.009	.0031	.008	−.001	.0031	.014	.017	.0033	.029
186	.000	.0022	.000	.018	.0024	.005	.032	.0038	.020
187	.009	.0031	−.008	.026	.0036	−.001	.029	.0069	.010

Combination	ΔC_L	ΔC_{D_s}	$\Delta C_{m_{c/4}}$	ΔC_L	ΔC_{D_s}	$\Delta C_{m_{c/4}}$	ΔC_L	ΔC_{D_s}	$\Delta C_{m_{c/4}}$
	$\alpha=0°$			$\alpha=4°$			$\alpha=12°$		
188	−0.006	0.0038	0.004	−0.002	0.0050	0.009	−0.017	0.0075	0.005
189	.004	.0038	−.012	.005	.0051	−.003	−.012	.0076	.002
190	.014	.0041	−.022	.014	.0051	−.016	−.006	.0077	−.004
191	.021	.0051	−.029	.023	.0055	−.025	.002	.0084	−.013
192	.003	.0043	.018	.004	.0053	.027	.013	.0079	.037
193	.012	.0042	.002	.011	.0045	.013	.015	.0056	.030
194	.016	.0047	−.016	.016	.0044	−.003	.022	.0043	.020
195	.026	.0054	−.030	.024	.0047	−.020	.022	.0042	.005
196	.028	.0073	−.032	.030	.0054	−.033	.020	.0062	−.013
197	.000	.0037	.000	.044	.0037	.009	.114	.0147	.003
198	−.016	.0047	.016	−.019	.0057	.026	−.016	.0097	.028
199	−.012	.0042	−.002	−.013	.0049	.013	−.019	.0074	.027
200	−.003	.0043	−.018	−.005	.0048	−.005	−.015	.0060	.020
201	.004	.0051	−.030	.006	.0047	−.021	−.006	.0054	.006
202	.008	.0065	−.038	.012	.0058	−.031	.004	.0053	−.013
203	.021	.0049	.010	.040	.0055	.012	.077	.0086	.011
204	.000	.0042	.000	.018	.0048	.006	.055	.0061	.011
205	−.021	.0049	−.010	−.003	.0051	−.005	.025	.0059	.004
206	.000	.0187	.000	.009	.0201	.006	.037	.0258	.016
207	.000	.0081	.000	.022	.0090	.010	.056	.0139	.027
	$\alpha=-4°$			$\alpha=0°$			$\alpha=8°$		
208	−0.019	0.0047	−0.006	0.003	0.0041	−0.001	0.039	0.0054	0.013
	$\alpha=0°$			$\alpha=4°$			$\alpha=12°$		
209	0.000	0.0034	0.000	0.014	0.0039	0.004	0.040	0.0058	0.011

TABLE IV.—INTERFERENCE DATA FOR DISCONNECTED COMBINATIONS

Combination	Interference on wing in presence of fuselage									Characteristics of fuselage in presence of wing								
	δC_L	δC_{D_s}	$\delta C_{m_{c/4}}$	δC_L	δC_{D_s}	$\delta C_{m_{c/4}}$	δC_L	δC_{D_s}	$\delta C_{m_{c/4}}$	C_L	C_{D_s}	$C_{m_{c/4}}$	C_L	C_{D_s}	$C_{m_{c/4}}$	C_L	C_{D_s}	$C_{m_{c/4}}$
	$\alpha=0°$			$\alpha=4°$			$\alpha=12°$			$\alpha=0°$			$\alpha=4°$			$\alpha=12°$		
26	−0.021	−0.0003	0.007	−0.022	−0.0023	0.006	−0.026	0.0011	0.004	0.015	0.0061	0.014	0.008	0.0081	0.022	0.004	0.0078	0.034
27	.006	.0001	.005	−.005	−.0029	.007	−.017	−.0002	.005	.005	.0055	−.007	.001	.0076	.006	−.003	.0084	.025
28	−.018	−.0004	.006	−.016	−.0022	.006	−.020	.0007	.003	.010	.0053	.013	.004	.0069	.022	.001	.0070	.032
29	−.005	.0003	.007	.001	−.0027	.006	−.007	−.0013	.003	.007	.0042	−.003	−.001	.0066	.009	−.007	.0075	.024
30	.010	.0006	.008	.013	−.0033	.007	.010	−.0044	.003	.004	.0039	−.020	−.003	.0073	−.008	−.012	.0090	.011
31	−.011	.0000	.004	−.013	−.0018	.004	−.018	−.0001	.002	.006	.0049	.015	.001	.0065	.024	−.001	.0064	.035
32	.002	.0003	.004	−.001	−.0022	.005	−.005	−.0026	.002	.004	.0042	−.001	−.004	.0064	.010	−.009	.0072	.026
33	.016	.0012	.004	.011	−.0026	.006	.008	−.0044	.001	.001	.0042	−.019	−.004	.0069	−.006	−.013	.0088	.013
34	.029	.0010	.005	.024	−.0030	.005	.021	−.0067	.001	−.003	.0050	−.033	−.008	.0083	−.024	−.016	.0110	−.003
35	.041	.0009	.006	.038	−.0040	.004	.035	−.0090	.000	−.011	.0069	−.039	−.013	.0105	−.036	−.017	.0137	−.021
36	−.004	.0001	.005	−.011	−.0015	.003	−.019	−.0002	.002	.003	.0037	.018	−.001	.0050	.025	−.002	.0055	.036
37	.009	.0004	.005	−.001	−.0017	.004	−.002	−.0031	.002	.001	.0034	.001	−.005	.0051	.012	−.009	.0060	.029
38	.022	.0008	.005	.011	−.0021	.004	.006	−.0041	.002	−.001	.0032	−.016	−.005	.0057	−.005	−.013	.0071	.018
39	.033	.0011	.005	.024	−.0026	.003	.017	−.0061	.001	−.005	.0039	−.028	−.007	.0067	−.021	−.016	.0090	.001
40	.046	.0009	.004	.037	−.0034	.003	.036	−.0084	.001	−.012	.0053	−.035	−.012	.0085	−.033	−.016	.0114	−.017
41	.000	.0004	.003	−.009	−.0010	.002	−.021	.0005	.003	.003	.0033	.015	.002	.0039	.024	.000	.0040	.038
42	.011	.0007	.003	.001	−.0015	.001	−.011	−.0013	.002	.002	.0028	−.001	−.002	.0043	.010	−.005	.0044	.030
43	.021	.0012	.003	.009	−.0017	.001	−.004	−.0026	.002	.000	.0026	−.017	−.003	.0047	−.005	−.009	.0055	.019
44	.031	.0013	.002	.019	−.0021	.001	.006	−.0040	.001	−.004	.0032	−.029	−.006	.0052	−.021	−.012	.0071	.002
45	.042	.0014	.002	.030	−.0028	.000	.029	−.0068	.000	−.009	.0049	−.035	−.009	.0069	−.032	−.011	.0091	−.014
46	−.010	.0002	.005	−.014	−.0021	.003	−.018	−.0011	.003	.012	.0056	.027	.008	.0087	.026	.005	.0121	.027
47	.003	.0010	.006	−.001	−.0024	.004	−.008	−.0026	.003	.007	.0042	.016	.002	.0079	.020	−.003	.0102	.026
48	.018	.0013	.007	.011	−.0028	.004	.005	−.0053	.002	.005	.0039	.000	−.002	.0079	.008	−.010	.0110	.020
49	.032	.0011	.006	.022	−.0030	.005	.019	−.0071	.001	.002	.0034	−.017	−.003	.0085	−.012	−.013	.0126	.008
50	.044	.0007	.006	.037	−.0036	.003	.032	−.0095	.001	−.003	.0045	−.029	−.006	.0092	−.029	−.015	.0145	−.008
51	.058	.0003	.005	.050	−.0046	.003	.046	−.0115	.000	−.011	.0067	−.033	−.012	.0111	−.038	−.015	.0169	−.028
52	−.024	−.0003	.004	−.026	−.0004	.003	−.028	.0036	.001	.007	.0050	.014	.003	.0060	.025	.003	.0037	.040
53	−.009	.0002	.004	−.012	−.0009	.004	−.016	.0013	.001	.005	.0044	−.001	−.002	.0057	.008	−.004	.0040	.029
54	.004	.0005	.005	−.001	−.0013	.004	−.002	−.0007	.001	.002	.0043	−.018	−.004	.0062	−.009	−.011	.0056	.018
55	.017	.0005	.006	.013	−.0020	.004	.010	−.0028	.002	−.004	.0048	−.034	−.008	.0073	−.025	−.017	.0077	.000
56	.030	.0006	.006	.028	−.0033	.003	.023	−.0054	.001	−.012	.0065	−.042	−.012	.0092	−.039	−.017	.0106	−.018
57	−.041	−.0009	.004	−.047	.0007	.004	−.049	.0068	.003	.007	.0061	.013	.004	.0047	.029	.011	.0011	.058
58	−.030	.0000	.005	−.036	.0004	.005	−.036	.0051	.002	.006	.0049	−.005	−.002	.0041	.014	.001	.0003	.043
59	−.018	.0005	.006	−.022	.0000	.006	−.026	.0039	.002	.002	.0044	−.022	−.003	.0044	−.005	−.008	.0012	.028
60	−.004	.0009	.006	−.010	−.0002	.006	−.012	.0016	.003	−.002	.0045	−.037	−.006	.0049	−.023	−.012	.0028	.011
61	.009	.0010	.007	.004	−.0012	.005	.002	−.0004	.003	−.009	.0058	−.050	−.011	.0065	−.038	−.015	.0053	−.009
74	−.006	.0001	−.005	−.036	.0061	−.004	−.068	.0265	−.007	−.005	.0055	.007	−.009	.0017	.018	−.020	.0110	.030
75	.021	−.0003	−.007	.020	.0039	−.007	−.083	.0252	−.004	−.015	.0061	.014	−.023	.0026	−.003	−.030	.0080	.021
76	.037	−.0010	−.007	.027	.0037	−.008	−.134	.0331	−.014	−.023	.0090	−.022	−.025	.0072	−.011	−.023	.0013	.018
77	−.010	.0006	−.008	.000	.0065	−.012	−.095	.0243	−.014	−.004	.0039	.020	−.010	−.0009	.027	−.019	−.0160	.034
78	.005	.0003	−.007	.012	.0052	−.009	.013	.0213	−.011	−.007	.0042	.003	−.016	.0000	.012	−.030	−.0139	.021
79	.018	−.0004	−.006	.027	.0037	−.008	.024	.0185	−.009	−.010	.0053	−.013	−.021	.0023	−.005	−.037	−.0101	.010
80	.032	−.0013	−.004	.043	.0017	−.006	.033	.0161	−.008	−.017	.0073	−.025	−.025	.0047	−.017	−.046	−.0054	.000
81	.046	−.0027	−.003	.055	−.0004	−.005	.040	.0131	−.006	−.026	−.0107	−.027	−.034	.0088	−.027	−.054	.0005	−.009
82	−.016	.0012	−.004	−.012	.0057	−.007	−.016	.0198	−.008	−.001	.0042	.019	−.006	.0000	.025	−.011	−.0128	.029
83	−.002	.0003	−.004	.002	.0047	−.007	.002	.0174	−.009	−.004	.0042	.001	−.010	.0006	.011	−.020	−.0109	.021
84	.011	.0000	−.004	.016	.0033	−.006	.012	.0151	−.007	−.006	.0049	−.015	−.015	.0021	−.006	−.027	−.0082	.011
85	.024	−.0009	−.004	.030	.0018	−.005	.030	.0116	−.006	−.012	.0063	−.026	−.017	.0041	−.020	−.033	−.0049	−.003

TABLE IV.—INTERFERENCE DATA FOR DISCONNECTED COMBINATIONS—Continued

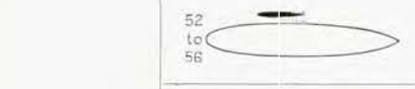
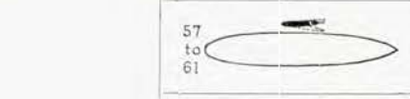
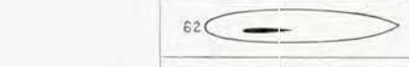
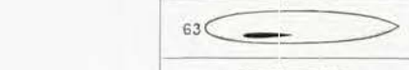
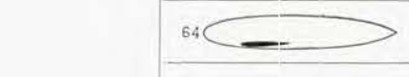
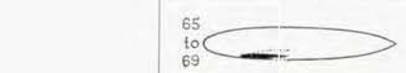
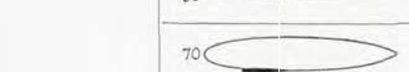
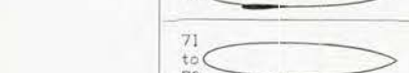
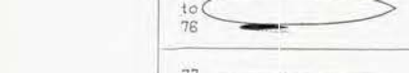
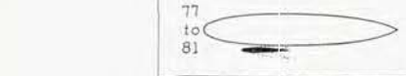
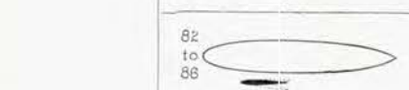
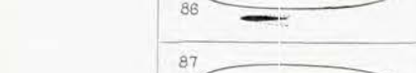
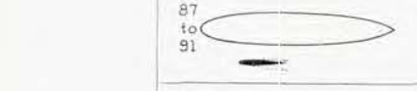
Combination	Interference on wing in presence of fuselage									Characteristics of fuselage in presence of wing								
	δC_L	δC_{D_x}	$\delta C_{m_{c/4}}$	δC_L	δC_{D_x}	$\delta C_{m_{c/4}}$	δC_L	δC_{D_x}	$\delta C_{m_{c/4}}$	C_L	C_{D_x}	$C_{m_{c/4}}$	C_L	C_{D_x}	$C_{m_{c/4}}$	C_L	C_{D_x}	$C_{m_{c/4}}$
	$\alpha=0°$			$\alpha=4°$			$\alpha=12°$			$\alpha=0°$			$\alpha=4°$			$\alpha=12°$		
86	0.037	−0.0018	−0.003	0.042	−0.0001	−0.004	0.041	0.0080	−0.005	−0.020	0.0089	−0.031	−0.025	0.0072	−0.028	−0.039	−0.0004	−0.018
87	−.022	.0008	−.005	−.022	.0049	−.005	−.032	.0160	−.006	.001	.0032	.016	−.002	−.0001	.022	−.001	−.0101	.026
88	−.009	.0004	−.005	−.009	.0038	−.006	−.025	.0148	−.006	−.001	.0034	−.001	−.005	.0002	.009	.009	−.0092	.020
89	.004	.0001	−.005	.004	.0028	−.006	−.003	.0125	−.006	−.003	.0037	−.018	−.009	.0013	−.008	−.016	−.0073	.009
90	.015	−.0004	−.004	.017	.0016	−.005	.011	.0098	−.005	−.008	.0050	−.029	−.011	.0029	−.021	−.021	−.0046	−.002
91	.026	−.0009	−.003	.029	.0005	−.004	.019	.0084	−.004	−.014	.0073	−.034	−.017	.0054	−.030	−.026	−.0010	−.018
92	−.021	.0012	−.003	−.023	.0041	−.002				.000	.0026	.017	−.001	.0004	.024			
93	−.011	.0007	−.003	−.011	.0028	−.003				−.002	.0028	.001	−.004	.0005	.011			
94	.000	.0004	−.003	.000	.0020	−.003				−.003	.0033	−.015	−.007	.0015	−.004			
95	.008	−.0002	−.003	.009	.0013	−.003				−.007	.0042	−.026	−.009	.0026	−.017			
96	.017	−.0007	−.003	.018	.0004	−.003				−.013	.0063	−.031	−.013	.0048	−.029			
97	−.044	.0007	−.006	−.043	.0072	−.007	−.056	.0234	−.010	.003	.0045	.029	.003	−.0011	.029	.005	−.0150	.019
98	−.032	.0011	−.006	−.031	.0068	−.007	−.038	.0220	−.010	−.002	.0034	.017	−.004	−.0016	.021	−.006	−.0158	.020
99	−.018	.0013	−.007	−.017	.0061	−.007	−.019	.0204	−.009	−.005	.0039	.000	−.009	−.0015	.006	−.016	−.0152	.013
100	−.003	.0010	−.006	−.002	.0050	−.007	−.008	.0188	−.010	−.007	.0042	−.016	−.013	.0000	−.010	−.022	−.0132	.002
101	.010	.0002	−.005	.012	.0039	−.006	.010	.0160	−.009	−.012	.0056	−.027	−.016	.0017	−.023	−.029	−.0105	−.011
102	.022	−.0007	−.004	.028	.0021	−.005	.024	.0129	−.008	−.020	.0078	−.029	−.024	.0046	−.030	−.035	−.0065	−.024
103	−.004	.0005	−.005	.002	.0045	−.007	.002	.0171	−.010	−.002	.0043	.018	−.007	.0012	.027	−.013	−.0103	.036
104	.009	.0002	−.004	.017	.0029	−.005	.018	.0140	−.009	−.005	.0044	.001	−.011	.0021	.011	−.022	−.0081	.026
105	.024	−.0003	−.004	.030	.0016	−.005	.029	.0111	−.006	−.007	.0050	−.014	−.016	.0035	−.004	−.031	−.0046	.015
106	.037	−.0011	−.002	.041	−.0003	−.003	.042	.0075	−.004	−.014	−.0064	−.027	−.017	.0058	−.019	−.035	−.0008	.001
107	.049	−.0019	−.001	.052	−.0021	−.003	.052	.0032	−.002	−.024	.0092	−.033	−.026	.0092	−.028	−.042	.0042	−.014
108	.018	.0005	−.006	.027	.0028	−.007	.028	.0132	−.007	−.002	.0044	.022	−.009	.0028	.034	−.017	−.0052	.052
109	.030	.0000	−.005	.037	.0011	−.006	.040	.0098	−.006	−.006	.0049	.005	−.013	.0041	.019	−.026	−.0023	.042
110	.041	−.0009	−.004	.050	−.0005	−.004	.052	.0055	−.004	−.007	.0061	−.013	−.016	.0062	.003	−.034	.0015	.029
111	.052	−.0018	−.003	.058	−.0025	−.003	.060	.0015	−.003	−.012	.0081	−.026	−.018	.0085	−.011	−.037	.0057	.015
112	.062	−.0028	−.002	.068	−.0047	−.002	.067	−.0025	−.001	−.019	.0105	−.035	−.023	.0120	−.024	−.041	.0112	.002
113	−.003	−.0001	.004	−.009	−.0015	.001	−.077	.0060	.000	.005	.0194	.004	.000	.0206	.012	.008	.0229	.027
114	.006	.0001	.004	.004	−.0022	.001	−.064	.0046	−.002	.004	.0187	−.009	−.003	.0205	−.002	.000	.0219	.017
115	.019	.0007	.005	.015	−.0026	.003	−.041	.0011	−.001	.001	.0187	−.024	−.003	.0208	−.014	−.006	.0219	.004
116	.032	.0007	.005	.026	−.0029	.002	−.012	−.0028	−.002	−.002	.0197	−.038	−.006	.0216	−.031	−.012	.0230	−.009
117	.044	.0004	.005	.041	−.0039	.002	−.013	−.0061	−.002	−.010	.0218	−.048	−.010	.0241	−.044	−.016	.0253	−.023
119	−.019	.0007	−.005	−.017	.0051	−.006	−.022	.0203	−.009	−.001	.0187	.024	−.007	.0159	.032	−.013	.0066	.040
120	−.006	.0001	−.004	−.001	.0044	−.006	−.006	.0173	−.008	−.004	.0187	.009	−.011	.0160	.018	−.021	.0073	.031
121	.003	−.0001	−.004	.011	.0027	−.004	.015	.0143	−.007	−.005	.0194	−.004	−.014	.0170	.003	−.027	.0095	.019
122	.012	−.0007	−.004	.019	.0015	−.004	.025	.0116	−.005	−.009	.0207	−.016	−.015	.0189	−.008	−.032	.0121	.006
123	.018	−.0014	−.002	.030	−.0003	−.003	.036	.0079	−.004	−.015	.0230	−.025	−.019	.0215	−.020	−.038	.0154	−.006
124	−.014	.0000	.005	−.019	−.0002	.003	−.047	.0054	−.001	.011	.0076	.010	.015	.0090	.017	.031	.0157	.036
125	.000	.0004	.005	−.004	−.0006	.004	−.022	.0020	.000	.002	.0065	−.003	.005	.0082	.004	.016	.0112	.026
126	.015	.0010	.005	.011	−.0014	.004	−.003	−.0006	−.001	−.007	.0067	−.017	−.005	.0084	−.010	.004	.0083	.012
127	.031	.0007	.005	.026	−.0019	.004	.015	−.0037	−.001	−.018	.0086	−.033	−.014	.0096	−.024	−.005	.0099	−.005
128	.043	.0002	.005	.040	−.0033	.003	.032	−.0065	−.002	−.032	.0122	−.044	−.024	.0127	−.038	−.013	.0125	−.022
130	−.015	.0010	−.005	−.015	.0047	−.006	−.024	.0182	−.009	.007	.0067	.017	.010	.0048	.025	.017	−.0013	.039
131	.000	.0004	−.005	.000	.0036	−.006	−.007	.0161	−.008	−.002	.0065	.003	−.001	.0044	.012	.004	−.0030	.027
132	.014	.0000	−.005	.015	.0026	−.006	.008	.0135	−.007	−.011	.0076	−.010	−.011	.0056	−.002	−.013	−.0021	.019
133	.027	−.0003	−.004	.028	.0011	−.005	.017	.0105	−.006	−.023	.0096	−.021	−.019	.0078	−.015	−.022	.0005	.006
134	.041	−.0011	−.002	.040	−.0008	−.004	.041	.0058	−.004	−.034	.0136	−.032	−.030	.0111	−.026	−.032	.0049	−.009
	$\alpha=-4°$			$\alpha=0°$			$\alpha=8°$			$\alpha=-4°$			$\alpha=0°$			$\alpha=8°$		
159	−0.003	0.0013	0.001	0.001	−0.0013	−0.001	0.001	−0.0013	−0.002	0.004	0.0024	0.006	−0.004	0.0046	0.0015	−0.010	0.0056	0.0029
160	.011	.0013	.000	.017	−.0020	−.002	.017	−.0039	−.004	−.001	.0024	−.012	−.005	.0052	−.002	−.014	.0072	.017
161	.027	.0012	−.001	.032	−.0030	−.001	.030	−.0061	−.004	−.005	.0032	−.026	−.009	.0065	−.020	−.017	.0093	−.001
162	.042	.0005	−.001	.045	−.0040	−.002	.041	−.0083	−.004	−.013	.0053	−.033	−.014	.0087	−.033	−.017	.0120	−.018
163	.054	.0000	−.001	.057	−.0050	−.002	.055	−.0109	−.005	−.024	.0091	−.033	−.023	.0121	−.035	−.021	.0152	−.033
167	.002	−.0009	−.010	.009	.0038	−.010	.006	.0172	−.010	−.005	.0055	.003	−.011	.0014	.014	−.022	−.0105	.024
168	.015	−.0014	−.009	.022	.0018	−.009	.019	.0138	−.008	−.006	.0062	−.011	−.015	.0033	−.004	−.028	−.0075	.014
169	.027	−.0023	−.008	.035	.0002	−.008	.030	.0101	−.006	−.012	.0078	−.022	−.017	.0052	−.018	−.032	−.0038	.000
170	.039	−.0032	−.008	.044	−.0020	−.006	.041	.0063	−.004	−.018	.0105	−.027	−.023	.0083	−.026	−.037	.0004	−.015
171	.052	−.0048	−.008	.058	−.0043	−.007	.052	.0022	−.003	−.029	.0146	−.031	−.031	.0126	−.028	−.041	.0056	−.024
	$\alpha=0°$			$\alpha=4°$			$\alpha=12°$			$\alpha=0°$			$\alpha=4°$			$\alpha=12°$		
181	−0.028	−0.0013	0.007	−0.024	−0.0042	0.006	−0.021	−0.0047	0.005	0.014	0.0054	0.015	0.007	0.0087	0.020	−0.002	0.0102	0.029
182	−.016	.0001	.010	−.013	−.0037	.008	−.008	−.0066	.005	.012	.0037	.002	.003	.0076	.007	−.009	.0103	.020
183	−.002	.0015	.011	−.001	−.0033	.008	.006	−.0082	.006	.008	.0023	−.015	.002	.0069	−.007	−.012	.0112	.009
184	.011	.0027	.013	.012	−.0030	.010	.018	−.0094	.007	.004	.0017	−.029	−.002	.0067	−.025	−.015	.0126	−.007
188	.002	.0015	−.011	.014	.0084	−.012	.008	.0269	−.014	−.008	.0023	.015	−.016	−.0034	.021	−.025	−.0194	.019
189	.016	.0001	−.010	.024	.0066	−.009	.021	.0238	−.011	−.012	.0037	−.002	−.019	−.0015	.006	−.033	−.0162	.013
190	.028	−.0013	−.007	.038	.0037	−.007	.034	.0197	−.008	−.014	.0054	−.015	−.024	.0014	−.009	−.040	−.0120	.004
191	.040	−.0031	−.004	.050	.0010	−.005	.048	.0154	−.006	−.019	.0082	−.025	−.027	.0045	−.020	−.046	−.0070	−.007
192	.002	.0003	.003	.002	−.0007	.003	.004	.0005	.003	.001	.0040	.015	.002	.0060	.024	.009	.0074	.034
193	.012	.0005	.003	.014	−.0013	.002	.014	−.0015	.004	.000	.0037	−.001	−.003	.0058	.011	.001	.0071	.026
194	.019	.0007	.003	.020	−.0017	.002	.025	−.0032	.003	−.003	.0040	−.019	−.004	.0061	−.005	−.003	.0075	.017
195	.033	.0003	.003	.030	−.0024	.003	.029	−.0044	.002	−.007	.0051	−.033	−.006	.0071	−.023	−.007	.0086	.003
196	.042	.0001	.005	.040	−.0033	.003	.027	−.0037	.000	−.014	.0072	−.037	−.010	.0087	−.036	−.007	.0099	−.013
198	−.019	.0007	−.003	−.022	.0039	−.003	−.024	.0139	−.003	.003	.0040	.019	.003	.0018	.029	.008	−.0042	.031
199	−.012	.0005	−.003	−.011	.0036	−.001	−.016	.0125	−.003	.000	.0037	.001	−.002	.0013	.014	−.003	−.0051	.030
200	−.002	.0003	−.003	.000	.0029	−.001	−.004	.0108	−.002	−.001	.0040	−.015	−.005	.0019	−.004	−.011	−.0048	.022
201	.011	.0000	−.003	.013	.0019	−.001	.008	.0090	.000	−.007	.0051	−.027	−.007	.0028	−.020	−.014	−.0036	.006
202	.023	−.0007	−.004	.026	.0007	−.001	.022	.0064	−.001	−.015	.0072	−.034	−.014	.0051	−.030	−.018	−.0011	−.012

TABLE V.—PRINCIPAL AERODYNAMIC CHARACTERISTICS OF WING-FUSELAGE COMBINATIONS

Diagrams representing combination	Combination	Remarks	Longitudinal position d/c	Vertical position k/c	Wing setting i_w	Lift-curve slope (per degree) a A. R. = 6.86	Span efficiency factor e	$C_{D_{\epsilon min}}$	$C_{L_{opt}}$	Aerodynamic center position n_0	C_{m_0}	Lift coefficient at interference burble [1] $C_{L_{tb}}$	[2] $C_{L_{max}}$ effective R. N. = 7.5×10^6	[2] $C_{L_{max}}$ effective R. N. = 3.4×10^6
Rectangular N. A. C. A. 0012 airfoil with round fuselage														
		Wing alone			*Degrees*	0.077	0.85	0.0080	.00	0.010	0.000	A1.5	c1.54	c1.39
1	1		0.64	0	0	.078	.85	.0111	.00	.012	.000	A1.4	b1.44	b1.33
2 to 4	2		.25	0	−8	.079	.85	.0121	−.02	.019	.025	B1.0	b1.24	a1.21
	3				0	.079	.85	.0112	.00	.025	.000	B1.1	b1.23	b1.25
	4				8	.079	.85	.0121	.02	.019	−.025	B1.2	c1.36	c1.33
5 to 9	5		0	0	−8	.080	.85	.0123	−.06	.034	.025	B1.0	b1.21	b1.17
	6				−4	.080	.85	.0116	.02	.035	.013	B1.0	b1.22	------
	7				0	.080	.85	.0115	.00	.040	.000	B1.0	b1.21	b1.20
	8				4	.080	.85	.0116	−.02	.035	−.013	B1.2	b1.20	------
	9				8	.080	.85	.0123	.06	.034	−.025	B1.2	b1.23	b1.25
10 to 12	10		−.25	0	−8	.080	.85	.0123	−.06	.048	.029	B.8	b1.20	b1.14
	11				0	.081	.85	.0115	.00	.054	.000	B1.0	b1.20	b1.14
	12				8	.080	.85	.0123	.06	.048	−.029	B1.1	b1.19	b1.21
13	13		−.75	0	0	.082	.85	.0118	.00	.067	.000	B.9	b1.17	b1.16
14	14		0	.08	0	.081	.90	.0116	.00	.032	.003	A1.2	b1.23	b1.24
15	15		0	.16	0	.081	.90	.0116	.00	.034	.003	A1.3	b.30	b1.30
16	16		0	.24	0	.080	.90	.0121	−.03	.035	.004	A1.4	c1.49	b1.36
17 to 21	17		0	.24	−8	.079	.85	.0133	−.05	.034	.034	B1.1	------	------
	18			.27	−4	.079	.85	.0127	−.02	.037	.021	------	------	------
	19			.28	0	.079	.85	.0122	−.05	.038	.006	A1.5	c1.52	c1.38
	20			.27	4	.079	.85	.0117	−.03	.026	−.008	A1.5	c1.56	c1.38
	21			.26	8	.080	.85	.0122	.05	.019	−.018	A1.5	c1.55	c1.35
22	22		0	.34	0	.078	.85	.0133	.10	.035	.002	A1.5	c1.54	c1.38
23 to 27	23		0	.40	−4	------	------	.0163	.37	.057	.007	------	------	------
	24			.40	0	.076	[3].80	.0153	.32	.022	−.004	A1.5	c1.57	c1.37
	25			.41	4	.075	[4].90	.0140	.33	.032	−.016	A1.5	c1.56	c1.39
	26		0	.40+	−4	.075	[3].85	.0138	.02	.042	.021	------	------	c1.36
	27		0		0	.071	[3].85	.0132	.19	.067	−.003	------	c1.55	c1.36
28 to 30	28		0	.44	−4	.076	[3].80	.0128	.09	.040	.023	------	------	c1.37
	29				0	.075	[3].85	.0124	.13	.042	.005	------	------	c1.37
	30				4	.075	[3].90	.0124	.13	.040	−.011	------	c1.54	c1.35
31 to 35	31		0	.54	−4	.075	.85	.0128	.04	.040	.029	------	------	------
	32				0	.075	.85	.0125	.08	.044	.004	------	------	c1.38
	33				4	.075	[3].90	.0129	.14	.040	−.012	------	c1.54	------
	34				8	.075	.90	.0138	.22	.020	−.025	------	c1.57	c1.34
	35				12	.076	[3].95	.0152	.35	.004	−.033	------	c1.59	------
36 to 40	36		0	.70	−4	.075	.85	.0117	.03	.033	.023	------	------	(c)
	37				0	.076	[3].90	.0116	.09	.043	.005	------	------	c1.39
	38				4	.075	[3].90	.0119	.14	.035	−.012	------	c1.51	c1.39
	39				8	.076	.90	.0127	.22	.020	−.024	------	------	c1.39
	40				12	.076	[3].95	.0138	.29	.005	−.031	------	c1.52	c1.41
41 to 45	41		0	1.00	−4	.075	.85	.0113	.05	.046	.018	------	------	c 1.38
	42				0	.075	.85	.0111	.11	.046	.001	------	------	c 1.35
	43				4	.075	[4].90	.0116	.18	.042	−.015	------	c 1.52	c 1.34
	44				8	.075	.90	.0120	.24	.026	−.028	------	------	c 1.35
	45				12	.075	[3].90	.0130	.37	.006	−.033	------	c 1.51	c 1.37
46 to 51	46		.25	.54	−8	.075	.80	.0138	−.08	.012	.030	------	------	c 1.36
	47				−4	.075	[3].85	.0132	−.05	.024	.022	------	------	c 1.35
	48				0	.075	.85	.0129	.01	.031	.006	------	------	c 1.32
	49				4	.075	.85	.0128	.08	.025	−.012	------	c 1.52	c 1.32
	50				8	.075	.90	.0134	.12	.008	−.028	------	(c)	c 1.33
	51				12	.076	.90	.0149	.15	−.008	−.030	------	c 1.52	c 1.35

[1] Letters refer to types of drag curves associated with the interference burble. See footnote 1, p. 34.
[2] Letters refer to condition at maximum lift as follows: [a] Reasonably steady at $C_{L_{max}}$; [b] small loss of lift beyond $C_{L_{max}}$; [c] large loss of lift beyond $C_{L_{max}}$; and uncertain value of $C_{L_{max}}$.
[3] Poor agreement in high-speed range.
[4] Poor agreement over whole range.
[5] Poor agreement in high-lift range.
[6] Rapid increase in drag preceding definite breakdown.

TABLE V.—PRINCIPAL AERODYNAMIC CHARACTERISTICS OF WING-FUSELAGE COMBINATIONS—Continued

Diagrams representing combination	Combination	Remarks	Longitudinal position d/c	Vertical position k/c	Wing setting i_w	Lift-curve slope (per degree) a A. R.= 6.86	Span efficiency factor e	$C_{D_{s_{min}}}$	$C_{L_{opt}}$	Aerodynamic center position η_0	C_{m_0}	Lift coefficient at interference burble $^1C_{L_{ib}}$	$^2C_{L_{max}}$ effective R. N.= 7.5×10^6	$^2C_{L_{max}}$ effective R. N.= 3.4×10^6
Rectangular N. A. C. A. 0012 airfoil with round fuselage														
	52		−0.25	0.54	*Degrees* −4	0.076	0.85	0.0127	−0.03	0.039	0.018	.....	.....	[c] 1.39
52 to 56	53				0	.076	.85	.0126	.02	.040	.003	.....	.....	[c] 1.39
	54				4	.076	.85	.0129	.08	.036	−.014	.....	[c] 1.50	[c] 1.39
	55				8	.076	[5].90	.0134	.15	.022	−.028	.....	.....	[c] 1.35
	56				12	.077	[5].90	.0146	.27	.011	−.037	.....	[c] 1.50	[c] 1.38
	57		−.75	.54	−4	.076	.80	.0132	−.03	.065	.019	.....	.....	[c] 1.35
57 to 61	58				0	.076	[5].85	.0128	.03	.065	.002	.....	.....	[c] 1.33
	59				4	.076	.85	.0128	.08	.053	−.015	.....	[c] 1.51	[c] 1.34
	60				8	.076	[5].90	.0131	.15	.047	−.031	.....	.....	[c] 1.36
	61				12	.076	[5].90	.0140	.25	.040	−.043	.....	[c] 1.48	[c] 1.28
	62		0	−.08	0	.081	.85	.0116	.00	.032	−.003	[B] 1.0	[b] 1.25	[b] 1.20
	63		0	−.16	0	.081	.85	.0116	.00	.034	−.003	[B] 1.0	[b] 1.24	[b] 1.18
	64		0	−.24	0	.080	.85	.0121	.03	.035	−.004	[B] .7	[b] 1.32	[b] 1.24
	65		0	−.26	−8	.080	.80	.0122	−.05	.019	.018	[B] .7	[c] 1.45	[c] 1.35
65 to 69	66			−.27	−4	.079	.80	.0117	.03	.026	.008	.....	.....	.....
	67			−.28	0	.079	.80	.0122	.05	.038	−.006	[B] .5	[c] 1.40	[c] 1.29
	68			−.27	4	.079	.75	.0127	.02	.037	−.021	[6] [B] .6	[c] 1.40	[c] 1.26
	69			−.24	8	.073	.80	.0133	.05	.034	−.034	[6] [B] .6	[c] 1.24	[c] 1.17
	70		0	−.34	0	.078	.50	.0133	−.10	.035	−.002	[C] .0	[c] 1.45	[c] 1.30
71 to 73	71		0	−.41	−4	.075	.70	.0140	−.33	.032	.016	[C] .3	[c] 1.52	[c] 1.34
	72			−.40	0	.074	.60	.0153	−.32	.022	.004	[C] −.3	[c] 1.49	[c] 1.31
	73			−.40	4	.065	[3].55	.0163	−.37	.057	−.007	[C] −.3	[c] 1.39	[c] 1.26
	74		0	−.40	0	.071	.70	.0132	−.19	.067	.003	[C] −.2	.....	[c] 1.28
74 to 76	75				4	.075	[5].70	.0138	−.02	.042	−.021	[C] .0	[c] 1.44	[c] 1.26
	76				8	.075	[5].60	.0155	−.18	.035	−.030	[C] −.2	.....	[c] 1.22
	77		0	−.44	−4	.075	.80	.0124	−.13	.040	.011	.....	.....	[c] 1.39
77 to 81	78				0	.075	.80	.0124	−.13	.042	−.005	.....	.....	[c] 1.38
	79				4	.076	.80	.0128	−.09	.040	−.021	.....	[c] 1.56	[c] 1.40
	80				8	.076	.80	.0140	.02	.030	−.030	.....	.....	[c] 1.35
	81				12	.076	[5].80	.0160	.05	.014	−.032	.....	[c] 1.49	[c] 1.35
	82		0	−.54	−4	.075	.85	.0129	−.14	.040	.012	.....	.....	[c] 1.40
82 to 86	83				0	.075	.85	.0125	−.08	.044	−.004	.....	.....	[c] 1.40
	84				4	.075	.85	.0128	−.04	.040	−.020	.....	[c] 1.57	[c] 1.40
	85				8	.076	.85	.0134	.03	.027	−.030	.....	.....	[c] 1.39
	86				12	.077	[4].85	.0151	.12	.020	−.034	.....	[c] 1.55	[c] 1.34
	87		0	−.70	−4	.075	.85	.0119	−.14	.035	.012	.....	.....	[c] 1.37
87 to 91	88				0	.075	.85	.0116	−.09	.043	−.005	.....	.....	[c] 1.37
	89				4	.075	.85	.0117	−.03	.033	−.023	.....	[c] 1.55	[c] 1.38
	90				8	.076	.85	.0126	.05	.025	−.033	.....	.....	[c] 1.36
	91				12	.076	.85	.0143	.15	.014	−.037	.....	[c] 1.57	[c] 1.37
	92		0	−1.00	−4	.075	.85	.0116	−.18	.042	.015	.....	.....	.....
92 to 96	93				0	.075	.85	.0111	−.11	.046	−.001	.....	.....	.....
	94				4	.075	.85	.0113	−.05	.046	−.018	.....	.....	.....
	95				8	.075	.90	.0120	.03	.038	−.029	.....	.....	.....
	96				12	.075	.90	.0135	.12	.020	−.034	.....	.....	.....
	97		.25	−.54	−8	.075	.80	.0134	−.12	.008	.024	.....	.....	[c] 1.41
97 to 102	98				−4	.075	.85	.0128	−.08	.025	.012	.....	.....	[c] 1.40
	99				0	.075	.85	.0129	−.01	.031	−.006	.....	.....	[c] 1.40
	100				4	.075	.85	.0132	.05	.024	−.022	.....	[c] 1.55	[c] 1.38
	101				8	.075	.85	.0138	.08	.012	−.030	.....	.....	[c] 1.37
	102				12	.076	[5].90	.0150	.10	.000	−.033	.....	[c] 1.56	[c] 1.39
	103		−.25	−.54	−4	.076	.85	.0129	−.08	.036	.014	.....	.....	[c] 1.39
103 to 107	104				0	.076	.85	.0126	−.02	.040	−.003	.....	.....	[c] 1.38
	105				4	.076	.85	.0127	.03	.039	−.018	.....	[c] 1.58	[c] 1.41
	106				8	.077	.85	.0132	.10	.027	−.029	.....	.....	[c] 1.41
	107				12	.077	[4].85	.0150	.18	.019	−.035	.....	[c] 1.53	[c] 1.37

[1] Letters refer to types of drag curves associated with the interference burble. See footnote 1, p. 34.

[2] Letters refer to condition at maximum lift as follows: [a] Reasonably steady at $C_{L_{max}}$; [b] small loss of lift beyond $C_{L_{max}}$; [c] large loss of lift beyond $C_{L_{max}}$ and uncertain value of $C_{L_{max}}$.

[3] Poor agreement in high-speed range.

[4] Poor agreement over whole range.

[5] Poor agreement in high-lift range.

[6] Rapid increase in drag preceding definite breakdown.

TABLE V.—PRINCIPAL AERODYNAMIC CHARACTERISTICS OF WING-FUSELAGE COMBINATIONS—Continued

Diagrams representing combination	Combination	Remarks	Longitudinal position d/c	Vertical position k/c	Wing setting i_w	Lift-curve slope (per degree) a A. R. = 6.86	Span efficiency factor e	$Cd_{e_{min}}$	Cl_{opt}	Aerodynamic center position x_0	Cm_0	Lift coefficient at interference burble [1] Cl_{ib}	[1] Cl_{max} effective R. N. = 7.5×10^6	[2] Cl_{max} effective R. N. = 3.4×10^6
Rectangular N. A. C. A. 0012 airfoil with round fuselage														
					Degrees									
108 to 112	108		−0.75	−0.50	−4	0.076	0.85	0.0128	−0.08	0.053	0.015			[c] 1.41
	109				0	.076	.85	.0128	−.03	.065	−.002			[c] 1.39
	110				4	.076	.85	.0132	.03	.065	−.019		[c] 1.56	[c] 1.32
	111				8	.076	.85	.0142	.10	.060	−.031			[c] 1.39
	112				12	.077	[4].85	.0155	.18	.054	−.040		[c] 1.47	[c] 1.28
113 to 117	113	Uncowled engine	0	−.54	−4	.075	.80	.0272	.06	.034	.008	[B] 0.5	[c] 1.48	
	114	do			0	.075	.85	.0266	.15	.031	−.006	[B, 6]	[c] 1.46	
	115	do			4	.075		.0268	.25	.033	−.020	[B, 7]	[c] 1.42	
	116	do			8	.075		.0274	.33	.026	−.034	[B, 7]	[c] 1.41	
	117	do			12	.076		.0287	.45	.010	−.044	[B, 7]	[c] 1.41	
118	118	Uncowled engine	0	0	0	.079	.80	.0258	.00	.041	.000	[B] 1.1	[b] 1.19	[b] 1.14
119 to 123	119	Uncowled engine	0	−.54	−4	.075	.75	.0268	−.25	.033	.020			[c] 1.36
	120	do			0	.075	.80	.0266	−.15	.031	.006			[c] 1.37
	121	do			4	.075	.80	.0272	−.06	.034	−.008		[c] 1.54	[c] 1.35
	122	do			8	.076	.80	.0280	.03	.031	−.019			[c] 1.36
	123	do			12	.078	[5].85	.0294	.13	.025	−.027		[c] 1.55	[c] 1.32
124 to 128	124	Cowled engine		.54	−4	.077	[5].70	.0155	−.02	.031	.015		[c] 1.54	
	125	do			0	.077	[5].80	.0150	.05	.033	.002		[c] 1.54	[c] 1.37
	126	do			4	.077	[5].85	.0155	.15	.031	−.013		[c] 1.55	
	127	do			8	.077	[4].90	.0164	.28	.027	−.028		[c] 1.56	[c] 1.38
	128	do			12	.078		.0180	.43	.022	−.039		[c] 1.56	
129	129	Cowled engine	0	0	0	.080	.80	.0141	.00	.041	.000	[A] 1.4	[c] 1.47	[c] 1.31
130 to 134	130	Cowled engine	0	−.54	−4	.077	.75	.0155	−.15	.031	.013			[c] 1.40
	131	do			0	.077	[4].75	.0150	−.05	.033	−.002			[c] 1.38
	132	do			4	.077	.80	.0155	.02	.031	−.015		[c] 1.57	[c] 1.40
	133	do			8	.077	[5].85	.0170	.13	.025	−.026			[c] 1.40
	134	do			12	.077		.0190	.27	.024	−.034		[c] 1.56	[c] 1.39
135	135	Small constant radius (0.03c) fillets.	0	0	0	.081	.85	.0112	.00	.037	.000	[B] 1.0	[b] 1.21	[b] 1.14
136	136	Large constant radius (0.12c) fillets.	0	0	0	.081	.85	.0114	.00	.034	.000	[B] 1.0	[a] 1.22	[a] 1.18
137	137	Tapered fillets	0	0	0	.081	.85	.0115	.00	.030	.000	[B] 1.0	[a] 1.23	[a] 1.22
138	138	Tapered fillets; uncowled engine.	0	0	0	.080	.80	.0256	.00	.035	.000	[B] 1.1	[a] 1.20	[a] 1.18
139	139	Tapered fillets; cowled engine.	0	0	0	.081	.80	.0138	.00	.039	.000	[A] 1.5	[c] 1.50	[c] 1.32
140	140	Washed-out plan-form fillets (2.29c radius).	0	0	0	.086	.90	.0135	.00	.007	.032	[B] 1.0	[a] 1.25	[a] 1.24
141	141	Straight plan-form fillets	0	0	0	.086	.90	.0120	.00	.009	.000	[B] 1.2	[b] 1.29	[b] 1.28
142	142	Washed-in plan-form fillets (2.29c radius).	0	0	0	.086	.90	.0135	.00	.007	−.032	[B] 1.1	[a] 1.35	[a] 1.35
143	143	Small tapered fillets	0	.40	0	.078	[5].85	.0128	−.02	.030	.009	[A] 1.5	[c] 1.56	[c] 1.38
144	144	Large tapered fillets	0	.40	0	.080	.85	.0131	.08	.020	−.005	[A] 1.6	[c] 1.62	[c] 1.44

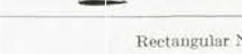
[1] Letters refer to types of drag curves associated with the interference burble. See footnote 1, p. 34.

[2] Letters refer to condition at maximum lift as follows: [a] Reasonably steady at $C_{L_{max}}$; [b] small loss of lift beyond $C_{L_{max}}$; [c] large loss of lift beyond $C_{L_{max}}$ and uncertain value of $C_{L_{max}}$.

[4] Poor agreement over whole range.

[5] Poor agreement in high-lift range.

TABLE V.—PRINCIPAL AERODYNAMIC CHARACTERISTICS OF WING-FUSELAGE COMBINATIONS—Continued

Diagrams representing combination	Combination	Remarks	Longitudinal position d/c	Vertical position k/c	Wing setting i_w	Lift-curve slope (per degree) a A. R.= 6.86	Span efficiency factor e	$C_{D_{min}}$	$C_{L_{opt}}$	Aerodynamic center position η_0	C_{m_0}	Lift coefficient at interference burble [1] $C_{L_{ib}}$	[2] $C_{L_{max}}$ effective R. N.= 7.5×10^6	[2] $C_{L_{max}}$ effective R. N.= 3.4×10^6
Rectangular N. A. C. A. 0012 airfoil with round fuselage														
	145	Large tapered fillets extended to L. E. of airfoil.	0	0.40	*Degrees* 0	0.080	0.85	0.0129	0.08	0.021	−0.006	[a] 1.5	[c] 1.57	[c] 1.40
	146	Same as combination 143.	0	−.40	0	.078	.80	.0128	.02	.030	−.009	[a b] .9	[c] 1.49	[c] 1.31
	147	Same as combination 144.	0	−.40	0	.080	.85	.0131	−.08	.020	.005	[a] 1.5	[c] 1.57	[c] 1.35
	148	Same as combination 145.	0	−.40	0	.080	.85	.0129	−.08	.021	.006	[a] 1.4	[c] 1.48	[c] 1.34
	149	Thin connecting plate (0.013c by 0.40c) 0.15c back of L. E. of airfoil.	0	.54	0	.077	.85	.0134	.08	.036	.006	[a] 1.4	[c] 1.47	[c] 1.37
	150	Moderately thick connecting strut (N. A. C. A. 0012 section with 0.85c chord).	0	.54	0	.076	.85	.0130	.05	.036	.009	[a] 1.4	[c] 1.48	[c] 1.30
	151	Thick connecting strut (N. A. C. A. 0025 section with 0.85c chord).	0	.54	0	.074	.85	.0142	.07	.047	.009	[a] 1.3	[c] 1.44	[c] 1.33
	152	Same as combination 151 but with strut in forward position.	0	.54	0	.076	.85	.0140	.09	.036	.008	[a] 1.5	[c] 1.52	[c] 1.37
	153	Same as combination 152 but with small fillets.	0	.54	0	.076	[d] .85	.0143	.05	.044	.008	[a] 1.3	[c] 1.38	[c] 1.38
	154	Same as combination 149.	0	−.54	0	.077	.85	.0134	−.08	.036	−.006	[a] 1.5	[c] 1.56	[c] 1.35
	155	Same as combination 150.	0	−.54	0	.076	.85	.0130	−.05	.036	−.009	[a] 1.5	[c] 1.55	[c] 1.31
	156	Same as combination 151.	0	−.54	0	.074	.65	.0142	−.07	.047	−.009	[a b] .9	[c] 1.43	[c] 1.28
	157	Same as combination 152.	0	−.54	0	.076	[d] .70	.0140	−.09	.036	−.008	[c] .0	[c] 1.44	[c] 1.27
	158	Same as combination 153.	0	−.54	0	.076	[d] .60	.0143	−.05	.044	−.008	[c] .0	[c] 1.41	[c] 1.30
Rectangular N. A. C. A. 4412 airfoil with round fuselage														
		Wing alone			*Degrees*	.076	.90	.0094	.22	.006	−.089	[a] 1.6	[a] 1.64	[a] 1.51
	159		0	0.54	−4	.075	[d] .90	.0127	.22	.035	−.082			[a] 1.54
	160				0	.075	[d] .90	.0127	.28	.030	−.101			[a] 1.54
159 to 163	161				4	.076	[d] .95	.0131	.36	.010	−.116		[a] 1.68	[a] 1.54
	162				8	.076		.0140	.45	−.006	−.123			[a] 1.54
	163				12	.077		.0160	.58	−.003	−.121		[a] 1.67	[a] 1.54
	164		0	−.04	−4	.080	.90	.0128	.21	.030	−.085	[a] 1.4	[a] 1.52	[a] 1.50
	165				0	.081	.90	.0126	.17	.026	−.100	[a] 1.5	[b] 1.52	[a] 1.49
164 to 166	166				4	.080	.90	.0134	.21	.027	−.112	[a] 1.5	[b] 1.56	[a] 1.47

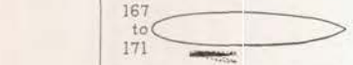
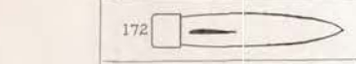
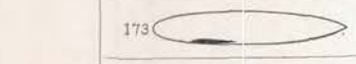
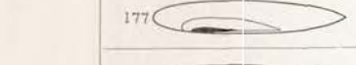
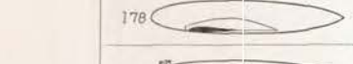
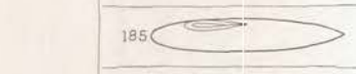
[1] Letters refer to types of drag curves associated with the interference burble. See footnote 1, p. 34.

[2] Letters refer to condition at maximum lift as follows: [a] Reasonably steady at $C_{L_{max}}$; [b] small loss of lift beyond $C_{L_{max}}$; [c] large loss of lift beyond $C_{L_{max}}$ and uncertain value of $C_{L_{max}}$.

[d] Poor agreement in high-lift range.

[e] Rapid increase in drag preceeding definite breakdown.

TABLE V.—PRINCIPAL AERODYNAMIC CHARACTERISTICS OF WING-FUSELAGE COMBINATIONS—Continued

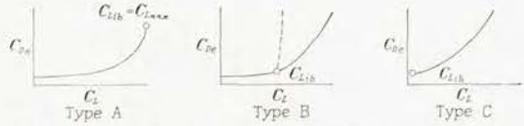
Diagrams representing combination	Combination	Remarks	Longitudinal position d/c	Vertical position k/c	Wing setting i_w	Lift-curve slope (per degree) a A. R.= 6.86	Span efficiency factor e	$C_{D_{min}}$	$C_{L_{opt}}$	Aerodynamic center position n_0	C_{m_0}	Lift coefficient at interference burble $^1C_{L_b}$	$^2C_{L_{max}}$ effective R. N.= 7.5×10^6	$^2C_{L_{max}}$ effective R. N.= 3.4×10^6
Rectangular N. A. C. A. 4412 airfoil with round fuselage														
	167		0	−0.54	Degrees −4	0.076	0.85	0.0142	0.06	0.036	−0.006	.....	.....	[a] 1.58
	168				0	.076	[3] .90	.0144	.11	.028	−.009	.....	.....	[a] 1.57
	169				4	.076	[3] .90	.0147	.20	.020	−.020	.....	[a] 1.65	[a] 1.57
	170				8	.076	[4] .90	.0158	.33	.015	−.024	.....	.....	[a] 1.56
	171				12	.077	.....	.0177	.40	.006	−.028	[B] 0.9	[a] 1.60	[a] 1.55
	172	Cowled engine	0	−.04	0	.081	[3] .90	.0154	.18	.041	−.009	[A] 1.7	[a] 1.76	[b] 1.59
	173		0	−.30	0	.077	.80	.0145	.09	.039	−.004	[C] .5	[a] 1.70	[b] 1.59
	174	Uncowled engine	0	−.30	0	.074	.....	.0288	.09	.063	−.100	[C] .4	[b] 1.65	[b] 1.52
	175	Cowled engine	0	−.30	0	.078	.....	.0166	.12	.053	−.006	[C] .3	[a] 1.70	[b] 1.58
	176	Inverted tapered fillets (large radius front to small radius rear)	0	−.30	0	.080	.90	.0137	.24	.041	−.007	[B] 1.3	[a] 1.56	[a] 1.47
	177	Straight fillets (large radius front and rear)	0	−.30	0	.080	.90	.0134	.20	.033	−.001	[B] 1.5	[a] 1.61	[a] 1.51
	178	Tapered fillets (small radius front to large radius rear)	0	−.30	0	.081	.90	.0143	.20	.027	−.001	[A] 1.6	[a] 1.67	[a] 1.57
	179	Tapered fillets; uncowled engine	0	−.30	0	.080	.85	.0284	.14	.026	−.005	[A] 1.6	[b] 1.66	[b] 1.60
	180	Tapered fillets; cowled engine	0	−.30	0	.082	.85	.0158	.23	.030	−.000	[A] 1.7	[b] 1.78	[b] 1.66
Tapered N. A. C. A. 0018-09 airfoil with round fuselage														
		Wing alone	.....	.....	Degrees	.077	.90	.0093	.00	.020	.000	[A] 1.4	[c] 1.48	[c] 1.23
	181		0	.54	−4	.075	[5] .90	.0136	.03	.036	.023	.....	[c] 1.50	[b] 1.30
	182				0	.075	[5] .90	.0132	.15	.042	.009	.....	[c] 1.50	[b] 1.31
	183				4	.075	.90	.0132	.18	.040	−.005	.....	[c] 1.52	[b] 1.30
	184				8	.075	.90	.0134	.18	.022	−.017	.....	[c] 1.54	[b] 1.33
	185		0	.22	0	.079	.90	.0124	.02	.039	.008	[A] 1.6	[c] 1.62	[b] 1.36
	186		0	0	0	.079	.90	.0115	.00	.040	.000	[A] 1.5	[c] 1.52	1.25
	187		0	−.22	0	.079	.85	.0124	−.02	.039	−.008	[B] .9	[c] 1.33	[a] 1.14
	188		0	−.54	−4	.075	.85	.0132	−.18	.040	.005	.....	[c] 1.44	[b] 1.22
	189				0	.075	.85	.0132	−.15	.042	−.009	.....	[c] 1.44	[b] 1.22
	190				4	.075	.85	.0136	−.03	.036	−.023	.....	[c] 1.44	[b] 1.22
	191				8	.076	.85	.0144	.05	.030	−.030	.....	[c] 1.42	[b] 1.19

[1] Letters refer to types of drag curves associated with the interference burble. See footnote 1, p. 34.
[2] Letters refer to condition at maximum lift as follows: [a] Reasonably steady at $C_{L_{max}}$; [b] small loss of lift beyond $C_{L_{max}}$; [c] large loss of lift beyond $C_{L_{max}}$ and uncertain value of $C_{L_{max}}$.
[4] Poor agreement over whole range.
[5] Poor agreement in high-lift range.
[6] Rapid increase in drag preceding definite breakdown.

TABLE V.—PRINCIPAL AERODYNAMIC CHARACTERISTICS OF WING-FUSELAGE COMBINATIONS—Continued

Diagrams representing combination	Combination	Remarks	Longitudinal position d/c	Vertical position k/c	Wing setting i_w	Lift-curve slope (per degree) a A. R. = 6.86	Span efficiency factor e	$C_{D_{e_{min}}}$	$C_{L_{opt}}$	Aerodynamic center position n_0	C_{m_0}	Lift coefficient at interference burble [1] $C_{L_{ib}}$	[2] $C_{L_{max}}$ effective R. N. = 7.5×10^6	[2] $C_{L_{max}}$ effective R. N. = $3.4+19^6$
Cut-out N. A. C. A. 0012 airfoil with round fuselage														
		Wing alone			Degrees	0.066	0.75	0.0074	0.00	0.027	0.000	[a] [B] 0.8	[b] 1.18	[b] 1.10
192 to 196	192		0	0.54	−4	.067	.70	.0117	−.01	.069	.017			[b] 1.16
	193				0	.066	.75	.0116	.02	.080	.000	[B] .8		[b] 1.15
	194				4	.066	[5].80	.0121	.06	.070	−.018	[B] .8	[a] 1.14	[b] 1.13
	195				8	.068	[4].80	.0127	.13	.047	−.032	[B] .8		[b] 1.11
	196				12	.069		.0139	.28	.025	−.037	[C] .3	[a] 1.14	[b] 1.10
197	197		0	0	0	.077	.80	.0111	.00	.050	.000	[B] .7	[a] 1.21	[a] 1.15
198 to 202	198		0	−.54	−4	.066	.65	.0121	−.06	.070	.018			[b] 1.18
	199				0	.066	.70	.0116	−.02	.080	.000			[b] 1.17
	200				4	.067	.70	.0117	.01	.069	−.017		[b] 1.40	[b] 1.15
	201				8	.067	[5].75	.0123	.06	.053	−.030			[b] 1.13
	202				12	.068	[5].80	.0136	.12	.040	−.038		[a] 1.26	[b] 1.11
Rectangular fuselage combinations														
203 to 205	203	Rectangular N. A. C. A. 0012 airfoil.	0	0	Degrees −4	.081	.85	.0129	.02	.023	.010	[A] 1.3	[c] 1.35	[c] 1.34
	204	do			0	.081	.85	.0122	.00	.023	.000	[A] 1.4	[c] 1.44	[c] 1.37
	205	do			4	.081	.85	.0129	−.02	.023	−.010	[A] 1.3	[c] 1.35	[c] 1.29
206	206	Rectangular N. A. C. A. 0012 airfoil; uncowled engine.	0	0	0	.080	.80	.0267	.00	.028	.000	[B] 1.0	[c] 1.34	[c] 1.27
207	207	Rectangular N. A. C. A. 0012 airfoil; cowled engine.	0	0	0	.082	.80	.0161	.00	.040	.000	[A] 1.5	[c] 1.52	[c] 1.38
208	208	Rectangular N. A. C. A. 4412 airfoil.	0	0	0	.081	.90	.0136	.25	.019	−.095	[A] 1.6	[B] 1.63	[a] 1.48
209	209	Tapered N. A. C. A. 0018-09 airfoil.	0	0	0	.080	.85	.0127	.00	.034	.000	[A] 1.5	[c] 1.51	[b] 1.26

[1] Letters refer to types of drag curves associated with the interference burble as follows:



[2] Letters refer to condition at maximum lift as follows: [a] Reasonably steady at $C_{L_{max}}$; [b] small loss of lift beyond $C_{L_{max}}$; [c] large loss of lift beyond $C_{L_{max}}$ and uncertain value of $C_{L_{max}}$.

[4] Poor agreement over whole range.
[5] Poor agreement in high-lift range.
[6] Rapid increase in drag preceding definite breakdown.

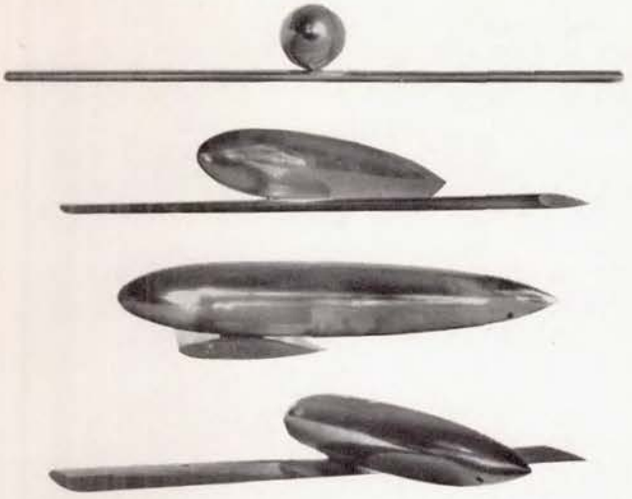


FIGURE 24.—Combination 72 (combination 24 inverted) showing poor junctures at the wing roots.

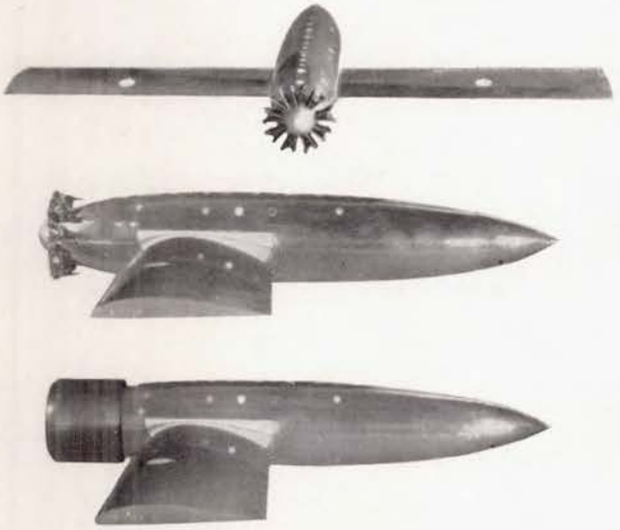


FIGURE 25.—Combinations showing round fuselage with cowled and uncowled engines.

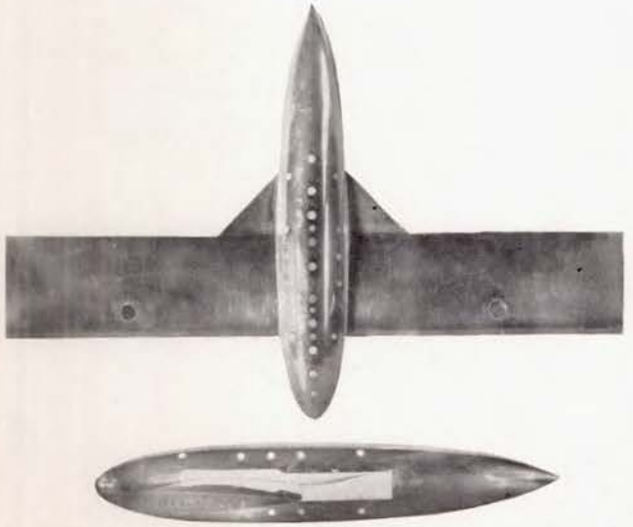


FIGURE 26.—Combination 140 (combination 142 inverted) showing curved plan-form fillets.

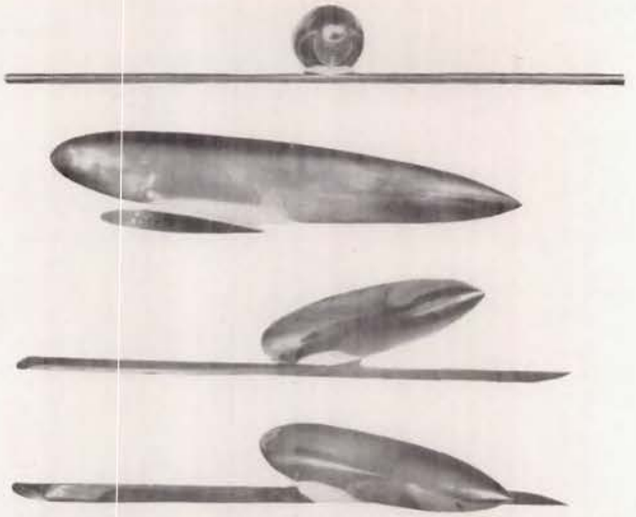


FIGURE 27.—Combination 146 (combination 143 inverted) showing small tapered fillets.

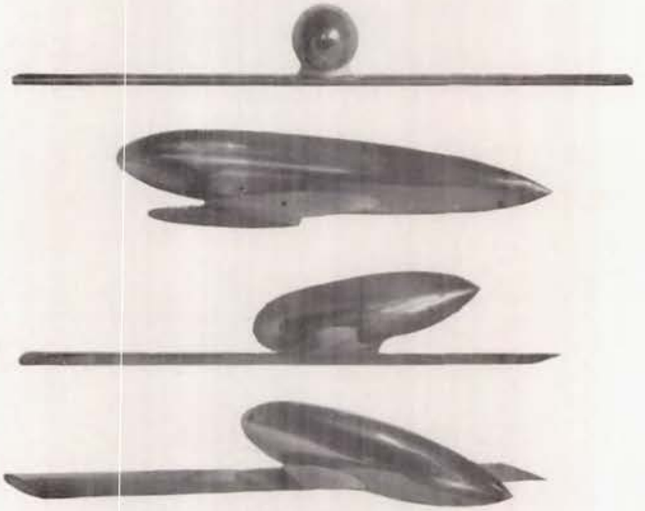


FIGURE 28.—Combination 147 (combination 144 inverted) showing large tapered fillets.

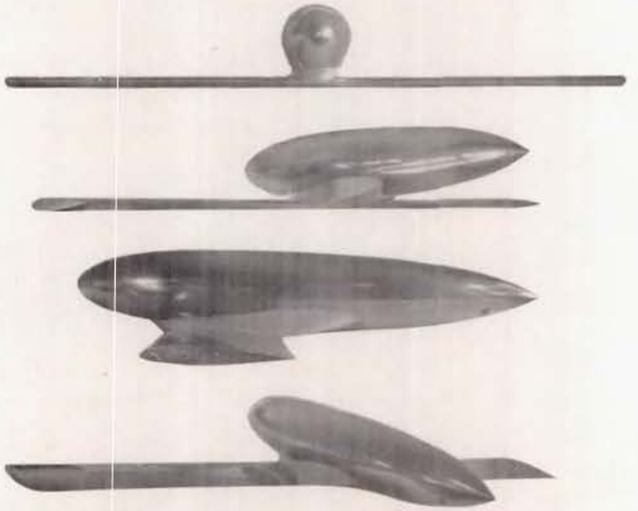


FIGURE 29.—Combination 148 (combination 145 inverted) showing large tapered fillets extended to the leading edge of the wing.

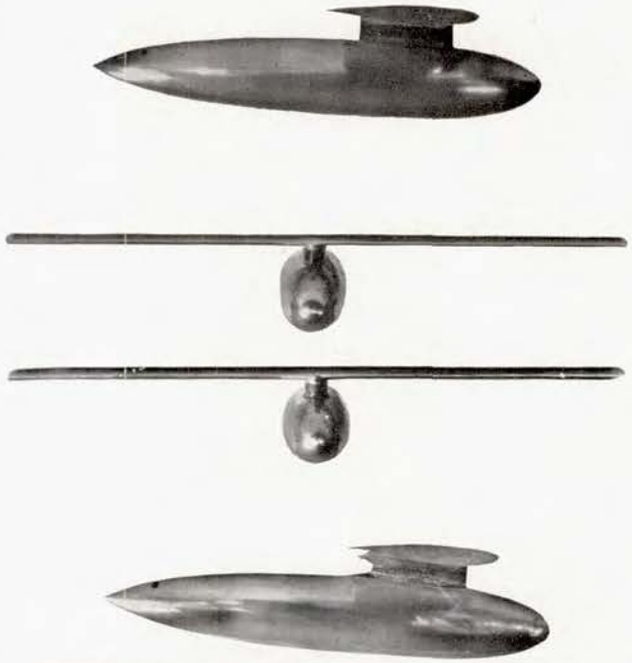


FIGURE 30.—Combinations 152 and 153 (combinations 157 and 158 inverted) showing the thick connecting strut in the forward position with and without fillets.

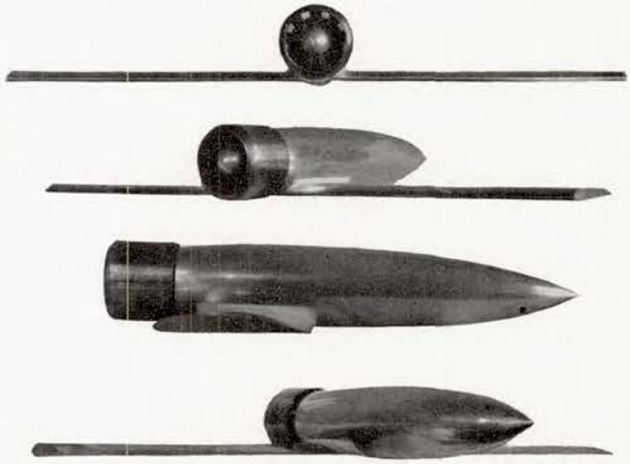


FIGURE 31.—Combination 175 showing the N. A. C. A. 4412 airfoil in a low-wing position.

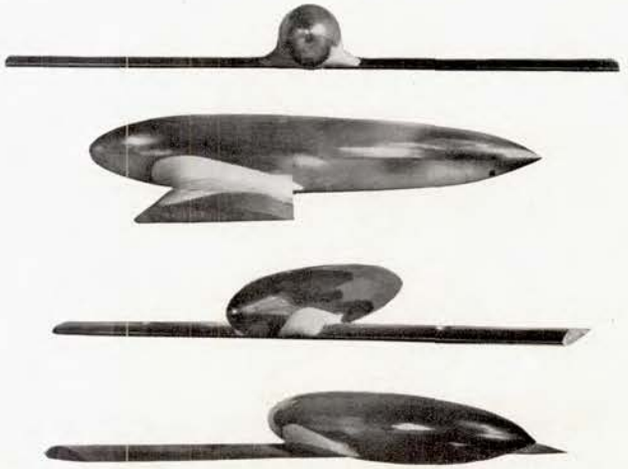


FIGURE 32.—Combination 176 showing inverted tapered fillets.

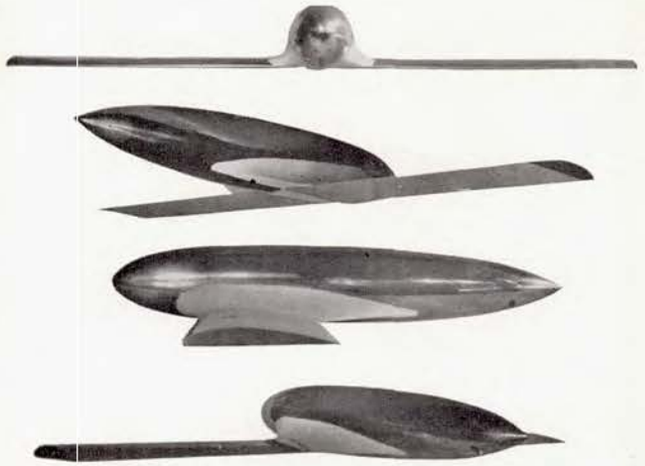


FIGURE 33.—Combination 177 showing straight fillets.

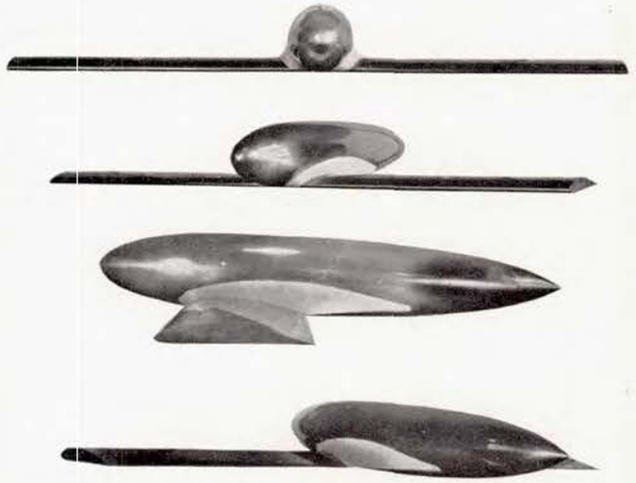


FIGURE 34.—Combination 178 showing tapered fillets.

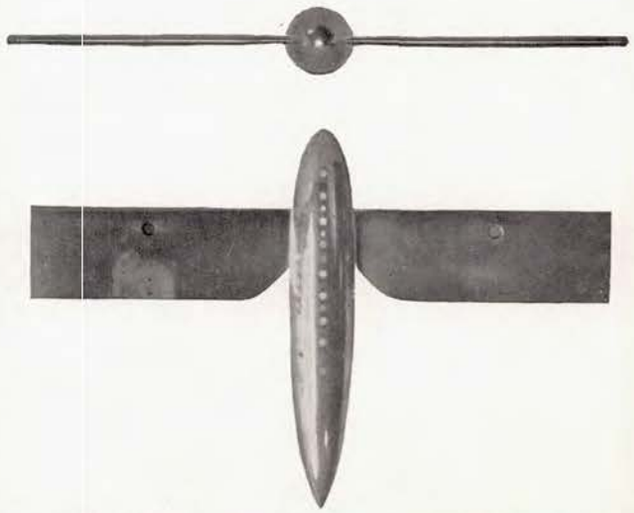


FIGURE 35.—Combination 197 showing the junctures at the wing roots of the cut-out wing.

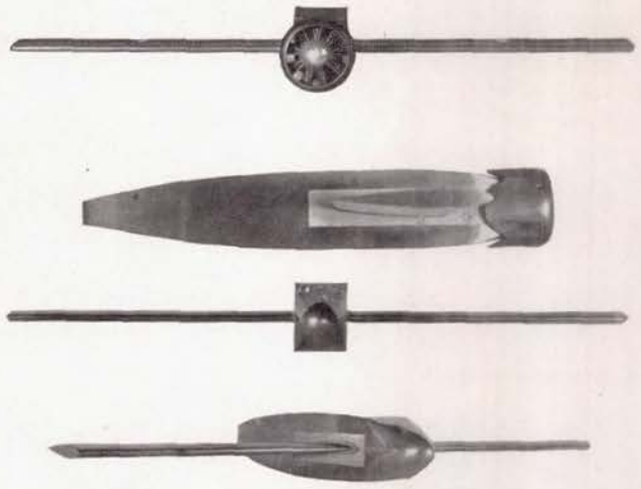


FIGURE 36.—Combinations 204 and 207 showing the rectangular fuselage with and without a cowled engine.

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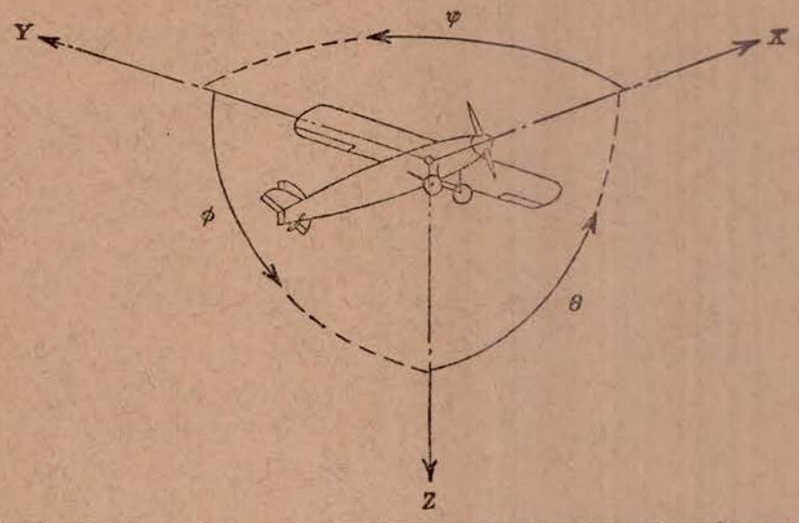

Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	Rolling	L	$Y \longrightarrow Z$	Roll	ϕ	u	p
Lateral	Y	Y	Pitching	M	$Z \longrightarrow X$	Pitch	θ	v	q
Normal	Z	Z	Yawing	N	$X \longrightarrow Y$	Yaw	ψ	w	r

Absolute coefficients of moment

$C_l = \frac{L}{qbS}$ (rolling) $\quad C_m = \frac{M}{qcS}$ (pitching) $\quad C_n = \frac{N}{qbS}$ (yawing)

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D, Diameter
p, Geometric pitch
p/D, Pitch ratio
V', Inflow velocity
V_s, Slipstream velocity
T, Thrust, absolute coefficient $C_T = \frac{T}{\rho n^2 D^4}$
Q, Torque, absolute coefficient $C_Q = \frac{Q}{\rho n^2 D^5}$
P, Power, absolute coefficient $C_P = \frac{P}{\rho n^3 D^5}$
C_s, Speed-power coefficient $= \sqrt[5]{\frac{\rho V^5}{P n^2}}$
η, Efficiency
n, Revolutions per second, r.p.s.
Φ, Effective helix angle $= \tan^{-1}\left(\frac{V}{2\pi r n}\right)$

5. NUMERICAL RELATIONS

1 hp. = 76.04 kg-m/s = 550 ft-lb./sec.
1 metric horsepower = 1.0132 hp.
1 m.p.h. = 0.4470 m.p.s.
1 m.p.s. = 2.2369 m.p.h

1 lb. = 0.4536 kg.
1 kg = 2.2046 lb.
1 mi. = 1,609.35 m = 5,280 ft.
1 m = 3.2808 ft.