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SOME LIFT AND DRAG MEASUREMENTS OF A REPRESENTATIVE BOMBER NACELLE ON A LOW-DRAG WING - II

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SOME LIFT AND DRAG MEASUREMENTS OF A REPRESENTATIVE BOMBER NACELLE ON A LOW-DRAG WING - II

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SUMMARY

Tests of a second representative bomber nacelle on a low-drag wing at a large value of the Reynolds number were made in the NACA two-dimensional low-turbulence pressure tunnel. Results show the drag and interference of the nacelle on the low-drag wing to be small.

INTRODUCTION

Tests in the NACA two-dimensional low-turbulence pressure tunnel of a representative bomber nacelle on a moderately thick low-drag wing have been reported in reference 1. The tests of this first nacelle show the drag and interference to be small.

The tests reported herein are of another nacelle mounted on the same wing as reported in reference 1 and represent a continuation of the program of tests of several typical manufacturers' nacelles mounted on low-drag wings. This program does not contemplate complete tests of the various nacelle combinations. It is hoped that the results will be of sufficient value, however, to warrant more thorough investigations of proposed military applications.

APPARATUS

The tests were conducted in the NACA two-dimensional low-turbulence pressure tunnel, which has an air stream of very low turbulence and which permits the attainment of large values of the Reynolds number.

Wing.- The model nacelle was mounted on an NACA

66,2-216, a = 0.6, airfoil section having a chord of 15 inches and a span of 3 feet (tunnel test-section width). The wing was set at an angle of incidence to the thrust line of the nacelle of $1/2^{\circ}$.

Nacelle.- The model tested was a scale model of the Vega Ventura twin-engine bomber nacelle and was built by the Vega Airplane Company. The nacelle as received was filled, faired, and painted; it was finished for the tests by sanding with No. 400 carborundum paper. This finish gave a surface that was intended to be aerodynamically smooth, that is, further smoothing would result in no decrease in drag. Three conditions of the nacelle model mounted on the test wing are shown in figure 1. It can be seen in figure 2 that the nacelle has a short afterbody which terminates at the trailing edge of the wing.

Internal-air flow.- Carburetor air taken in through the scoop at the top of the cowl was exhausted through the stack, which can be seen in figures 1(a) and 2(a). Oil-cooler air was taken in through the scoop at the bottom of the cowl and exhausted through two side exits on the bottom portion of the afterbody (fig. 2(a)). For the model in its original condition, engine cooling air was exhausted through an annular exit interrupted only by the carburetor-scoop fairing and the oil-cooler duct entrance. Both of the other conditions of the model left this annular engine-cooling-air exit broken only by the oil-cooler duct entrance (fig. 1(b)) or by the afterbody fairing at the same point (fig. 2(b)).

The entrance and exit areas of the model were fixed and the engine pressure drop was simulated by means of a perforated plate. This plate was designed for a pressure drop through the engine of $\Delta p = 12$ inches of water for full-throttle operation at 350 miles per hour at an altitude of 25,000 feet. The pressure-drop ratio from these assumed values is then $\Delta p/q_0 = 0.45$ where q_0 is the free-stream dynamic pressure. The pressure-drop ratio assumed for the oil cooler was $\Delta p/q_0 = 0.34$. Internal-flow measurements and corresponding drag increments for the tests are given in table I with the use of the following symbols:

A_e model exit area, square inches

v_e/v_0 ratio of exit velocity to free-stream velocity

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$\Delta H_e/q_o$ ratio of total-pressure loss at exit to free-stream dynamic pressure

ΔC_{D_F} coefficient of drag due to internal loss

ΣC_{D_F} coefficient of total drag and interference

C_{D_F} coefficient of external drag and interference $(\Sigma C_{D_F} - \Delta C_{D_F})$

Values of the drag coefficient C_{D_F} are based on the model frontal area, 24.90 square inches.

TEST METHODS[1]

Drag measurements were obtained from wake surveys at a series of spanwise stations. Points were taken far enough outside the nacelle disturbance to establish the section drag of the wing. The integral, against spanwise location, of the curve of section profile-drag coefficient (fig. 3) in excess of the section drag of the wing c_{d_W} was then taken as the total drag and interference of the nacelle. Internal-drag measurements were made by making total-head and static-pressure measurements in the exits. The method for calculating the drag due to internal losses is given in reference 2. The external drag and interference is then the total drag and interference minus the drag due to internal losses.

All lift and drag section coefficients are based on the wing chord of 15 inches. All tests reported herein were run at a wing Reynolds number R_W of 6.5 million. Angles of attack shown are those of the wing α_W.

RESULTS AND DISCUSSION

Values of C_{D_F} for the nacelle in three test conditions are given in figure 4 and corresponding drag increments ΔC_{D_F} due to internal losses are given in table I. The value of the external-drag coefficient for the nacelle in its original condition is $C_{D_F} = 0.084$. The removal of

[1]At the time this report was originally published, some of the corrections required for reducing the test data to free-air conditions had not been determined. The values of section lift coefficient c_l (fig. 5) should be corrected by the following equation

$$c_{l(\text{corrected})} = 0.965c_l + 0.006$$

the carburetor scoop and exhaust stack reduced this value to $C_{D_F} = 0.066$, a reduction of about 21 percent. Further reduction in drag resulted from removing the oil-cooler scoop and fairing in this portion of the afterbody (fig. 2(b)). The value $C_{D_F} = 0.057$ for the nacelle in this smooth condition is a total reduction of 32 percent from the original condition. This value of the external-drag coefficient for the nacelle in the smooth condition can be seen to be higher than that for the nacelle reported in reference 1. However, these values do not represent true drag differences because values for the nacelle tested herein are based on a smaller frontal area.

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The adverse pressure gradient over a nacelle afterbody is superimposed on the adverse gradient of the wing if the nacelle is terminated at or near the trailing edge of the wing. The resulting pressure gradient will be more severe than for either wing or nacelle alone. The fact that the nacelle reported herein has an afterbody terminating at the trailing edge of the wing may make these pressure gradients steeper than the optimum.

In regard to the large drag increments of the scoops, clean-up investigations made at the Laboratory have shown that excessive drag increments commonly result from the addition of protruding scoops. In other words, the results of this investigation tend further to confirm the conclusion that external scoops and appendages as means of providing air inlets and discharges should be avoided.

Figure 5 shows a lift comparison of the wing alone and the wing with the nacelle in the original condition and in the smooth condition. It can be seen from this comparison that the slopes of the lift curves are essentially the same but that the addition of the nacelle has resulted in a small loss in lift at a given angle of attack. Such a loss of lift, if large and localized near the nacelle, could lead to lift disturbances which would result in an increase in induced drag. Incidentally, a comparison of the lift curve of the wing alone with the corresponding curve given in reference 1 shows that the curve given herein has been reduced by an increment of $c_l = 0.04$. This reduction is due to checks on the lift measurements made throughout these tests, which removed a large part of the error mentioned in reference 1.

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Pressure-distribution measurements over the top of the cowl in the smooth condition for a range of angles of attack are presented in figure 6 in terms of the pressure coefficient S defined as

$$S = \frac{H - p}{q_o}$$

where

H free-stream total pressure

p local static pressure

q_o free-stream dynamic pressure

From the magnitude of the peak pressure at the design angle of attack, the critical Mach number of the cowl seems reasonably high.

It may be concluded that, after the appendages are removed, a reasonably low drag and interference is obtained for both this nacelle and the nacelle on the same low-drag wing, reported in reference 1.

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Langley Field, Va.

REFERENCES

1. Ellis, Macon C., Jr.: Some Lift and Drag Measurements of a Representative Bomber Nacelle on a Low-Drag Wing. NACA C.B., May 1942.

2. Becker, John V.: Wind-Tunnel Tests of Air Inlet and Outlet Openings on a Streamline Body. NACA A.C.R., Nov. 1940.

TABLE I

INTERNAL-FLOW MEASUREMENTS AND DRAG INCREMENTS

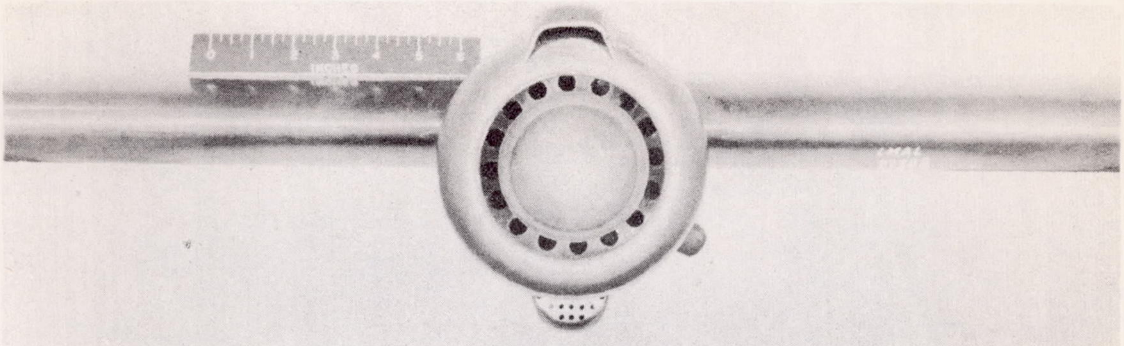
$$\left[\alpha_w = \frac{1}{2}^{\circ} \right]$$

Model condition	A_e			v_e/v_o			$\Delta H_e/q_o$			ΔC_{D_F}			ΣC_{D_F}	C_{D_F}
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)		
Original	1.28	0.16	0.40	0.66	0.63	0.66	0.51	0.59	0.81	0.020	0.003	0.012	0.119	0.084
Carburetor scoop and exhaust stack removed	1.61	.16	---	.70	.63	---	.51	.59	---	.027	.003	---	.096	.066
Smooth	1.61	---	---	.70	---	---	.51	---	---	.027	---	---	.084	.057

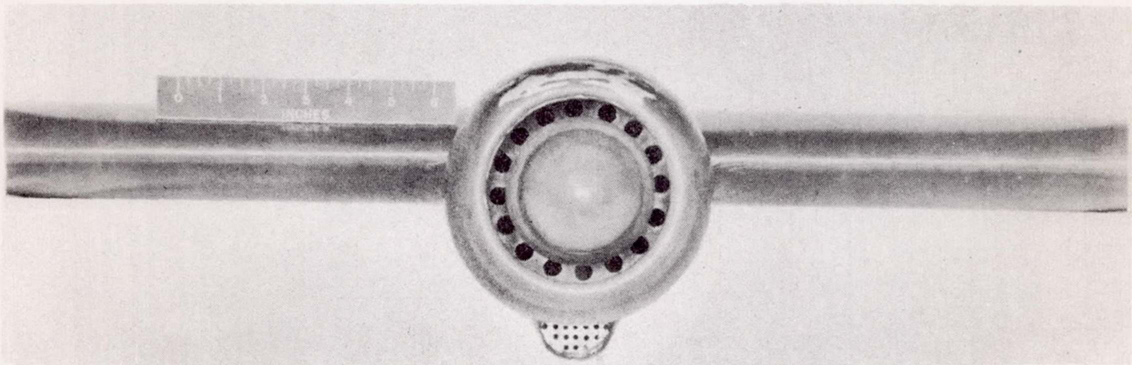
[a]Engine-cooling-air exit.

[b]Oil-cooler-air exit.

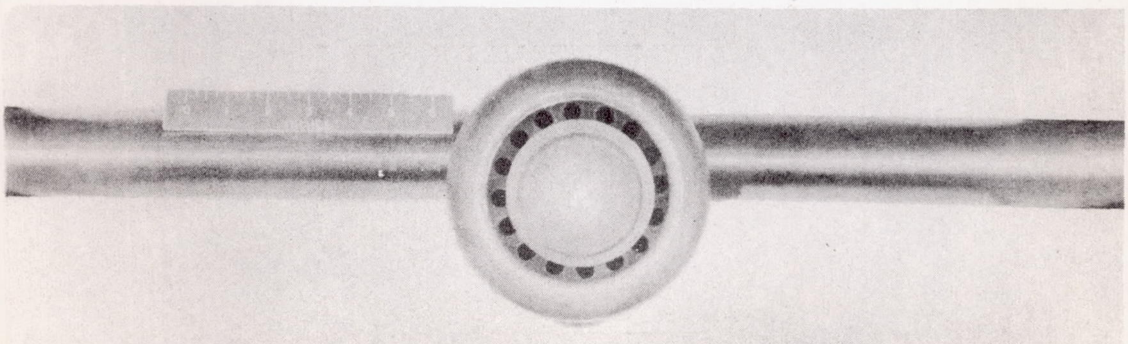
[c]Exhaust-stack-air exit.



(A) MODEL WITH CARBURETOR SCOOP, OIL-COOLER SCOOP, AND EXHAUST STACK. (ORIGINAL CONDITION)

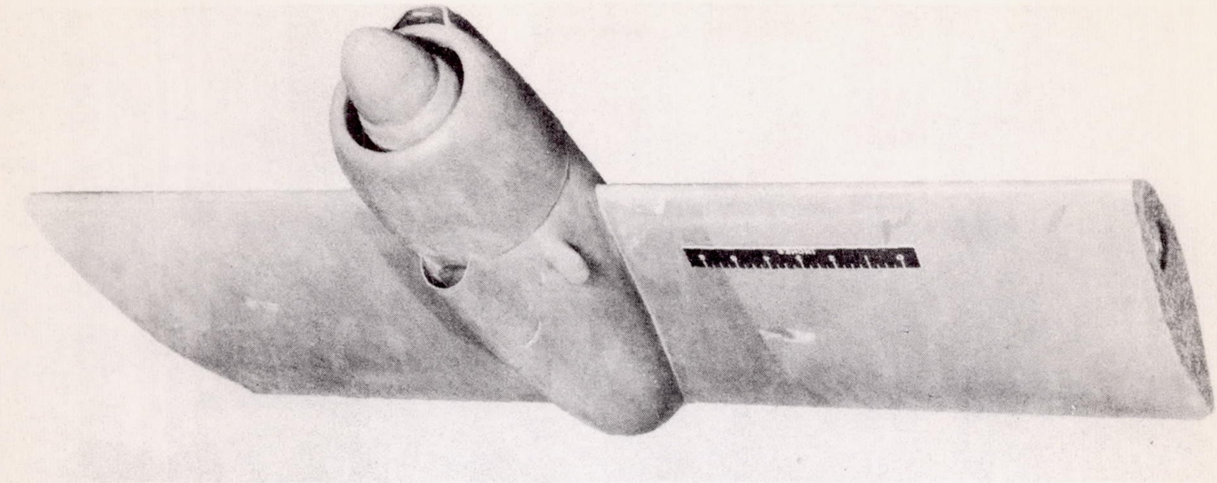


(B) MODEL WITH CARBURETOR SCOOP AND EXHAUST STACK REMOVED.

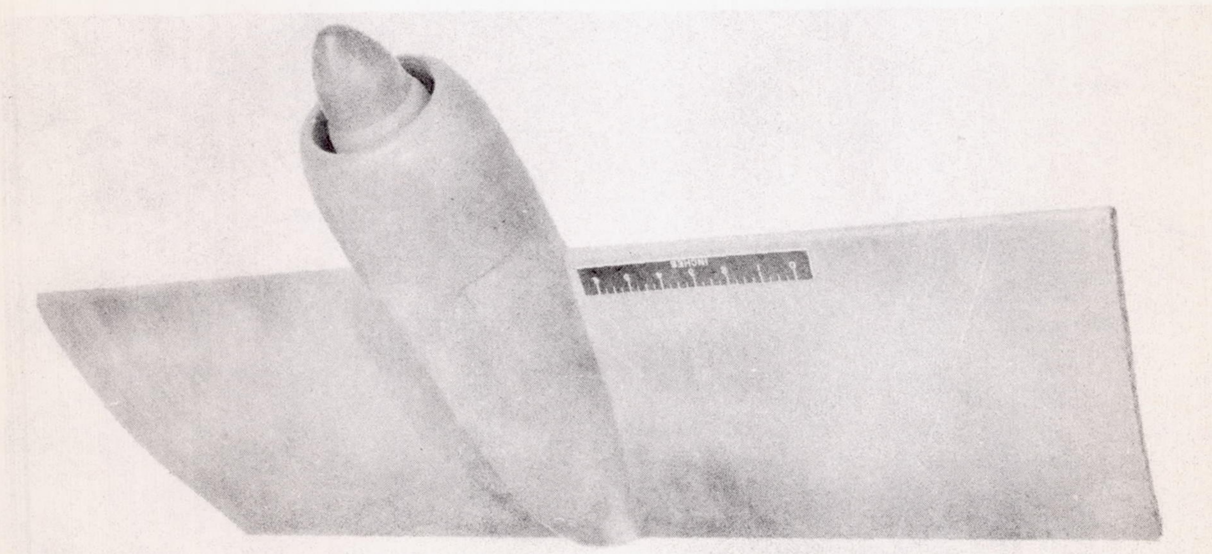


(C) MODEL WITH CARBURETOR SCOOP, OIL-COOLER SCOOP, AND EXHAUST STACK REMOVED. (SMOOTH CONDITION)

FIGURE 1.- FRONT VIEW OF NACELLE MODEL ON LOW-DRAG WING SHOWING TEST CONFIGURATIONS.



(A) Model with carburetor scoop, oil-cooler scoop, and exhaust stack.



(B) Model with carburetor scoop, oil-cooler scoop, and exhaust stack removed.

Figure 2.- Three-quarter view of under side of nacelle model on low-drag wing.

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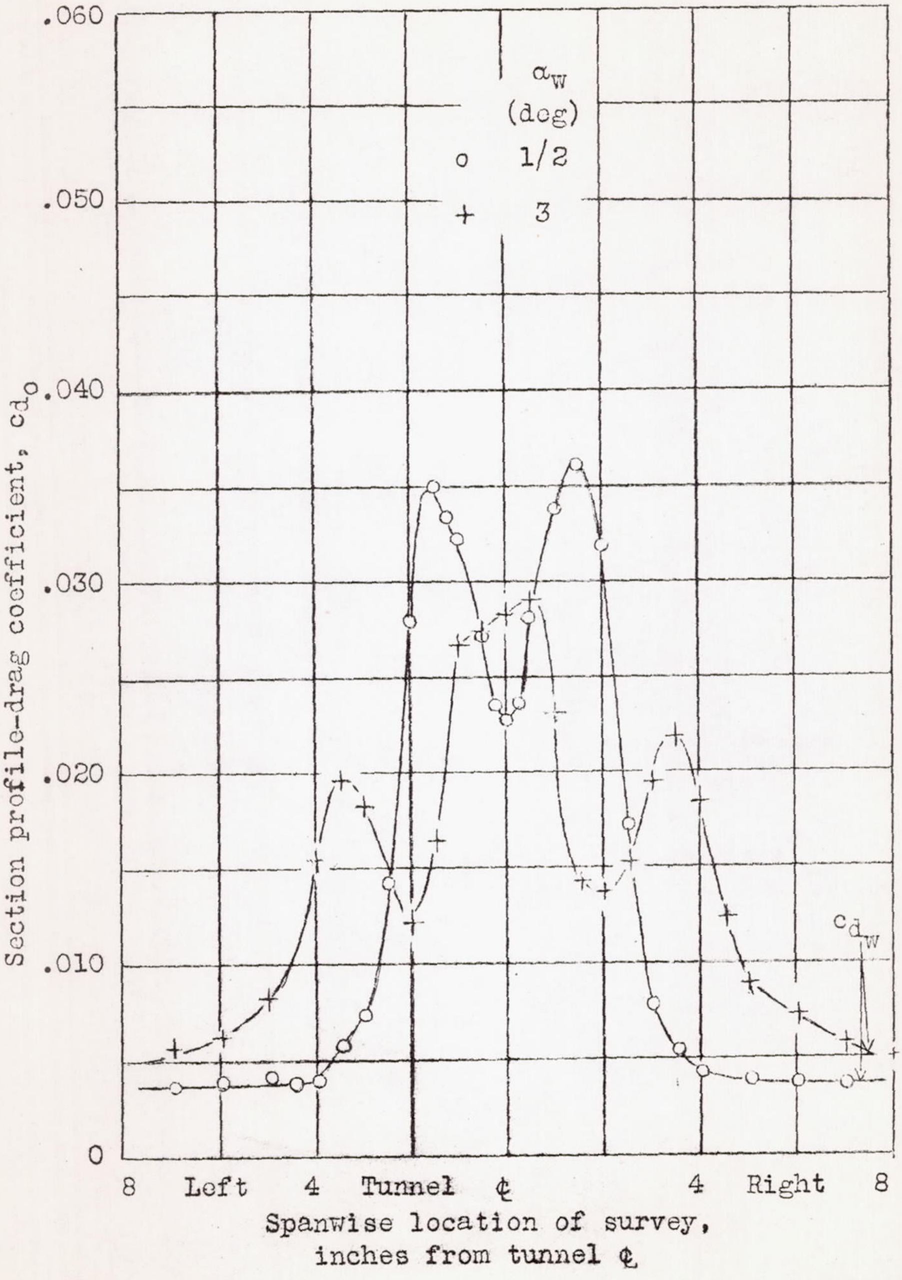

Figure 3.- Typical spanwise drag plot. Nacelle in smooth condition; R_W, 6.5×10^6.

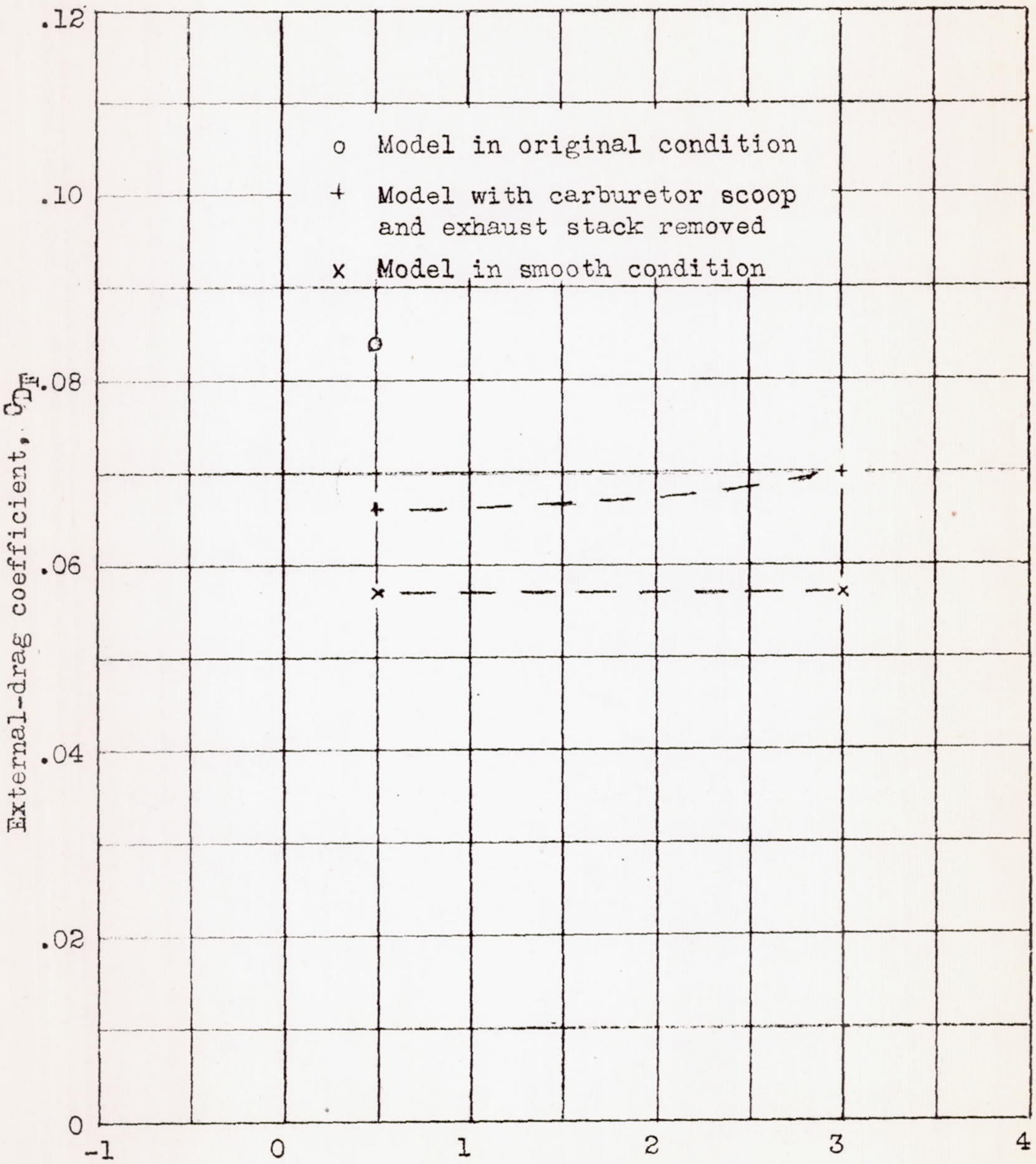

Figure 4.- Nacelle external-drag coefficients. R_W, 6.5×10^6.

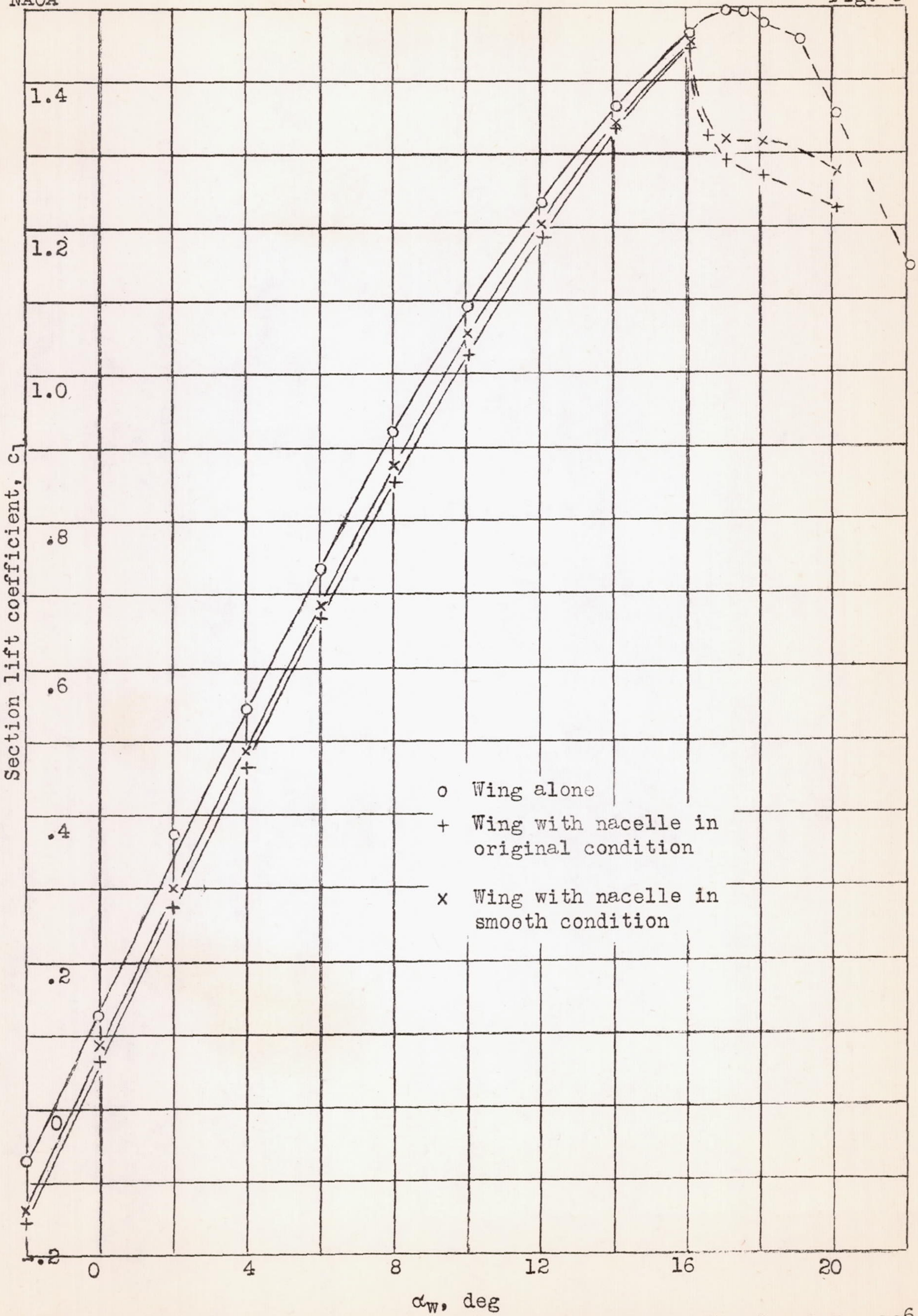

Figure 5.- Lift comparison of wing with and without nacelle. R_w, 6.5×10^6.

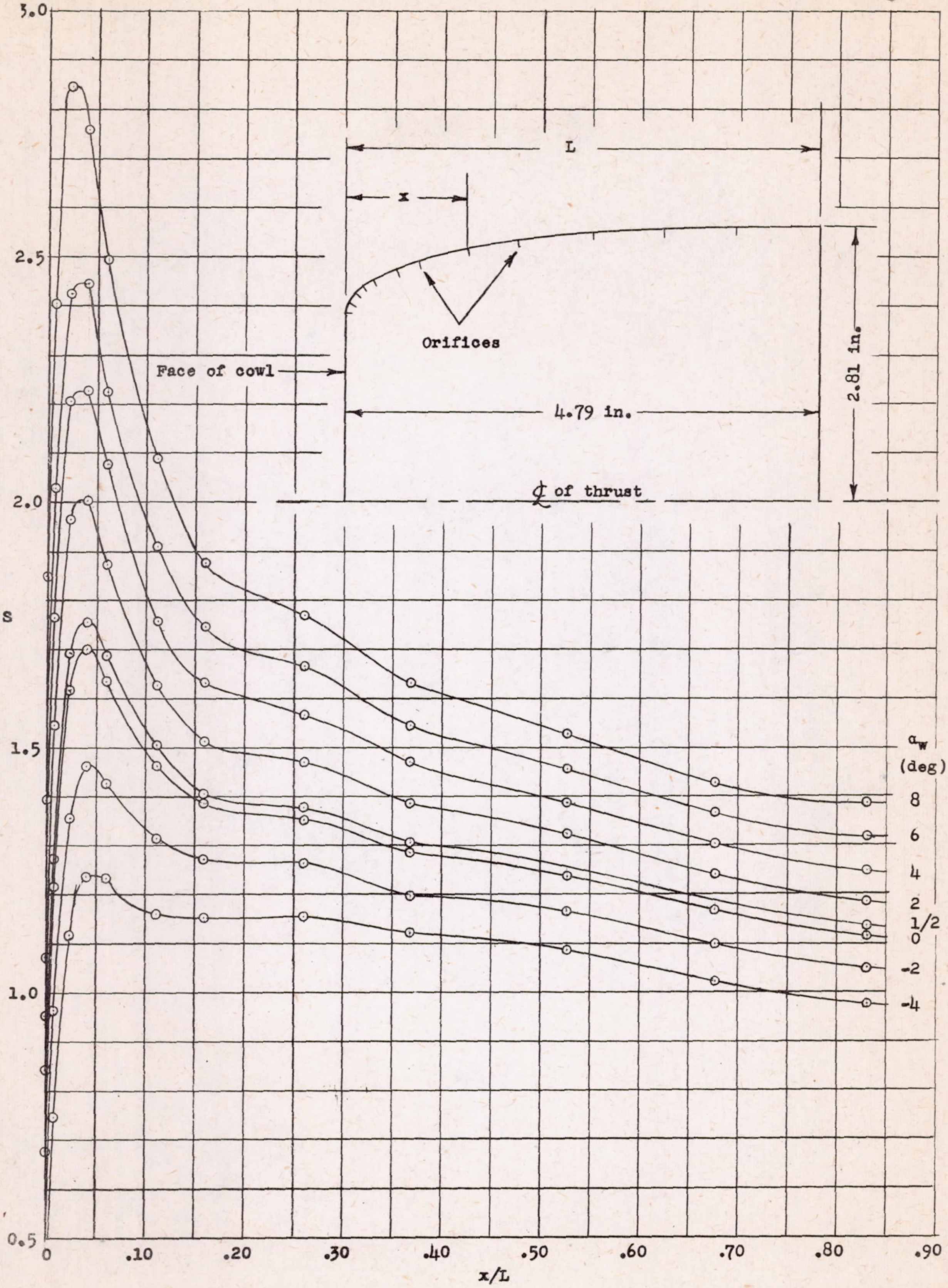

Figure 6.- Pressure distribution over top of cowl. R_W, 6.5×10^6. (Angles of attack are those of wing which has 1/2° incidence to nacelle thrust line.)