REPORT No. 415

TESTS OF NACELLE-PROPELLER COMBINATIONS IN VARIOUS POSITIONS WITH REFERENCE TO WINGS. PART I. THICK WING—N. A. C. A. COWLED NACELLE—TRACTOR PROPELLER

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SUMMARY

This report gives the results obtained in the 20-foot propeller-research tunnel of the National Advisory Committee for Aeronautics on the interference drag and propulsive efficiency of a nacelle-propeller combination located in 21 positions with reference to a thick wing.

The wing had a 5-foot chord, a 15-foot span, and a maximum thickness of 20 per cent of the chord. The engine was a ⅕-scale model of a Wright J–5 radial air-cooled engine and installed in a nacelle with a cowling of the N. A. C. A. type. The propeller was a 4-foot diameter model of the standard Navy adjustable-pitch metal propeller No. 4412.

The lift, drag, and propulsive efficiency were obtained at several angles of attack for each of the 21 locations. A net efficiency was derived for determining the over-all effectiveness of each nacelle location.

Best results were obtained with the propeller about 25 per cent of the chord directly ahead of the leading edge. A location immediately above or below the wing near the leading edge was very poor.

INTRODUCTION

At the Fourth Annual Aircraft Engineering Research Conference held at Langley Field, Va., in May, 1929, several manufacturers pointed out the lack of data on the relative merits of nacelle positions and suggested certain tests that might be made to shed some light on the problem.

Previous tests in the variable-density wind tunnel (reference 1) had shown the importance of the interference effects between a wing and a nacelle with N. A. C. A. cowling. These tests did not, however, include propeller effects nor cover a sufficient range of angles of attack and of nacelle positions. Propulsive efficiency is known to be affected by the shape and location of the nacelle; the characteristics of a wing are known to be affected by the presence of a nacelle and by the propeller slipstream.

At the time of the next annual conference, in May, 1930, a research with a tractor propeller and monoplane wing had been started. Further suggestions made at this time have resulted in the extension of the program to include pusher and tandem propellers, as well as biplane wings.

This report presents the results obtained with a thick airfoil (20 per cent) 5 by 15 feet, a ⅕-scale model of a cowled radial engine and nacelle, and a 4-foot metal propeller located in 21 positions, above, below, and forward of the airfoil's leading edge. This series of tests constitutes the first main division of the program. Work on the remaining portion of the program is in progress and will be reported later. All the tests are being made in the 20-foot propeller-research tunnel of the National Advisory Committee for Aeronautics.

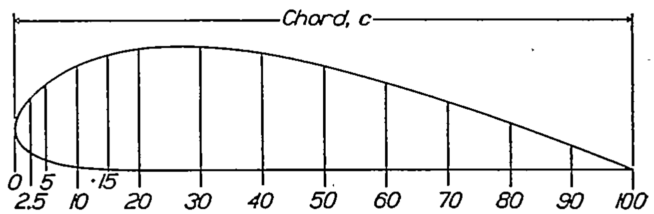

FIGURE 1.—Section of wing used in tests

60-INCH CHORD MAXIMUM ORDINATE=20 PER CENT CHORD

Distance from L. E. in per cent chord	Distance from L. E. in inches	Ordinate upper surface in per cent chord	Ordinate upper surface in inches	Ordinate lower surface in per cent chord	Ordinate lower surface in inches
0.0	0.00	6.7	4.00	6.7	4.00
2.5	1.50	12.0	7.20	3.0	1.82
5.0	3.00	14.2	8.50	1.8	1.10
10.0	6.00	17.1	10.26	.6	.34
15.0	9.00	18.7	11.24	.2	.10
20.0	12.00	19.6	11.75	.0	.02
30.0	18.00	20.0	12.00	.0	.00
40.0	24.00	18.9	11.34	.0	.00
50.0	30.00	16.9	10.14	.0	.00
60.0	36.00	14.1	8.48	.0	.00
70.0	42.00	11.0	6.58	.0	.00
80.0	48.00	7.5	4.52	.0	.00
90.0	54.00	3.8	2.30	.0	.00
100.0	60.00	0.0	0.00	.0	.00

APPARATUS AND METHODS

The propeller-research tunnel has been described in reference 2. The standard apparatus and test methods were used with certain exceptions mentioned later.

The wing was constructed of wood with a 5-foot chord and a 15-foot span. The airfoil section, the ordinates of which are shown in Figure 1, had a maximum thickness of 20 per cent of the chord. The central portion of the wing was provided with suitable metal ribs and plates for the connection of the struts required in attaching the nacelle to the wing. The duralumin nacelle was similar to the nacelle required for a Wright J–5 radial air-cooled engine, and was four-ninths (0.445) full scale. A detailed wooden model of this engine (fig. 2) was installed in the proper position in the nacelle. The engine model was fitted with an N. A. C. A. cowling, the inside lines of which were modified to fit around the electric motor used to drive the propeller. The principal dimensions of the nacelle, engine, and cowling are shown in Figure 3. The propeller, which was 4 feet in diameter, was made geometrically similar to the Navy standard 4412 nine-foot diameter aluminum-alloy propeller, tests of which are discussed in references 3 and 4. The blades could be turned in the hub to give different pitch settings. In the tests discussed here, the pitch setting was 17° at $0.75R$, which is about average for usual operating conditions. Some tests were made with a 22° pitch setting for comparison.

FIGURE 2.—Photograph of model engine and propeller

For driving this propeller a 25-horsepower 220-volt direct-current motor was mounted within the nacelle. Wires were led from the motor down the struts into the wing, and along the supporting members to the control equipment on the floor below. These wires were carefully taped to the struts, preserving a streamline shape which, in subsequent tests, showed a negligible effect on the tare drag. A Prony brake was used for calibrating the motor, and curves were obtained giving armature current against torque for several values of the field current. During the tests the field current was held at one of these calibrated values. Revolution speed was indicated by a condenser-type electric tachometer which occupied a small space in the nacelle and was connected by wires to an indicating instrument on the floor below.

The wing and nacelle combinations were mounted on the balance by means of standard supports, which have been described in reference 5. With these supports the airfoil pivots about a line near the lower surface 25 per cent of the chord back from the leading edge, and the angle of attack is adjusted by a crank operating a post connected with a sting on the airfoil. The airfoil and nacelle mounted in one test position are shown in Figure 4.

For use in subsequent analyses, a series of tests at various air speeds was made with the wing alone at angles of attack of −5°, 0°, +5°, +10°, +12°, and +15°. Similar tests were made with the nacelle alone. In each case separate tare drag tests were also made. The lift and drag forces were measured simultaneously by balances on the floor below. The Reynolds Number varied from about 2,300,000 at the lowest air speed (54 m. p. h.) to 4,300,000 at the highest speed (99 m. p. h.).

The wing-nacelle-propeller combination was tested with the nacelle and wing in the 21 relative positions shown in Figure 5. In this figure the crosses indicate the positions of the center line of the propeller hub. The nacelle positions are designated by the convenient system of letters shown. Figures 6, 7, and 8 are photographs of the actual wing-nacelle set-ups arranged in the order of the nacelle locations. In all cases the thrust line of the propeller was fixed parallel to the wing chord.

The first test with each combination was a run at several air speeds, with the propeller removed. The lift, drag, and air speed were measured. A second test was then made with the propeller in place, and with the tunnel operating at several air speeds. In this test the lift, drag (or thrust), torque, propeller revolutions, and air speed were measured. Separate tests were made at angles of attack of −5°, 0°, +5°, +10°, and +12°. At the 12° angle only a few points were determined near zero thrust.

The most unfavorable interference was expected when the nacelle was near the wing. This interference occurred in the first position tried near the wing (B–1–A), therefore in all the tests with the nacelle near or partly within the wing, the gap between was carefully faired. The photograph of position B–1–A in Figure 6 shows the nacelle unfaired. The fairing used was similar to that of position B–1–B

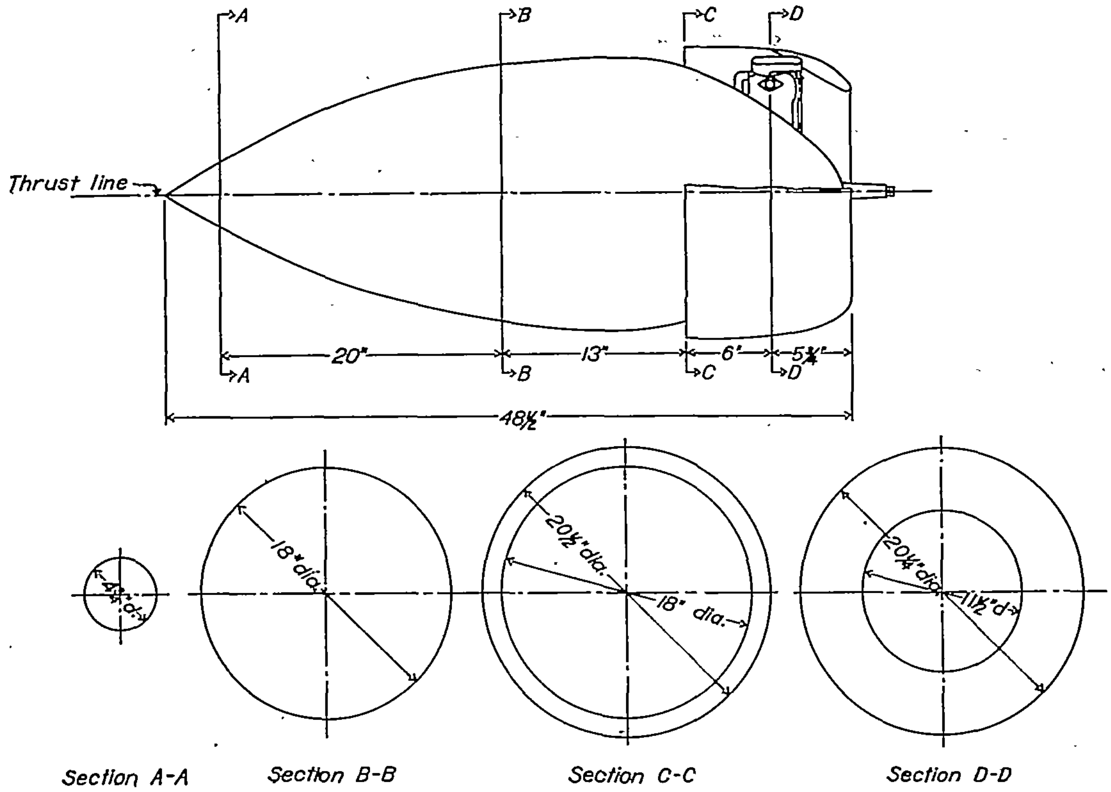

FIGURE 3.—Nacelle, engine, and N. A. C. A. cowling assembly

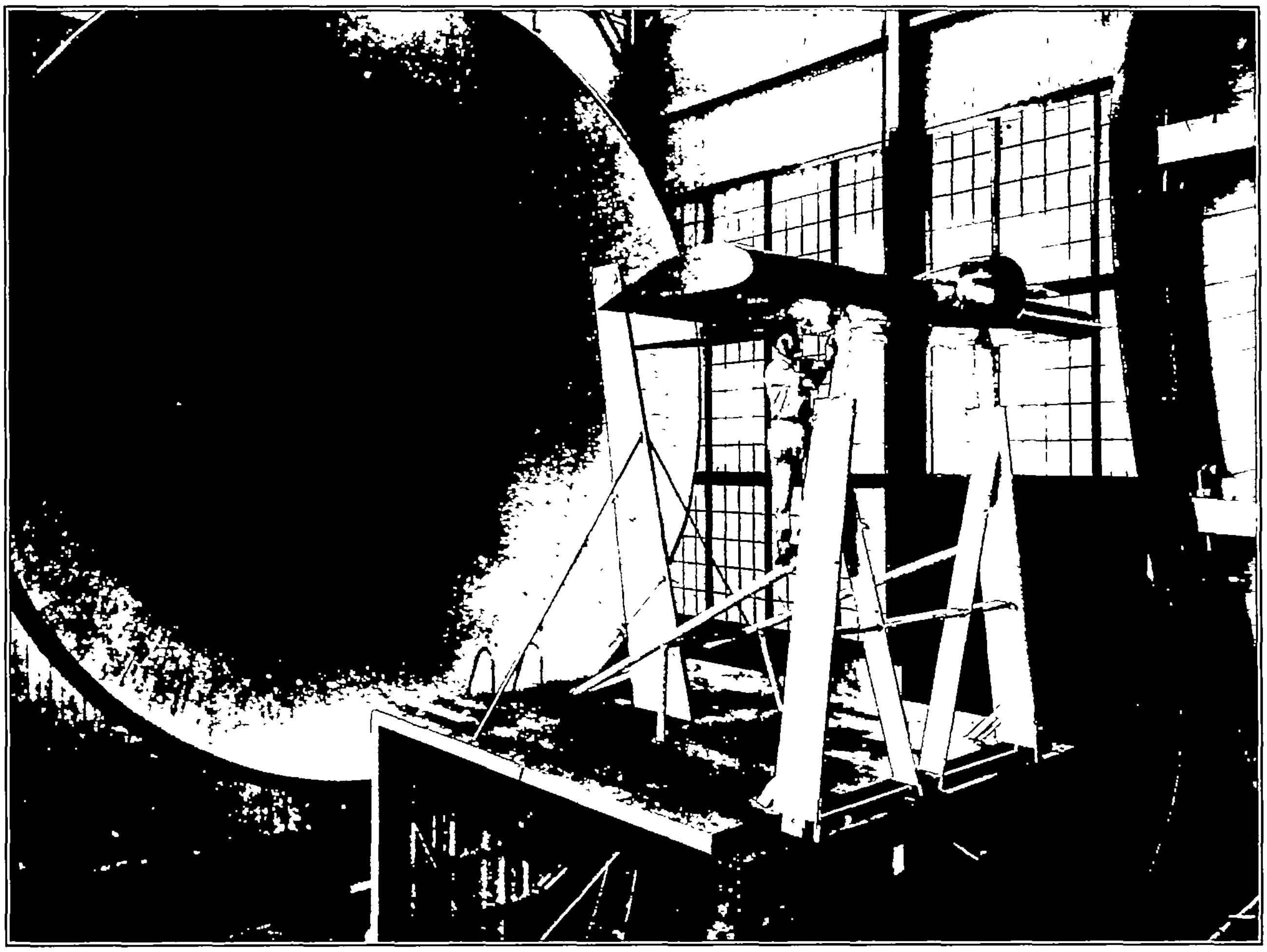

FIGURE 4.—Photograph of wing-nacelle combination in position B mounted for test

shown in Figure 8. The results of the tests in these locations are therefore somewhat better than they would have been if the nacelle had been supported by struts without fairing, as will be seen by comparing the results, with and without fairing, for the above-mentioned position (B–1–A).

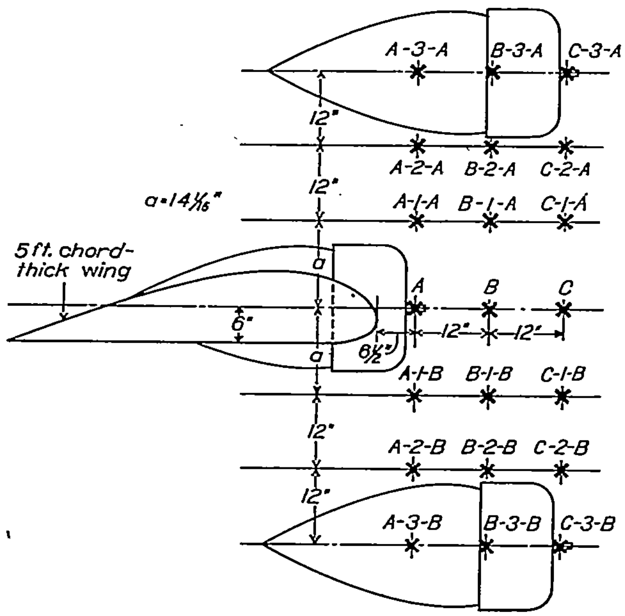

FIGURE 5.—Wing-nacelle test locations

RESULTS

The measured lift, drag, and moment were reduced to the usual coefficients

$$C_L = \frac{\text{Lift}}{qS} \qquad C_D = \frac{\text{Drag}}{qS} \qquad C_m = \frac{\text{Moment}}{qSc}$$

where

q, the dynamic pressure ($\frac{1}{2} \rho V^2$).
ρ, mass density of the air.
V, velocity.
S, the area of the wing.
c, chord of the wing.

(All moments are taken about the quarter-chord point of the wing.) These coefficients were first plotted against the dynamic pressure q and then cross plotted as C_L, C_D, and C_m against α (angle of attack) at values of the dynamic pressure corresponding to 50, 75, and 100 m. p. h. The results of the tests, in general, are quite similar for the different positions. Only a sample series of curves is given. Figure 9 shows the results for the wing alone, the nacelle alone, and the sum of the two for a dynamic pressure of 25.6 pounds per square foot, which corresponds to 100 miles per hour in standard air. Figures 10 and 11 give similar results for the wing-nacelle combination in position B and in position A–1–A, the best and the worst positions, respectively. As the complete data would occupy many pages, only the values read from carefully faired curves are given in the tables: Table I, C_L; Table II, C_D; and Table III, C_m. Values are given for three air speeds (50, 75, and 100 m. p. h.). All the useful information is thus reduced to manageable proportions.

The results with the propeller operating are reduced to the usual coefficients

$$C_T = \frac{T - \Delta D}{\rho n^2 D^4} \qquad C_P = \frac{P}{\rho n^3 D^5}$$

where

T, thrust of propeller operating in front of a body (tension in crankshaft).
ΔD, change in drag of body due to action of propeller.
$T - \Delta D$, effective thrust (discussed in references 3 and 4).
n, revolutions per unit of time.
D, propeller diameter.
P, motor power.

and

η = propulsive efficiency

$$= \frac{\text{effective thrust} \times \text{velocity of advance}}{\text{motor power}}$$

$$= \frac{(T - \Delta D)V}{P} = \left(\frac{C_T}{C_P}\right) \frac{V}{nD}$$

and

C_L is computed as before, but is now called C_{L_P}.

Results of one of the tests are given in Figures 12 and 13. Figure 12 shows C_{L_P} versus $\frac{V}{nD}$ for each angle of attack with the propeller operating. The curve obtained without the propeller is also given for comparison. The curvature in this line is due to the variation of the lift coefficient with air speed (i. e., Reynolds Number). The values plotted were taken for the actual dynamic pressures at the values of $\frac{V}{nD}$ at which the propeller operated. In Figure 13, C_T, C_P, and η are plotted against $\frac{V}{nD}$ with separate lines for each angle of attack. The coefficients for all nacelle positions at various values of $\frac{V}{nD}$ and the different angles of attack are given in Tables IV to VIII, inclusive: Table IV, Thrust Coefficient (C_T); Table V, Power Coefficient (C_P); Table VI, Propulsive Efficiency (η); Table VII, Lift Coefficient with Propeller Operating (C_{L_P}); Table VIII, Moment Coefficient with Propeller Operating (C_{m_P}).

The foregoing two types of curves are ordinarily employed in presenting airfoil data and propeller data. For comparing the efficiencies of the nacelle-propeller combination in the various positions, however, other curves are required, which depend on further analysis, and will be given later.

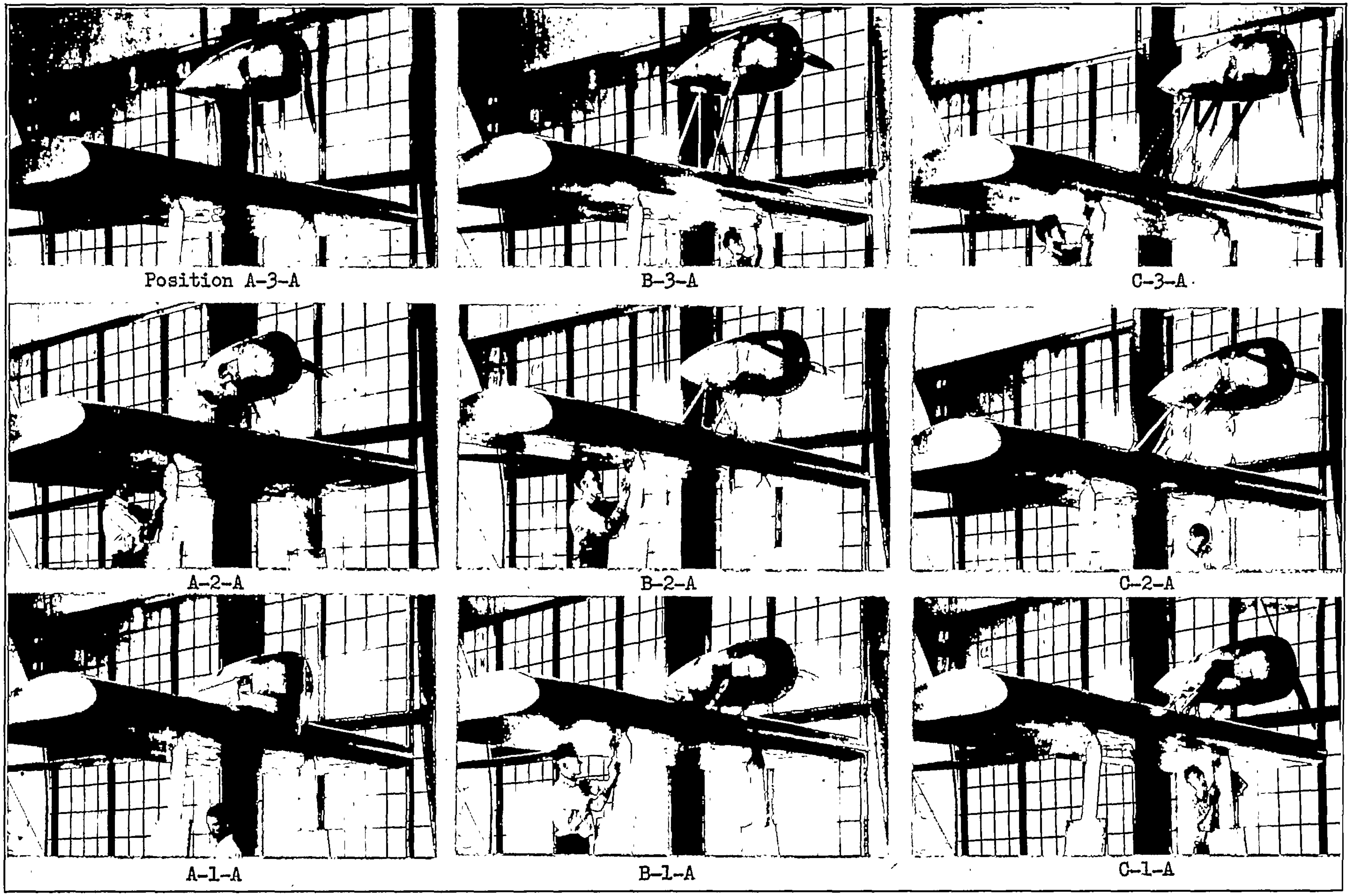

FIGURE 6.—Nacelles above wing

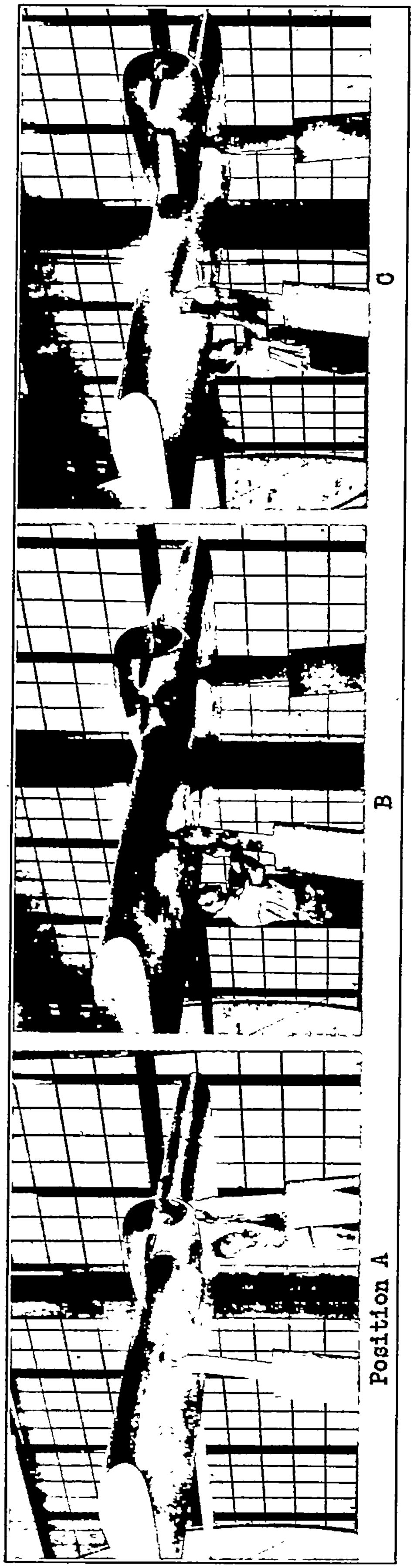

FIGURE 7.—Nacelles in front of wing

The moment coefficients C_m computed for the tests show an interesting characteristic. A comparison of the moments with propeller operating with the moments without propeller shows, to a very close approximation, that the moment of the wing-nacelle-propeller combination is equal to the sum of the wing-nacelle moment without propeller and the moment of the horizontal component of the effective thrust.

ACCURACY

All readings were taken on scales and instruments which were calibrated frequently during the tests. The angles of attack of the airfoil were set within 5′ of the desired angles with an inclinometer. The motor calibration showed a scattering of the points representing a maximum error of 1 per cent. The tachometer readings were accurate within 10 revolutions per minute. The lift and drag balances were read to the nearest pound.

With certain nacelle positions at high angles of attack the forces fluctuated rapidly and the above accuracy could not be obtained. This fluctuation was particularly noticeable near the burble point of the airfoil. The major portion of the faired results are believed to be correct within ±2 per cent, when the scattering of the test points and the accuracy of the instruments are considered.

DISCUSSION

A consideration of the general problem of a nacelle with a propeller operating in proximity to a wing indicates that several factors should be considered.

1. The slipstream from the propeller produces changes in the velocities of the air over parts in its path, and these parts, in turn, act to change the velocity and direction of the air flow in their vicinity. The propulsive efficiency of the propeller is therefore affected by its location with respect to the wing and by the angle of attack of the propeller-wing combination, in addition to the usual effects of changes of the air speed and the engine revolutions.

2. The nacelle alone and wing alone have drags which, when added numerically, are different from the drag of a combination of the wing and nacelle. This difference is called interference drag. A favorable interference occurs when the drag of the combination is less than the sum of the wing and nacelle drags. The interference may pass from favorable to unfavorable, and vice versa, with changes in the angle of attack.

3. A combination of wing and nacelle has a lift which, in general, is different from that of the wing alone plus nacelle alone. The action of the propeller may also change the lift at a given angle of attack.

4. A comparison of the relative merits of wing-nacelle-propeller combinations in various positions must therefore include (1) propulsive efficiency; (2) interference-drag effects; (3) lift effects. The following

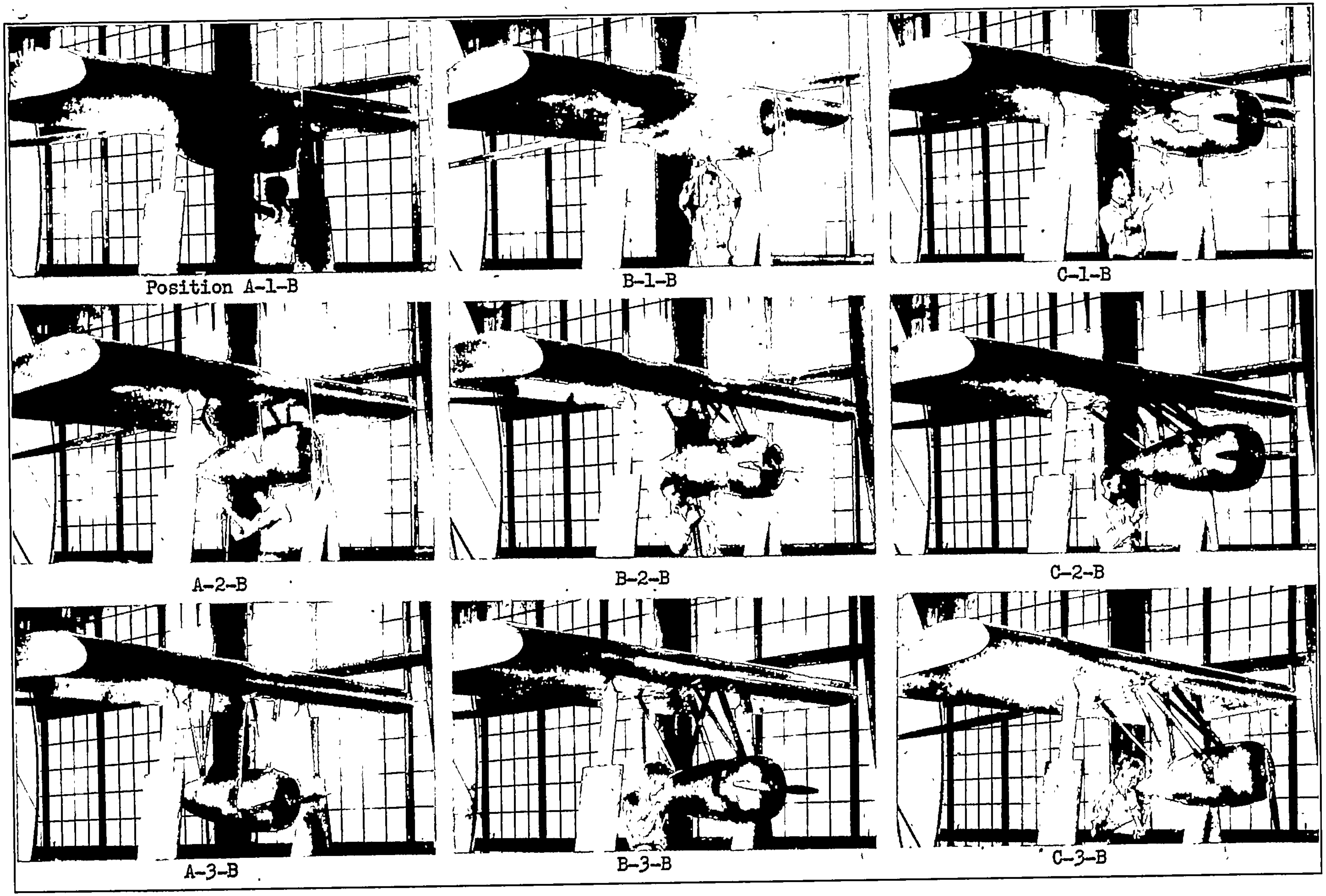

FIGURE 8.—Nacelles below wing

discussion contains an analysis and derivation of a method of comparison which takes these effects into account.

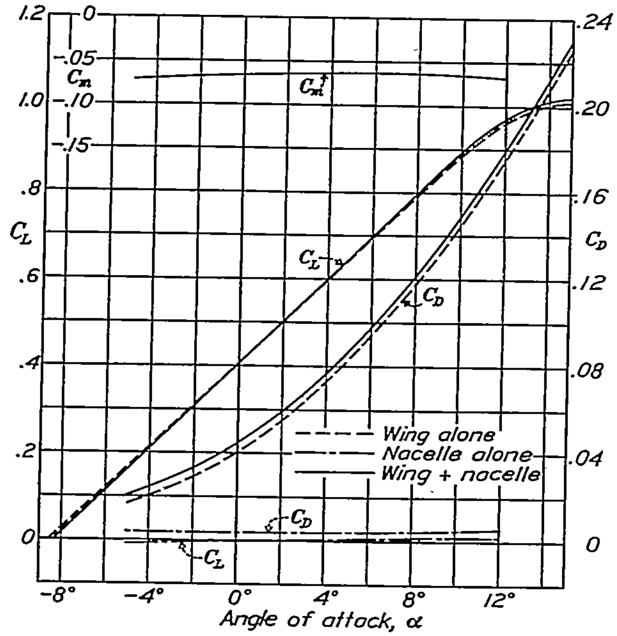

FIGURE 9.—Lift, drag, and moment characteristics for wing alone and nacelle alone

NET EFFICIENCY

Careful study of the problem shows that in spite of its apparent complexity, a satisfactory method of comparison incorporating the three essential effects

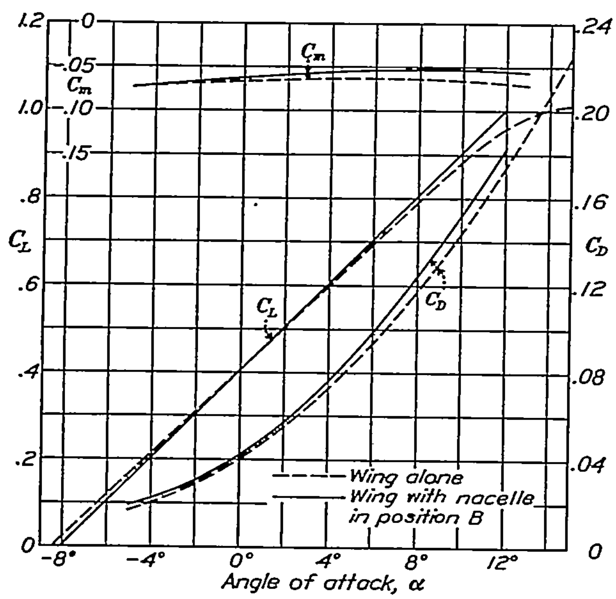

FIGURE 10.—Comparison of lift, drag, and moment characteristics for wing alone and nacelle combination in position B

discussed in the preceding section (propulsive efficiency, interference drag, and lift) can be obtained by deriving a net efficiency for each nacelle-propeller location. A direct comparison of the net efficiencies then gives the relative merit of the different nacelle locations.

In other words, it is convenient to consider the nacelle, the engine within it, and the propeller as a propulsive unit. The only reason for the nacelle is to house the motor driving the propeller. As the same

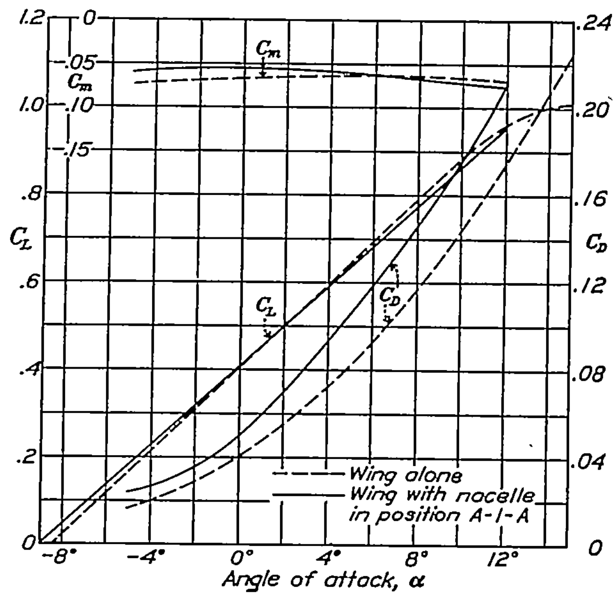

FIGURE 11.—Comparison of lift, drag, and moment characteristics for wing alone and nacelle combination in position A-1-A

wing was employed throughout the investigation, the drag and lift of the wing will be taken as a basis and all changes in lift and drag will be charged to the propeller-nacelle combination. If the drag of the combination is greater, the propulsive efficiency, which represents the

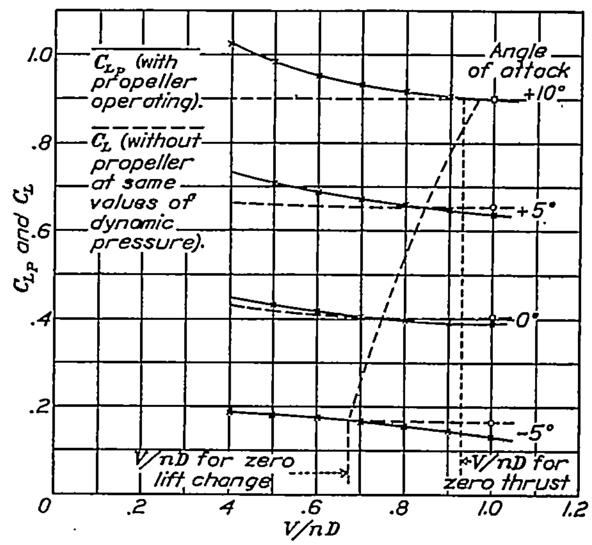

FIGURE 12.—Effect of propeller on lift of wing-nacelle combination in position B

ratio of the effective thrust horsepower to the total motor power, will be charged with the drag and interference of the nacelle, and with any changes in lift which may occur.

A consideration of the matter shows, at once, that if a greater lift was obtained with the nacelle in place and the propeller operating than was obtained with the wing alone, this additional lift must have been due to the action of the propeller and the presence of the nacelle, and the propulsive unit should consequently receive credit. It is very difficult to obtain a factor satisfying all conditions—one that will give a horizontal force or drag equivalent to a vertical force or lift. This question has been discussed in a very interesting paper by Betz. (Reference 6.) He comes to the conclusion that no method gives entire satisfaction. After considering the question from several angles, the author has concluded that the practical considerations can be sufficiently well satisfied by making the comparison at a constant lift so that the lift effects are automatically eliminated. The angles of attack are so selected that the lift coefficient remains constant; i. e., equal to that of the wing alone at the angle of attack selected for comparison. If the lift is higher with the propeller operating at a given angle of attack, the same lift as that of the wing alone can be produced at a lower angle of attack of any wing-nacelle combination, and vice versa.

The difference between the drag of the wing-nacelle combination and the drag of the wing alone (at the same lift coefficient) when multiplied by the velocity gives the thrust horsepower consumed in overcoming the effective drag (drag plus interference) of the nacelle. If this thrust horsepower is deducted from the total effective thrust horsepower, there remains the net thrust horsepower available for overcoming the drag of other parts of the airplane exclusive of the nacelle drag and interference. The effective thrust, already defined, has taken into account any drag effects produced by the propeller and any changes in thrust produced by the action of the body. Then if the ratio of the net thrust horsepower to the total motor power is taken, the net efficiency is obtained; that is, the nacelle drag efficiency factor represents the fractional part of the total motor power which is expended in overcoming the drag and interference of the nacelle (at a given lift coefficient), and the net efficiency is the fraction of the total motor power which is available for overcoming the drag of other parts of the airplane, exclusive of the propeller losses, and nacelle drag and interference.

In practical terms, if two airplanes have the same weight and dimensions except for nacelle location, the net efficiencies show the comparative useful power available at the same speed from nacelle propeller units located in the different positions with respect to the wing. These considerations may be expressed mathematically as follows:

Let D_W, drag of the wing at a given angle of attack.
D_C, drag of the wing-nacelle combination at the same lift coefficient as the wing.

then

Effective nacelle drag = (nacelle drag) + (wing-nacelle interference drag)

$$=D_C-D_W \qquad \text{(I)}$$

Thrust horsepower to overcome effective nacelle drag

$$=(D_C-D_W) \text{ velocity} \qquad \text{(II)}$$

Nacelle drag efficiency factor = fraction of the total motor power used by effective nacelle drag

$$=\frac{(D_C-D_W)\ V}{P} \qquad \text{(III)}$$

Net efficiency = (propulsive efficiency) − (nacelle drag efficiency factor)

$$=\frac{(T-\Delta D)V}{P}-\frac{(D_C-D_W)V}{P}$$

$$=\frac{[(T-\Delta D)-(D_C-D_W)]V}{P} \qquad \text{(IV)}$$

After introducing coefficients and simplifying, the final equations become

Propulsive efficiency

$$=\frac{C_T}{C_P}\times\frac{V}{nD} \qquad \text{(V)}$$

Nacelle drag efficiency factor

$$=\frac{C_{D_C}-C_{D_W}}{C_P}\frac{S}{2D^2}\left(\frac{V}{nD}\right)^3 \qquad \text{(VI)}$$

Net efficiency

$$=\frac{C_T}{C_P}\frac{V}{nD}-\frac{(C_{D_C}-C_{D_W})}{C_P}\frac{S}{2D^2}\left(\frac{V}{nD}\right)^3 \qquad \text{(VII)}$$

If a series of values of the net efficiency and the factors composing it are computed and plotted on a sheet

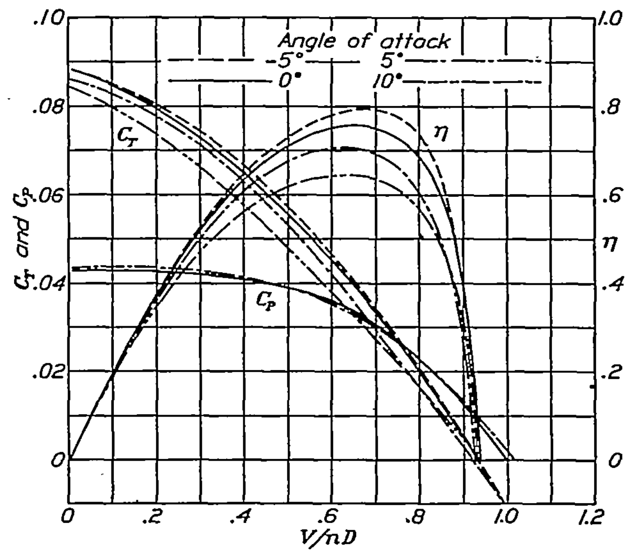

FIGURE 13.—Effect of angle of attack of wing on propulsive efficiency, for wing-nacelle combination in position B

with the various nacelle locations drawn to scale and then cross-plotted, a series of contours representing equal values of the factors are obtained. It is then easy to determine how the factors vary with nacelle location, where they are of the greatest and least magnitudes, and their actual value for any nacelle position.

An examination of flight reports and computations from the dimensions of several airplanes employing nacelles indicates that high and cruising speeds occur at angles of attack between −2° and 0°. In most airplanes the propeller is designed to give maximum propulsive efficiency at about these speeds. A series of three charts (figs. 14 to 16, inclusive) show the contour lines for the "peak" propulsive efficiency

$$\frac{(T-\Delta D)V}{P}$$

the nacelle drag efficiency factor

$$\frac{(D_C-D_W)V}{P}$$

and the net efficiency

$$\frac{[(T-\Delta D)-(D_C-D_W)]V}{P}$$

respectively, all for the lift coefficient corresponding to 0° angle of attack of the wing alone ($C_L=0.409$).

A value of $\frac{V}{nD}=0.65$ was found to be the average value at which maximum efficiency occurred with all nacelle positions. The actual maximum in the extreme case was less than one-fourth of 1 per cent from that at this $\frac{V}{nD}$. As the nacelle drag factor is directly dependent on $\left(\frac{V}{nD}\right)^3$, a much more satisfactory result is obtained by using the constant value. The charts thus computed may be used to compare the high and cruising speed performance of the 21 combinations.

Like considerations indicate that the best rate of climb occurs at about 5° angle of attack and at a speed equal to 60 per cent of high speed. A second series of charts (figs. 17 to 19, inclusive) presents contours of the same factors at a lift coefficient corresponding to 5° angle of attack of the wing alone ($C_L=0.652$), a value of $\frac{V}{nD}$ of 0.42, and at a speed equal to 60 per cent of high speed. The value (0.42) is determined from the high-speed condition by assuming that $V=0.6\ V_{max}$ and that the power varies directly with the revolutions per minute (i. e., constant torque), which is approximately true for airplane engines. These charts may be used to compare the climbing performance of the 21 combinations.

It should be noted in connection with charts of this kind that an increase of 10 per cent in net efficiency does not mean a 10 per cent increase in speed, for example. The increase will rather be only a little more than one-third of 10 per cent, or 3.3 per cent, since the power varies as the cube of the speed for a given drag coefficient, and the change in drag coefficient will be small.

It will be evident from the preceding derivation that the nacelle drag efficiency factor could have been separated into two factors—one giving the fraction of the power used by the nacelle alone, and the other the fraction of the power used by the wing-nacelle interference. This separation is of general interest in showing the wing-nacelle interference by itself. When comparing nacelles of different types, however, both factors are necessary, as will be evident in the later reports of the program, and the use of a single factor combining the two is therefore justified. The part of the nacelle drag efficiency factor due to the drag of the nacelle alone may, however, be taken as constant within about one-fourth per cent. If 7.7 is subtracted from the values of Figure 15 and 2.5 from the values of Figure 18, the resulting values represent the part of the nacelle drag efficiency factor that is due to wing-nacelle interference. Hence, all points between the dotted lines drawn at 7.7 on Figure 15 and at 2.5 on Figure 18, are in an area of favorable wing-nacelle interference. The desired interference-drag information is thus easily obtained.

One other operating condition is of considerable importance, namely, the landing. In a normal landing the engine is throttled down so that the propeller is operating at a value of $\frac{V}{nD}$ near that of zero thrust. Under unusual conditions the propeller may be stopped. In either case, the landing speed depends on the lift coefficient under the particular condition.

Table IX gives the lift coefficients at 12° angle of attack for the several locations of the wing and nacelle with the propeller operating at zero thrust, and also without the propeller. These values of lift coefficient indicate the relative merits of the various nacelle positions for conditions near the landing speed. Several tests have been made with the propeller stopped. The results will be discussed in a report now being prepared. In the last column of Table IX the landing speeds with the various combinations are compared with those with the wing alone. The ratio of the landing speed of the combination to the landing speed of the wing alone is taken as the square root of the inverse ratio of the lift coefficients. The values given are qualitative only, since the wing used in the tests is not necessarily of the same proportional total area as that which would be used on an airplane. If the area of the airplane wing is relatively larger, the effect of the nacelle and propeller on the landing speed will be correspondingly less. In general, the area ratio here used seems about correct, and the values in Column 3 show that the effect of the nacelle location on landing speed is small.

RÉSUMÉ OF RESULTS

The results show several general characteristics. The lift when the propeller is operating at full power, is increased when the nacelle is located above the wing, decreased when below, and practically unaffected when

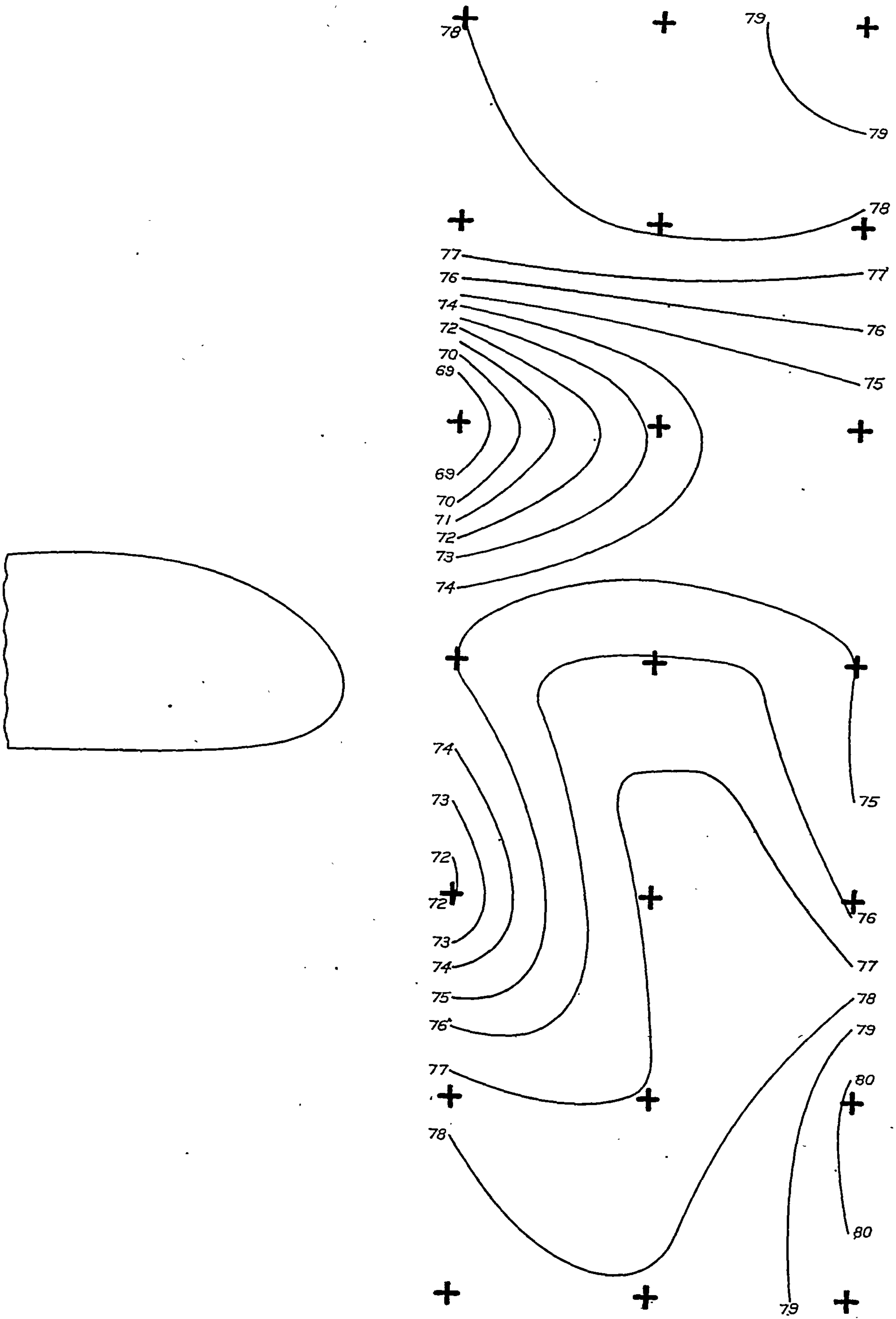

FIGURE 14.—Propulsive efficiency (per cent) at cruising and high-speed condition. (C_L=0.409. Propeller set 17° at 0.75 R, η taken at $\frac{V}{nD}$=0.65)

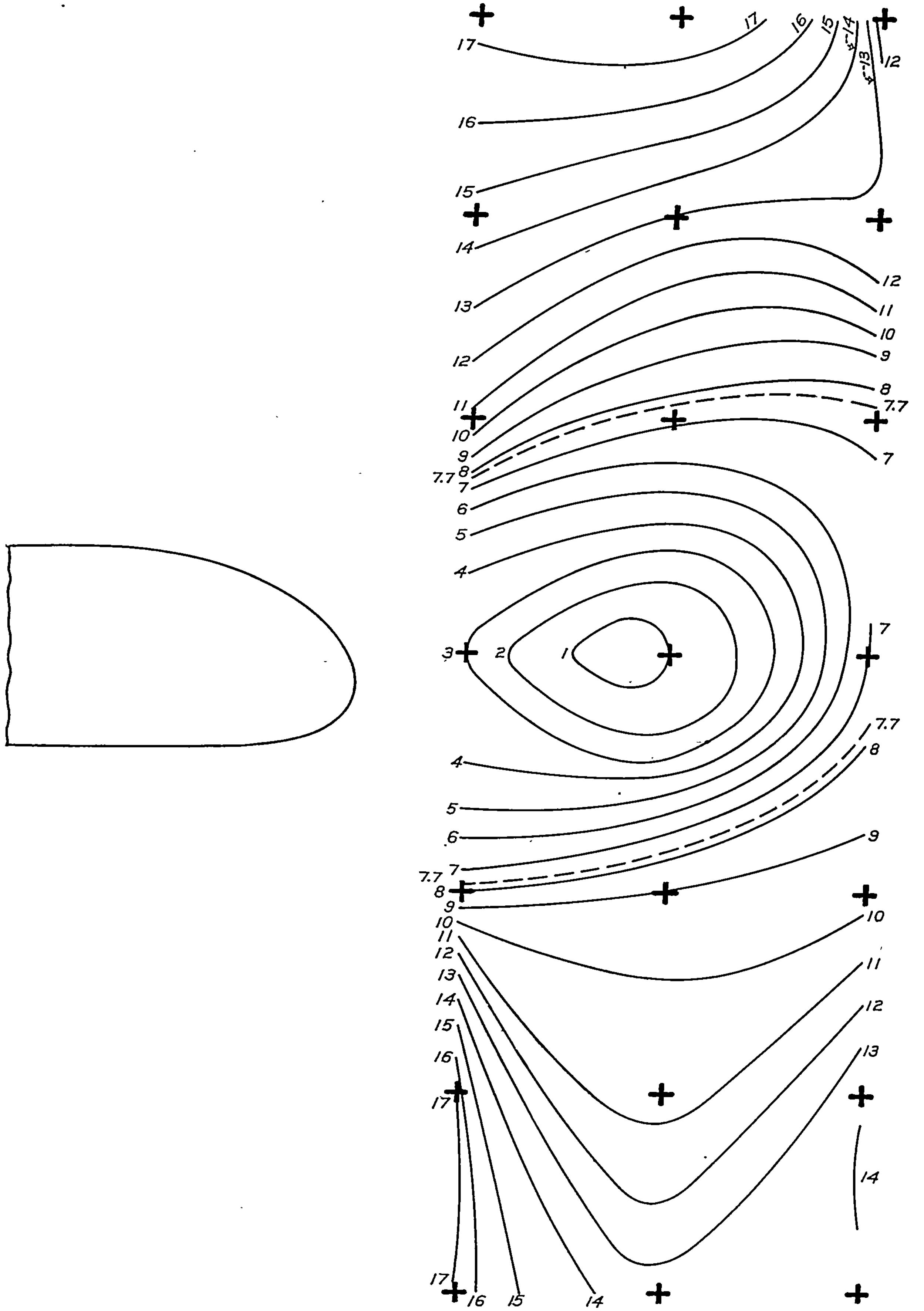

FIGURE 15.—Nacelle drag efficiency factor (per cent) at cruising and high-speed condition. (C_L=0.409. Propeller set 17° at 0.75 R. η taken at $\frac{V}{nD}$=0.65.) To obtain nacelle interference drag efficiency factor, subtract 7.7 from values on contours

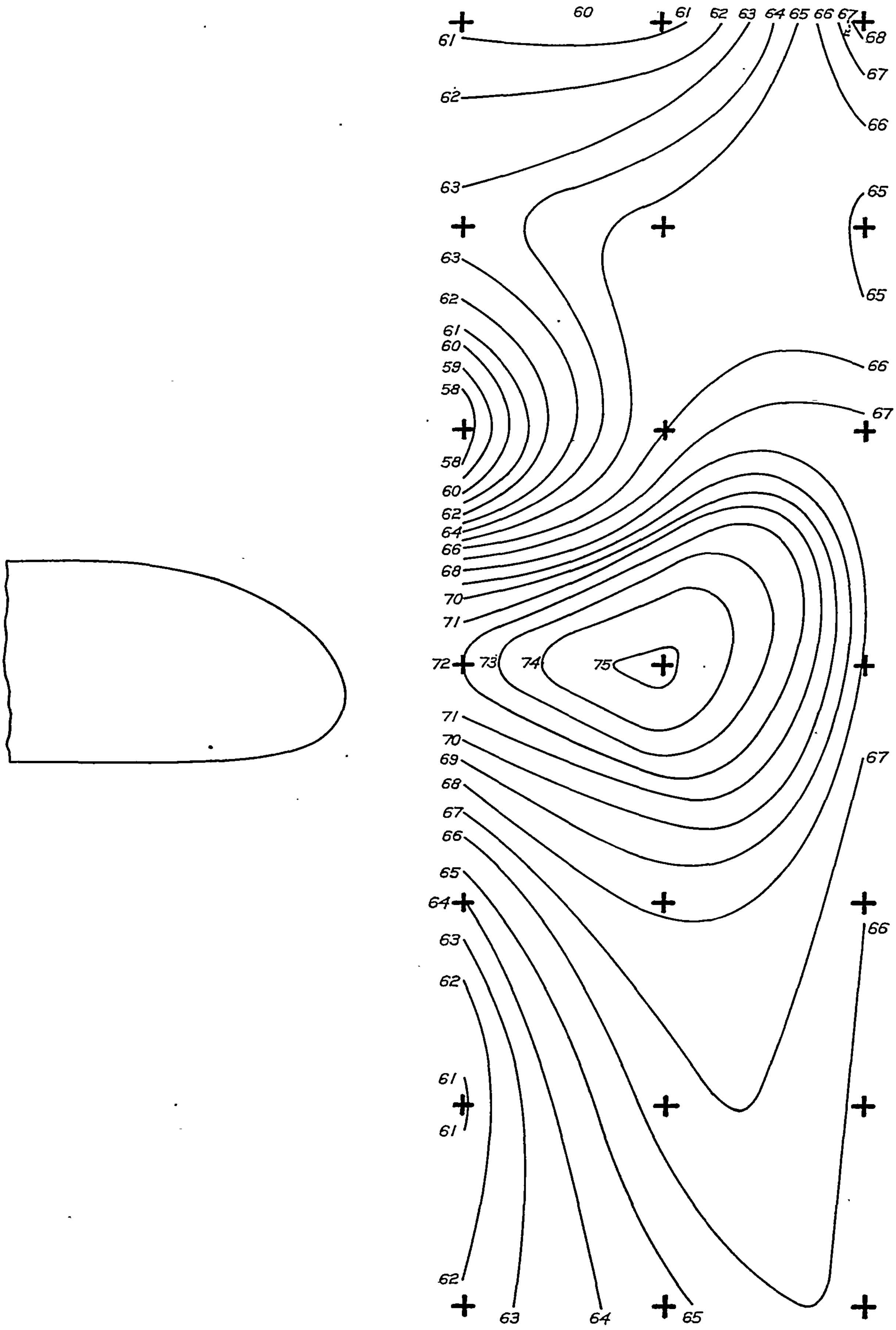

FIGURE 16.—Net efficiency (per cent) at cruising and high-speed condition. (C_L=0.409. Propeller set 17° at 0.75 R. η taken at $\frac{V}{nD}$=0.65)

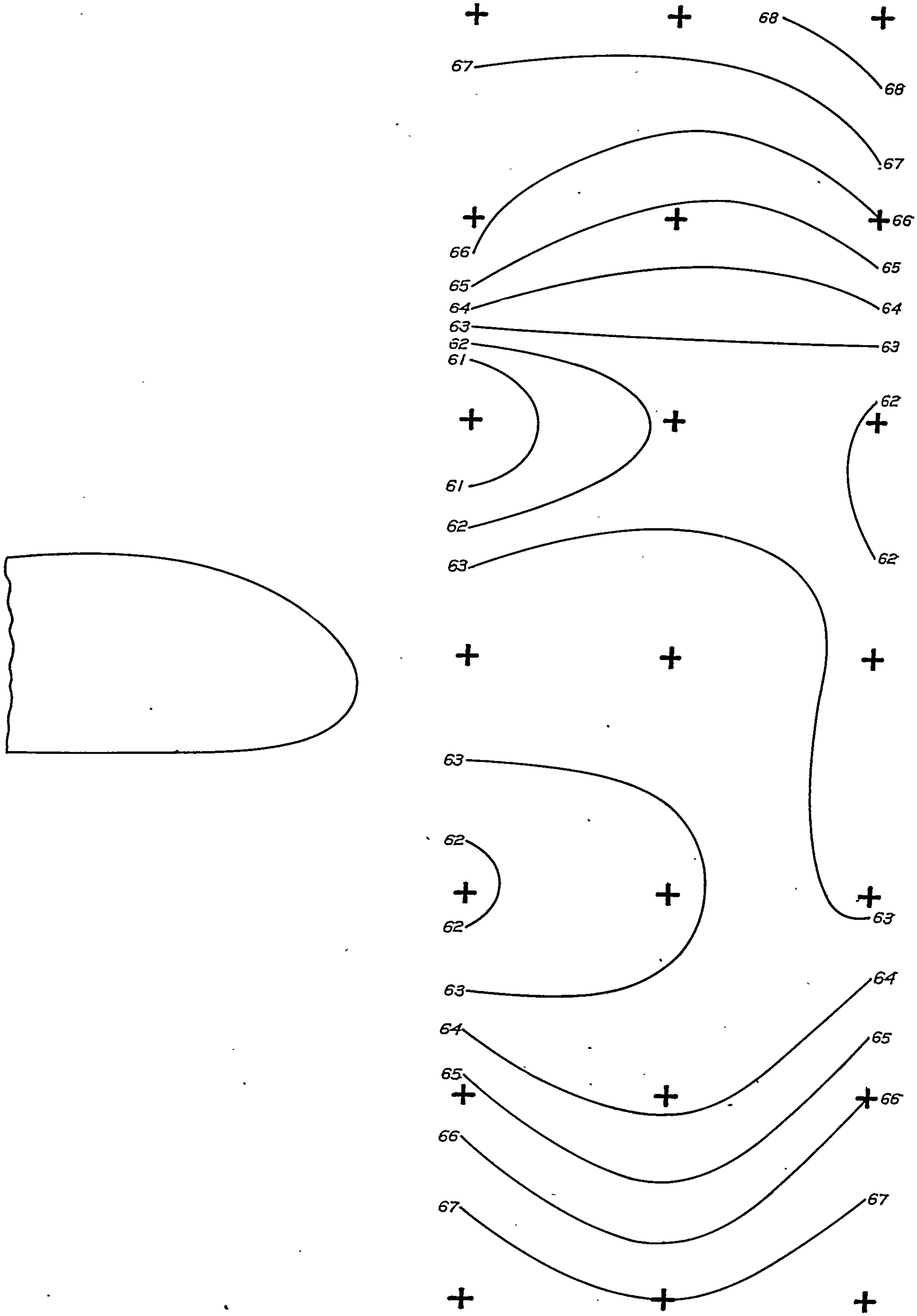

FIGURE 17.—Propulsive efficiency (per cent) at climbing condition. (C_L=0.652. Propeller set 17° at 0.75 R. η taken at $\frac{V}{nD}$=0.42)

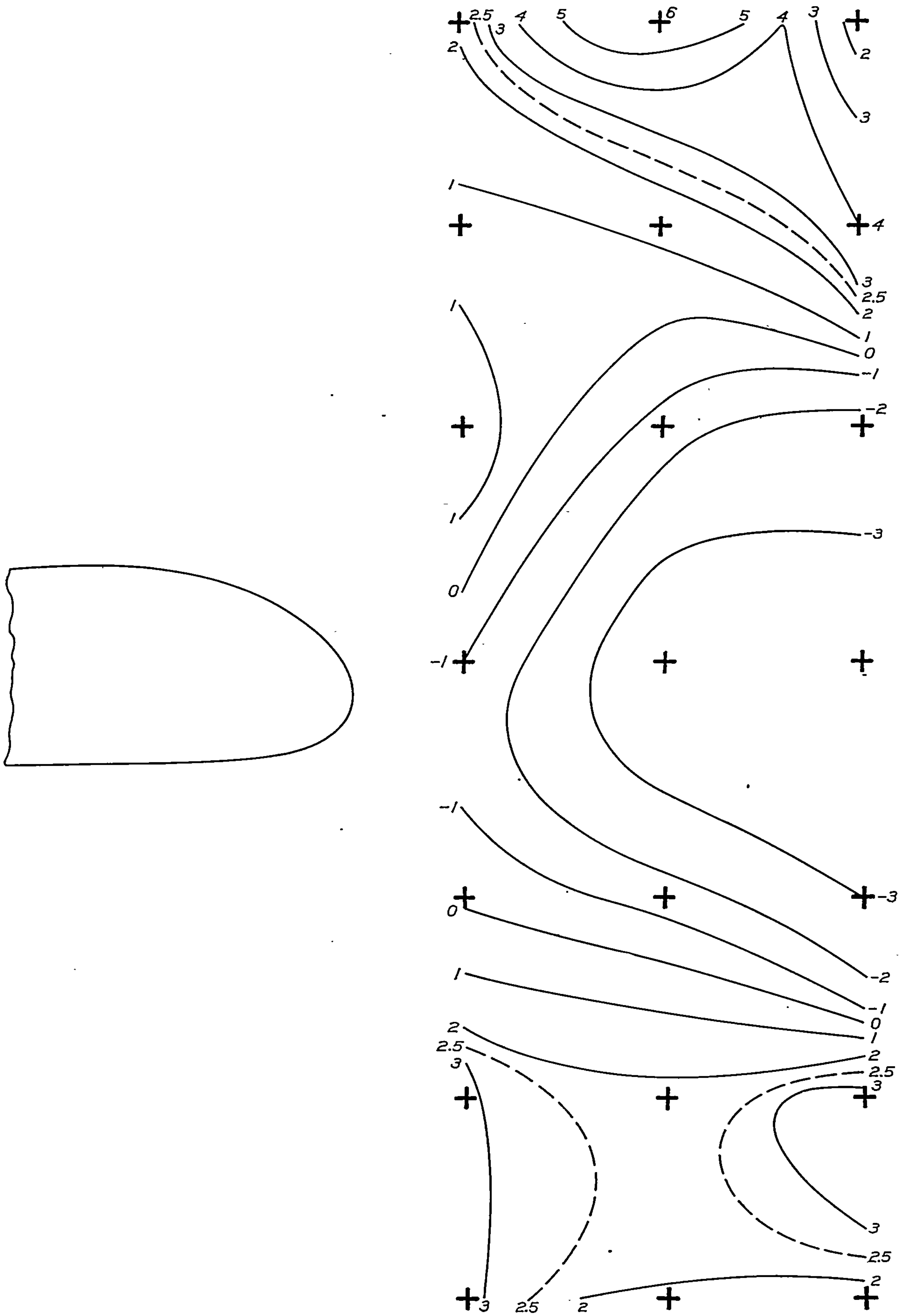

FIGURE 18.—Nacelle drag efficiency factor (per cent) at climbing condition. (C_L=0.652. Propeller set 17° at 0.75 R. η taken at $\frac{V}{nD}$=0.42.) To obtain nacelle interference drag efficiency factor, subtract 2.5 from values on contours

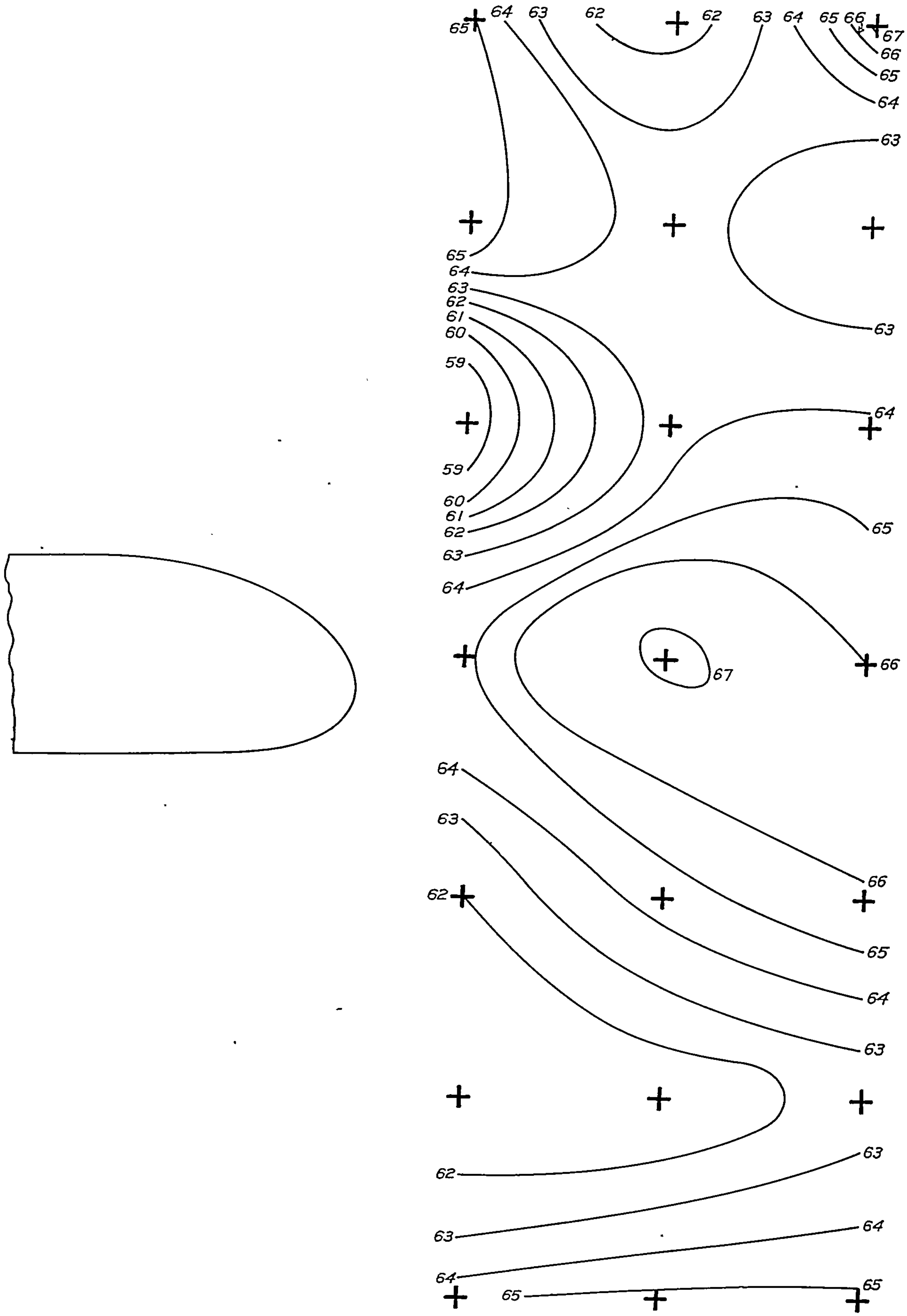

FIGURE 19.—Net efficiency (per cent) at climbing condition. (C_L=0.652. Propeller set 17° at 0.75 R. η taken at $\frac{V}{nD}$=0.42)

directly ahead of the wing. The interference drag (without propeller) is unfavorable when the nacelle is placed above the wing, and favorable when placed below the wing. These changes are not a simple function of the distance from the wing, since position A–1–A shows the greatest increase in lift and the most unfavorable interference, whereas position B–2–B shows the most favorable interference. On the other hand, the propulsive efficiency increases as the vertical distance of the propeller from the wing increases, the highest efficiencies occurring in positions C–3–A and C–3–B. Here again the change is irregular. Combining all factors, the highest net efficiency for both the high-speed and the climbing conditions is obtained when the nacelle is just back of position B (i. e., with the center line of the propeller about 25 per cent of the chord ahead of the leading edge).

For both high speed and climbing, position A–1–A even with fillets is by far the poorest. The net efficiency for other locations may be read directly from the charts. In the landing condition, position B also appears to the best advantage. It may therefore be stated that a position slightly in the rear of position B will be best for practically all conditions of flight, and a location such as A–1–A will be very poor.

DESIGN CONSIDERATIONS

In estimating the performance of a proposed airplane design, the designer usually plots the basic curves—horsepower required against air speed and horsepower available against air speed. The horsepower required is obtained by summing up the wing-profile drag, the induced drag, and the parasite drag. The parasite drag has included in it the nacelle drag and interference. In Tables X and XI, the lift and drag changes due to adding the nacelle are given for all positions and all angles of attack. It is to be noted that the coefficients in these tables are based on the wing area.

The controlling factor in the size of the nacelle is the size of the engine, and as most airplane-engine builders give the principal dimensions of the engine in inches, a more convenient form of coefficient for comparing nacelle drags would be one based on engine diameter. The coefficients given can be then applied as follows:

$$\begin{aligned}\text{Nacelle drag} &= C_D \text{ (wing basis) } q\, S \\ &= C_{D_1}\, q\, 75. \qquad \text{(VIII)} \\ &= C_D \text{ (engine diam. basis) } q\, (D_e)^2 \qquad \text{(IX)} \\ &= C_{D_2}\, q\, (20)^2\end{aligned}$$

where D_e = Engine diameter in inches

then $C_{D_1}\, q\, 75 = C_{D_2}\, q\, 400$

$$C_{D_2} = C_{D_1}\frac{75}{400} = 0.1875\ C_{D_1} \qquad \text{(X)}$$

and similarly for the lift

$$C_{L_2} = 0.1875\ C_{L_1}$$

If the coefficients of Table XI are multiplied by 0.1875, then equation (IX) may be used with some saving of time when the drags of nacelles with different engines is being computed. This method also eliminates the wing area as a variable in nacelle drag. It is clear, however, that the wing-area basis was necessary in the other comparisons made in this report.

The second section in Table XI gives the ratio of the effective drag of the nacelle in any position to the drag of the nacelle alone. If unity is subtracted from the values in this column the fractional interference drag is obtained. The third section, giving the ratio of effective nacelle drag to the drag of the nacelle at 0°, may be conveniently used in estimating drags from other tests, assuming that the interferences obtained here apply. Similarly, the lift due to adding the nacelle may be obtained from the second section in Table X.

The lift due to the propeller is probably affected by the airfoil section, chord, and nacelle location. It has not been possible, therefore, to derive a rational expression for this factor. Table VII, however, gives the lift coefficients based on the wing area of these tests with the propeller operating under all conditions. The designer may therefore make a judicious estimate of the lift increment that will be obtained under any given conditions by comparing the values from this table with values from Table I, which gives the corresponding lift coefficients without propeller.

The power-available curve previously mentioned presents no difficulty because it is obtained by multiplying the motor power by the value of the propulsive efficiency at any speed. Since a method of selection of propellers involving a coefficient C_s has been shown to greatly simplify computations (references 3 and 4), values of this coefficient are given in Table XII. Some tests in the present series were run with a propeller pitch setting of 22°. Cross-plotting the results for the two pitch settings gives a curve which is substantially parallel to the results of references 3 and 4. The designer may therefore obtain a close estimate of the propulsive efficiency for any pitch setting by multiplying the efficiency obtained from references 3 and 4 by the ratio of efficiency between the two sets of tests at 17° pitch.

It is realized that all users of nacelles do not employ a complete cowling such as was used in these tests. Other tests have already been made without cowling, and with another cowling similar to the Townend ring. Similar tests have also been made with a thinner wing section of smaller chord. The results of these tests are now being prepared and will appear in a separate report.

CONCLUSIONS

1. The lift of a wing-nacelle-propeller combination with propeller operating at full power as compared to

the lift of a wing alone is increased when a nacelle is placed above and forward of a wing, decreased when placed below and forward, and is practically unaffected when the nacelle is in line with the wing.

2. An unfavorable interference drag (without propeller) results when a nacelle is placed above and forward of a wing; a favorable interference drag results when the nacelle is below and forward, and practically no interference drag results when the nacelle is in line with the wing.

3. The propulsive efficiency of a propeller mounted on a nacelle-propeller combination in various positions with respect to a wing increases with the increase in the vertical distance between the propeller and the wing.

4. Taking into account the lift, interference, and propulsive efficiency, the best location of the nacelle, with tractor propeller on a monoplane wing, for high speed and cruising, is with the thrust axis in line with the center line of the wing and with the propeller about 25 per cent of the chord ahead of the leading edge. This same location also appears to be the best in climb and landing, therefore excels in all conditions of flight.

5. The most unfavorable location of a nacelle and propeller is with the thrust axis about one-third of the wing chord above the chord line and with the propeller 10 per cent of the chord ahead of the leading edge of the wing, i. e., with nacelle very close to the upper surface of the wing.

6. Nacelles located above or below and forward of the wing in corresponding positions have about equal merit, but are inferior to locations in line with the wing. Nacelles located close to the wing below are slightly more effective than those located above.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., *November 18, 1931.*

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TABLE I

LIFT COEFFICIENT WITHOUT PROPELLER

$$C_L=\frac{\text{Lift}}{qS}$$

Nacelle position	50 m. p. h. R. N.=2,150,000					75 m. p. h. R. N.=3,220,000					100 m. p. h. R. N.=4,300,000				
Angle of attack	−5°	0°	+5°	+10°	+12°	−5°	0°	+5°	+10°	+12°	−5°	0°	+5°	+10°	[d] +12°
Nacelle alone [a]	−0.008	−0.001	0.004	0.009	0.010	−0.008	−0.001	0.004	0.009	0.010	−0.008	−0.001	0.004	0.009	0.010
Wing alone	.179	.417	.652	.889	-------	.175	.414	.650	.887	-------	.169	.409	.646	.885	.960
A-3-A	.167	.405	.643	.878	-------	.167	.405	.643	.878	-------	.167	.405	.643	878	.955
B-3-A	.168	.401	.637	.873	-------	.161	.396	.632	.868	-------	.151	.388	.625	.862	.925
C-3-A	.189	.428	.668	.906	-------	.171	.410	.650	.888	-------	.148	.385	.625	.865	.965
A-2-A	.177	.406	.634	.860	-------	.175	.404	.632	.856	-------	.172	.400	.629	.851	.904
B-2-A	.172	.412	.656	.893	-------	.162	.404	.649	.888	-------	.149	.393	.639	.882	.981
C-2-A	.141	.389	.637	.881	-------	.133	.381	.630	.876	-------	.122	.371	.621	.869	.969
A-1-A [b]	.195	.424	.651	.879	-------	.190	.419	.646	.872	-------	.184	.412	.639	.866	.955
B-1-A [b]	.197	.433	.671	.914	-------	.183	.422	.664	.908	-------	.163	.407	.653	.900	.996
B-1-A	.182	.403	.621	.821	-------	.166	.388	.609	.814	-------	.141	.368	.593	.804	.871
C-1-A	.187	.420	.650	.873	-------	.170	.408	.640	.871	-------	.145	.387	.627	.868	.961
A	.180	.416	.656	.896	-------	.164	.404	.646	.889	-------	.142	.386	.632	.879	.977
B	.189	.427	.664	.902	-------	.174	.417	.659	.902	-------	.154	.403	.652	.902	1.004
C	.166	.411	.659	.911	-------	.159	.407	.656	.908	-------	.150	.401	.651	.903	.996
A-1-B [b]	.150	.388	.620	[c] .764	-------	.145	.381	.613	[c] .762	-------	.139	.372	.603	[c] .760	[c] .783
B-1-B [b]	.160	.399	.636	.873	-------	.152	.391	.630	.868	-------	.140	.379	.621	.861	.960
C-1-B	.185	.419	.655	.891	-------	.172	.407	.645	.881	-------	.153	.391	.629	.868	.963
A-2-B	.155	.389	.623	.856	-------	.152	.384	.619	.850	-------	.147	.378	.613	.844	.877
B-2-B	.150	.382	.616	.849	-------	.150	.382	.616	.849	-------	.150	.382	.616	.849	-------
C-2-B	.151	.387	.624	.860	-------	.148	.384	.620	.858	-------	.143	.380	.615	.854	.951
A-3-B	.161	.393	.628	.860	-------	.154	.388	.624	.859	-------	.144	.381	.619	.857	.951
B-3-B	.188	.412	.641	.865	-------	.168	.398	.633	.865	-------	.138	.379	.622	.865	.970
C-3-B	.173	.406	.638	.870	-------	.163	.399	.633	.869	-------	.148	.388	.626	.868	.965

[a] Based on wing area.
[b] Nacelle faired into airfoil.
[c] Accuracy doubtful.
[d] Average of 80, 90, and 100 m. p. h.

TABLE II

DRAG COEFFICIENT WITHOUT PROPELLER

$$C_D=\frac{\text{Drag}}{qS}$$

Nacelle position	50 m. p. h. R. N.=2,150,000					75 m. p. h. R. N.=3,220,000					100 m. p. h. R. N.=4,300,000				
Angle of attack	−5°	0°	+5°	+10°	+12°	−5°	0°	+5°	+10°	+12°	−5°	0°	+5°	+10°	[d] +12°
Nacelle alone [a]	0.0058	0.0058	0.0059	0.0061	0.0066	0.0049	0.0049	0.0050	0.0065	0.0062	0.0039	0.0040	0.0041	0.0050	0.0058
Wing alone	.0180	.0425	.0830	.1440	-------	.0175	.0415	.0825	.1440	-------	.0165	.0405	.0825	.1440	.1740
A-3-A	.0275	.0515	.0945	.1580	-------	.0260	.0490	.0925	.1565	-------	.0250	.0480	.0920	.1560	.1875
B-3-A	.0270	.0505	.0950	.1560	-------	.0260	.0490	.0925	.1560	-------	.0250	.0475	.0920	.1560	.1910
C-3-A	.0245	.0480	.0905	.1540	-------	.0240	.0470	.0900	.1540	-------	.0230	.0450	.0890	.1500	.1815
A-2-A	.0245	.0500	.0945	.1555	-------	.0235	.0490	.0925	.1565	-------	.0220	.0480	.0920	.1570	.1890
B-2-A	.0250	.0490	.0920	.1560	-------	.0230	.0470	.0910	.1555	-------	.0235	.0465	.0905	.1540	.1900
C-2-A	.0240	.0470	.0915	.1520	-------	.0225	.0460	.0900	.1525	-------	.0220	.0445	.0885	.1535	.1830
A-1-A [b]	.0260	.0520	.1080	.1810	-------	.0250	.0510	.1070	.1780	-------	.0240	.0500	.1060	.1760	.2105
B-1-A [b]	.0230	.0480	.0965	.1620	-------	.0220	.0470	.0945	.1610	-------	.0220	.0455	.0940	.1605	.1910
B-1-A	.0300	.0580	.1100	.1795	-------	.0290	.0565	.1070	.1775	-------	.0280	.0545	.1060	.1740	.2055
C-1-A	.0230	.0480	.0930	.1605	-------	.0220	.0465	.0920	.1585	-------	.0220	.0460	.0920	.1595	.1925
A	.0210	.0445	.0855	.1510	-------	.0200	.0420	.0845	.1470	-------	.0190	.0410	.0840	.1450	.1760
B	.0205	.0440	.0890	.1530	-------	.0200	.0425	.0880	.1525	-------	.0195	.0420	.0870	.1520	.1830
C	.0230	.0460	.0910	.1565	-------	.0210	.0435	.0890	.1550	-------	.0205	.0430	.0885	.1545	.1865
A-1-B [b]	.0260	.0460	.0850	[c] .1570	-------	.0240	.0425	.0825	[c] .1525	-------	.0230	.0420	.0815	[c] .1510	[c] .1820
B-1-B [b]	.0225	.0410	.0810	.1425	-------	.0225	.0410	.0810	.1425	-------	.0225	.0410	.0810	.1425	.1700
C-1-B	.0280	.0440	.0830	.1420	-------	.0245	.0430	.0825	.1420	-------	.0230	.0425	.0820	.1420	.1700
A-2-B	.0245	.0455	.0825	.1410	-------	.0240	.0440	.0825	.1410	-------	.0235	.0425	.0820	.1410	.1720
B-2-B	.0235	.0440	.0835	.1405	-------	.0230	.0430	.0825	.1405	-------	.0220	.0420	.0820	.1405	-------
C-2-B	.0280	.0465	.0850	.1415	-------	.0245	.0430	.0830	.1415	-------	.0235	.0425	.0820	.1415	.1710
A-3-B	.0260	.0465	.0870	.1440	-------	.0250	.0455	.0855	.1440	-------	.0250	.0445	.0845	.1440	.1720
B-3-B	.0260	.0460	.0860	.1440	-------	.0250	.0450	.0840	.1435	-------	.0245	.0490	.0830	.1420	.1710
C-3-B	.0255	.0460	.0840	.1445	-------	.0245	.0450	.0840	.1445	-------	.0240	.0440	.0840	.1445	.1730

[a] Based on wing area.
[b] Nacelle faired into airfoil.
[c] Accuracy doubtful.
[d] Average of 80, 90, and 100 m. p. h.

TABLE III

MOMENT COEFFICIENT WITHOUT PROPELLER

$$C_m=\frac{\text{Moment}}{qSc}$$

Nacelle position	Nacelle cowling No. 1				
Angle of attack	−5°	0°	+5°	+10°	+12°
Wing alone	−0.073	−0.067	−0.063	−0.066	−0.069
A-3-A	−.069	−.064	−.060	−.062	−.065
B-3-A	−.065	−.058	−.053	−.055	−.065
C-3-A	−.065	−.058	−.053	−.050	−.049
A-2-A	−.066	−.060	−.057	−.066	−.075
B-2-A	−.066	−.056	−.051	−.052	−.055
C-2-A	−.065	−.056	−.049	−.046	−.046
A-1-A [a]	−.060	−.055	−.061	−.071	−.076
B-1-A [a]	−.051	−.044	−.040	−.043	−.045
B-1-A	−.061	−.050	−.045	−.045	−.047
C-1-A	−.061	−.050	−.045	−.044	−.047
A	−.075	−.066	−.060	−.063	−.065
B	−.074	−.063	−.056	−.054	−.055
C	−.083	−.066	−.052	−.048	−.050
A-1-B [a]	−.081	−.075	−.073	−.083	−.087
B-1-B [a]	−.094	−.086	−.080	−.076	−.077
C-1-B	−.090	−.079	−.071	−.069	−.070
A-2-B	−.078	−.071	−.068	−.070	−.079
B-2-B	−.082	−.077	−.072	−.068	----------
C-2-B	−.086	−.078	−.071	−.069	−.070
A-3-B	−.076	−.070	−.068	−.070	−.072
B-3-B	−.080	−.072	−.068	−.069	−.070
C-3-B	−.082	−.075	−.069	−.069	−.070

[a] Nacelle faired into airfoil.

TABLE IV

THRUST COEFFICIENT

$$C_T=\frac{(T-\Delta D)}{\rho\, n^2 D^4}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 R. Angle of attack = −5°

Nacelle position	$\frac{V}{nD}$									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	0.0878	0.0832	0.0769	0.0685	0.0578	0.0455	0.0318	0.0165	0	−0.0190
B-3-A	.0895	.0841	.0771	.0683	.0578	.0460	.0332	.0188	.0020	−.0160
C-3-A	.0891	.0842	.0776	.0690	.0587	.0468	.0335	.0192	.0033	−.0140
A-2-A	.0881	.0822	.0750	.0663	.0570	.0463	.0344	.0213	.0075	−.0088
B-2-A	.0844	.0795	.0730	.0651	.0559	.0455	.0335	.0196	.0046	−.0117
C-2-A	.0870	.0819	.0751	.0673	.0578	.0466	.0340	.0200	.0049	−.0118
A-1-A [a]	.0797	.0755	.0700	.0630	.0548	.0453	.0350	.0237	.0113	−.0020
B-1-A [a]	.0845	.0800	.0739	.0663	.0571	.0469	.0352	.0220	.0072	−.0095
C-1-A	.0848	.0802	.0741	.0665	.0571	.0460	.0336	.0204	.0050	−.0114
A	.0838	.0796	.0735	.0661	.0571	.0467	.0348	.0217	.0075	−.0092
B	.0852	.0805	.0741	.0665	.0570	.0463	.0339	.0208	.0050	−.0115
C	.0847	.0801	.0739	.0662	.0569	.0461	.0334	.0191	.0039	−.0120
A-1-B [a]	.0805	.0766	.0709	.0636	.0548	.0445	.0332	.0211	.0078	−.0072
B-1-B [a]	.0847	.0799	.0732	.0650	.0555	.0447	.0330	.0200	.0058	−.0095
C-1-B	.0873	.0826	.0761	.0680	.0578	.0457	.0321	.0173	.0015	−.0149
A-2-B	.0853	.0809	.0747	.0669	.0571	.0453	.0320	.0171	.0009	−.0167
B-2-B	.0866	.0818	.0751	.0670	.0570	.0455	.0328	.0190	.0040	−.0114
C-2-B	.0872	.0832	.0773	.0696	.0598	.0480	.0340	.0203	.0015	−.0133
A-3-B	.0883	.0833	.0764	.0679	.0575	.0453	.0317	.0164	.0013	−.0204
B-3-B	.0867	.0823	.0761	.0680	.0576	.0453	.0317	.0163	−.0003	−.0180
C-3-B	.0884	.0836	.0769	.0685	.0585	.0467	.0330	.0178	.0015	−.0155

Propeller No. 4412—4 feet. Set 17° at 0.75 R. Angle of attack = 0°

A-3-A	0.0879	0.0830	0.0761	0.0677	0.0572	0.0447	0.0300	0.0130	−0.0059	----------
B-3-A	.0898	.0841	.0770	.0681	.0579	.0458	.0320	.0161	−.0020	----------
C-3-A	.0891	.0842	.0776	.0691	.0588	.0465	.0327	.0174	0	−0.0177
A-2-A	.0872	.0816	.0745	.0660	.0559	.0444	.0314	.0170	0	−.0180
B-2-A	.0851	.0800	.0733	.0655	.0561	.0451	.0322	.0176	.0018	−.0156
C-2-A	.0872	.0822	.0760	.0680	.0580	.0464	.0336	.0191	.0032	−.0136
A-1-A [a]	.0790	.0746	.0687	.0610	.0520	.0415	.0300	.0180	.0052	−.0083
B-1-A [a]	.0843	.0790	.0722	.0640	.0542	.0436	.0310	.0190	.0045	−.0112
C-1-A	.0840	.0788	.0722	.0638	.0542	.0438	.0318	.0190	.0042	−.0124
A	.0837	.0793	.0733	.0655	.0560	.0451	.0332	.0205	.0065	−.0081
B	.0849	.0793	.0725	.0645	.0554	.0450	.0328	.0195	.0052	−.0110
C	.0846	.0798	.0733	.0652	.0551	.0440	.0322	.0190	.0046	−.0107
A-1-B [a]	.0805	.0765	.0709	.0635	.0550	.0449	.0339	.0222	.0098	−.0036
B-1-B [a]	.0848	.0799	.0734	.0655	.0560	.0455	.0340	.0212	.0065	−.0094
C-1-B	.0860	.0811	.0745	.0664	.0563	.0450	.0322	.0182	.0035	−.0123
A-2-B	.0861	.0813	.0750	.0672	.0575	.0464	.0338	.0201	.0053	−.0102
B-2-B	.0860	.0813	.0750	.0672	.0574	.0462	.0366	.0199	.0054	−.0098
C-2-B	.0877	.0832	.0771	.0693	.0597	.0480	.0349	.0201	.0040	−.0140
A-3-B	.0884	.0838	.0772	.0690	.0581	.0458	.0325	.0182	.0016	−.0166
B-3-B	.0865	.0823	.0758	.0676	.0578	.0462	.0334	.0188	.0022	−.0158
C-3-B	.0879	.0834	.0772	.0692	.0591	.0471	.0339	.0193	.0037	----------

[a] Nacelle faired into airfoil.

TABLE IV—Continued

THRUST COEFFICIENT—Continued

$$C_T=\frac{(T-\Delta D)}{\rho\, n^2 D^4}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=+5°

Nacelle position	$\frac{V}{nD}$									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	0.0875	0.0838	0.0760	0.0670	0.0557	0.0418	0.0261	0.0100	−0.0085	----------
B-3-A	.0888	.0837	.0768	.0680	.0572	.0448	.0314	.0150	−.0040	----------
C-3-A	.0873	.0830	.0766	.0680	.0575	.0451	.0309	.0154	−.0015	−0.0188
A-2-A	.0863	.0808	.0733	.0643	.0535	.0410	.0268	.0116	−.0048	−.0215
B-2-A	.0835	.0790	.0727	.0644	.0548	.0436	.0305	.0162	.0010	−.0153
C-2-A	.0860	.0814	.0751	.0673	.0575	.0460	.0327	.0182	.0029	−.0137
A-1-A[a]	.0763	.0724	.0671	.0600	.0512	.0406	.0288	.0157	.0022	−.0121
B-1-A[a]	.0820	.0765	.0696	.0611	.0513	.0407	.0287	.0157	.0021	−.0125
C-1-A	.0821	.0763	.0691	.0608	.0511	.0406	.0290	.0170	.0032	−.0118
A	.0805	.0760	.0698	.0619	.0525	.0418	.0303	.0178	.0040	−.0094
B	.0829	.0779	.0712	.0630	.0530	.0413	.0293	.0167	.0032	−.0110
C	.0817	.0763	.0697	.0615	.0525	.0422	.0306	.0183	.0055	−.0080
A-1-B[a]	.0796	.0775	.0699	.0627	.0533	.0437	.0338	.0231	.0123	.0005
B-1-B[a]	.0818	.0768	.0705	.0629	.0537	.0435	.0233	.0200	.0070	−.0067
C-1-B	.0845	.0778	.0704	.0625	.0538	.0440	.0323	.0192	.0048	−.0106
A-2-B	.0854	.0807	.0741	.0662	.0571	.0462	.0349	.0229	.0105	−.0024
B-2-B	.0855	.0802	.0736	.0653	.0568	.0448	.0327	.0220	.0063	−.0078
C-2-B	.0866	.0822	.0762	.0683	.0589	.0477	.0352	.0215	.0060	−.0112
A-3-B	.0881	.0832	.0767	.0682	.0581	.0468	.0346	.0210	.0050	−.0130
B-3-B	.0865	.0820	.0756	.0674	.0578	.0462	.0336	.0199	.0051	−.0102
C-3-B	.0873	.0827	.0762	.0682	.0586	.0473	.0346	.0212	.0068	----------

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=+10°

Nacelle position	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	0.0858	0.0808	0.0740	0.0651	0.0543	0.0411	0.0260	0.0094	−0.0085	----------
B-3-A	.0863	.0810	.0740	.0650	.0552	.0434	.0297	.0143	−.0013	----------
C-3-A	.0866	.0822	.0759	.0674	.0570	.0445	.0293	.0120	−.0070	----------
A-2-A[b]	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
B-2-A	.0825	.0776	.0710	.0624	.0523	.0406	.0273	.0120	−.0042	−0.0218
C-2-A	.0850	.0799	.0722	.0651	.0556	.0446	.0320	.0180	.0022	−.0141
A-1-A[a]	.0750	.0708	.0652	.0578	.0487	.0380	.0260	.0132	----------	−.0146
B-1-A[a]	.0786	.0722	.0645	.0559	.0461	.0353	.0249	.0120	−.0025	−.0183
C-1-A	.0798	.0738	.0666	.0580	.0485	.0386	.0277	.0161	.0038	−.0100
A	.0793	.0735	.0665	.0583	.0488	.0386	.0279	.0167	.0047	−.0087
B	.0798	.0788	.0660	.0572	.0480	.0380	.0275	.0161	.0041	−.0100
C	.0787	.0729	.0658	.0574	.0478	.0373	.0264	.0148	.0028	−.0096
A-1-B[a, b]	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
B-1-B[a]	.0790	.0738	.0675	.0600	.0519	.0427	.0330	.0215	.0098	−.0030
C-1-B	.0837	.0761	.0676	.0588	.0494	.0398	.0299	.0188	.0068	−.0074
A-2-B	.0837	.0777	.0707	.0629	.0541	.0450	.0352	.0251	.0149	.0044
B-2-B	.0830	.0775	.0700	.0612	.0515	.0410	.0300	.0183	.0061	−.0070
C-2-B	.0842	.0790	.0720	.0637	.0541	.0437	.0318	.0192	.0060	−.0078
A-3-B	.0856	.0809	.0744	.0669	.0580	.0479	.0361	.0229	.0083	−.0068
B-3-B	.0861	.0815	.0752	.0675	.0579	.0470	.0352	.0225	.0085	−.0061
C-3-B	.0870	.0824	.0758	.0673	.0578	.0472	.0359	.0234	.0100	----------

[a] Nacelle faired into airfoil. [b] Data unreliable.

TABLE V

POWER COEFFICIENT

$$C_P=\frac{P}{\rho n^3 D^5}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=−5°

Nacelle position	$\frac{V}{nD}$ 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.9	1.0
A-3-A	0.0440	0.0440	0.0432	0.0420	0.0392	0.0351	0.0286	0.0195	0.0083	--------
B-3-A	.0431	.0431	.0426	.0411	.0390	.0353	.0298	.0212	.0100	--------
C-3-A	.0430	.0430	.0425	.0412	.0391	.0356	.0300	.0218	.0105	--------
A-2-A	.0420	.0418	.0414	.0406	.0390	.0356	.0302	.0227	.0125	--------
B-2-A	.0419	.0423	.0421	.0410	.0389	.0350	.0295	.0218	.0121	.0004
C-2-A	.0461	.0450	.0437	.0420	.0400	.0364	.0306	.0201	.0116	--------
A-1-A [a]	.0430	.0430	.0426	.0416	.0400	.0373	.0330	.0268	.0137	.0083
B-1-A [a]	.0433	.0427	.0420	.0407	.0391	.0362	.0312	.0238	.0145	.0026
C-1-A	.0433	.0433	.0429	.0415	.0392	.0358	.0302	.0224	.0120	--------
A	.0428	.0427	.0420	.0412	.0396	.0365	.0315	.0240	.0145	.0020
B	.0425	.0422	.0418	.0410	.0390	.0355	.0300	.0227	.0121	--------
C	.0426	.0422	.0417	.0405	.0389	.0355	.0298	.0220	.0115	--------
A-1-B [a]	.0439	.0436	.0430	.0421	.0101	.0370	.0325	.0256	.0167	.0057
B-1-B [a]	.0427	.0422	.0415	.0403	.0385	.0355	.0302	.0228	.0135	.0010
C-1-B	.0435	.0431	.0424	.0412	.0390	.0352	.0295	.0214	.0111	--------
A-2-B	.0439	.0440	.0434	.0419	.0396	.0353	.0290	.0202	.0104	--------
B-2-B	.0439	.0440	.0434	.0421	.0398	.0360	.0302	.0220	.0115	--------
C-2-B	.0440	.0440	.0433	.0420	.0396	.0361	.0306	.0227	.0121	--------
A-3-B	.0432	.0431	.0423	.0411	.0387	.0345	.0282	.0194	.0078	--------
B-3-B	.0431	.0433	.0430	.0417	.0393	.0353	.0291	.0206	.0095	--------
C-3-B	.0439	.0432	.0423	.0111	.0392	.0356	.0298	.0216	.0108	--------

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=0°

A-3-A	0.0433	0.0435	0.0430	0.0414	0.0389	0.0345	0.0278	0.0184	0.0063	--------
B-3-A	.0432	.0133	.0426	.0412	.0390	.0352	.0290	.0198	.0076	--------
C-3-A	.0430	.0130	.0425	.0412	.0388	.0351	.0291	.0205	.0095	--------
A-2-A	.0420	.0417	.0412	.0403	.0382	.0347	.0289	.0206	.0095	--------
B-2-A	.0424	.0428	.0122	.0411	.0388	.0350	.0290	.0209	.0100	--------
C-2-A	.0448	.0442	.0429	.0425	.0402	.0364	.0302	.0214	.0110	--------
A-1-A [a]	.0430	.0430	.0426	.0415	.0397	.0366	.0314	.0245	.0157	0.0053
B-1-A [a]	.0435	.0429	.0422	.0412	.0391	.0360	.0306	.0231	.0131	--------
C-1-A	.0433	.0432	.0428	.0415	.0392	.0358	.0302	.0223	.0120	--------
A	.0427	.0424	.0419	.0409	.0393	.0363	.0311	.0236	.0139	.0018
B	.0427	.0423	.0418	.0408	.0390	.0360	.0305	.0226	.0125	--------
C	.0430	.0428	.0420	.0408	.0387	.0353	.0299	.0219	.0114	--------
A-1-B [a]	.0440	.0438	.0432	.0423	.0406	.0377	.0333	.0273	.0190	.0086
B-1-B [a]	.0432	.0429	.0121	.0409	.0388	.0355	.0308	.0238	.0140	.0016
C-1-B	.0433	.0430	.0423	.0413	.0393	.0359	.0301	.0222	.0122	--------
A-2-B	.0438	.0439	.0433	.0420	.0399	.0361	.0309	.0230	.0132	--------
B-2-B	.0439	.0440	.0435	.0422	.0399	.0362	.0304	.0225	.0125	--------
C-2-B	.0442	.0441	.0433	.0420	.0397	.0361	.0308	.0227	.0121	--------
A-3-B	.0429	.0432	.0429	.0414	.0391	.0351	.0291	.0209	.0102	--------
B-3-B	.0431	.0433	.0430	.0416	.0393	.0358	.0300	.0218	.0111	--------
C-3-B	.0433	.0431	.0426	.0415	.0395	.0360	.0300	.0219	.0112	--------

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=+5°

A-3-A	0.0431	0.0433	0.0428	0.0411	0.0382	0.0332	0.0260	0.0163	0.0038	--------
B-3-A	.0433	.0434	.0426	.0411	.0386	.0345	.0282	.0190	.0065	--------
C-3-A	.0433	.0430	.0424	.0410	.0386	.0343	.0283	.0198	.0090	--------
A-2-A	.0420	.0418	.0413	.0404	.0381	.0333	.0266	.0173	.0058	--------
B-2-A	.0422	.0426	.0423	.0411	.0387	.0347	.0284	.0201	.0097	--------
C-2-A	.0435	.0436	.0431	.0419	.0398	.0360	.0297	.0210	.0101	--------
A-1-A [a]	.0428	.0428	.0424	.0412	.0391	.0359	.0307	.0232	.0138	0.0016
B-1-A [a]	.0434	.0429	.0421	.0412	.0393	.0358	.0302	.0222	.0119	--------
C-1-A	.0433	.0430	.0421	.0408	.0386	.0350	.0293	.0210	.0105	--------
A	.0426	.0422	.0417	.0405	.0388	.0355	.0304	.0232	.0140	.0020
B	.0431	.0430	.0424	.0412	.0388	.0351	.0295	.0221	.0120	--------
C	.0435	.0430	.0424	.0411	.0389	.0350	.0294	.0217	.0116	--------
A-1-B [a]	.0432	.0429	.0423	.0414	.0400	.0378	.0338	.0284	.0208	.0115
B-1-B [a]	.0437	.0433	.0425	.0412	.0391	.0360	.0311	.0243	.0150	.0021
C-1-B	.0434	.0430	.0424	.0414	.0396	.0362	.0307	.0230	.0130	.0005
A-2-B	.0439	.0440	.0432	.0421	.0400	.0366	.0318	.0250	.0166	.0065
B-2-B	.0439	.0440	.0433	.0420	.0399	.0365	.0310	.0237	.0144	.0030
C-2-B	.0439	.0440	.0436	.0424	.0402	.0368	.0312	.0235	.0132	--------
A-3-B	.0433	.0431	.0423	.0411	.0391	.0360	.0306	.0230	.0131	--------
B-3-B	.0431	.0433	.0429	.0416	.0395	.0368	.0303	.0229	.0132	--------
C-3-B	.0444	.0439	.0431	.0419	.0396	.0360	.0304	.0232	.0126	--------

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=+10°

A-3-A	0.0440	0.0437	0.0426	0.0409	0.0378	0.0330	0.0260	0.0159	0.0027	--------
B-3-A	.0432	.0432	.0426	.0411	.0389	.0347	.0280	.0187	.0069	--------
C-3-A	.0434	.0430	.0425	.0412	.0387	.0348	.0288	.0203	.0095	--------
A-2-A	.0419	.0414	.0407	.0396	.0375	.0331	.0261	.0169	.0047	--------
B-2-A	.0425	.0428	.0422	.0409	.0382	.0340	.0279	.0194	.0088	--------
C-2-A	.0430	.0431	.0426	.0412	.0392	.0354	.0291	.0206	.0097	--------
A-1-A [a]	.0428	.0428	.0422	.0411	.0390	.0355	.0301	.0228	.0130	0.0003
B-1-A [a]	.0434	.0430	.0425	.0417	.0398	.0359	.0303	.0223	.0116	--------
C-1-A	.0433	.0430	.0423	.0414	.0395	.0357	.0297	.0213	.0113	--------
A	.0427	.0423	.0418	.0410	.0391	.0358	.0309	.0235	.0140	.0025
B	.0428	.0423	.0418	.0405	.0389	.0358	.0301	.0230	.0131	--------
C	.0427	.0423	.0418	.0405	.0388	.0353	.0298	.0222	.0124	--------
A-1-B [a]	.0425	.0423	.0421	.0417	.0408	.0393	.0366	.0313	.0240	.0147
B-1-B [a]	.0430	.0427	.0421	.0411	.0399	.0374	.0330	.0260	.0170	.0055
C-1-B	.0433	.0430	.0425	.0418	.0397	.0362	.0312	.0238	.0142	.0020
A-2-B	.0437	.0439	.0436	.0427	.0410	.0381	.0340	.0280	.0206	.0110
B-2-B	.0438	.0438	.0431	.0420	.0400	.0370	.0322	.0255	.0170	.0063
C-2-B	.0435	.0439	.0436	.0427	.0406	.0375	.0322	.0250	.0155	.0040
A-3-B	.0432	.0434	.0430	.0420	.0401	.0371	.0324	.0258	.0169	.0059
B-3-B	.0432	.0433	.0429	.0418	.0397	.0365	.0317	.0248	.0156	.0043
C-3-B	.0444	.0442	.0435	.0423	.0400	.0370	.0321	.0248	.0152	--------

[a] Nacelle faired into airfoil.

TABLE VI

PROPULSIVE EFFICIENCY

$$\eta = \frac{(T-\Delta D)V}{P}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 R. Angle of attack = −5°

Nacelle position	$\frac{V}{nD}$ 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
A-3-A	0.200	0.378	0.533	0.652	0.737	0.778	0.778	0.677	--------
B-3-A	.207	.390	.544	.665	.740	.781	.781	.710	0.180
C-3-A	.207	.392	.548	.670	.750	.789	.783	.705	.283
A-2-A	.210	.393	.543	.653	.731	.781	.797	.749	.540
B-2-A	.201	.376	.520	.635	.718	.780	.795	.719	.342
C-2-A	.189	.364	.515	.640	.722	.768	.777	.725	.386
A-1-A [a]	.186	.351	.493	.605	.635	.728	.742	.707	.550
B-1-A [a]	.195	.375	.528	.651	.730	.778	.790	.740	.447
C-1-A	.196	.370	.517	.642	.728	.771	.779	.728	.375
A	.196	.373	.525	.642	.721	.767	.774	.723	.465
B	.200	.381	.532	.649	.731	.783	.792	.735	.372
C	.199	.380	.530	.654	.731	.780	.785	.695	.325
A-1-B [a]	.183	.351	.494	.604	.633	.721	.715	.660	.420
B-1-B [a]	.198	.379	.529	.646	.720	.756	.765	.701	.387
C-1-B	.201	.393	.537	.661	.741	.779	.761	.628	.120
A-2-B	.194	.368	.516	.639	.720	.770	.771	.675	--------
B-2-B	.197	.372	.519	.636	.716	.758	.760	.690	.313
C-2-B	.198	.378	.535	.664	.755	.798	.794	.715	.334
A-3-B	.204	.386	.541	.660	.744	.787	.787	.675	--------
B-3-B	.201	.380	.531	.652	.733	.770	.763	.633	--------
C-3-B	.201	.387	.545	.667	.746	.787	.775	.659	.125

Propeller No. 4412—4 feet. Set 17° at 0.75 R. Angle of attack = 0°

A-3-A	0.203	0.381	0.532	0.655	0.735	0.778	0.755	0.566	--------
B-3-A	.208	.389	.542	.661	.741	.781	.772	.650	--------
C-3-A	.207	.392	.548	.671	.757	.794	.787	.679	0
A-2-A	.208	.392	.543	.655	.732	.768	.761	.660	0
B-2-A	.201	.374	.521	.638	.723	.773	.777	.674	0.162
C-2-A	.194	.372	.519	.640	.721	.765	.778	.715	.262
A-1-A [a]	.183	.347	.484	.589	.655	.680	.669	.588	.298
B-1-A [a]	.194	.368	.513	.621	.687	.727	.728	.658	.309
C-1-A	.194	.365	.506	.615	.692	.735	.738	.632	.314
A	.196	.374	.525	.641	.712	.745	.747	.695	.421
B	.198	.375	.521	.632	.710	.750	.752	.690	.374
C	.197	.373	.525	.640	.714	.748	.754	.694	.403
A-1-B [a]	.183	.349	.492	.601	.677	.715	.713	.651	.464
B-1-B [a]	.196	.373	.522	.641	.721	.769	.773	.712	.418
C-1-B	.198	.377	.528	.642	.716	.752	.749	.656	.253
A-2-B	.196	.370	.519	.640	.720	.770	.765	.700	.360
B-2-B	.196	.370	.517	.637	.718	.765	.773	.707	.389
C-2-B	.198	.378	.534	.660	.751	.797	.794	.708	.297
A-3-B	.206	.388	.540	.666	.744	.782	.784	.695	.141
B-3-B	.201	.380	.529	.650	.735	.775	.779	.690	.179
C-3-B	.203	.387	.544	.666	.748	.785	.791	.705	.297

Propeller No. 4412—4 feet. Set 17° at 0.75 R. Angle of attack = +5°

A-3-A	0.203	0.387	0.533	0.652	0.729	0.756	0.703	0.490	--------
B-3-A	.205	.386	.540	.660	.740	.779	.778	.632	--------
C-3-A	.202	.386	.542	.664	.745	.789	.765	.622	--------
A-2-A	.206	.386	.532	.637	.701	.740	.706	.537	--------
B-2-A	.198	.371	.515	.626	.707	.754	.752	.644	0.093
C-2-A	.198	.372	.523	.644	.721	.765	.771	.695	.258
A-1-A [a]	.178	.338	.470	.583	.655	.679	.656	.541	.144
B-1-A [a]	.189	.357	.496	.593	.652	.682	.665	.557	.159
C-1-A	.190	.355	.493	.596	.662	.696	.693	.647	.274
A	.189	.360	.502	.611	.676	.706	.697	.615	.260
B	.192	.363	.504	.611	.684	.706	.695	.605	.240
C	.188	.355	.494	.598	.675	.723	.729	.676	.427
A-1-B [a]	.185	.352	.496	.607	.666	.693	.700	.651	.532
B-1-B [a]	.185	.355	.498	.611	.687	.725	.726	.658	.420
C-1-B	.195	.362	.498	.603	.679	.730	.737	.668	.332
A-2-B	.195	.367	.514	.629	.714	.760	.767	.731	.570
B-2-B	.195	.364	.510	.622	.699	.736	.738	.674	.394
C-2-B	.197	.374	.525	.644	.733	.778	.790	.731	.408
A-3-B	.204	.386	.544	.664	.743	.780	.790	.731	.344
B-3-B	.201	.379	.529	.648	.732	.774	.776	.695	.348
C-3-B	.196	.377	.530	.652	.740	.788	.796	.732	.471

Propeller No. 4412—4 feet. Set 17° at 0.75 R. Angle of attack = +10°

A-3-A	0.195	0.370	0.521	0.638	0.719	0.748	0.699	0.473	--------
B-3-A	.199	.375	.521	.632	.710	.751	.743	.614	--------
C-3-A	.200	.382	.535	.654	.736	.767	.712	.473	--------
A-2-A [b]	--------	--------	--------	--------	--------	--------	--------	--------	--------
B-2-A	.194	.363	.505	.610	.685	.718	.685	.495	--------
C-2-A	.198	.371	.516	.632	.710	.756	.769	.700	0.204
A-1-A [a]	.175	.331	.464	.562	.624	.642	.605	.463	0
B-1-A [a]	.181	.336	.455	.537	.578	.590	.564	.430	--------
C-1-A	.184	.344	.472	.561	.615	.649	.654	.605	.303
A	.186	.348	.478	.569	.624	.647	.632	.569	.302
B	.186	.349	.474	.565	.617	.637	.640	.560	.281
C	.184	.345	.472	.566	.616	.635	.621	.533	.203
A-1-B [a, b]	--------	--------	--------	--------	--------	--------	--------	--------	--------
B-1-B [a]	.184	.346	.481	.584	.650	.686	.700	.660	.520
C-1-B	.193	.354	.477	.563	.622	.660	.671	.632	.431
A-2-B	.191	.354	.487	.589	.660	.709	.725	.716	.650
B-2-B	.190	.354	.487	.583	.644	.665	.652	.574	.323
C-2-B	.194	.360	.496	.597	.666	.699	.692	.614	.348
A-3-B	.198	.373	.519	.637	.724	.775	.780	.711	.442
B-3-B	.200	.376	.526	.645	.729	.772	.776	.726	.490
C-3-B	.196	.323	.523	.636	.722	.765	.783	.755	.592

[a] Nacelle faired into airfoil.

[b] Thrust data unreliable.

TABLE VII

LIFT COEFFICIENT WITH PROPELLER OPERATING

$$C_{L_P}=\frac{L_P}{qS}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack = −5°

Nacelle position	$\frac{V}{nD}$ 0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	0.185	0.163	0.152	0.150	0.154	0.163
B-3-A	.170	.153	.145	.140	.142	.145
C-3-A	.182	.166	.159	.158	.156	.155
A-2-A	.226	.202	.187	.176	.169	.163
B-2-A	.192	.178	.170	.170	.173	.181
C-2-A	.169	.151	.140	.135	.134	.136
A-1-A [a]	.230	.206	.194	.187	.187	.190
B-1-A [a]	.210	.200	.190	.184	.179	.174
C-1-A	.190	.177	.169	.164	.163	.164
A	.168	.160	.155	.152	.150	.150
B	.181	.175	.168	.157	.145	.132
C	.169	.158	.152	.150	.151	.155
A-1-B [a]	.146	.133	.127	.127	.131	.139
B-1-B [a]	.140	.133	.130	.130	.131	.136
C-1-B	.141	.135	.133	.138	.148	.165
A-2-B	.113	.110	.113	.120	.129	.142
B-2-B	.122	.130	.134	.138	.142	.145
C-2-B	.136	.134	.135	.137	.142	.149
A-3-B	.127	.122	.125	.132	.142	.154
B-3-B	.151	.145	.144	.147	.152	.159
C-3-B	.148	.148	.148	.149	.149	.150

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack = 0°

Nacelle position	0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	0.415	0.407	0.404	0.406	0.410	------
B-3-A	.400	.396	.393	.392	.392	------
C-3-A	.403	.400	.400	.400	.400	------
A-2-A	.440	.421	.404	.392	.387	0.386
B-2-A	.419	.407	.401	.399	.398	.399
C-2-A	.401	.390	.389	.388	.390	.393
A-1-A [a]	.460	.438	.429	.423	.420	.420
B-1-A [a]	.438	.424	.416	.410	.408	.404
C-1-A	.446	.427	.412	.405	.402	.401
A	.425	.409	.401	.400	.400	.403
B	.432	.418	.406	.397	.392	.390
C	.422	.403	.396	.392	.392	.393
A-1-B [a]	.388	.384	.382	.380	.381	.383
B-1-B [a]	.405	.380	.363	.359	.360	.368
C-1-B	.390	.380	.380	.383	.387	.387
A-2-B	.356	.358	.360	.361	.363	.364
B-2-B	.372	.374	.377	.379	.383	.389
C-2-B	.371	.368	.366	.368	.372	.378
A-3-B	.370	.370	.372	.376	.380	.385
B-3-B	.395	.387	.382	.380	.382	.385
C-3-B	.382	.384	.388	.392	.397	.403

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack = +5°

Nacelle position	0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	0.662	0.645	0.636	0.631	0.631	------
B-3-A	.635	.630	.628	.626	.627	------
C-3-A	.654	.640	.630	.630	.635	0.643
A-2-A	.675	.654	.642	.633	.629	.625
B-2-A	.665	.652	.643	.640	.640	.640
C-2-A	.642	.639	.634	.628	.622	.618
A-1-A [a]	.726	.703	.688	.678	.670	.667
B-1-A [a]	.719	.700	.685	.673	.665	.658
C-1-A	.710	.680	.661	.648	.640	.634
A	.705	.682	.668	.655	.649	.642
B	.709	.688	.672	.660	.648	.639
C	.713	.683	.666	.652	.643	.640
A-1-B [a]	.651	.639	.631	.625	.621	.621
B-1-B [a]	.645	.633	.626	.622	.622	.626
C-1-B	.671	.651	.638	.630	.623	.620
A-2-B	.616	.614	.614	.614	.614	.614
B-2-B	.625	.629	.630	.629	.627	.624
C-2-B	.623	.623	.621	.620	.618	.615
A-3-B	.632	.627	.624	.622	.621	.621
B-3-B	.620	.615	.613	.614	.616	.618
C-3-B	.629	.626	.625	.626	.628	.632

[a] Nacelle faired into airfoil.

TABLE VII—Continued

LIFT COEFFICIENT WITH PROPELLER OPERATING—Continued

$$C_{L_P}=\frac{L_P}{qS}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack = +10°

Nacelle position	$\frac{V}{nD}$ 0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	0.895	0.890	0.884	0.876	0.808	------
B-3-A	.883	.875	.870	.869	.868	------
C-3-A	.916	.890	.885	.881	.883	0.892
A-2-A	.910	.884	.817	.853	.843	.836
B-2-A	.905	.896	.888	.881	.890	.880
C-2-A	.893	.885	.879	.873	.869	.866
A-1-A [a]	.988	.950	.922	.903	.892	.886
B-1-A [a]	.990	.959	.935	.917	.902	.893
C-1-A	.953	.918	.899	.890	.883	.881
A	.974	.935	.918	.906	.895	.889
B	.983	.952	.930	.916	.905	.899
C	.990	.954	.932	.919	.911	.007
A-1-B [a]	.942	.918	.901	.890	.880	.872
B-1-B [a]	.931	.903	.886	.875	.869	.806
C-1-B	.944	.915	.894	.880	.870	.861
A-2-B	.873	.871	.868	.865	.863	.860
B-2-B	.904	.897	.890	.883	.876	.868
C-2-B	.906	.892	.881	.872	.865	.859
A-3-B	.877	.867	.861	.860	.860	.800
B-3-B	.881	.872	.866	.862	.800	.860
C-3-B	.888	.882	.876	.872	.869	.860

[a] Nacelle faired into airfoil.

TABLE VIII

MOMENT COEFFICIENT WITH PROPELLER OPERATING

$$C_{m_P}=\frac{M_P}{q\ S\ c}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack = −5°

Nacelle position	$\frac{V}{n\ D}$ 0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	−0.142	−0.107	−0.092	−0.084	−0.072	−0.063
B-3-A	−.139	−.103	−.090	−.078	−.068	−.061
C-3-A	−.141	−.107	−.087	−.077	−.069	−.062
A-2-A	−.125	−.100	−.085	−.074	−.067	−.063
B-2-A	−.117	−.093	−.080	−.070	−.063	−.059
C-2-A [a]	−.123	−.099	−.084	−.074	−.067	−.062
A-1-A	−.095	−.082	−.071	−.065	−.061	−.059
B-1-A [a]	−.113	−.090	−.077	−.070	−.066	−.063
C-1-A	−.102	−.085	−.075	−.068	−.064	−.061
A	−.093	−.083	−.077	−.075	−.075	−.075
B	−.092	−.087	−.083	−.080	−.077	−.075
C	−.098	−.089	−.086	−.084	−.082	−.080
A-1-B [a]	−.082	−.084	−.086	−.087	−.087	−.080
B-1-B [a]	−.090	−.093	−.094	−.096	−.097	−.098
C-1-B	−.084	−.090	−.093	−.095	−.095	−.091
A-2-B	−.048	−.062	−.068	−.074	−.077	−.079
B-2-B	−.057	−.070	−.080	−.085	−.088	−.088
C-2-B	−.057	−.070	−.079	−.084	−.088	−.091
A-3-B	−.026	−.050	−.064	−.073	−.079	−.082
B-3-B	−.031	−.056	−.070	−.079	−.084	−.087
C-3-B	−.028	−.054	−.068	−.078	−.084	−.087

[a] Nacelle faired into airfoil.

TABLE VIII—Continued

MOMENT COEFFICIENT WITH PROPELLER OPERATING—Continued

$$C_{m_P}=\frac{M_P}{q\ S\ c}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=0°

Nacelle position	V/nD 0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	−0.133	−0.098	−0.080	−0.070	−0.061	--------
B-3-A	−.129	−.097	−.078	−.065	−.056	--------
C-3-A	−.125	−.097	−.079	−.069	−.057	--------
A-2-A	−.110	−.085	−.073	−.065	−.061	−0.058
B-2-A	−.100	−.080	−.066	−.056	−.052	−.049
C-2-A	−.108	−.086	−.072	−.062	−.056	−.052
A-1-A[a]	−.089	−.075	−.065	−.058	−.054	−.050
B-1-A[a]	−.063	−.052	−.045	−.040	−.035	−.031
C-1-A	−.089	−.070	−.060	−.054	−.050	−.047
A	−.079	−.074	−.070	−.067	−.066	−.065
B	−.077	−.072	−.068	−.066	−.064	−.063
C	−.082	−.074	−.069	−.066	−.064	−.062
A-1-B[a]	−.073	−.076	−.078	−.079	−.080	−.080
B-1-B[a]	−.083	−.084	−.085	−.086	−.087	−.087
C-1-B	−.073	−.077	−.081	−.083	−.084	−.085
A-2-B	−.046	−.058	−.065	−.071	−.075	−.078
B-2-B	−.047	−.061	−.071	−.077	−.081	−.083
C-2-B	−.045	−.061	−.068	−.073	−.077	−.081
A-3-B	−.021	−.044	−.058	−.066	−.072	−.076
B-3-B	−.023	−.044	−.059	−.068	−.075	−.079
C-3-B	−.022	−.044	−.058	−.068	−.074	−.078

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=+5°

Nacelle position	V/nD 0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	−0.125	−0.095	−0.077	−0.065	−0.055	--------
B-3-A	−.119	−.091	−.072	−.059	−.050	--------
C-3-A	−.117	−.090	−.074	−.061	−.050	--------
A-2-A	−.107	−.085	−.071	−.063	−.057	−0.054
B-2-A	−.092	−.072	−.059	−.050	−.045	−.040
C-2-A	−.103	−.080	−.066	−.056	−.049	−.046
A-1-A[a]	−.085	−.070	−.061	−.055	−.051	−.050
B-1-A[a]	−.076	−.061	−.050	−.043	−.038	−.037
C-1-A	−.077	−.062	−.053	−.047	−.042	−.038
A	−.075	−.067	−.064	−.061	−.059	−.058
B	−.066	−.063	−.060	−.057	−.056	−.056
C	−.068	−.060	−.054	−.051	−.050	−.049
A-1-B[a]	−.070	−.073	−.075	−.075	−.075	−.074
B-1-B[a]	−.077	−.079	−.080	−.080	−.080	−.080
C-1-B	−.070	−.071	−.072	−.073	−.074	−.073
A-2-B	−.042	−.057	−.063	−.065	−.067	−.068
B-2-B	−.040	−.055	−.066	−.072	−.075	−.076
C-2-B	−.035	−.052	−.061	−.067	−.071	−.074
A-3-B	−.010	−.034	−.050	−.062	−.069	−.075
B-3-B	−.017	−.039	−.054	−.064	−.070	−.072
C-3-B	−.013	−.037	−.052	−.061	−.067	−.070

[a] Nacelle faired into airfoil.

TABLE VIII—Continued

MOMENT COEFFICIENT WITH PROPELLER OPERATING—Continued

$$C_{m_P}=\frac{M_P}{q\ S\ c}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=+10°

Nacelle position	V/nD 0.5	0.6	0.7	0.8	0.9	1.0
A-3-A	−0.129	−0.092	−0.078	−0.068	−0.057	--------
B-3-A	−.122	−.091	−.072	−.059	−.051	--------
C-3-A	−.119	−.088	−.071	−.061	−.054	--------
A-2-A	−.109	−.086	−.073	−.064	−.059	−0.057
B-2-A	−.100	−.077	−.064	−.055	−.049	−.047
C-2-A	−.094	−.074	−.061	−.051	−.046	−.043
A-1-A[a]	−.093	−.080	−.071	−.066	−.064	−.063
B-1-A[a]	−.074	−.060	−.051	−.045	−.042	−.041
C-1-A	−.079	−.060	−.051	−.046	−.043	−.040
A	−.078	−.067	−.062	−.058	−.056	−.054
B	−.065	−.058	−.055	−.053	−.052	−.050
C	−.055	−.050	−.048	−.046	−.044	−.044
A-1-B[a]	−.072	−.074	−.075	−.075	−.075	−.075
B-1-B[a]	−.071	−.073	−.075	−.076	−.077	−.079
C-1-B	−.060	−.064	−.066	−.067	−.069	−.070
A-2-B	−.040	−.058	−.064	−.066	−.069	−.070
B-2-B	−.038	−.052	−.062	−.067	−.069	−.070
C-2-B	−.033	−.048	−.056	−.062	−.066	−.069
A-3-B	−.012	−.033	−.048	−.058	−.065	−.070
B-3-B	−.012	−.036	−.050	−.061	−.067	−.070
C-3-B	−.007	−.032	−.047	−.056	−.063	−.068

[a] Nacelle faired into airfoil.

TABLE IX

LANDING-SPEED RATIOS FOR NACELLE LOCATIONS

C_L Wing alone=0.960. Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=12°

Nacelle position	1 C_L with propeller operating at zero thrust	2 C_L without propeller	3 Landing speed ratio $=\sqrt{\frac{0.960}{C_L\text{ (Col. 1.)}}}$
A-3-A	0.953	0.955	1.00
B-3-A	.923	.925	1.02
C-3-A	.972	.965	.99
A-2-A	.918	.904	1.02
B-2-A	.980	.981	.99
C-2-A	.970	.969	1.00
A-1-A[a]	.968	.955	1.00
B-1-A[a]	1.005	.996	.98
B-1-A	.900	.871	1.03
C-1-A	.973	.961	.99
A	.993	.977	.98
B	1.007	1.004	.98
C	1.001	.996	.98
A-1-B[a]	.960	.783	1.00
B-1-B[a]	.965	.960	1.00
C-1-B	.964	.963	1.00
A-2-B	.945	.877	1.01
B-2-B[b]	--------	--------	--------
C-2-B	.957	.951	1.00
A-3-B	.955	.951	1.00
B-3-B	.952	.970	1.00
C-3-B	.955	.965	1.00

[a] Nacelle faired into airfoil. [b] Not tested at 12°.

TABLE X

EFFECTIVE NACELLE LIFT RATIOS

Effective nacelle lift = (lift of wing-nacelle combination) − (lift of wing alone)

Nacelle position	Effective nacelle lift coefficient					Effective nacelle lift / Drag of nacelle alone at 0°				
Angle of attack	−5°	0°	+5°	+10°	+12°	−5°	0°	+5°	+10°	+12°
A-3-A	−0.002	−0.004	−0.003	−0.008	−0.005	−0.50	−1.00	−0.75	−2.00	−1.25
B-3-A	−.018	−.021	−.021	−.023	−.035	−4.50	−5.25	−5.25	−5.75	−8.75
C-3-A	−.021	−.024	−.021	−.020	.005	−5.25	−6.00	−5.25	−5.00	1.25
A-2-A	.003	−.009	−.017	−.034	−.056	7.50	−2.25	−4.25	−8.50	−14.00
B-2-A	−.020	−.016	−.007	−.003	.021	−5.00	−4.00	−1.75	−.75	5.25
C-2-A	−.047	−.038	−.025	−.016	.009	−11.75	−9.50	−6.25	−4.00	2.25
A-1-A[a]	.015	.003	−.007	−.019	−.005	3.75	−.75	−1.75	−4.75	−1.25
B-1-A[a]	−.006	−.002	.007	.015	.036	−1.50	−.50	1.75	3.75	9.00
B-1-A	−.028	−.041	−.053	−.081	−.091	−7.00	−10.25	−13.25	−20.50	−22.75
C-1-A	−.024	−.022	−.019	−.017	.001	−6.00	−5.50	−4.75	−4.25	.25
A	−.027	−.023	−.014	−.006	.017	−6.75	−5.75	−3.50	−1.50	4.25
B	−.015	−.006	.006	.017	.044	−3.75	−1.50	1.50	4.25	11.00
C	−.019	−.008	.005	.018	.036	−4.75	−2.00	1.25	4.50	9.00
A-1-B[a]	−.030	−.037	−.043	−.125	−.177	−7.50	−9.25	−10.75	−31.25	−44.25
B-1-B[a]	−.029	−.030	−.025	−.024	0	−7.25	−7.50	−6.25	−6.00	0
C-1-B	−.016	−.018	−.017	−.017	.003	−4.00	−4.50	−4.25	−4.25	.75
A-2-B	−.022	−.031	−.033	−.041	−.083	−5.50	−7.75	−8.25	−10.25	−20.75
B-2-B	−.019	−.027	−.030	−.036	-----	−4.75	−6.75	−7.50	−9.00	-----
C-2-B	−.026	−.029	−.031	−.031	−.009	−6.50	−7.25	−7.75	−7.75	−2.25
A-3-B	−.025	−.028	−.027	−.028	−.009	−6.25	−7.00	−6.75	−7.00	−2.25
B-3-B	−.031	−.030	−.024	−.020	.010	−7.75	−7.50	−6.00	−5.00	2.50
C-3-B	−.021	−.021	−.020	−.017	−.005	−5.25	−5.25	−5.00	−4.25	1.25

[a] Nacelle faired into airfoil.

TABLE XI

EFFECTIVE NACELLE DRAG RATIOS

Effective nacelle drag = (drag of wing-nacelle combination) − (drag of wing alone)

Nacelle position	Effective nacelle drag coefficient					Effective nacelle drag / Drag of nacelle alone					Effective nacelle drag / Drag of nacelle alone at 0°				
Angle of attack	−5°	0°	+5°	+10°	+12°	−5°	0°	+5°	+10°	+12°	−5°	0°	+5°	+10°	+12°
A-3-A	0.0085	0.0075	0.0095	0.0120	0.0135	2.18	1.88	2.37	2.40	2.33	2.12	1.88	2.38	3.00	3.38
B-3-A	.0085	.0070	.0095	.0120	.0170	2.18	1.75	2.37	2.40	2.93	2.12	1.75	2.38	3.00	4.25
C-3-A	.0065	.0045	.0065	.0060	.0075	1.67	1.13	1.62	1.20	1.29	1.62	1.13	1.63	1.50	1.88
A-2-A	.0055	.0075	.0095	.0130	.0150	1.41	1.88	2.37	2.60	2.58	1.37	1.88	2.38	3.25	3.75
B-2-A	.0070	.0060	.0080	.0100	.0160	1.79	1.50	2.00	2.00	2.76	1.75	1.50	2.00	2.50	4.00
C-2-A	.0055	.0040	.0060	.0095	.0090	1.41	1.00	1.50	1.90	1.55	1.38	1.00	1.50	2.38	2.25
A-1-A[a]	.0075	.0095	.0235	.0320	.0365	1.92	2.38	5.86	6.40	6.30	1.88	2.38	5.88	8.00	9.01
B-1-A[a]	.0055	.0050	.0115	.0165	.0170	1.41	1.25	2.87	3.30	2.93	1.38	1.25	2.88	4.13	4.25
B-1-A	.0115	.0140	.0235	.0300	.0315	2.95	3.50	5.74	6.00	5.44	2.88	3.50	5.88	7.50	7.87
C-1-A	.0055	.0055	.0095	.0155	.0185	1.41	1.38	2.37	3.10	3.19	1.38	1.38	2.38	3.88	4.63
A	.0025	.0005	.0015	.0010	.0020	.64	.13	.37	.20	.34	.63	.13	.38	.25	.50
B	.0030	.0015	.0045	.0080	.0090	.77	.38	1.12	1.60	1.55	.75	.38	1.13	2.00	2.25
C	.0040	.0025	.0060	.0105	.0125	1.03	.63	1.50	2.10	2.16	1.00	.63	1.50	2.63	3.13
A-1-B[a]	.0065	.0015	−.0010	.0070	.0030	1.67	.38	−.25	1.40	1.88	1.63	.38	−.25	1.75	2.00
B-1-B[a]	.0060	.0005	−.0015	−.0015	−.0040	1.54	.13	−.37	−.30	−.69	1.50	.13	−.38	−.38	−1.00
C-1-B	.0065	.0020	−.0005	−.0020	−.0040	1.67	.50	−.12	−.40	−.69	1.63	.50	−.13	−.50	−1.00
A-2-B	.0070	.0020	−.0005	−.0030	−.0020	1.79	.50	−.12	−.60	−.34	1.75	.50	−.13	−.75	−.50
B-2-B	.0055	.0015	−.0005	−.0035	-----	1.41	.38	−.12	−.70	-----	1.38	.38	−.13	−.88	-----
C-2-B	.0070	.0020	−.0005	−.0025	−.0030	1.79	.50	−.12	−.50	−.52	1.75	.50	−.13	−.63	−.75
A-3-B	.0085	.0040	.0020	0	−.0020	2.18	1.00	.50	0	−.34	2.12	1.00	.50	0	−.50
B-3-B	.0080	.0035	.0005	−.0020	−.0030	2.05	.88	.12	−.40	−.52	2.00	.88	.13	−.50	−.75
C-3-B	.0075	.0035	.0015	.0005	−.0010	1.92	.88	.37	.10	−.17	1.88	.88	.38	.13	−.25

[a] Nacelle faired into airfoil.

TABLE XII

PROPELLER OPERATING COEFFICIENT

$$C_S=\sqrt[5]{\frac{\rho V^5}{Pn^2}}=\frac{\frac{V}{nD}}{\sqrt[5]{C_P}}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=−5°

Nacelle position	V/nD								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
A-3-A	0.187	0.374	0.563	0.755	0.956	1.17	1.42	1.76	2.35
B-3-A	.187	.375	.564	.757	.956	1.17	1.41	1.73	2.26
C-3-A	.188	.375	.565	.758	.956	1.17	1.41	1.72	2.24
A-2-A	.189	.377	.567	.759	.956	1.17	1.41	1.71	2.16
B-2-A	.189	.377	.566	.758	.956	1.17	1.41	1.72	2.18
C-2-A	.185	.372	.561	.755	.952	1.16	1.41	1.75	2.20
A-1-A [a]	.188	.375	.564	.756	.952	1.16	1.38	1.65	1.99
B-1-A [a]	.187	.376	.566	.759	.957	1.17	1.40	1.69	2.10
C-1-A	.187	.375	.563	.756	.956	1.17	1.41	1.71	2.18
A	.188	.376	.566	.758	.954	1.16	1.40	1.69	2.10
B	.188	.376	.566	.758	.957	1.17	1.41	1.71	2.18
C	.188	.377	.568	.760	.956	1.17	1.41	1.76	2.20
A-1-B [a]	.187	.374	.563	.755	.950	1.16	1.39	1.65	2.04
B-1-B [a]	.188	.377	.567	.760	.958	1.17	1.41	1.71	2.13
C-1-B	.187	.375	.565	.758	.956	1.17	1.41	1.72	2.22
A-2-B	.187	.374	.562	.755	.954	1.17	1.42	1.74	2.24
B-2-B	.187	.374	.562	.755	.952	1.17	1.41	1.72	2.19
C-2-B	.187	.374	.562	.755	.955	1.17	1.40	1.70	2.18
A-3-B	.187	.375	.565	.757	.957	1.18	1.43	1.76	2.37
B-3-B	.187	.374	.563	.756	.954	1.17	1.42	1.74	2.28
C-3-B	.187	.375	.565	.757	.955	1.17	1.41	1.72	2.22

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=0°

A-3-A	0.187	0.375	0.563	0.755	0.957	1.18	1.43	1.78	2.48
B-3-A	.187	.374	.564	.758	.955	1.17	1.42	1.75	2.39
C-3-A	.188	.375	.565	.758	.958	1.17	1.42	1.74	--------
A-2-A	.189	.378	.568	.760	.959	1.17	1.40	1.74	--------
B-2-A	.188	.376	.565	.758	.957	1.17	1.42	1.73	2.26
C-2-A	.186	.373	.561	.752	.950	1.16	1.41	1.73	2.22
A-1-A [a]	.188	.375	.564	.756	.952	1.16	1.40	1.68	2.06
B-1-A [a]	.187	.375	.565	.758	.954	1.17	1.41	1.70	2.14
C-1-A	.187	.376	.564	.756	.956	1.17	1.41	1.71	2.18
A	.188	.377	.566	.759	.954	1.17	1.40	1.70	2.12
B	.188	.376	.566	.759	.956	1.17	1.41	1.71	2.16
C	.188	.376	.566	.759	.957	1.17	1.41	1.72	2.21
A-1-B [a]	.187	.374	.562	.754	.949	1.16	1.38	1.64	1.99
B-1-B [a]	.188	.376	.566	.759	.958	1.17	1.40	1.69	2.11
C-1-B	.187	.375	.565	.758	.954	1.17	1.41	1.71	2.17
A-2-B	.187	.374	.562	.755	.955	1.16	1.40	1.70	2.14
B-2-B	.187	.374	.562	.752	.952	1.16	1.41	1.71	2.16
C-2-B	.187	.373	.563	.755	.952	1.17	1.40	1.70	2.18
A-3-B	.187	.375	.562	.756	.956	1.17	1.42	1.73	2.25
B-3-B	.187	.374	.563	.756	.954	1.17	1.41	1.72	2.22
C-3-B	.187	.375	.563	.756	.954	1.16	1.41	1.72	2.21

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=+5°

A-3-A	0.187	0.375	0.564	0.758	0.961	1.19	1.45	1.82	2.74
B-3-A	.187	.374	.564	.758	.957	1.18	1.43	1.77	--------
C-3-A	.188	.375	.565	.758	.958	1.18	1.43	1.75	--------
A-2-A	.189	.377	.568	.760	.961	1.19	1.45	1.80	--------
B-2-A	.188	.376	.565	.758	.957	1.17	1.42	1.75	2.27
C-2-A	.187	.375	.563	.755	.952	1.17	1.41	1.73	2.26
A-1-A [a]	.188	.376	.565	.759	.956	1.17	1.41	1.70	2.12
B-1-A [a]	.187	.375	.565	.758	.954	1.17	1.41	1.71	2.18
C-1-A	.187	.376	.566	.759	.958	1.17	1.42	1.75	2.24
A	.188	.377	.567	.759	.958	1.17	1.41	1.70	2.11
B	.188	.375	.565	.758	.958	1.17	1.42	1.72	2.18
C	.187	.375	.565	.758	.956	1.17	1.48	1.72	2.20
A-1-B [a]	.188	.375	.565	.757	.953	1.15	1.38	1.63	1.95
B-1-B [a]	.187	.374	.564	.758	.956	1.17	1.40	1.68	2.08
C-1-B	.187	.375	.565	.756	.954	1.17	1.41	1.70	2.14
A-2-B	.187	.374	.563	.755	.953	1.16	1.39	1.67	2.04
B-2-B	.187	.374	.562	.755	.952	1.16	1.40	1.69	2.10
C-2-B	.187	.374	.562	.754	.951	1.16	1.40	1.69	2.14
A-3-B	.187	.375	.565	.758	.956	1.17	1.40	1.70	2.14
B-3-B	.187	.374	.563	.756	.954	1.16	1.41	1.70	2.14
C-3-B	.187	.374	.563	.755	.955	1.17	1.41	1.70	2.16

[a] Nacelle faired into airfoil.

TABLE XII—Continued

PROPELLER OPERATING COEFFICIENT—Continued

$$C_S=\sqrt[5]{\frac{\rho V^5}{Pn^2}}=\frac{\frac{V}{nD}}{\sqrt[5]{C_P}}$$

Propeller No. 4412—4 feet. Set 17° at 0.75 *R*. Angle of attack=+10°

Nacelle position	$\frac{V}{nD}$								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
A-3-A	0.187	0.374	0.564	0.760	0.961	1.19	1.45	1.83	--------
B-3-A	.187	.375	.564	.758	.957	1.17	1.43	1.77	--------
C-3-A	.188	.375	.564	.757	.958	1.17	1.42	1.74	--------
A-2-A	.189	.378	.569	.763	.963	1.19	1.45	1.81	2.63
B-2-A	.188	.376	.565	.759	.958	1.18	1.43	1.76	--------
C-2-A	.188	.375	.564	.758	.956	1.17	1.42	1.74	2.27
A-1-A [a]	.188	.376	.565	.758	.956	1.17	1.41	1.70	2.14
B-1-A [a]	.187	.375	.564	.756	.952	1.17	1.41	1.71	--------
C-1-A	.187	.376	.565	.757	.955	1.17	1.41	1.73	2.21
A	.188	.377	.566	.758	.957	1.17	1.40	1.70	2.11
B	.188	.376	.566	.759	.956	1.17	1.41	1.70	2.14
C	.188	.376	.566	.759	.957	1.17	1.41	1.71	2.17
A-1-B [a]	.188	.377	.566	.756	.948	1.15	1.36	1.60	1.90
B-1-B [a]	.188	.376	.566	.758	.952	1.16	1.38	1.66	2.03
C-1-B	.187	.375	.564	.759	.952	1.17	1.40	1.69	2.11
A-2-B	.187	.374	.562	.752	.947	1.15	1.38	1.63	1.96
B-2-B	.187	.374	.564	.755	.953	1.16	1.39	1.67	2.03
C-2-B	.187	.374	.562	.752	.949	1.16	1.39	1.67	2.07
A-3-B	.187	.374	.562	.755	.951	1.16	1.39	1.66	2.04
B-3-B	.187	.374	.563	.755	.952	1.16	1.40	1.68	2.07
C-3-B	.187	.373	.563	.754	.952	1.16	1.39	1.68	2.03

[a] Nacelle faired into airfoil.