NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL MEMORANDUM REPORT

for

Army Air Corps, Materiel Division, War Department

TESTS OF THE XP-46 AIRPLANE IN THE N. A. C. A. FULL-SCALE WIND TUNNEL

By F. R. NICKLE and W. J. NELSON

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INTRODUCTION

An investigation has been conducted on a full-scale model of the proposed XP-46 airplane in the N. A. C. A. full-scale wind tunnel pursuant to the request of the Army Air Corps, Materiel Division. The primary purpose of the investigation was to determine the optimum arrangement of the various component parts to obtain the maximum high speed and to provide adequate engine cooling. Additional tests included a determination of the stalling characteristics and the effectiveness of ailerons and elevators. The profile drag of the wing was ascertained by the momentum method; the location of the transition point on the wing and the critical compressibility velocities of the various airplane components were determined from surface pressure surveys.

The design characteristics of the XP-46, a single-place Curtiss pursuit, were as follows:

Gross weight (estimated)	6,600 lb.
Wing area	170 sq. ft.
Wing section	23016.5 to 23009
Propeller	3-blade, 10 ft. 6 in. diameter, Curtiss controllable pitch
Engine	Allison V-1710-F3R
Military rating	1,150 horsepower at 3,000 r. p. m. and 12,000 ft. altitude
Propeller shaft ratio	2:1

The test model was constructed of wood with the external surface finished with glazing clay and polished to a mirror-like smoothness.

AIRPLANE MODIFICATIONS AND TESTS

The N. A. C. A. full-scale wind tunnel and the balance equipment used for the force measurements are described in reference 1. The method of mounting the airplane on the balance in the tunnel jet is illustrated in figure 1. The special techniques and the apparatus used for the momentum and transition measurements are described in references 2 and 3. The static pressure measurements required for the determination of the critical compressibility velocities were obtained with flush orifices in certain locations and with 1/16-inch-diameter static pressure tubes mounted 3/16 inch from the surface for other locations.

The air velocities through the various cooling ducts were measured by means of rakes of pitot-static tubes located several inches behind the radiators. Wool tufts were used from time to time throughout the entire investigation as an aid in visualizing the air flow over the airplane and through the ducts.

The two 8-inch-diameter oil coolers, having a total frontal area of 0.699 square foot, were located in wing ducts approximately 5 feet each side of the thrust axis. The oil coolers, as well as the various Prestone radiators, were of standard cartridge core construction using 0.230-by 0.260-inch copper tubes 12 inches long. The original installation provided two interchangeable sharp-edge inlets and an outlet with an external flap. One additional inlet with rounded edges and a refaired outlet employing the internal N. A. C. A. flap arrangement were prepared as part of the wind-tunnel investigation in an effort to decrease the detrimental effect of the ducts on the stalling characteristics. A detailed view of all arrangements tested is shown in table III. All inlets were of approximately equal area, and varied only in vertical location relative to the wing stagnation point. Figure 2a pictures a typical duct inlet. Between the inlet and the cooler the ducts were sharply curved to pass over the retracted landing-gear strut. Vanes were located through the region of maximum curvature in an effort to improve the passage. The outlets (fig. 2) are located on the upper surface of the wing and flow control is provided by means of flaps.

The carburetor installation provided for air to enter the scoop, pass through a duct, and be discharged from the exhaust stacks. By means of conical reducers on the exhaust stacks it was possible to regulate this air flow for the various drag and ramming pressure measurements. The three intake arrangements tested are shown in figures 3 and 4. The original duct inlet, with an area of 37.1 square inches, was elliptical in cross section and raised above the surface of the fuselage. The revised forward inlet fitted close to the fuselage, was more nearly rectangular, and had an area of only 26.9 square inches. The third arrangement consisted of a recess in the fuselage nose which faired into a 27.8-square-inch flush inlet so that the fuselage lines remained unbroken. All inlets expanded to the same 6-inch by 9-inch elliptical duct. The rake of pitot-static tubes used for determining the air flow and ram was located at this station.

The Prestone radiator duct investigation included a study of two radiator locations, designated as forward and rear, with a number of inlet and outlet arrangements for each position. Two 9-inch by 19-1/2-inch elliptical radiators, located close to the outside skin so as to fit around the Allison engine, were used in conjunction with three inlets and six outlets (fig. 5) in the forward installation. The underslung inlet (fig. 6) was approximately rectangular in cross section and extended for its full depth below the original surface. The two other inlets, designated as the flush type, did not extend below the normal fuselage lines and varied only in the size and consequent location of the opening. As originally installed these flush inlets had a pronounced longitudinal roll in the upper corners of the duct forcing the air not entering the duct to flow outward over a relatively sharp edge. For certain of the tests this roll was eliminated by means of the large plasticene fairing shown in figure 7b. The outlets were identical for all inlets and included three flush type, two flapped arrangements, and one cover plate for zero air flow.

The rear radiator installation used a single 20-1/2-inch-diameter radiator located in the fuselage behind the wing. The three inlet arrangements, with modifications, and three outlets are detailed in figure 9. Inlet A was tested with two upper duct surfaces giving different rates of expansion immediately behind the inlet. Inlet B, smaller and farther forward, was investigated both with and without the dividing vanes. In addition, this inlet was rotated 30° down about a point 20-1/2 inches back of the duct leading edge producing a large inlet scoop. The last arrangement tested, inlet C, was the original sloping inlet provided by the Curtiss Company. The outlets included two flush arrangements with a flap provided for the larger. Typical inlet and outlet arrangements are pictured in figures 10 and 11.

Preliminary tuft observations and force tests indicated that the original model stalled relatively early at the wing roots producing a low maximum lift. Since it was apparent that the trouble was primarily wing-fuselage interference, two modifications of the wing-fuselage juncture were studied. The first arrangement, designated as the large fillet, was designed to eliminate the reentrant angle between wing and fuselage. Figure 12 gives details of the new arrangement as well as a comparison with the original fillet at the wing trailing edge. The second modification for eliminating the root stall was a new leading edge for a portion of the wing close to the fuselage. This arrangement, shown in figure 13, increased the effective camber of the wing root section thereby decreasing the adverse pressure gradient over that portion of the wing. It was designed to be used in connection with either the original or the new large fillet.

The landing gear retracted laterally into the lower surface of the wing. The wheel was then covered by flush plates making an exceptionally smooth installation. With the landing gear down (fig. 14) the wheel wells are left open and a portion of the wheel well cover extends vertically down from the bottom of the fuselage.

The windshield built into the model as an integral part of the fuselage was a well-rounded double-curvature design which faired quite smoothly into the fuselage lines. The more favorable vision through flat as compared with double-curvature surfaces led to the design shown in figure 15. A long sloping surface extending well forward was connected by curved surfaces of varying radii to flat surfaces on either side. The entire assembly was then faired smoothly into the original cockpit cover. Figure 5 shows this arrangement mounted on the airplane.

The armament consisted of two fuselage guns, mounted on the under part of the fuselage nose (fig. 16a), and four internal wing guns in each wing. These wing guns were designed to be entirely concealed and were simulated in the tests by 2-inch round holes drilled in the leading edge of the wing (fig. 16b).

Two fuselage noses were available for the model. A short nose, designed to accommodate the Allison F-type engine, was used for the majority of the investigations. The longer nose, suitable for the Allison C-type engine, was used for all the Prestone radiator tests.

The complete detailed test program is shown in table I.

RESULTS AND DISCUSSION

The high-speed drag coefficients of the model with the optimum arrangements of the necessary appendages, as determined from the various test conditions, are presented in figure 17 and table II. Results are given for a test speed of 100 miles per hour. The variation in drag coefficient with tunnel speed for two of the test conditions is shown in figure 18.

Oil coolers. - The results of the oil cooler wing duct investigation are presented in table III with the detailed dimensions of the various arrangements. The air quantities have been extrapolated to a flight speed of 216 miles per hour for the climb attitude and to 430 miles per hour for high-speed attitude. Drag increments were obtained for each high-speed arrangement by the momentum method at a tunnel speed of 78 miles per hour and were checked in two cases by force tests. The duct properties (efficiency and power coefficient) have been computed from these data for the high-speed arrangements.

It will be noted that for the high-speed condition, with outlet flaps closed, all oil cooler arrangements, except those with the 1-percent inlet, provide more than 6,000 cubic feet of air per minute, and those arrangements using the 1-percent inlet provide less then 4,000 cubic feet per minute. Since 4,280 cubic feet per minute are required for proper cooling, the former arrangements deliver nearly 50 percent excess air, while the 1-percent inlet and N. A. C. A. outlet gives an 8-percent deficit. This would indicate that with the 2-percent and 3-percent inlets the outlet opening could be greatly reduced with a consequent reduction in drag. The deflection of the outlet flaps (both types) produced sufficient air for climb when used in connection with the 2-percent inlet, but gave insufficient air flow with the 1-percent inlet. It is of particular interest to note the high efficiency of the ducts with the 2-percent and 3-percent inlets and the poor efficiency of the same ducts when the 1-percent inlet is used. This is believed to be largely due to the sharp upward curvature of the duct upper surface just inside the inlet.

The various duct inlet arrangements decreased the maximum lift of the model in increasing amounts as the inlet was raised above the stagnation point (dimension 'a' increased). This effect was particularly marked with the large N. A. C. A. wing fuselage fillet in place. More complete discussion of this effect will be found in a later section of this report.

Redesign of the duct inlet is therefore indicated to provide sufficient air flow without adverse maximum lift effects. It is possible that increasing the lip radius of the 2-percent inlet would decrease the effect on maximum lift without seriously affecting the air flow. Redesign of the 1-percent inlet so as to give a smooth even expansion without reverse curvature, however, would probably allow sufficient air flow at good efficiency with even less effect on the maximum lift. Further information regarding optimum duct design may be found in reference 4.

Carburetor and exhaust stacks. - The addition of the exhaust stacks to the airplane increased the high-speed drag coefficient by 0.0003.

The results of the carburetor intake investigation, corrected to 12,000 feet altitude and extrapolated to the estimated flight speed, are presented in table IV. Since the engine to be used requires 8,100 pounds of air per hour, any of the three arrangements tested satisfies the flow requirements. It is interesting to note that the revised forward inlet gave considerably more air flow for each exhaust stack outlet area than the larger original inlet.

In order to obtain a correct indication of the relative merit of the three inlets tested, drag and ramming pressure must be compared on a basis of equal air flow. For the required 8,100 pounds per hour the following values of ram and drag are indicated at high speed:

Arrangement	Ram (percent q)	ΔC_D
Original inlet	97.4	0.0008
Revised forward inlet	97.6	.0001
Flush inlet	65.0	0

The available ramming pressure is therefore practically identical for the two forward arrangements but is 30 percent lower for the flush type inlet. The drag results indicate that both the flush and revised forward inlets are of approximately equal merit and that both are definitely superior to the original arrangement.

The effect of the rotation of the slipstream (not possible to investigate on this model) may appreciably increase the drag of all arrangements tested, as was observed during recent tests of a pursuit airplane with an air-cooled engine and external carburetor scoop. The drag was appreciably reduced by improving the inlet fairing so as to provide a smoother flow across the scoop. This would suggest the use of a flatter arrangement faired smoothly into the fuselage.

All drag measurements include the recovery of energy obtained by ejecting the carburetor air through the exhaust stacks. Under actual flight conditions the exhaust thrust would be considerably greater due to the addition of heat energy from the engine and it is probable that the carburetor scoop-engine-exhaust stack combination (power on) would produce a net thrust.

Prestone radiator ducts. - The Prestone radiator duct results as obtained on the model with the long fuselage nose are presented in the four sets of curves shown in figure 19. Comparative tests of the two fuselage noses showed the same high-speed drag for the model with the long nose as with the short nose. Drawings of the ducts are given in figures 6 and 10. Air quantities for the high-speed attitude are indicated by curves of the flow ratio, V_R/V, versus exit area, and for climb by curves of V_R/V versus exit flap chord with outlet area remaining constant. The drag of the various high-speed arrangements is presented by curves of ΔC_D versus outlet area. Arrows on the latter family of curves indicate the conditions under which proper air flow will be obtained. The fourth set of curves illustrates the scale effect on C_D for two of the arrangements tested. Final drag data are taken for a test speed of 100 miles per hour.

The forward underslung duct will furnish sufficient air (14,320 cubic feet per minute at 430 miles per hour at 12,000 feet, or $V_R/V = 0.19$) with an outlet of 90 square inches. The drag increment for this arrangement would be 0.0011, which is 6.4 percent of the smooth model drag and gives a duct efficiency of 26 percent. Proper cooling for climb can be obtained by using an outlet of approximately 226 square inches with a 6-inch flap deflected 45°. It will be noted in a later section of this report that the outlet flaps on the forward radiator ducts have a beneficial effect on the maximum lift of the airplane.

The flush type ducts produced excessive drag for all arrangements, and with the smaller inlet failed to give sufficient air flow for climb regardless of exit area or flap size. The high drag values are attributed in large part to the longitudinal roll in the upper corners of the inlet and to the rapid expansion in the diffuser. An attempt to improve the duct corners by means of the large plasticene fillet resulted in better external flow but very little increase in duct efficiency. Previous tests, however, have indicated the value of this type of inlet and further research on flush type scoops is recommended.

The rear radiator installation will give sufficient air flow for high speed with all the inlet arrangements tested if an outlet of approximately 140 square inches is employed. For the climb condition results indicate that an exit flap larger than the 5-inch flap tested will be necessary to provide sufficient air flow. It will be noted, however, from the curves in the upper right-hand corner of figure 19 that flap effectiveness decreases for flaps larger than 5 inches. If a larger flap fails to provide the required air, the tests indicate that an inlet flap with a 5-inch outlet flap will provide more air than needed for the climb condition. The high-speed drag for inlet B with vanes will be 0.0010 for proper air flow. This is slightly less than for the forward underslung arrangement.

The addition of the vanes to inlet B had little effect on total air flow or drag increment but produced a much better flow distribution at the radiator as shown in figure 20. With this inlet, lowering the wing landing flaps decreased the air flow by approximately 3 percent. With inlet and outlet flaps down to obtain sufficient air for climb the maximum lift was decreased 9 percent.

Windshields. - The plasticene fillet at the intersection of the original windshield and fuselage, which had a 5-inch radius on the fuselage center line and faded out along the sides, failed to decrease the high-speed drag coefficient of the model. The flat-sided windshield, however, gave a decrease of 0.0002 when tested on the smooth model. When tested in the presence of the revised forward carburetor inlet, this gain was not obtained and the drag was the same as for the original windshield. The flow disturbance induced by the protruding carburetor inlet was unquestionably responsible for this difference in results. The more favorable vision through the flat surfaces of this windshield together with test results which indicate that the compressibility burble will not occur any earlier than with the original windshield suggests that this design is worthy of consideration.

Armament. - The addition of the fuselage guns and blast tubes increased the high-speed drag coefficient by 0.0003. The addition of the eight internal wing guns, four in each wing, brought the total armament drag coefficient increment to 0.0005.

Wing drag. - The results of the wing profile-drag measurements obtained by the momentum method are shown in figure 21. The profile-drag coefficient of the wing, including the wing duct (2-percent inlet and original outlet with flap closed), is 0.0080. With the oil cooler ducts sealed the profile drag is 0.0074, as compared with an estimated smooth wing drag of 0.0061 at the same average Reynolds Number. The locations of the transition points on the upper wing surface for two stations, one inboard of the slat and aileron and the other in the span of the aileron and closed slat, are shown in figure 22 at the approximate high-speed lift coefficient, $C_L = 0.12$. On the smooth wing section the transition point occurred at $s/c' = 0.18$, and on the slotted section at $s/c' = 0.15$, which corresponds to the trailing edge of the slot. The relatively large profile drag of the outboard portion of the wing can therefore be attributed in part to the early transition from laminar to turbulent flow induced by the rough wing slat installation. The remainder of the drag difference between the XP-46 model wing and the smooth wing is attributed to surface waves and irregularities, the aileron slot, and the landing flap installation.

Critical compressibility speeds. - Measurements were made of the maximum negative pressures on the large fillet, original fillet, wing, revised forward carburetor scoop, exhaust stacks, and windshields for the high-speed flight attitude for determination of the critical compressibility speeds. The results obtained by the method of reference 5 are shown in figure 23.

Results indicate that a compressibility burble will occur first in the wing-fuselage fillet. The critical speed is 450 miles per hour at 12,000 feet with the large fillet or 470 miles per hour with the original fillet. The results predicted by this method are not conservative and the actual compressibility burble may occur at speeds as much as 10 to 20 miles below those indicated.

High-speed estimate. - The high-speed determination of this airplane as presented in figure 17 was based strictly on the wind-tunnel results obtained for a test speed of 100 miles per hour. It is of interest to predict as closely as possible from these results the probable free-flight high speed of the airplane. The necessary extrapolation is at best approximate, and for the present calculations it has been assumed that the decrease in drag will be the same as that of the completely smooth model as computed by the equation

$$C_{D_{flight}} = C_{D_{test}} \left(\frac{R_{test}}{R_{flight}}\right)^{0.11}$$

This extrapolation is carried to a speed of 300 miles per hour; above this speed it is assumed that compressibility effects will offset scale effects. In the present case a ΔC_D = 0.0020 was subtracted from the 100-mile-per-hour test results for scale effect. The curves of figure 24 have been computed in this manner and indicate a high speed of 417 miles per hour at 12,000 feet altitude with 1,150 horsepower.

Aileron and elevator effectiveness. - The rolling and yawing moments produced by deflection of the left aileron of the model are shown in coefficient form in figure 25. It is significant that the maximum rolling moment will be secured with an aileron deflection of approximately -20° (trailing edge up). The presence of positive roll with zero deflection is due to unsymmetrical lift distribution over the wing.

The elevator pitching-moment coefficients are shown in figure 26 for flaps up and in figure 27 for flaps down. The slope of the curves is constant for both conditions but begins to break at slightly lower deflection with flaps down. The elevator effectiveness decreases rapidly for deflections greater than -20°.

Maximum-lift investigation. - The tuft observations (fig. 28) and the lift curve (fig. 29) of the smooth model indicated that an early wing root stall was occurring which produced jagged peaks on the lift curve and a low maximum lift. This is believed to be due to the rapid divergence of the air flow along the wing-fuselage juncture. Since the maximum fuselage section occurs forward of the wing leading edge, the effect is accentuated on this model. In order to study this situation and the effects of various changes a comprehensive series of tests was conducted on the model. These test results have been presented as a series of lift, drag, and pitching-moment curves in figures 29 to 41. The condition of the machine is specified on each figure and the run number is also given so that detailed data for each particular arrangement may be obtained in table I.

It will be noted in figure 29 that the maximum lift coefficient of the model in the smooth condition is 1.23 with flaps and landing gear up and 1.66 with flaps and landing gear down. The installation of the oil cooler wing ducts with the 2-percent inlet and the original outlet with flap open 30° decreased the maximum lift of the model in the landing condition from 1.66 to 1.56 (fig. 30). The addition of the revised forward carburetor scoop and exhaust stacks increased the maximum lift coefficient for the landing condition by 0.05 as shown by a comparison of figures 30 and 31. Opening the wing slots did not have any effect on the maximum lift as indicated in figure 32.

Installation of the large fillet (fig. 12) on the model in the smooth condition, except for the revised forward carburetor scoop and exhaust stacks, increased the maximum lift coefficient for the flight condition over that for the smooth condition from 1.23 to 1.56 and for the landing condition from 1.66 to 2.01. (Compare figs. 29 and 33.) The comparison of results as shown in figures 30 and 31 would show that a small portion of this gain was due to the presence of the carburetor scoop and exhaust stacks. The further addition of the new leading edge (fig. 13) produced an additional small increase in the maximum lift coefficient as indicated by a comparison of figures 33 and 34. The new leading edge, when used with the original fillet, produced a maximum lift coefficient for the flight condition of 1.58 (fig. 35). For the high-speed flight condition the following drag coefficient increments were measured for the various arrangements:

Arrangement	ΔC_D
Large fillet	0.0002
New leading edge	.0009
Large fillet and new leading edge	.0007

The large fillet is therefore the most favorable arrangement and is recommended for use on this airplane. The additional drag of this fillet, however, has not been included in the high-speed estimates. Comparison of figures 33, 36, and 37 shows the effect of the oil cooler ducts upon the model equipped with the large fillet. It will be noted that the ducts with 2-percent inlet eliminated the gain due to the large fillet by reducing the maximum lift coefficient to that obtained with the original fillet (fig. 31). The ducts with the 1-percent inlet, however, had a decidedly less detrimental effect.

The results of a few tests with the long fuselage nose and Prestone radiator installations are shown in figures 38 to 41. It will be noted that the maximum lift coefficient obtained with the long fuselage nose is slightly higher than that obtained with the short nose. The two flush type forward radiator installations with 7-inch exit flap deflected 45° increased the maximum lift nearly as much as the large fillet. This is attributed to the radiator installation setting up favorable turbulence over the wing roots. The rear underslung radiator with inlet scoop and outlet flaps open markedly decreased the maximum lift below that obtained with the smooth nose.

A summary of the foregoing results is presented in table V.

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REFERENCE

1. DeFrance, Smith J.: The N. A. C. A. Full-Scale Wind Tunnel. T. R. No. 459, N. A. C. A., 1933.

2. Goett, Harry J.: Experimental Investigation of the Momentum Method for Determining Profile Drag. T. R. No. 660, N. A. C. A., 1939.

3. Silverstein, Abe, and Becker, John V.: Determination of Boundary-Layer Transition on Three Symmetrical Airfoils in the N. A. C. A. Full-Scale Wind Tunnel. T. R. No. 637, N. A. C. A., 1939.

4. Nickle, F. R., and Freeman, Arthur B.: Full-Scale Wind-Tunnel Investigation of Wing Cooling Ducts. Advance Confidential Report, N. A. C. A., Oct. 1938.

5. Stack, John, Lindsey, W. F., and Littell, Robert E.: The Compressibility Burble and the Effect of Compressibility on Pressures and Forces Acting on an Airfoil. T. R. No. 646, N. A. C. A., 1938.

TABLE I: XP-46 TEST PROGRAM

Test No.	Arrangement of Airplane																			Type of Test						Remarks
	Fuselage Nose	Flaps	Landing Gear	Oil Coolers			Windshield	Exhaust Stacks	Carburetor		Fuselage Guns	Wing Guns	Prestone Radiators			Elevator	Ailerons	Fillets	Wing L.E.	High Speed Drag	Force C_L, C_D, C_m, C_r	Airflow	Momentum	Transition	Compressibility	
				Inlet	Outlet	Flap			Inlet	Outlet			Arrangement	Inlet	Outlet											
1.	Short	Up	Up	—	—	—	Round	—	—	—	—	—	—	—	—	0°	0°	Orig.	Orig.	x	x		x			Smooth condition
2.	"	Dn	Dn	—	—	—	"	—	—	—	—	—	—	—	—	"	"	"	"		x					
	Wing Duct Oil Cooler Investigation																									
3.	Short	Up	Up	3%	Orig.	Closed	Round	—	—	—	—	—	—	—	—	0°	0°	Orig.	Orig.			x	x			See figure
4	"	"	"	2%	"	"	"	—	—	—	—	—	—	—	—	"	"	"	"	x		x	x			
5.	"	"	"	"	"	½ open	"	—	—	—	—	—	—	—	—	"	"	"	"			x				
6.	"	"	"	"	"	Open	"	—	—	—	—	—	—	—	—	"	"	"	"			x				
7.	"	"	"	1%	"	Closed	"	—	—	—	—	—	—	—	—	"	"	"	"	x		x	x			
8.	"	"	"	"	N.A.C.A.	"	"	—	—	—	—	—	—	—	—	"	"	"	"			x	x			
9.	"	"	"	"	"	Open	"	—	—	—	—	—	—	—	—	"	"	"	"			x				
10.	"	"	"	2%	"	Closed	"	—	—	—	—	—	—	—	—	"	"	"	"			x	x			
11.	"	"	"	"	"	Open	"	—	—	—	—	—	—	—	—	"	"	"	"			x				
12	"	Dn	Dn	"	"	"	"	—	—	—	—	—	—	—	—	"	"	"	"		x					
13.	"	"	"	1%	"	"	"	—	—	—	—	—	—	—	—	"	"	"	"		x					
14.	"	"	"	2%	Orig.	"	"	—	—	—	—	—	—	—	—	"	"	"	"		x					
	Windshield Investigation																									
15.	Short	Up	Up	2%	Orig.	Closed	Flat	—	—	—	—	—	—	—	—	0°	0°	Orig.	Orig.	x					x	See figure
16.	"	"	"	"	"	"	Round with fillet	—	—	—	—	—	—	—	—	"	"	"	"	x						
17.	"	"	"	"	"	"	Round	On	—	—	—	—	—	—	—	"	"	"	"	x						
	Carburetor Intake Investigation																									
18.	Short	Up	Up	2%	Orig.	Closed	Round	On	Orig.	Small	—	—	—	—	—	0°	0°	Orig.	Orig.	x		x				See figure
19.	"	"	"	"	"	"	"	"	"	Med.	—	—	—	—	—	"	"	"	"	x		x				
20.	"	"	"	"	"	"	"	"	"	Large	—	—	—	—	—	"	"	"	"	x		x				
21.	"	"	"	"	"	"	"	"	Revised	Closed	—	—	—	—	—	"	"	"	"	x		x				
22.	"	"	"	"	"	"	"	"	"	Small	—	—	—	—	—	"	"	"	"	x		x				
23.	"	"	"	"	"	"	"	"	"	Med.	—	—	—	—	—	"	"	"	"	x		x				
24.	"	"	"	"	"	"	"	"	"	Large	—	—	—	—	—	"	"	"	"	x		x				
25.	"	"	"	"	"	"	"	"	Flush	Small	—	—	—	—	—	"	"	"	"	x		x				
26.	"	"	"	"	"	"	"	"	"	Med.	—	—	—	—	—	"	"	"	"	x		x				
27.	"	"	"	"	"	"	"	"	"	Large	—	—	—	—	—	"	"	"	"	x		x				
	Windshield Investigation continued for Effect of Carburetor Scoop																									
28.	Short	Up	Up	2%	Orig.	Closed	Flat	On	Revised	Small	—	—	—	—	—	0°	0°	Orig.	Orig.	x						
29.	"	"	"	"	"	"	Round	"	"	"	—	On	—	—	—	"	"	"	"	x						

30	"	"	"	"	"	"	"	"	"	"	On	"	—	—	—	"	"	"	"	X						
	Control Effectiveness Measurements																									
31.	Short	Up	Up	2%	Orig.	Closed	Round	On	Revised	Small	—	—	—	—	—	0°	Defl.	Orig.	Orig.		X					
32.	"	"	"	"	"	"	"	"	"	"	—	—	—	—	—	Defl.	0°	"	"		X					
33.	"	Dn	Dn	"	"	"	"	"	"	"	—	—	—	—	—	"	"	"	"		X					
	Transition and Compressibility																									
34.	Short	Up	Up	2%	Orig.	Closed	Round	On	Revised	Small	—	—	—	—	—	0°	0°	Orig.	Orig.					X	X	
	Maximum Lift and Interference Investigation.																									
35.	Short	Up	Up	2%	Orig.	Closed	Round	On	Revised	Small	—	—	—	—	—	0°	0°	Orig.	Orig.		X					
36.	"	Dn	Dn	"	"	"	"	"	"	"	—	—	—	—	—	"	"	"	"		X					
37.	"	"	"	"	"	"	"	"	"	"	—	—	—	—	—	"	"	"	"		X					Slats open
38.	"	Up	Up	"	"	"	"	"	"	"	—	—	—	—	—	"	"	"	"		X					" "
39.	"	"	"	—	—	—	"	"	"	"	—	—	—	—	—	"	"	Large	New	X	X					
40.	"	Dn	"	—	—	—	"	"	"	"	—	—	—	—	—	"	"	"	"		X					
41.	"	Up	"	—	—	—	"	"	"	"	—	—	—	—	—	"	"	"	Orig.	X	X					
42.	"	Dn	"	—	—	—	"	"	"	"	—	—	—	—	—	"	"	"	"		X					
43.	"	"	Dn	—	—	—	"	"	"	"	—	—	—	—	—	"	"	"	"		X					
44.	"	"	"	2%	NACA	Open	"	"	"	"	—	—	—	—	—	"	"	"	"		X					
45.	"	"	"	1%	"	"	"	"	"	"	—	—	—	—	—	"	"	"	"		X					
46.	"	"	"	"	"	"	"	"	"	"	—	—	—	—	—	"	"	Orig.	"		X					
47.	"	Up	Up	—	—	—	"	"	"	"	—	—	—	—	—	"	"	"	New	X	X					
	Prestone Radiator Duct Investigation																									
48.	Long	Up	Up	—	—	—	Round	—	—	—	—	—	—	—	—	0°	0°	Orig.	Orig.	X	X		X			
49.	"	"	"	—	—	—	"	—	—	—	—	—	Forward	Underslung.	Large	"	"	"	"	X		X				See figure
50.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Med.	"	"	"	"	X		X				
51.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Small	"	"	"	"	X		X				
52.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	5" Flap	"	"	"	"			X				
53.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	7" "	"	"	"	"			X				
54.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Closed	"	"	"	"	X						
55.	"	"	"	—	—	—	"	—	—	—	—	—	"	Small Flush	Large	"	"	"	"	X		X				
56.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Med.	"	"	"	"	X		X				
57.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	5" Flap	"	"	"	"			X				
58.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	7" "	"	"	"	"		X	X				
59.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Large	"	"	"	"	X						Refaired inlet, figure
60.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Med.	"	"	"	"	X						" "
61.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Closed	"	"	"	"	X						" "
62.	"	"	"	—	—	—	"	—	—	—	—	—	"	Large Flush	Large	"	"	"	"	X		X				
63.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Med.	"	"	"	"	X		X				
64.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Small	"	"	"	"	X		X				
65.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	5" Flap	"	"	"	"			X				
66.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	7" "	"	"	"	"		X	X				
67.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Closed	"	"	"	"	X						
68.	"	"	"	—	—	—	"	—	—	—	—	—	Rear	A	Small	"	"	"	"	X		X				See figure
69.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	"	"	"	"	"			X				Refaired inlet, figure
70.	"	"	"	—	—	—	"	—	—	—	—	—	"	B	"	"	"	"	"			X				
71.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	"	"	"	"	"	X		X				Vanes in place
72.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	Large	"	"	"	"	X		X				" " "
73.	"	"	"	—	—	—	"	—	—	—	—	—	"	"	5" Flap	"	"	"	"			X				" " "
74.	"	"	"	—	—	—	"	—	—	—	—	—	"	Flap	"	"	"	"	"		X	X				" " "
75.	"	Dn	"	—	—	—	"	—	—	—	—	—	"	"	"	"	"	"	"			X				" " "
76.	"	Up	"	—	—	—	"	—	—	—	—	—	"	C		"	"	"	"							
77.	"	"	"	—	—	—	"	—	—	—	—	—	—	—	—	"	"	"	"	X						

TABLE II: HIGH SPEED DRAG SUMMARY

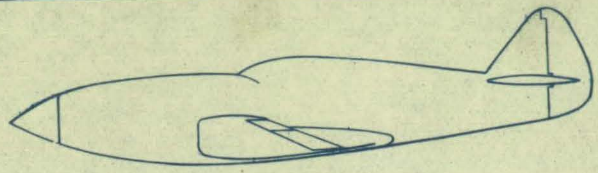
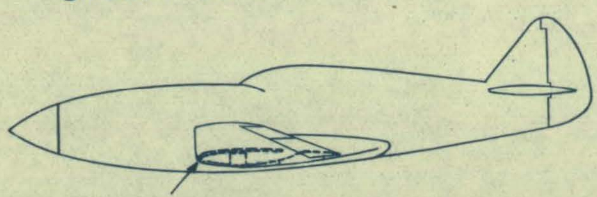
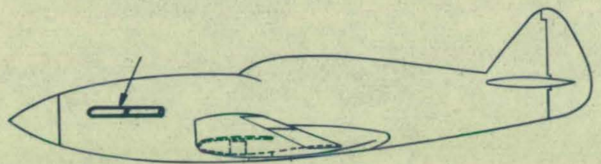
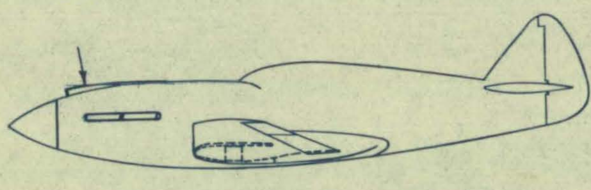
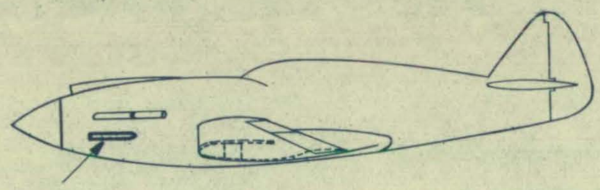
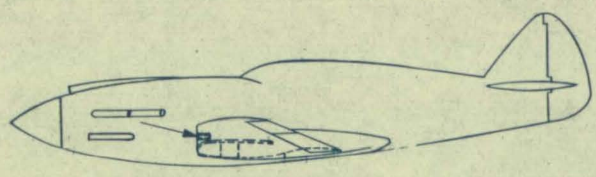
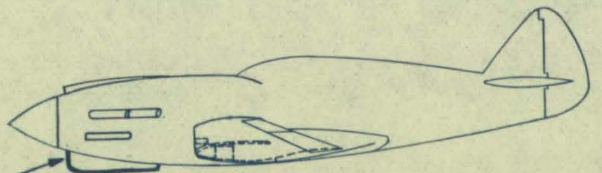
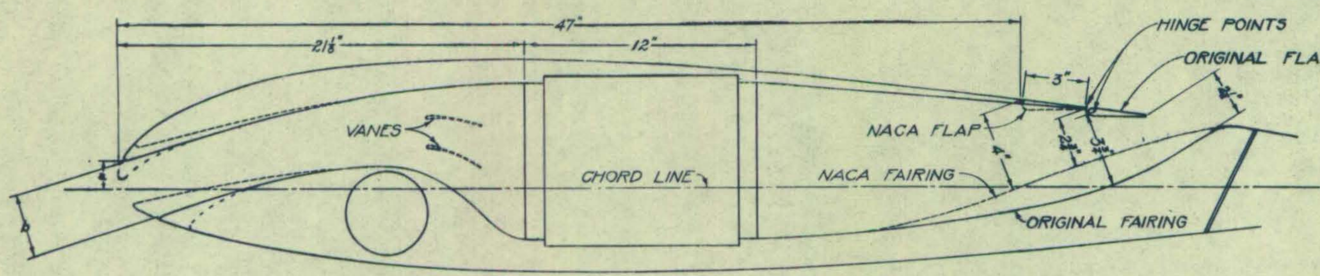
TEST CONDITION	ΔC_D	$C_{D_{HS}}$
 SMOOTH CONDITION	—	0.0173
 WING DUCT OIL COOLERS	0.0006	0.0179
 EXHAUST STACKS	0.0003	0.0182
 CARBURETOR AIR SCOOP	0.0001	0.0183
 FUSELAGE GUNS	0.0003	0.0186
 WING GUNS	0.0002	0.0188
 PRESTONE RADIATOR DUCT	0.0012	0.0200

TABLE III - WING DUCT OIL COOLERS



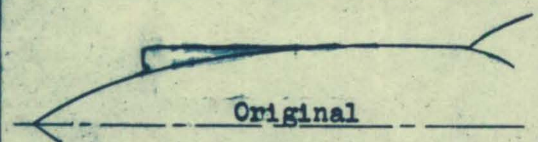
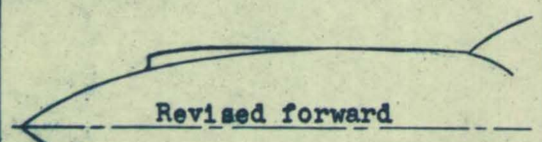
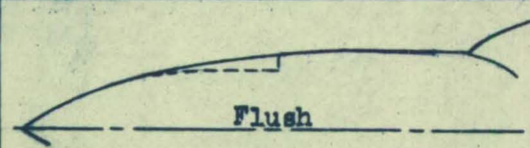
MILITARY RATING AT 12000 FT. ALT. REQUIRES 4280 CU. FT./MIN. AT HIGH SPEED AND 4130 CU. FT./MIN. IN CLIMB

INLET			OUTLET			AIR QUANTITY CU. FT. PER MIN. AT 12000 FEET		DRAG INCREMENT ΔC_D @ $C_L = 0.12$		DUCT PROPERTIES* @ $C_L = 0.12$	
a % CHORD	b % CHORD	AREA SQ. IN.	ARRANGE-MENT	FLAP POSITION	AREA SQ. IN.	$C_L = 0.48$ V = 216 M.P.H.	$C_L = 0.12$ V = 430 M.P.H.	FORCE TESTS	MOMENTUM MEASUREMENTS	EFFICIENCY η	POWER COEFFICIENT C_P
3 %	4.2 %	18.9	ORIGINAL	CLOSED	22.5	2840	6770	—	0.0006	0.52	0.13
2 %	4.6 %	23.3	ORIGINAL	CLOSED	22.5	3360	6820	0.0009	0.0006	0.54	0.12
2 %	4.6 %	23.3	ORIGINAL	15°	—	4550	8370	—	—	—	—
2 %	4.6 %	23.3	ORIGINAL	30°	33.7	4640	8180	—	—	—	—
1 %	4.2 %	18.9	ORIGINAL	CLOSED	22.5	2960	3420	0.0007	0.0007	0.06	0.28
1 %	4.2 %	18.9	NACA	CLOSED	23.7	3060	3940	—	0.0008	0.08	0.29
1 %	4.2 %	18.9	NACA	OPEN	35.0	3360	4450	—	—	—	—
2 %	4.6 %	23.3	NACA	CLOSED	23.7	3590	6070	—	0.0007	0.32	0.17
2 %	4.6 %	23.3	NACA	OPEN	35.0	4130	7330	—	—	—	—

* $\eta = \frac{\text{USEFUL WORK}}{\text{TOTAL WORK}} = \frac{Q \cdot \Delta P}{\Delta D \cdot V}$; $C_P = \frac{(V_0/V_1)^2}{\eta}$ (SEE REFERENCE

TABLE IV

CARBURETOR INTAKE SCOOPS

Duct Characteristics			Flow Characteristics				Drag Data
Type	Inlet Area (sq. in.)	Outlet Area (sq. in.)	$C_L=0.48$ $V = 216$ m.p.h. Ram (% q)	$C_L=0.48$ $V = 216$ m.p.h. Quantity lbs./hr.	$C_L=0.12$ $V = 430$ m.p.h. Ram (% q)	$C_L=0.12$ $V = 430$ m.p.h. Quantity lbs./hr.	ΔC_D $C_L=0.12$
 Original	37.1	22	---	---	95.0	13,820	0.0010
	37.1	15	---	---	97.0	10,390	.0007
	37.1	9	---	---	97.5	7,930	.0008
 Revised forward	26.9	22	94.5	7,960	97.0	14,940	.0005
	26.9	15	94.5	6,170	98.0	12,420	.0003
	26.9	9	95.5	5,260	97.8	8,310	.0001
	26.9	0	---	---	88.0	0	.0000
 Flush	27.8	22	---	---	70.5	12,100	-.0002
	27.8	15	63.0	5,580	73.5	9,810	.0000
	27.8	9	57.4	3,720	61.6	7,200	.0000

Flow characteristics are corrected to 12,000 feet altitude.
Military rating requires 8,100 pounds of air per hour.

TABLE V

MAXIMUM LIFT SUMMARY

	C_L max Flaps & L.G. up	C_L max Flaps & L.G. down	Run No.
Large wing fillet and new leading edge.* (Figure 12)			
Smooth condition	1.23	1.66	1, 2
Large fillet only	1.56	2.01	41, 43
New leading edge only	1.58		47
Large fillet and new leading edge	1.59	2.08**	39, 40
Wing ducts (outlet flaps open). (Table III)			
2% inlet, original outlet. Original wing fillet		1.56	14
2% " NACA " . " " "		1.60	12
1% " " " . " " "		1.66	13
2% " " " . Large " "		1.63	44
1% " " " " " "		1.79	45
Prestone ducts (long fuselage nose on). (Figures 6 & 10)			
Smooth condition	1.28		48
Small flush forward inlet, 7" exit flap	1.49		58
Large " " " " " "	1.51		66
Rear duct, 30° inlet flap, 5" exit flap	1.16		73
Wing slots			
Slots closed	1.32	1.61	35, 36
Slots open	1.31	1.61	37, 38

* Small forward carburetor scoops and exhaust stacks on.
** Landing gear up, flaps down.

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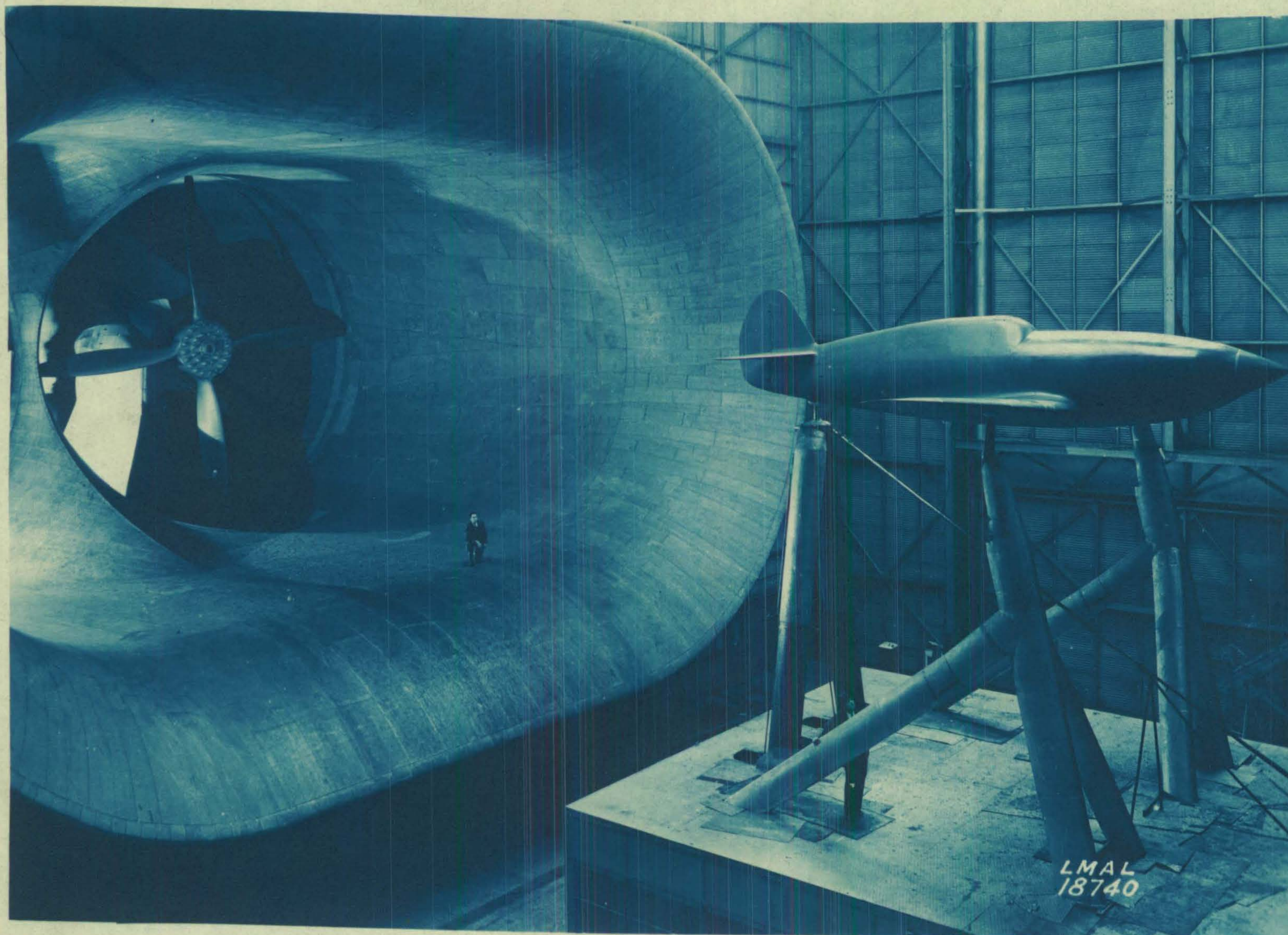

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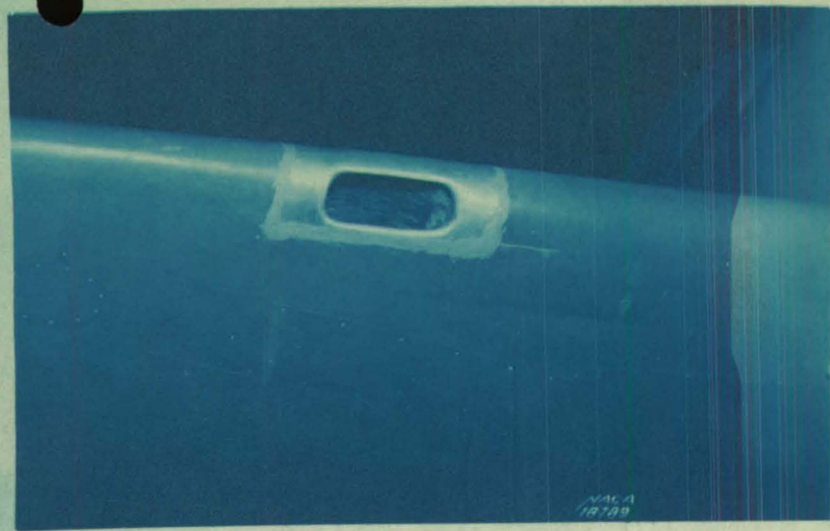
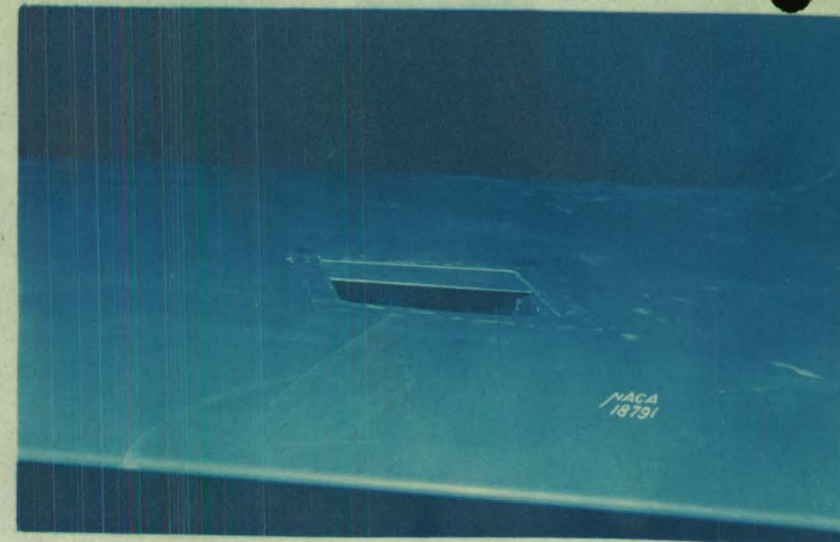
FIGURE 1. - INSTALLATION OF THE XP-46 ON THE FULL-SCALE WIND-TUNNEL BALANCE SUPPORTS.

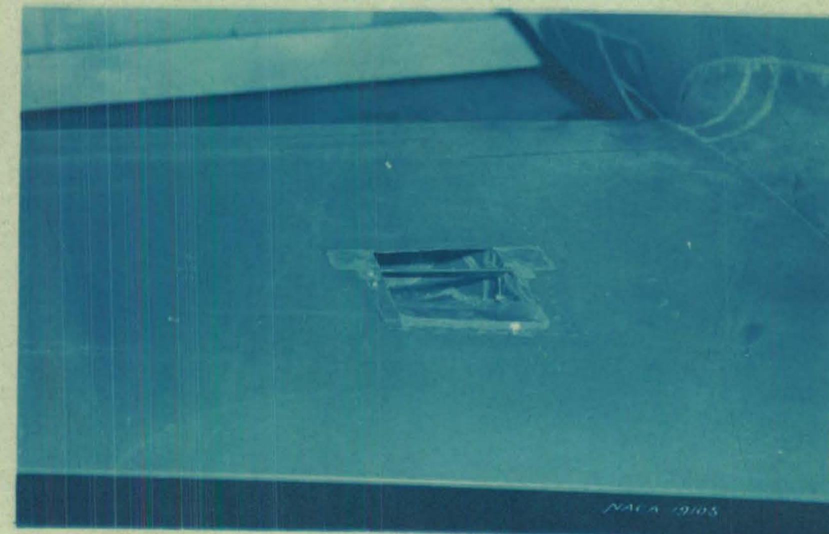


(A) 1 PERCENT C INLET IN PLACE.



B) ORIGINAL OUTLET, FLAP CLOSED.

(C) ORIGINAL OUTLET, FLAP FULL OPEN.



(D) N. A. C. A. OUTLET, FLAP FULL OPEN.

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FIGURE 2. - OIL COOLER WING DUCT INSTALLATIONS.

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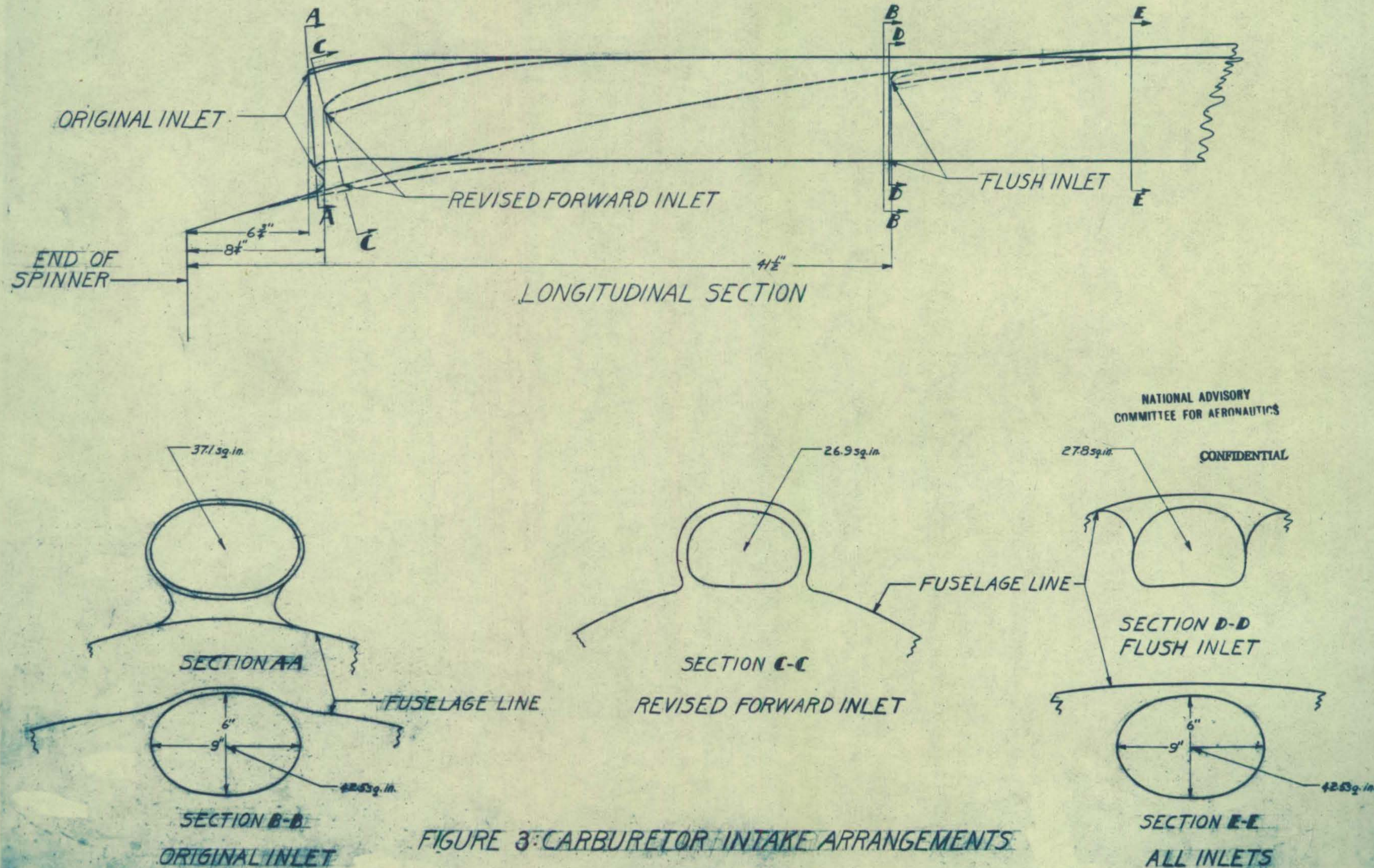

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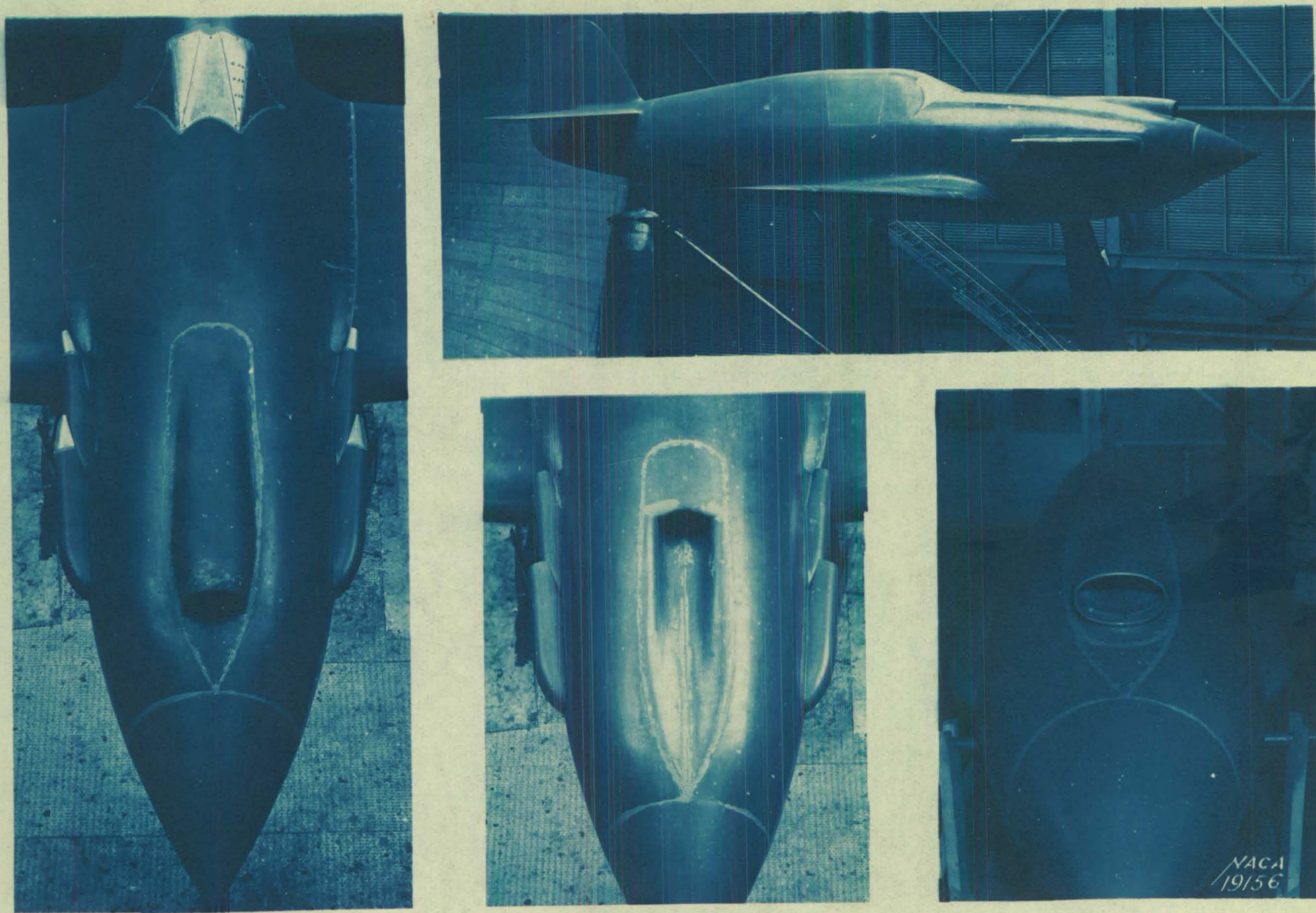
FIGURE 3: CARBURETOR INTAKE ARRANGEMENTS



REVISED FORWARD INLET. FLUSH INLET. ORIGINAL FORWARD INLET.

FIGURE 4. - CARBURETOR DUCT INLET ARRANGEMENTS, EXHAUST STACKS AND FLAT WINDSHIELD IN PLACE.

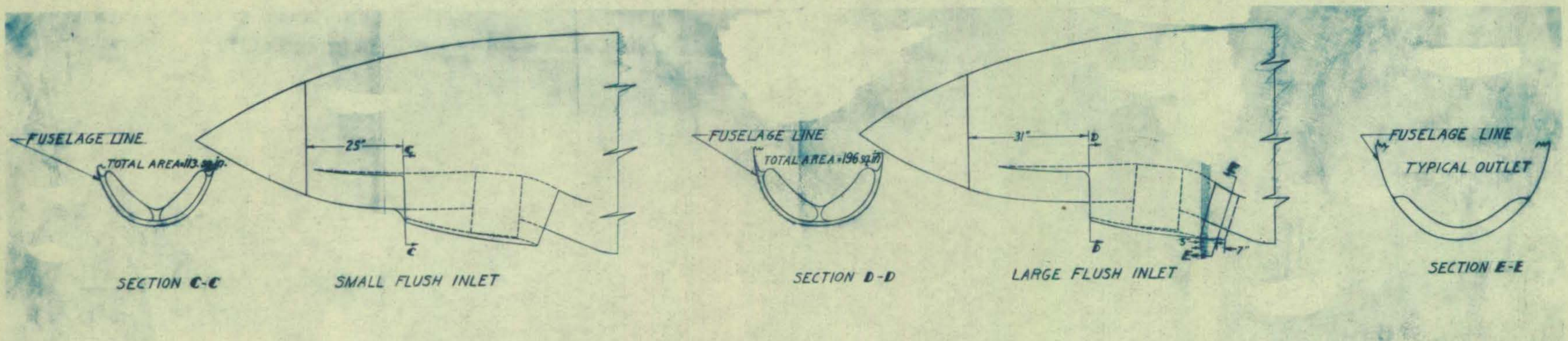
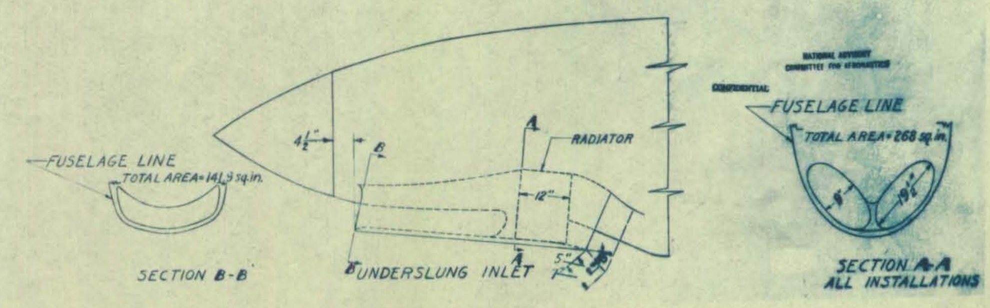


FIGURE 5: FORWARD PRESTONE RADIATOR DUCT ARRANGEMENTS



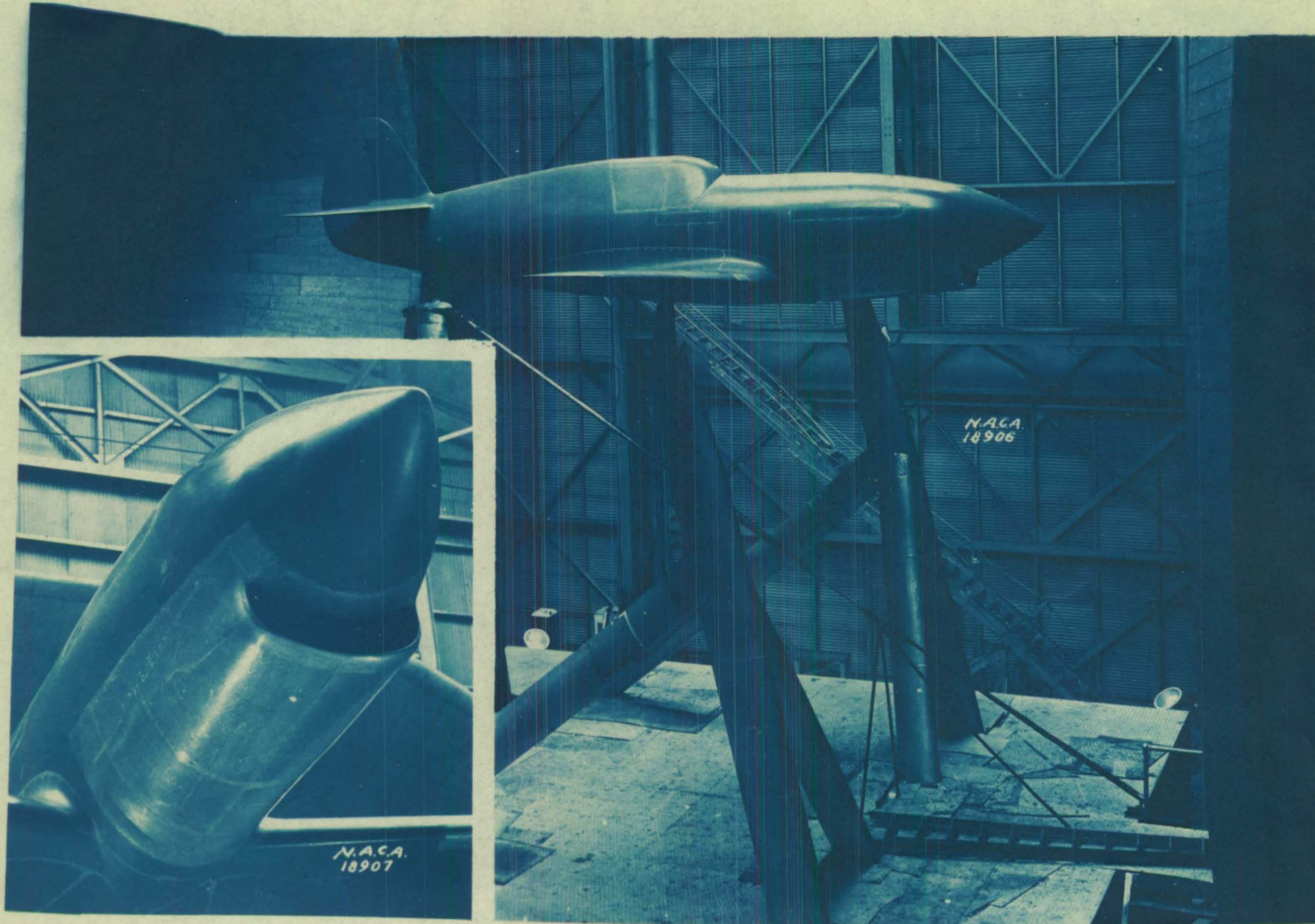
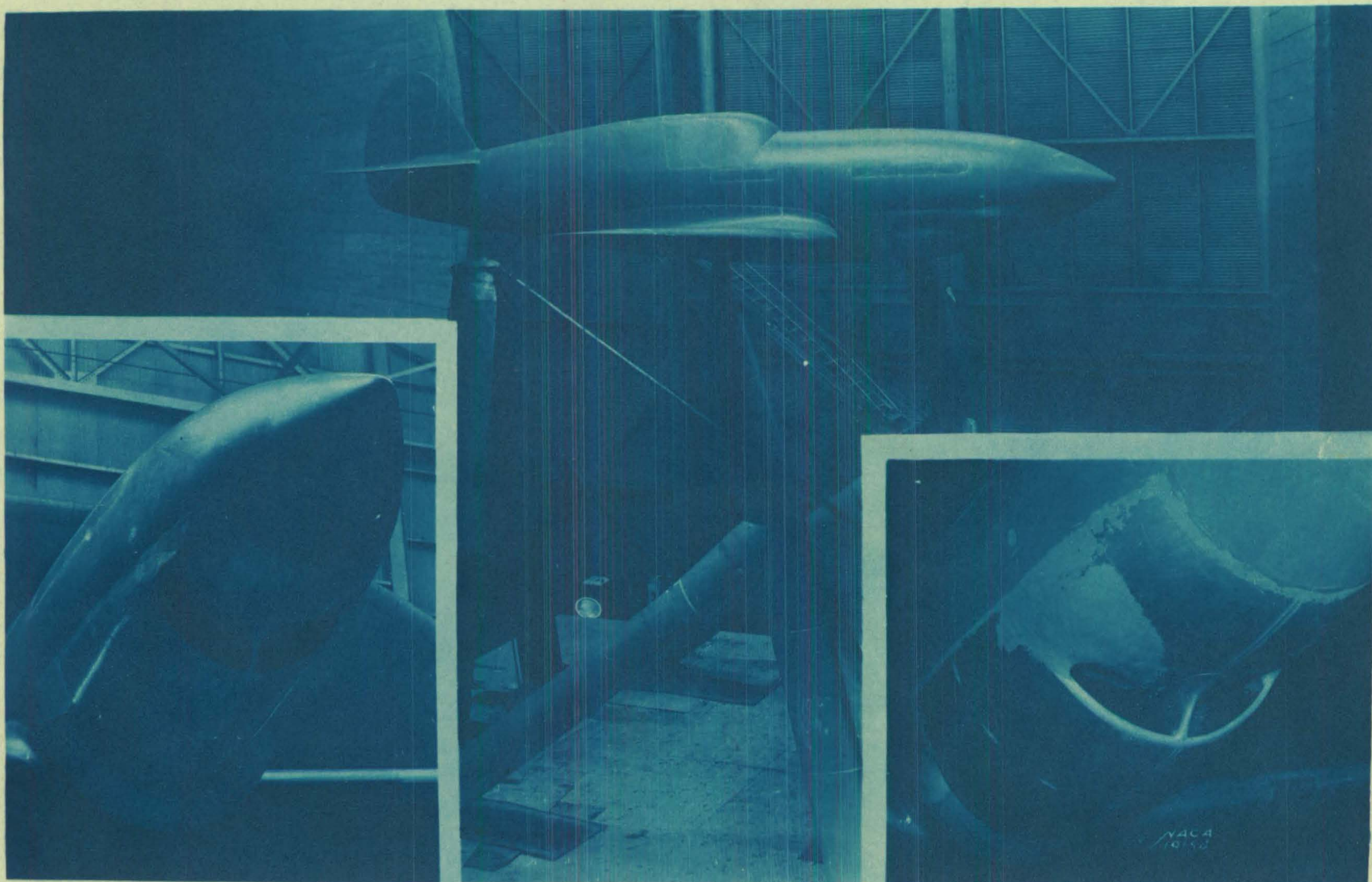


FIGURE 6. - UNDERSLUNG DUCT ARRANGEMENT FOR FORWARD PRESTONE RADIATOR INSTALLATION.



(A) ORIGINAL INLET.

(B) REFAIRED INLET.

FIGURE 7. - SMALL FLUSH INLET FOR FORWARD PRESTONE RADIATOR DUCT INSTALLATION.

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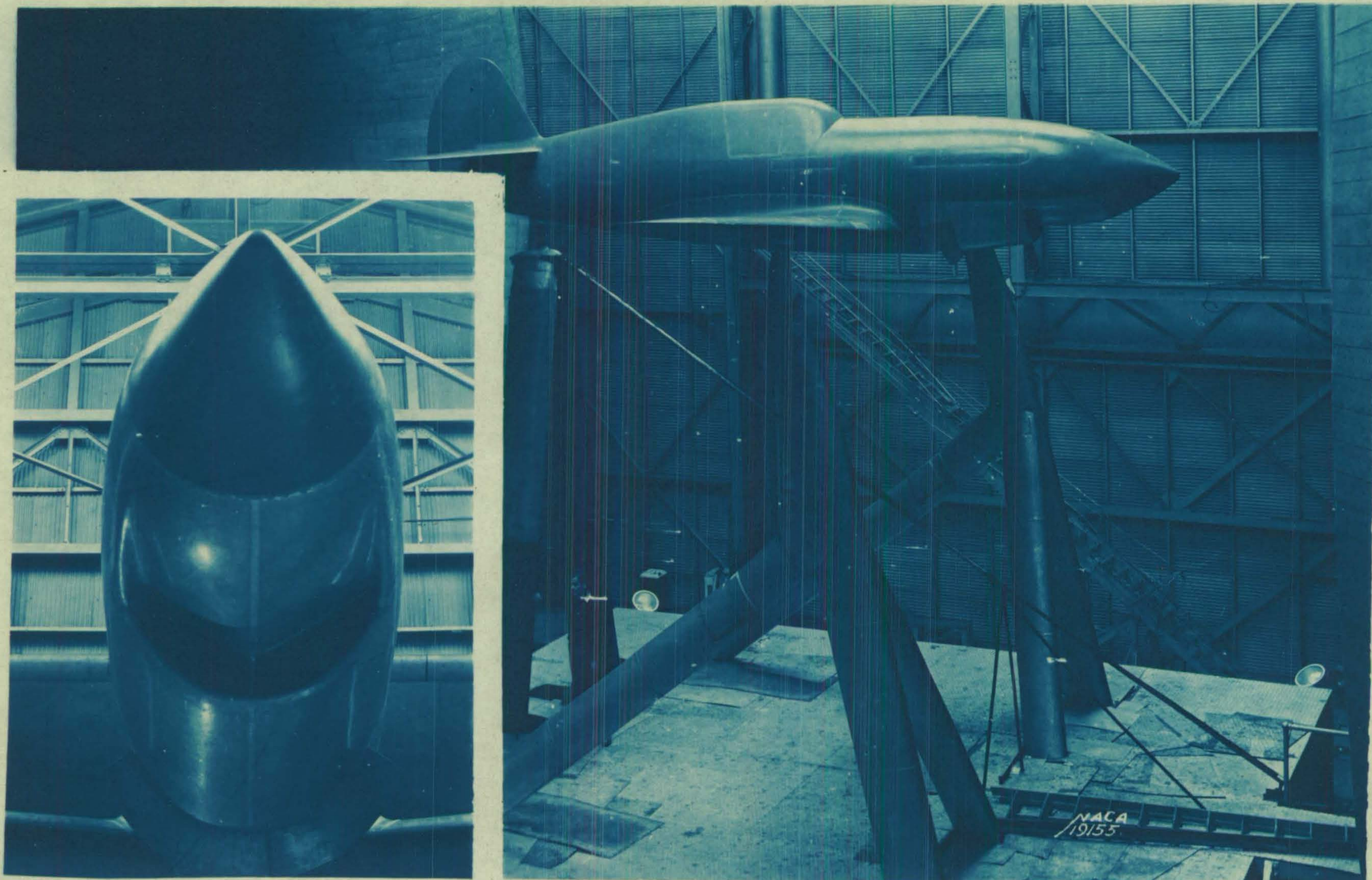


FIGURE 8. - LARGE FLUSH INLET FOR FORWARD PRESTONE RADIATOR DUCT; 7- INCH FLAP ON OUTLET.

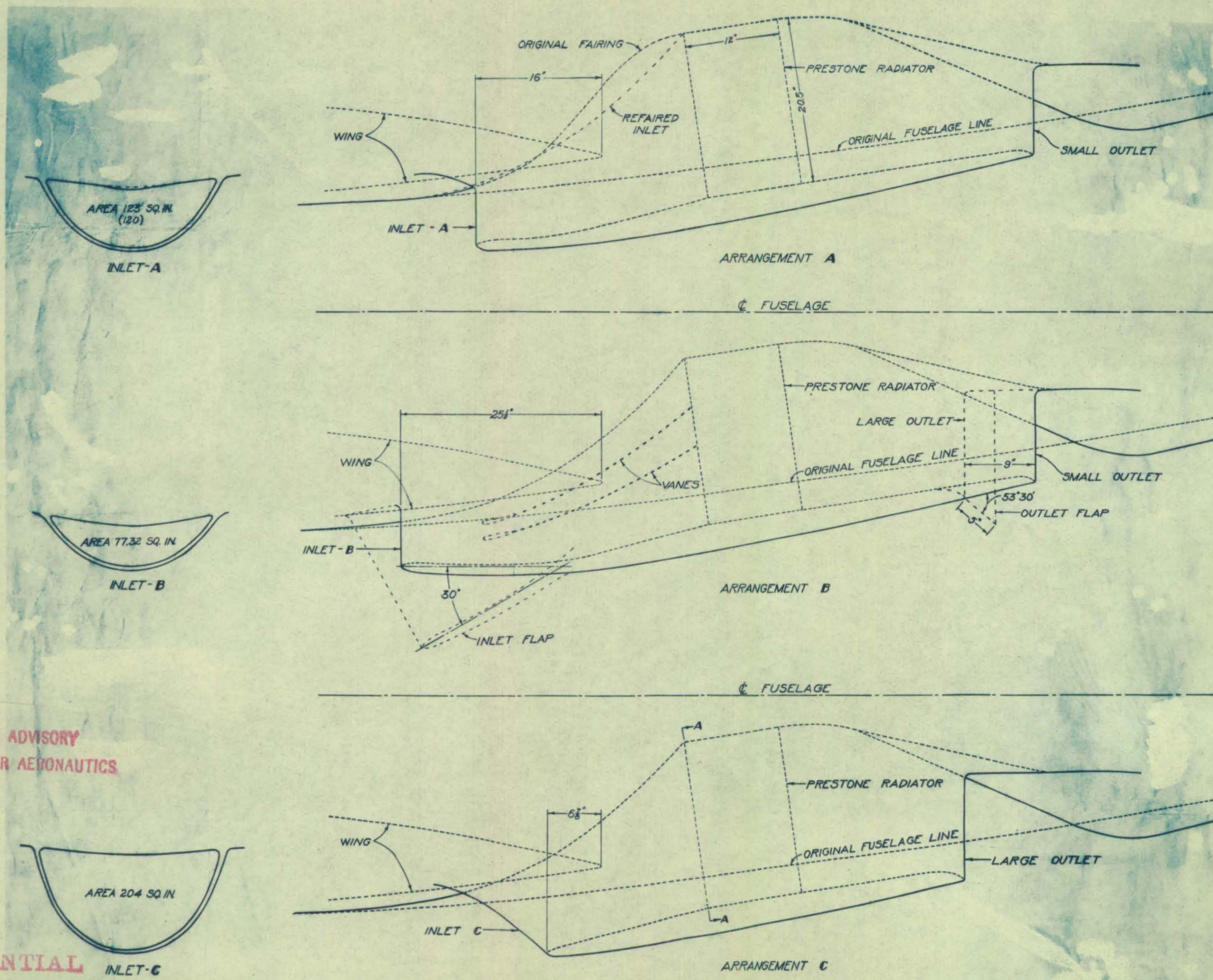


FIGURE 9.- REAR PRESTONE RADIATOR DUCT ARRANGEMENTS

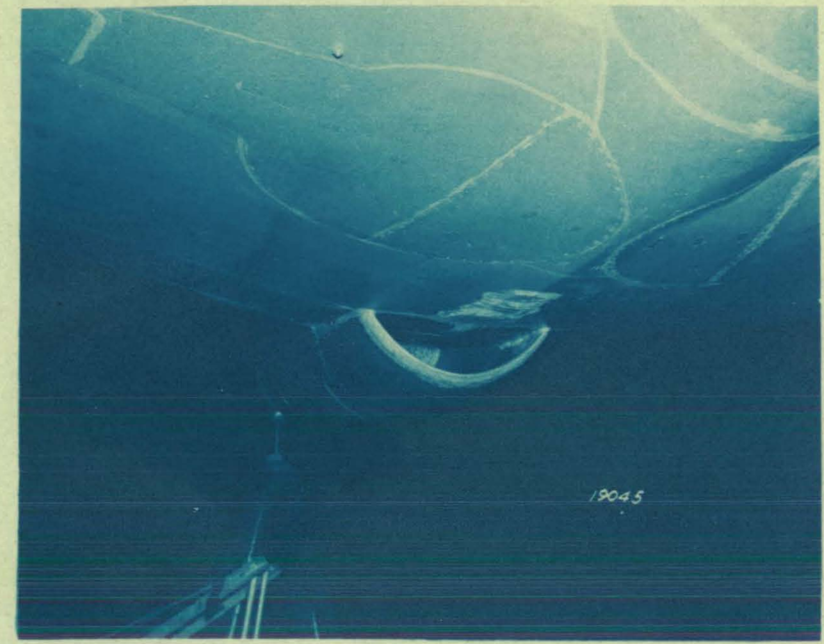


FIGURE 10. - REAR PRESTONE RADIATOR DUCT.
INLET B.

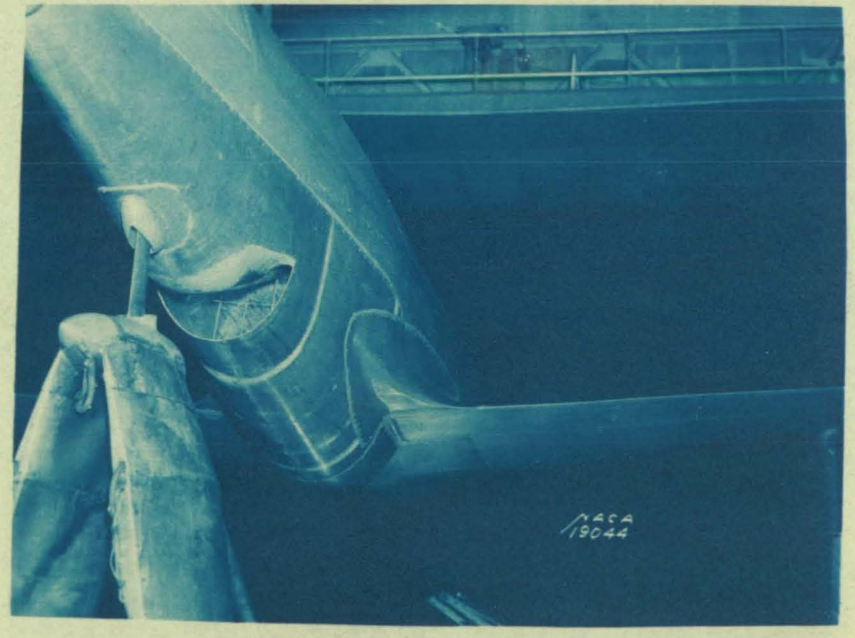


FIGURE 11. - REAR PRESTONE RADIATOR DUCT.
SMALL OUTLET.

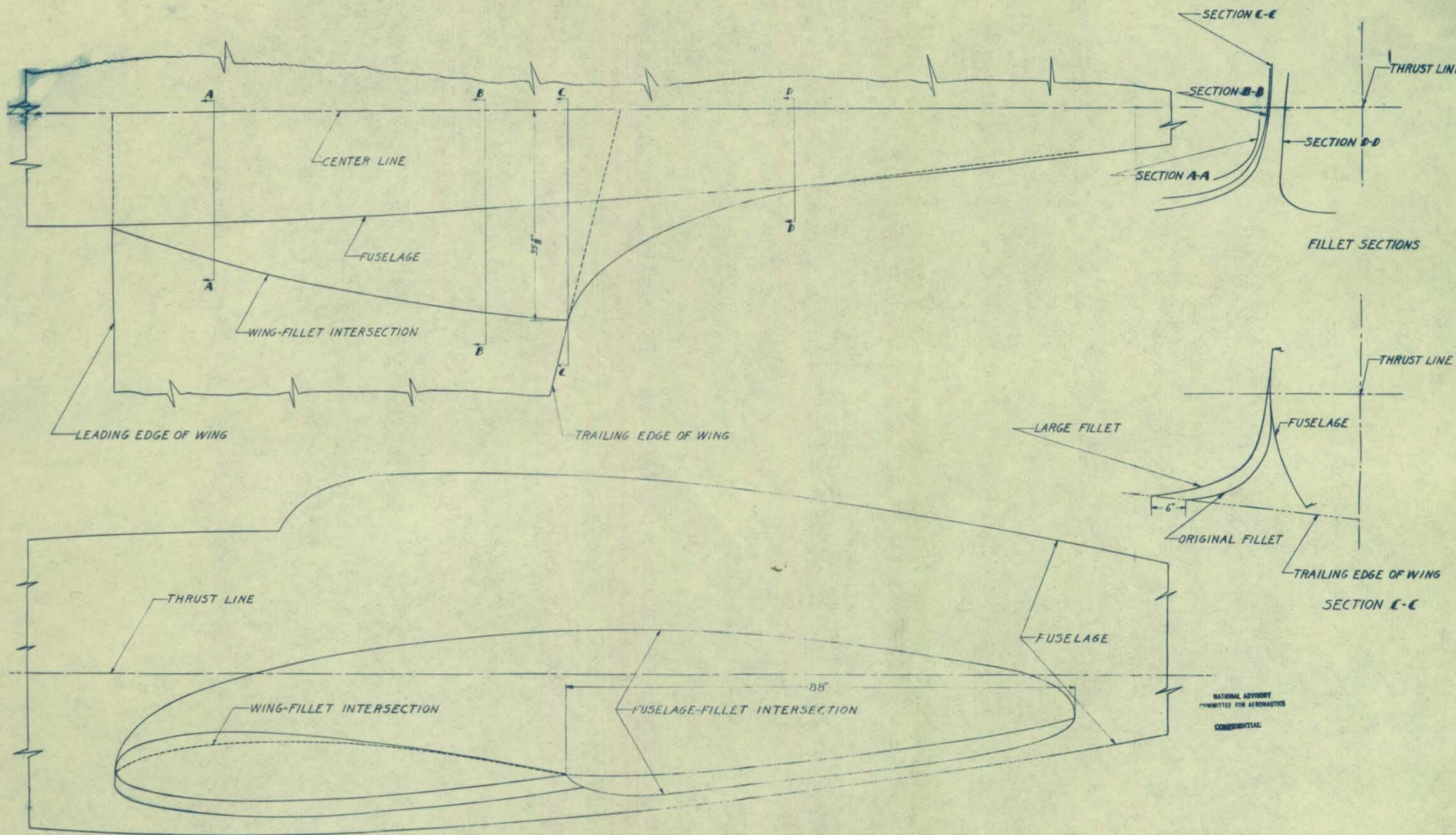
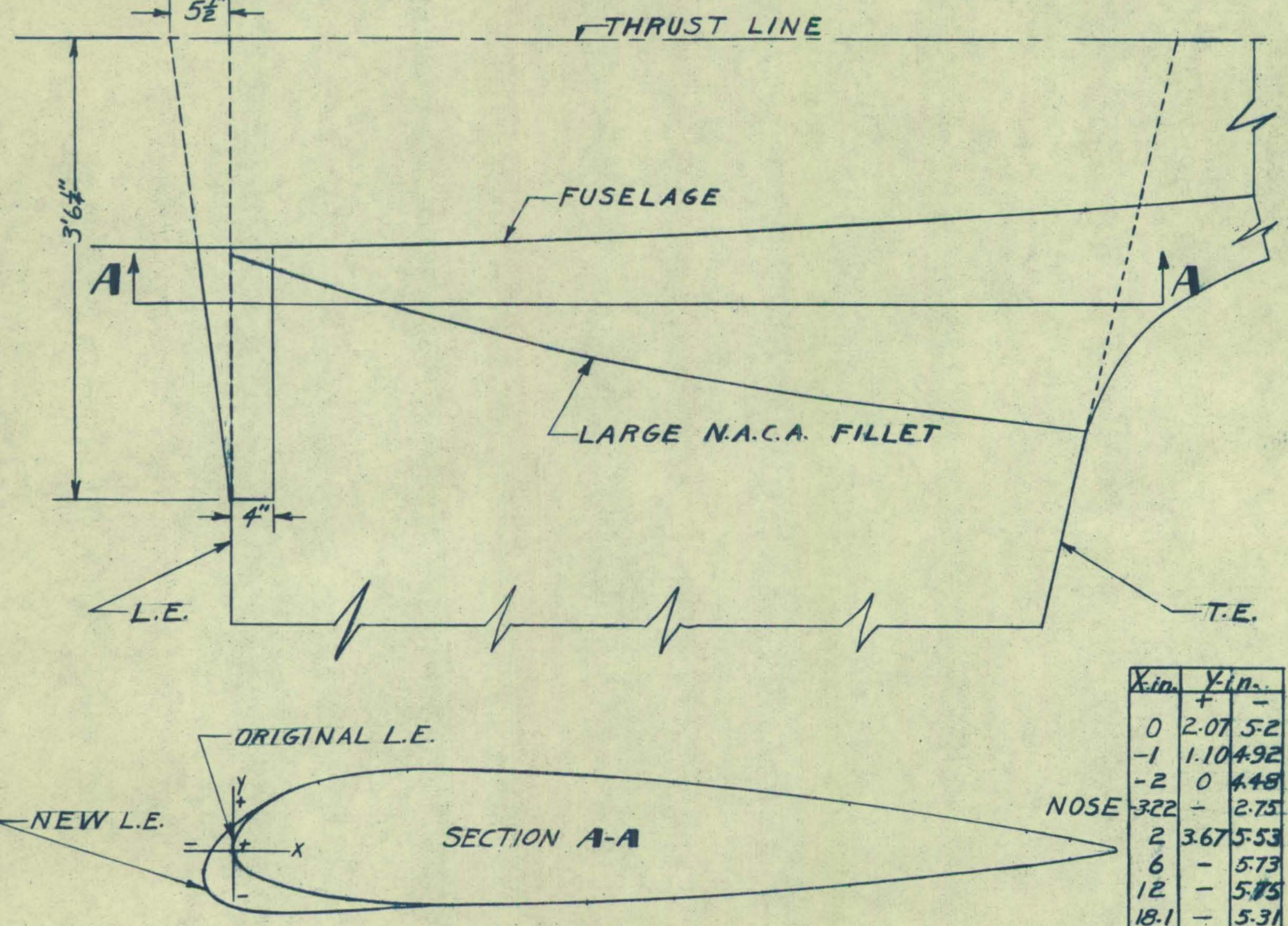


FIGURE 12: LARGE N.A.C.A. FILLET INSTALLATION



X-in.	Y-in. +	Y-in. −
0	2.07	5.2
-1	1.10	4.92
-2	0	4.48
NOSE -3.22	-	2.75
2	3.67	5.53
6	—	5.73
12	—	5.75
18.1	—	5.31

ORIGINAL CHORD=82.4"

FIGURE 13: NEW LEADING EDGE INSTALLATION

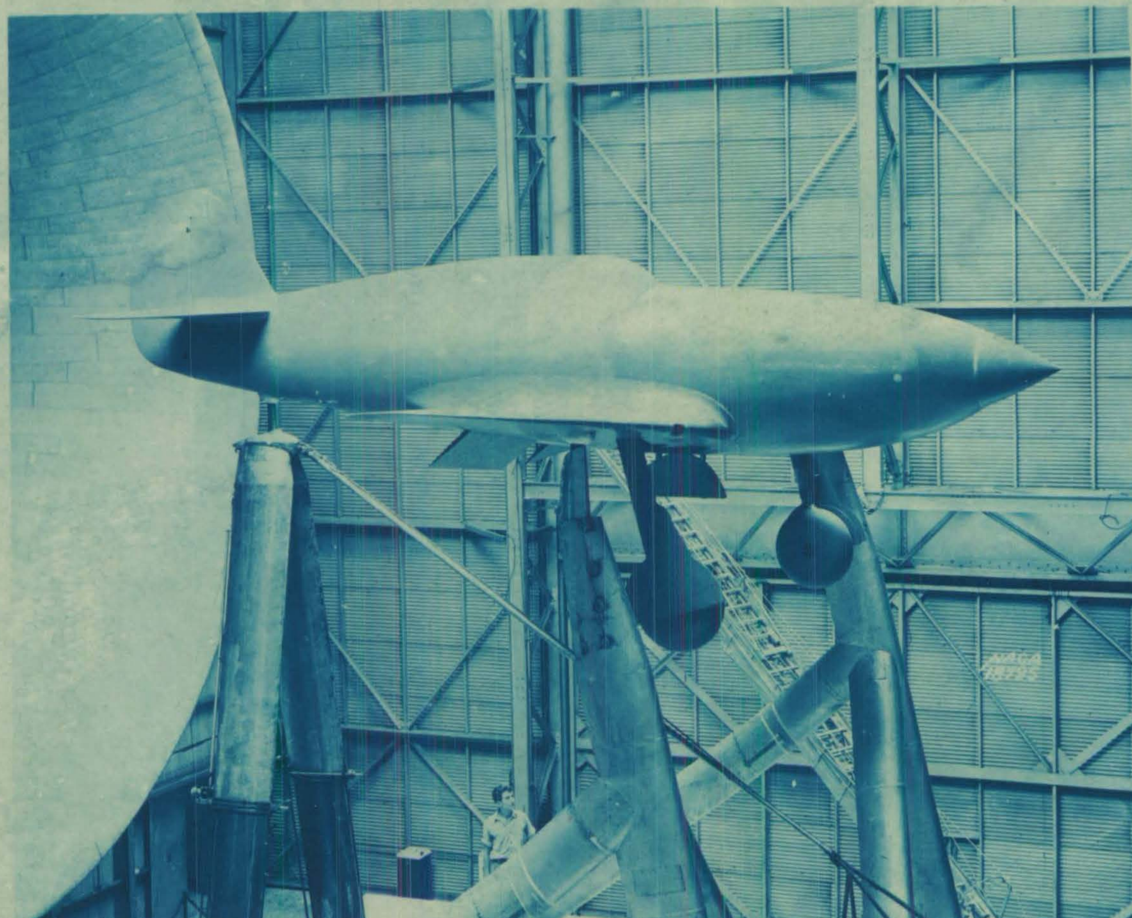
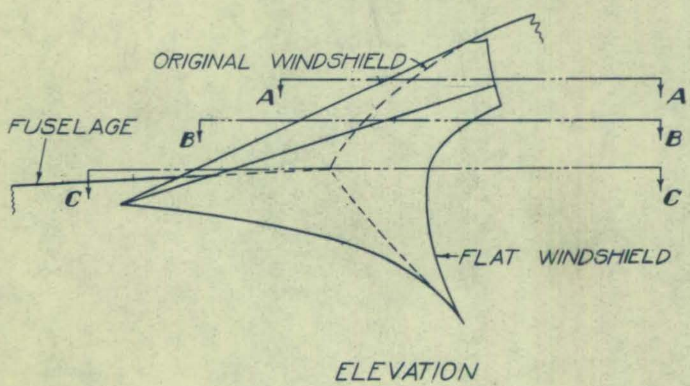


FIGURE 14. - XP-46 WITH LANDING GEAR AND FLAPS DOWN.



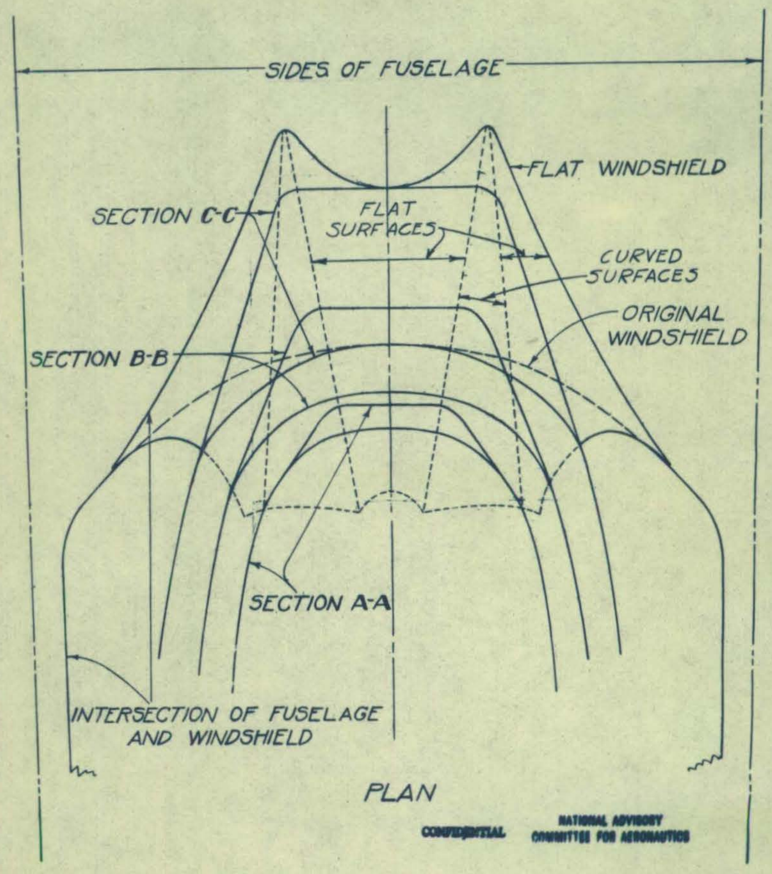
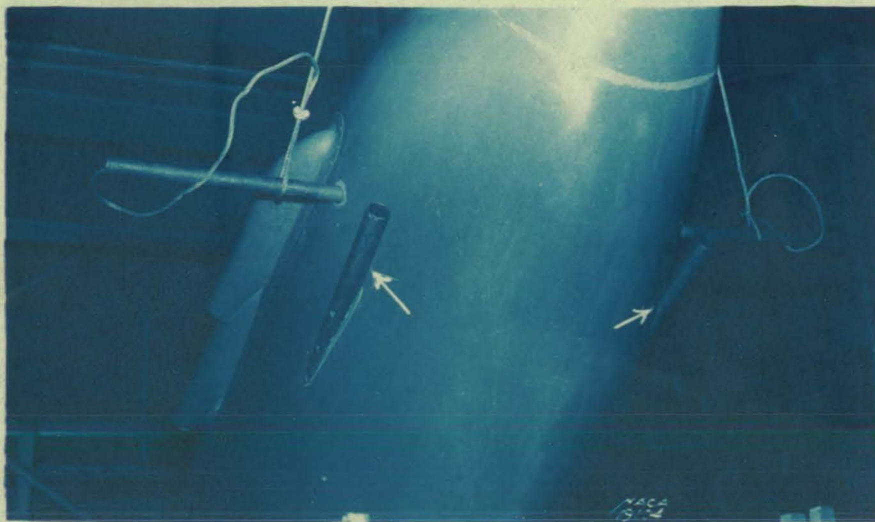
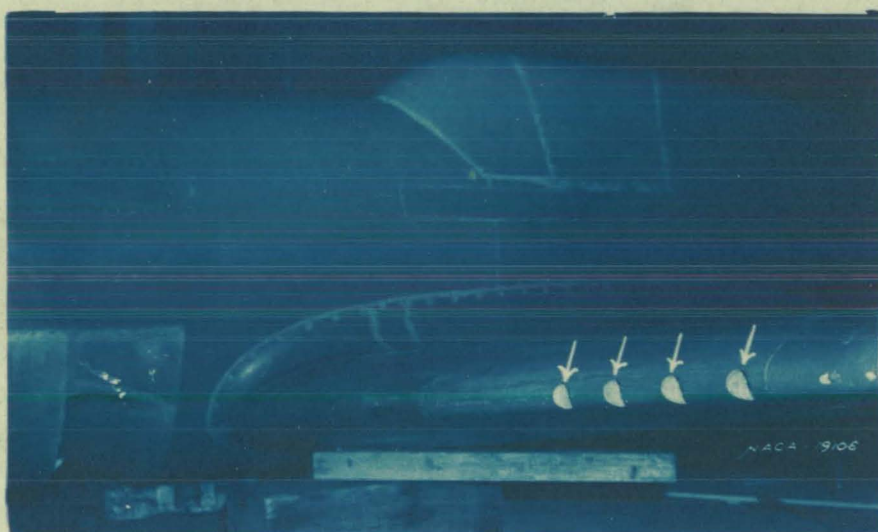


FIGURE 15.- FLAT WINDSHIELD



(A) FUSELAGE GUNS, 2- INCH DIAMETER.



(B) WING GUNS, 2- INCH DIAMETER.

FIGURE 16. - ARMAMENT INSTALLATION.

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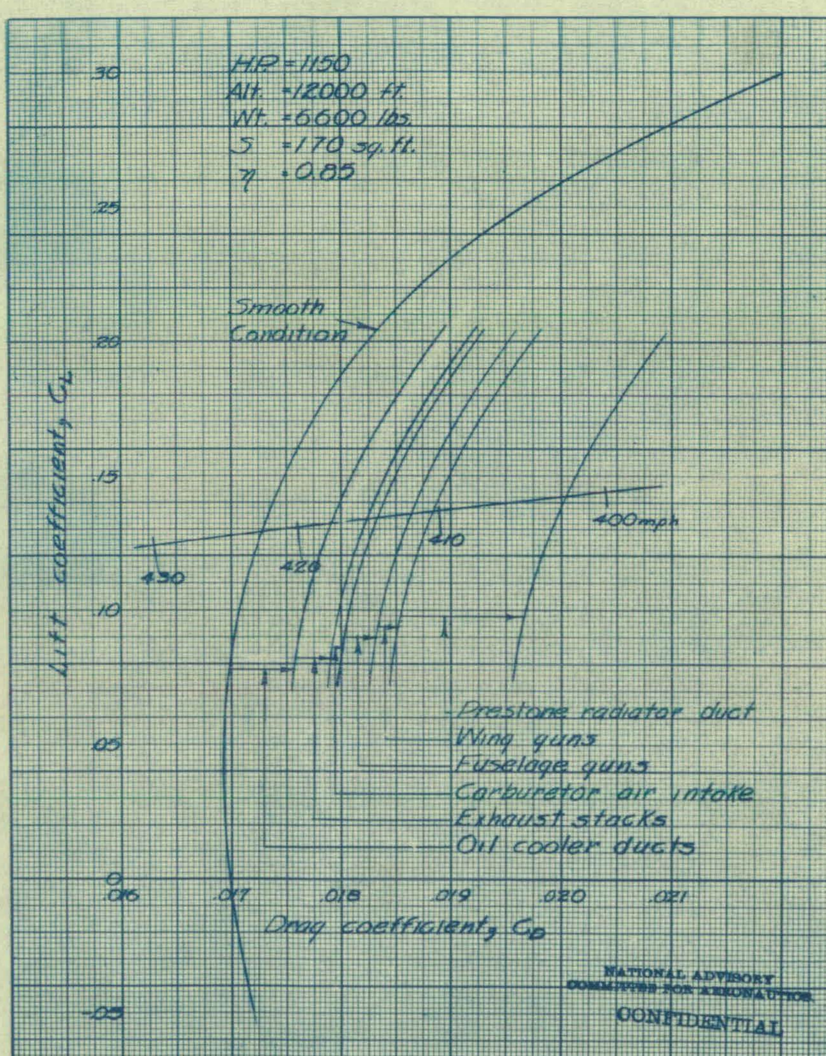


Figure 17. - High speed of XP-46 airplane with optimum arrangements of test conditions. (Note that test conditions correspond with test conditions of table II.) Air speed 100 miles per hour.

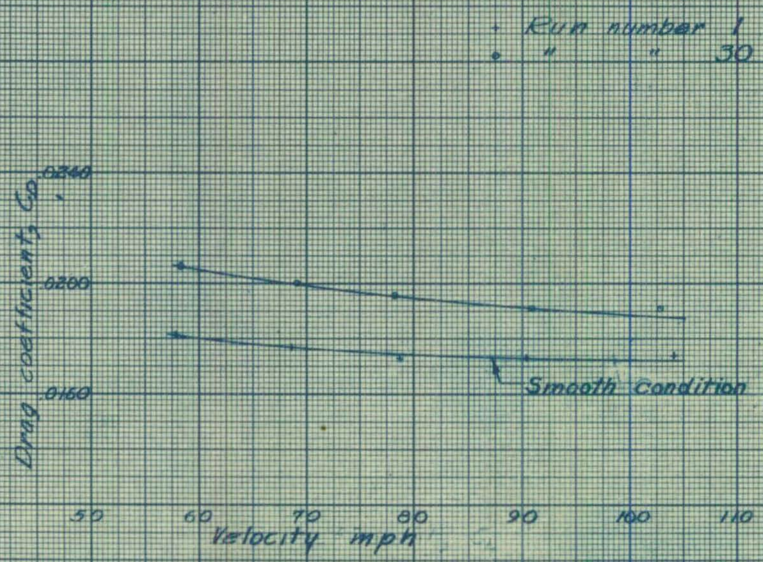


Figure 18. - Scale effect on XP-46 drag coefficient for two test conditions. C_L = 0.11.

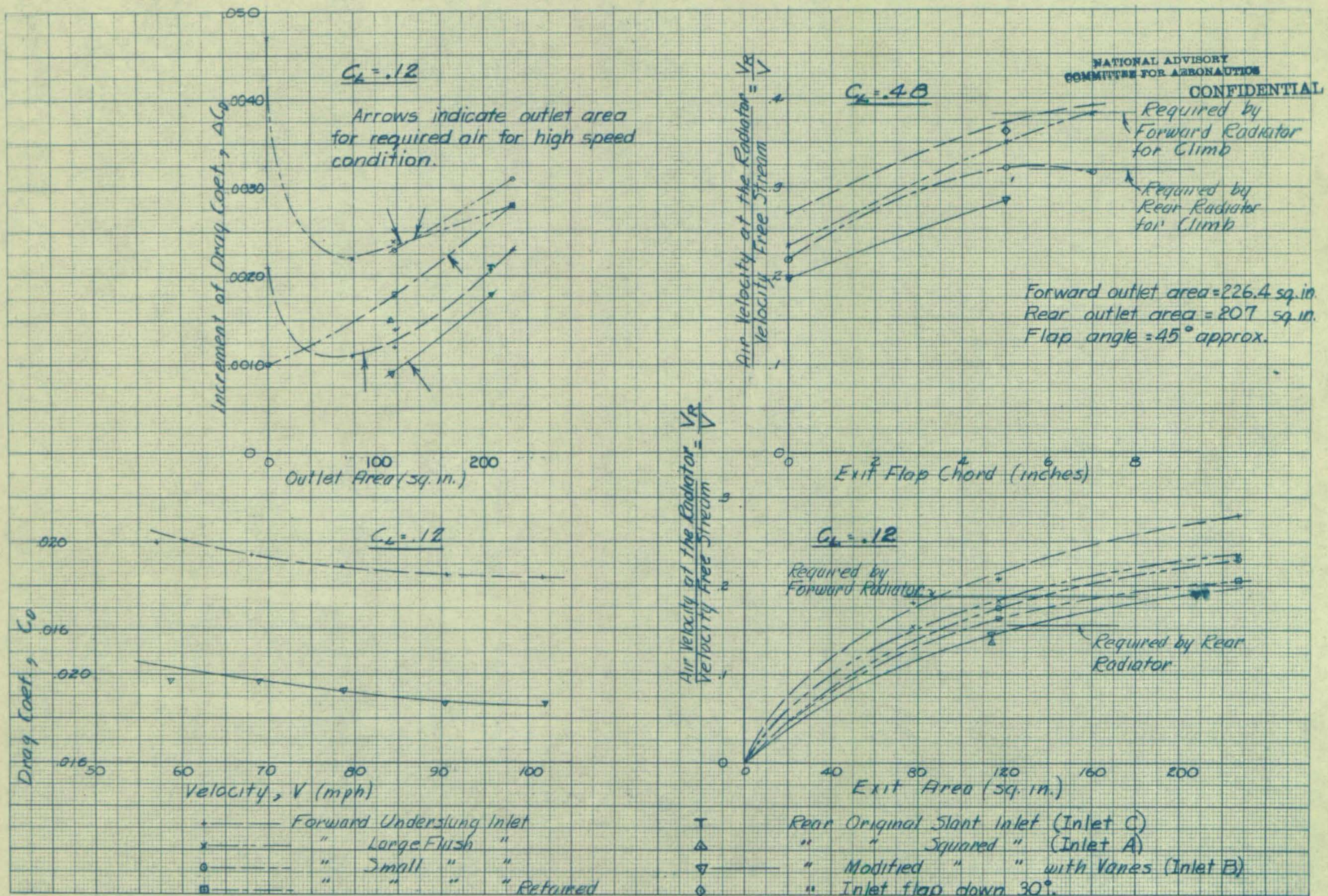
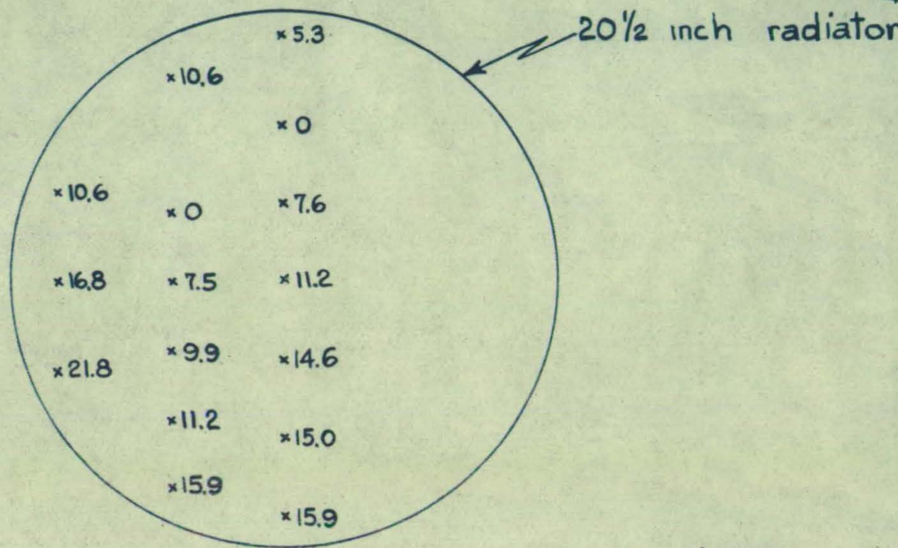
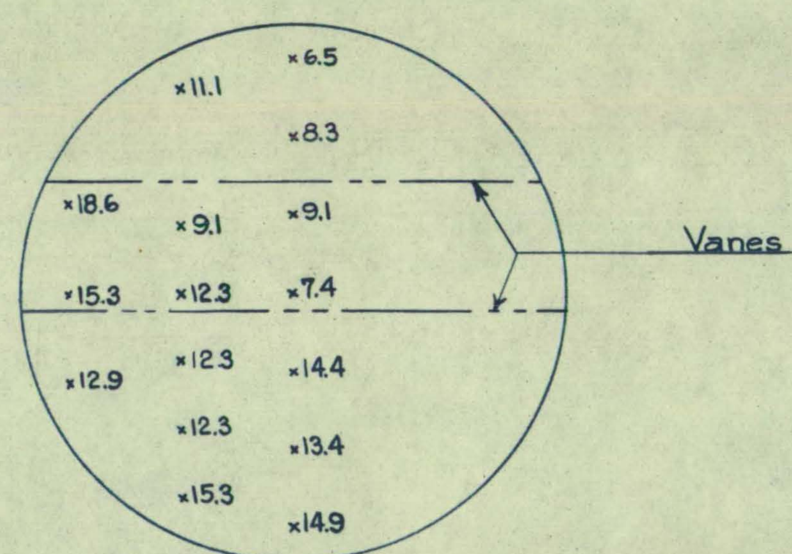


Figure 19. - Prestone radiator duct characteristics.



Inlet B, small outlet.

Numbers indicate velocities in feet per second.



Inlet B with vanes, small outlet.

Figure 20: Velocity distribution at rear radiator.

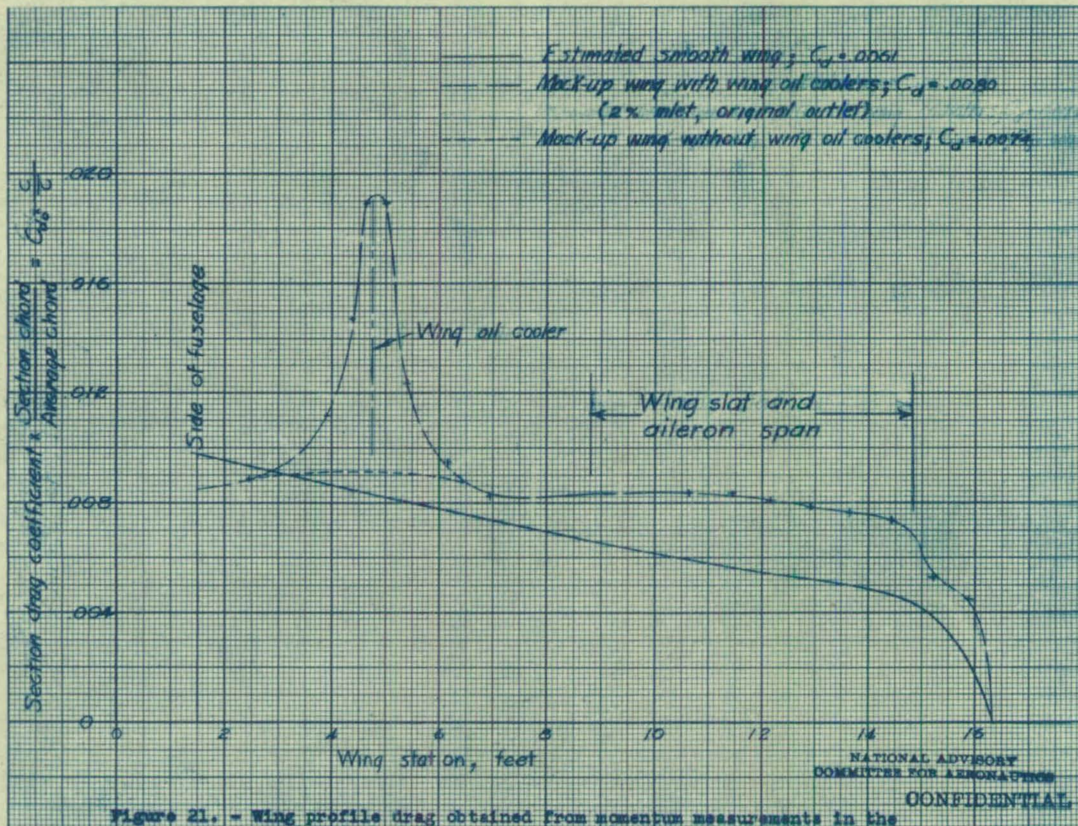
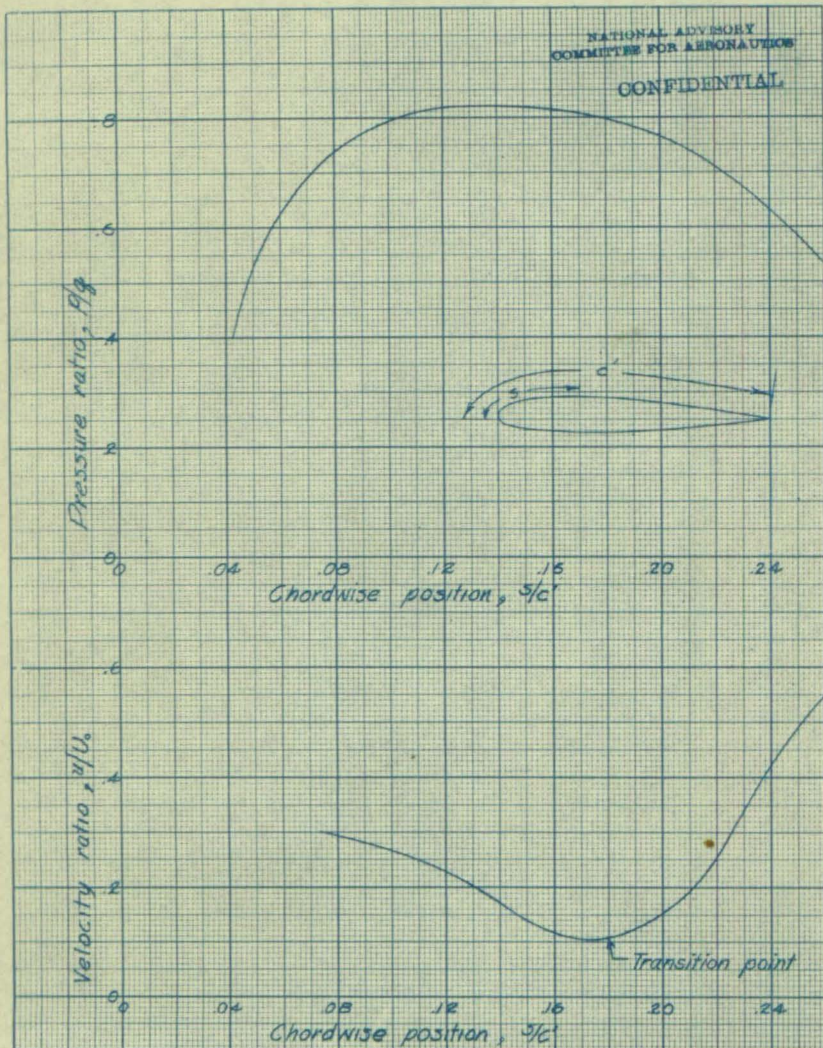
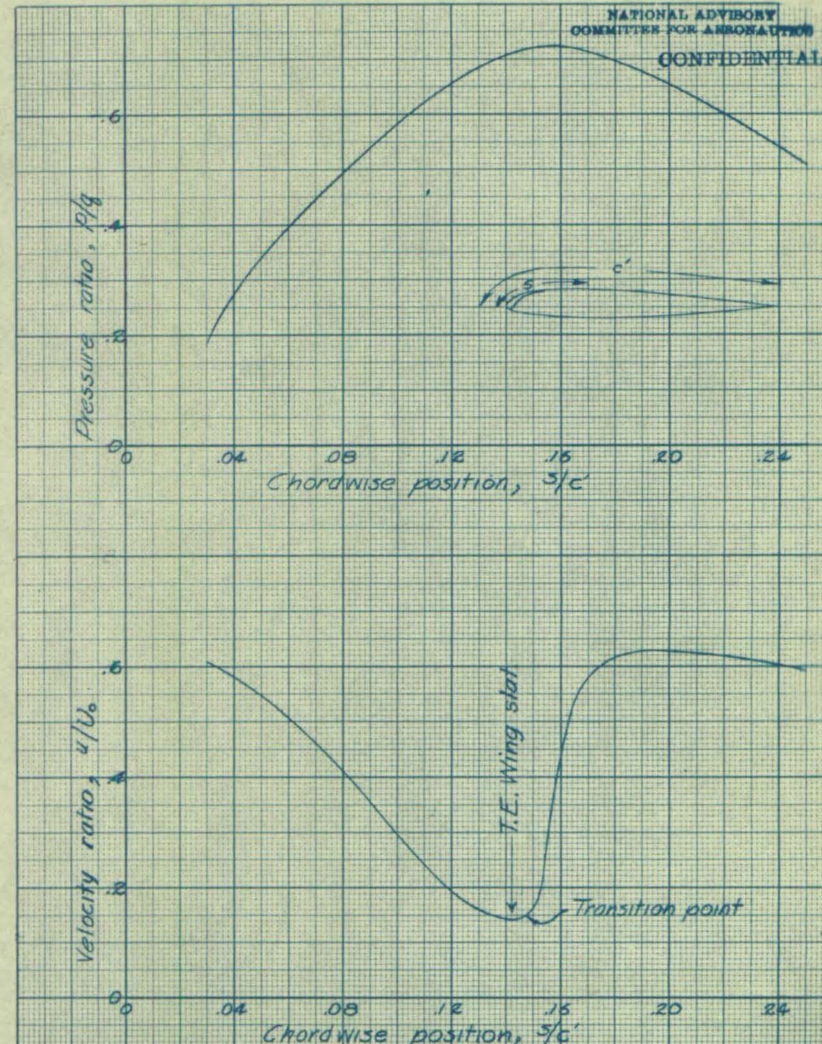


Figure 21. - Wing profile drag obtained from momentum measurements in the wake of the wing. Air speed 78 miles per hour.



a. Inboard of wing slat.

Figure 22. - Determination of high-speed transition point on upper wing surface. Air speed 58 miles per hour. Lift coefficient, $C_L = 0.12$.



b. Slotted wing section, slot closed.

Figure 22. - Determination of high-speed transition point on upper wing surface. Air speed 58 miles per hour. Lift coefficient, $C_L = 0.12$.

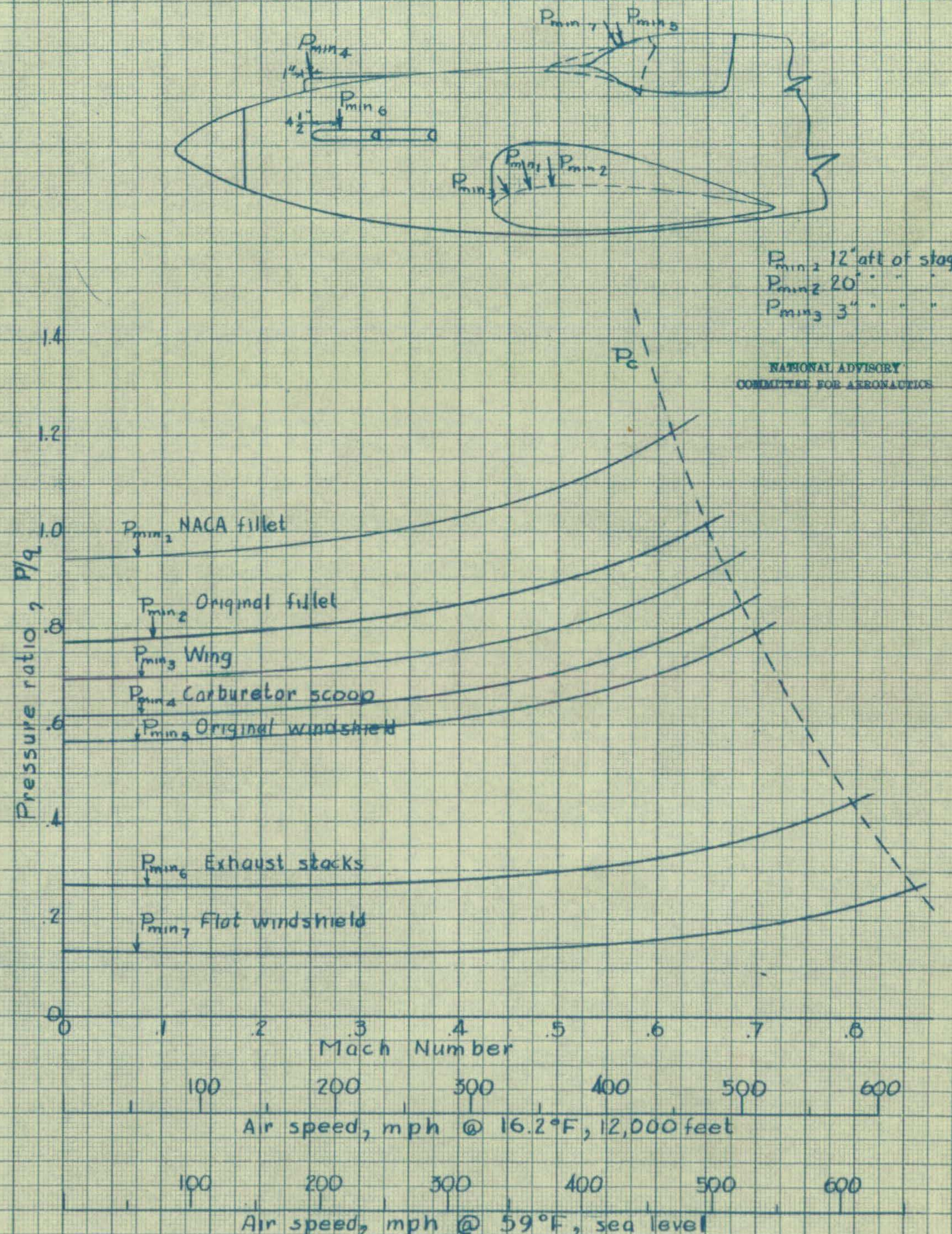


Figure 23. - Critical velocities for various parts of the XP-46 model.

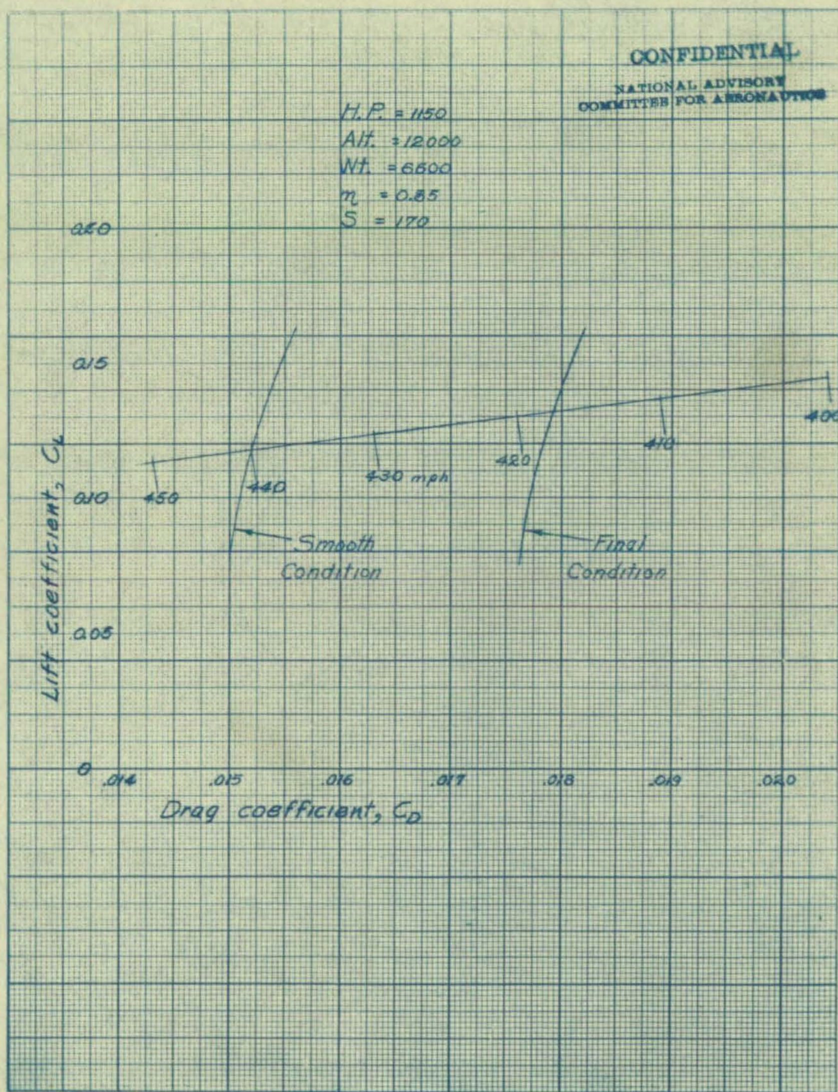


Figure 24. - Estimated high speed of the XP-46 in free flight.

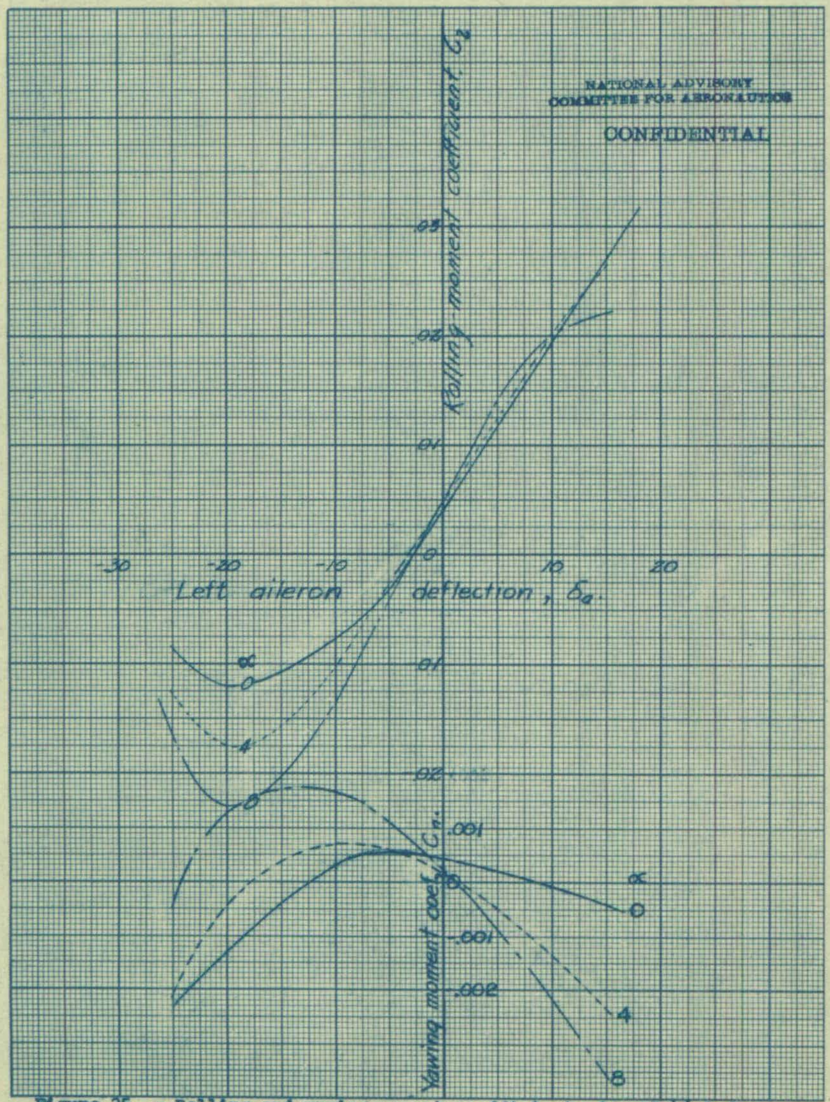


Figure 25. - Rolling- and yawing-moment coefficients for XP-46 left aileron. Test velocity 58 miles per hour.

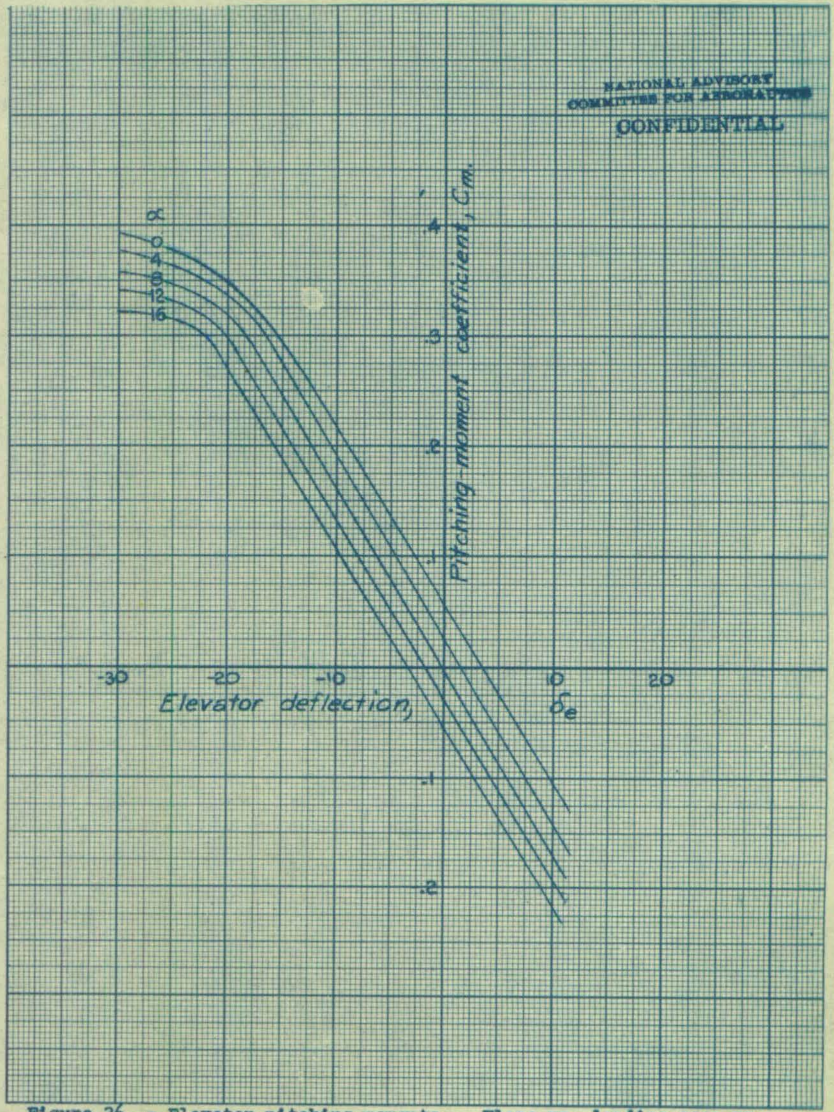


Figure 26. - Elevator pitching moments. Flaps up, landing gear up. Test speed 58 miles per hour.

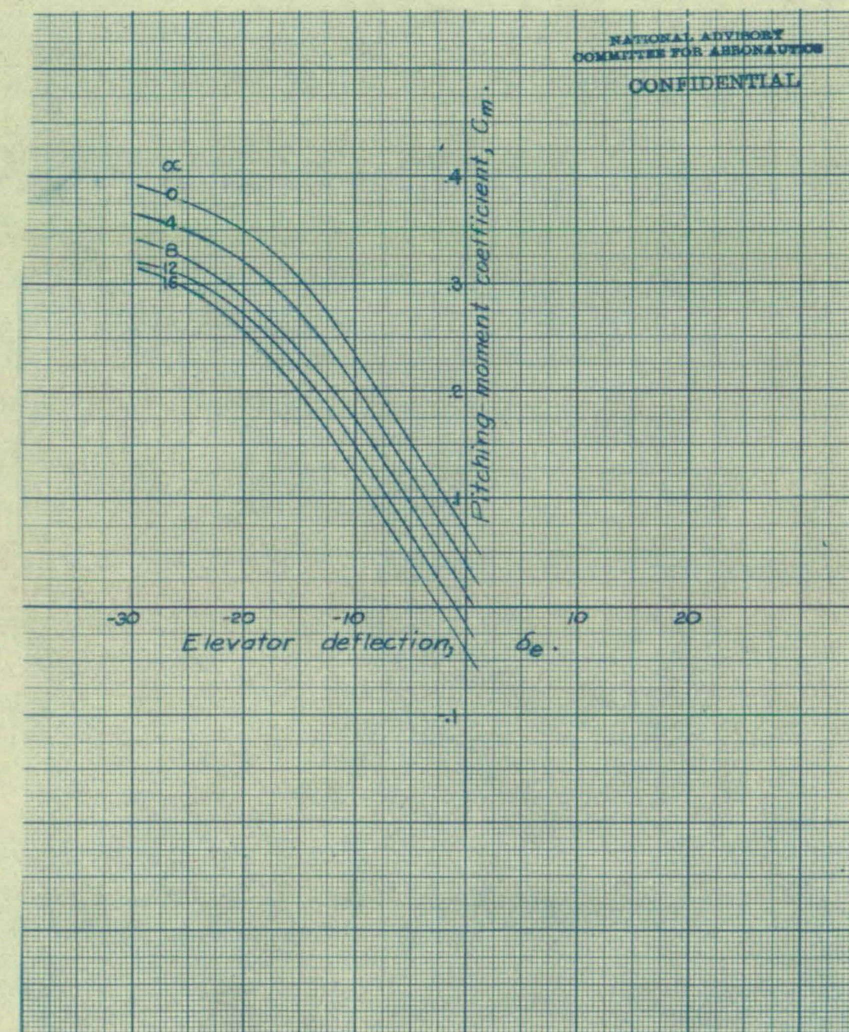


Figure 27. - Elevator pitching moments. Flaps down, landing gear down. Test speed 58 miles per hour.

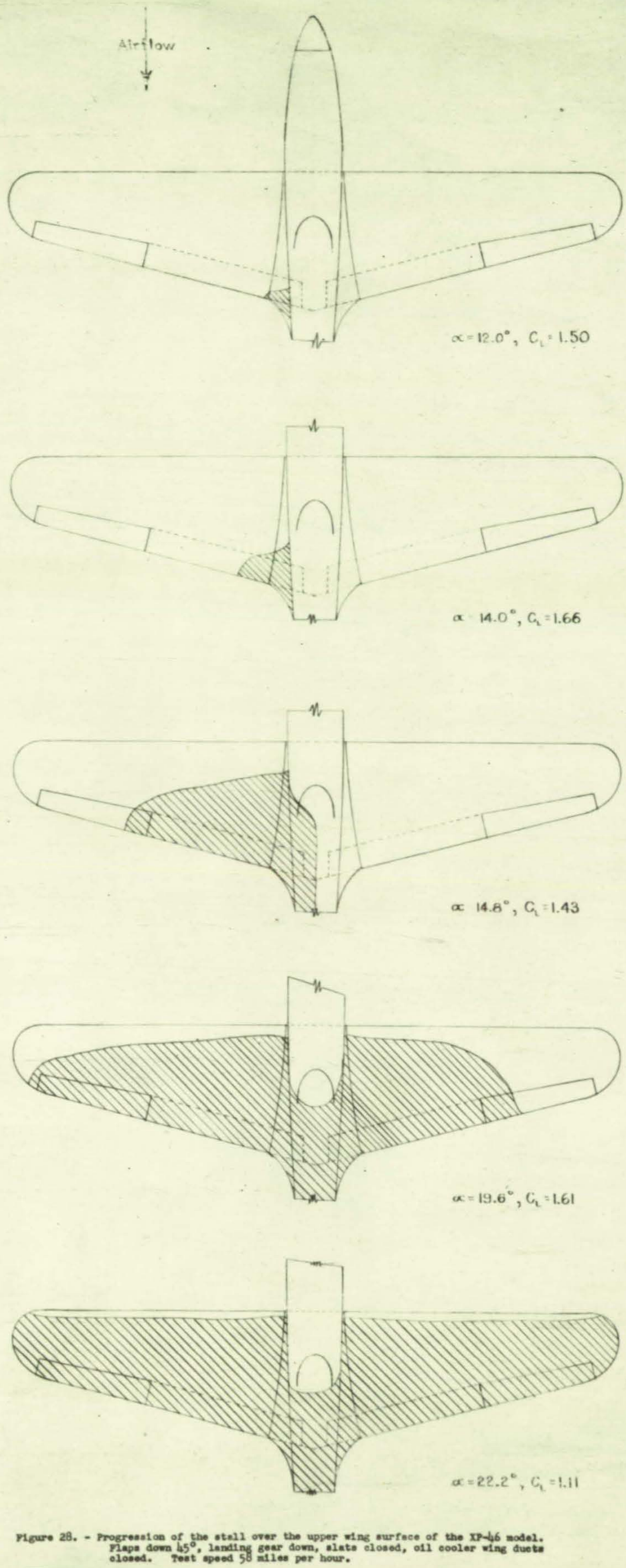


Figure 28. - Progression of the stall over the upper wing surface of the XP-46 model. Flaps down 45°, landing gear down, slats closed, oil cooler wing ducts closed. Test speed 58 miles per hour.

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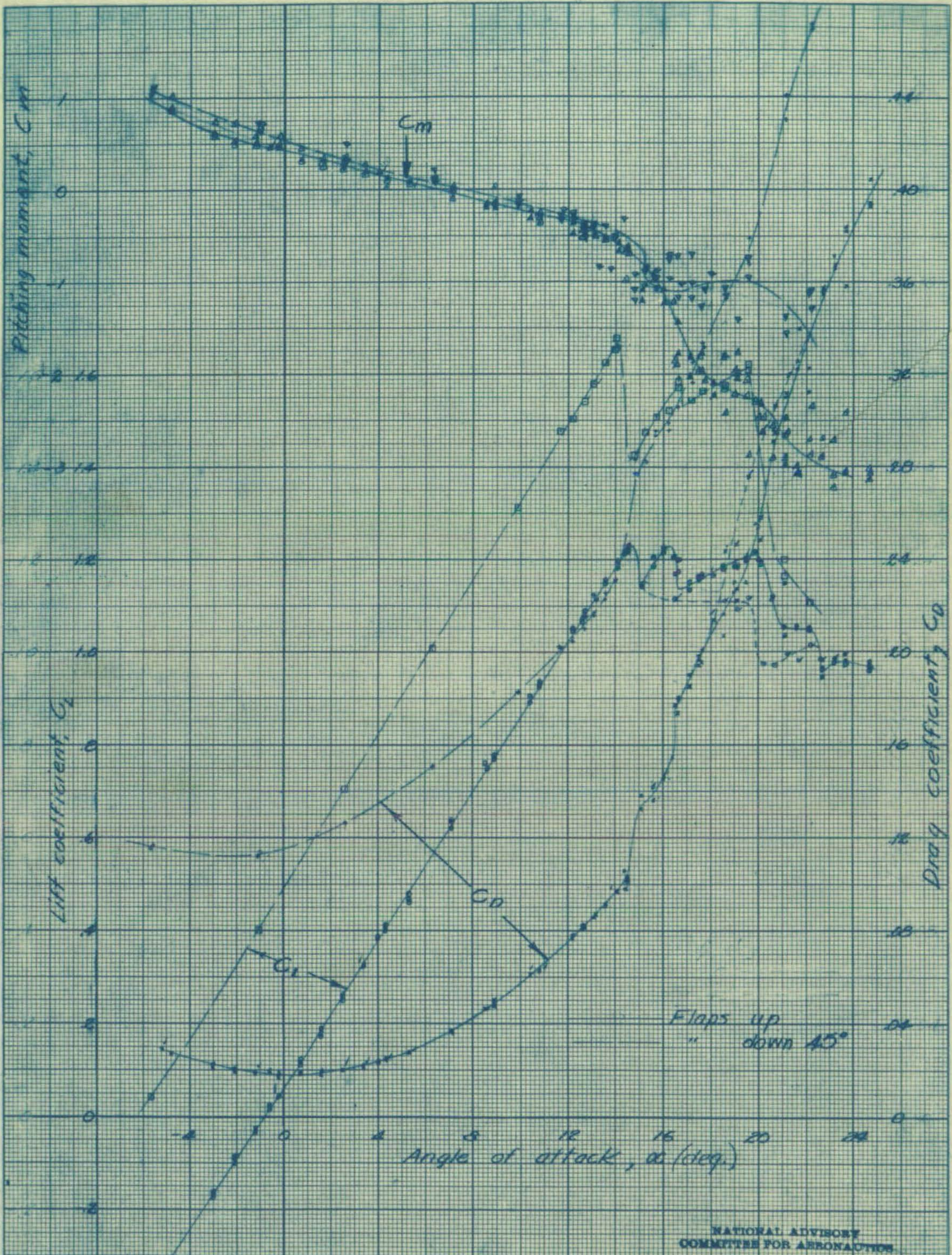

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Figure 29. - Lift, drag, and pitching moments for model in smooth condition. Flaps and landing gear up and down. Test speed 58 miles per hour. Runs 1 and 2.

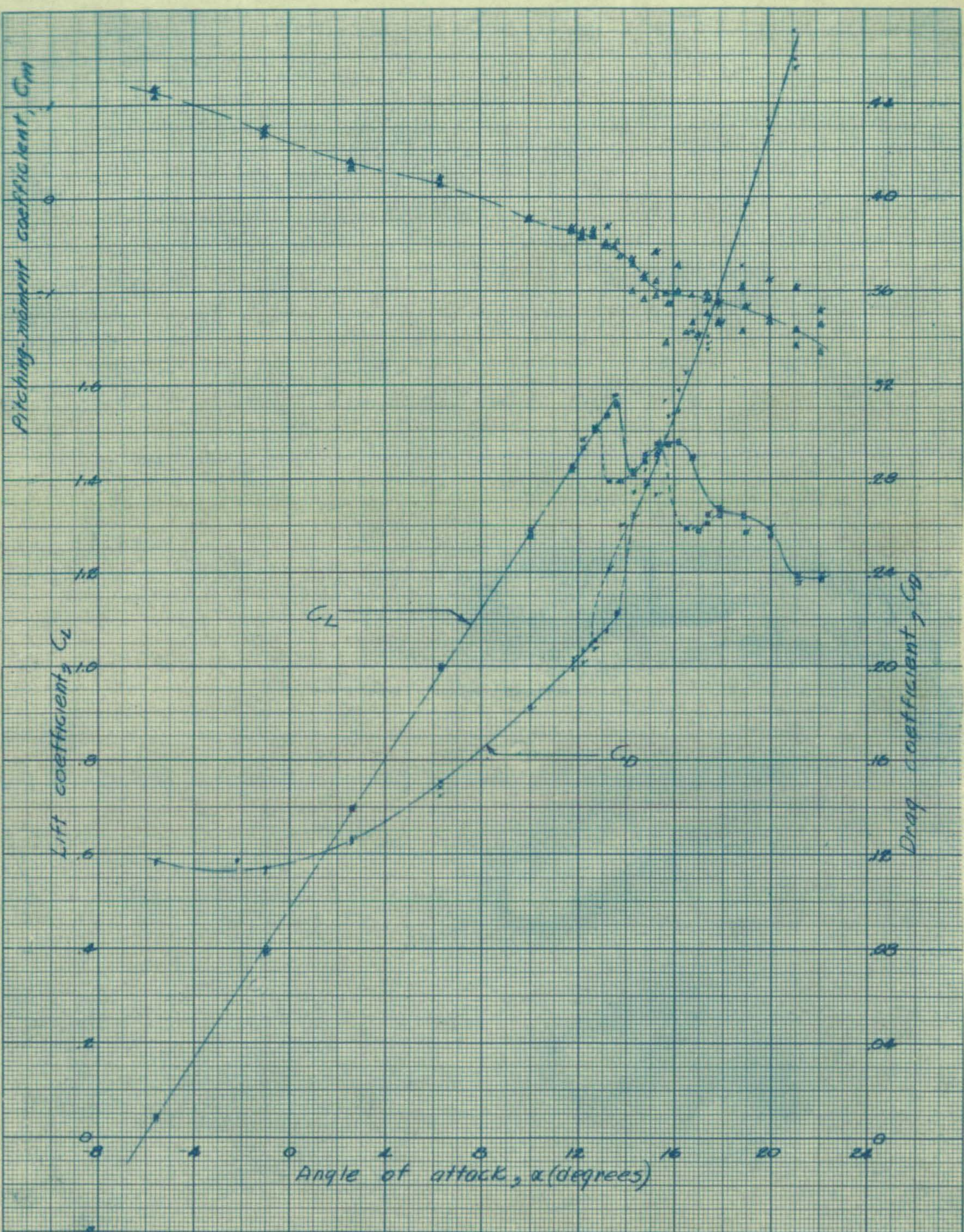

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Figure 30. - Lift, drag, and pitching moments for the model with the original wing fillet in place and oil cooler wing ducts open (2 percent c inlet, original outlet, with outlet flap open). Landing gear and flaps down. Test speed 58 miles per hour. Run 14.

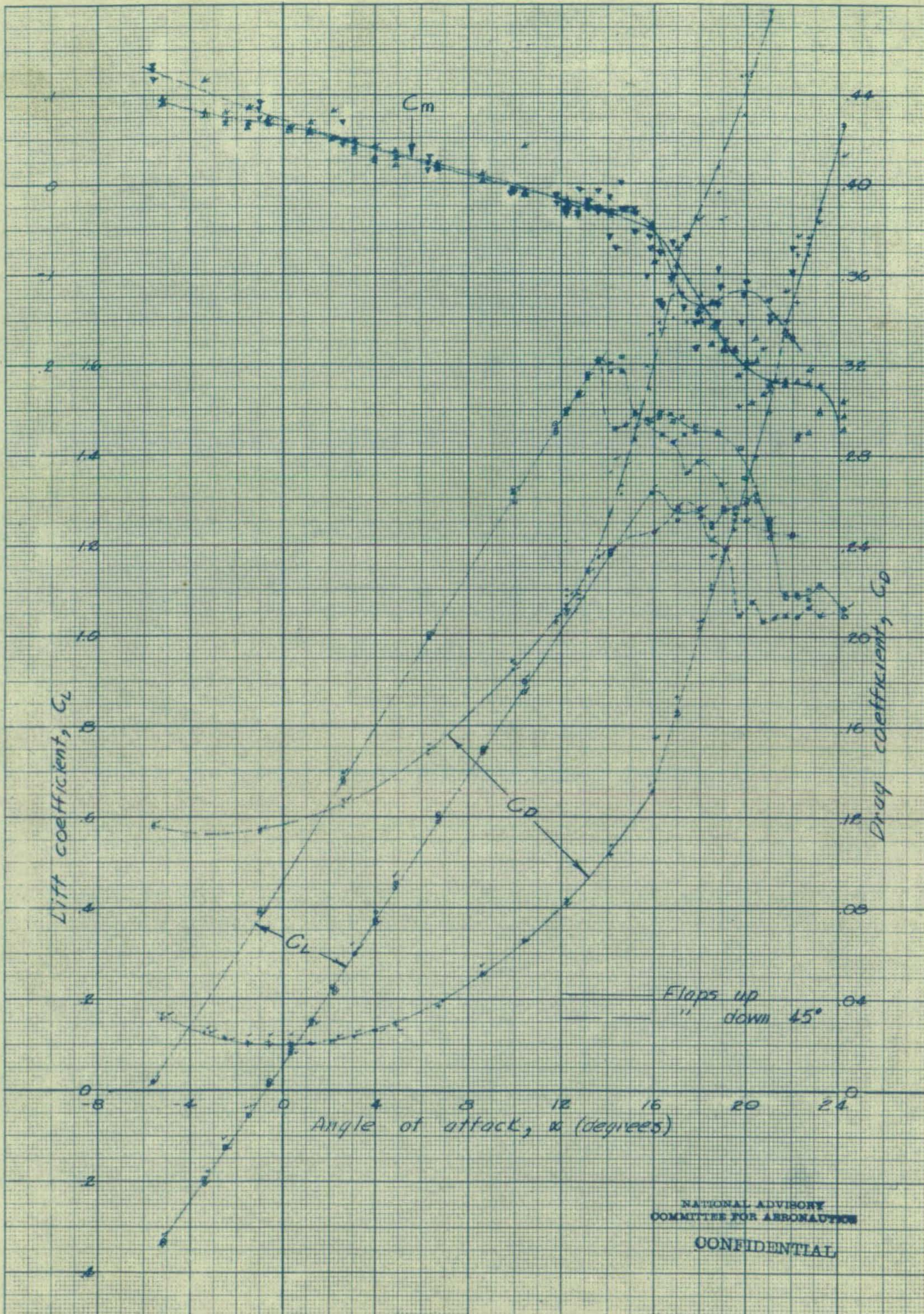

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Figure 31. - Lift, drag, and pitching moments for model with wing ducts open (2 percent c inlet, original outlet), exhaust stacks and revised forward carburetor inlet on, flaps and landing gear up and down. Test speed 58 miles per hour. Runs 35 and 36.

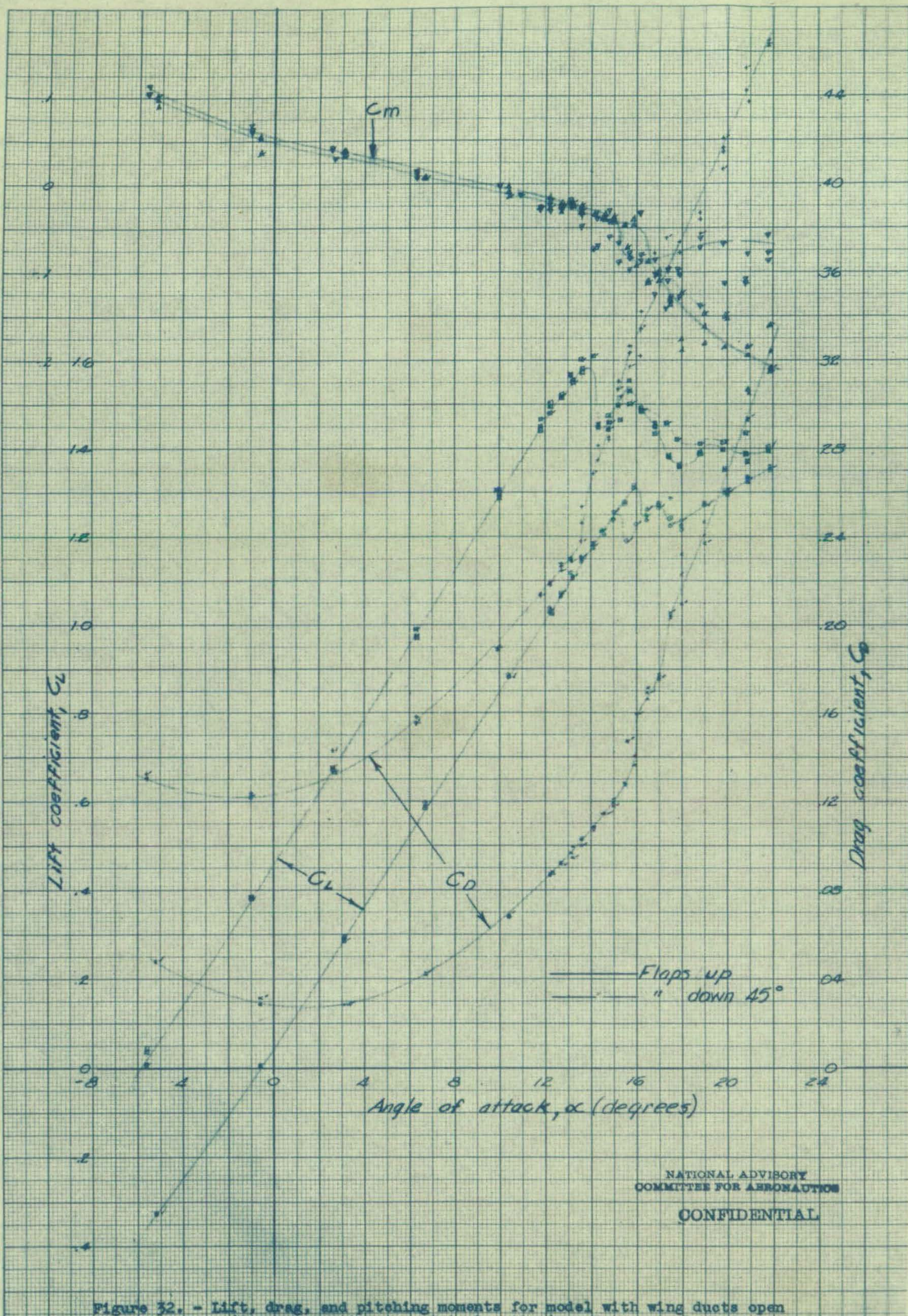

Figure 32. - Lift, drag, and pitching moments for model with wing ducts open (2 percent c inlet, original outlet), exhaust stacks and revised forward carburetor inlet on, slats open, flaps and landing gear up and down. Test speed 58 miles per hour. Runs 37 and 38.

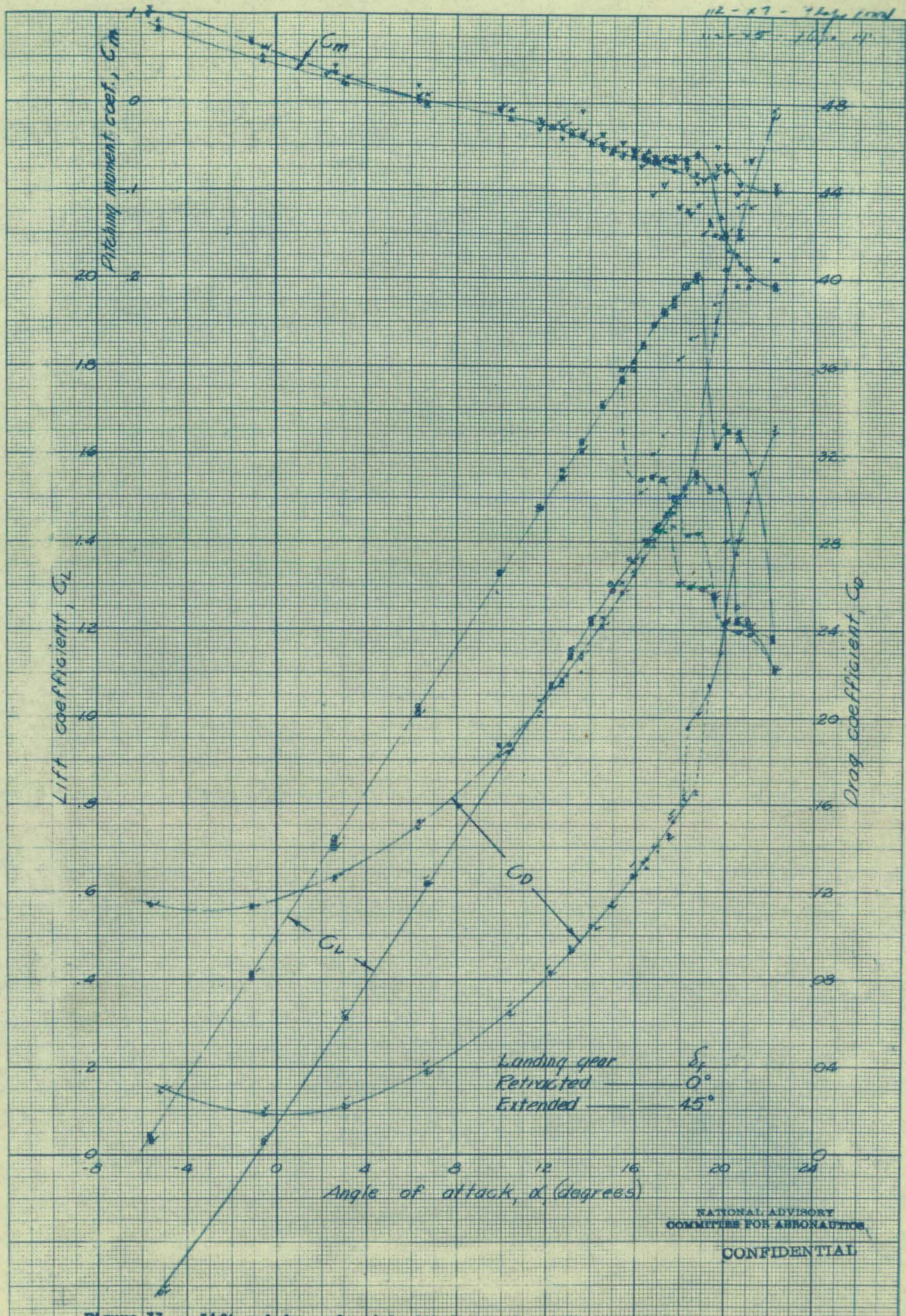

Figure 33. - Lift and drag of model with large wing fillet. Revised forward carburetor scoop and exhaust stacks on. Flaps and landing gear up and down. Test speed 58 miles per hour. Runs 41 and 43.

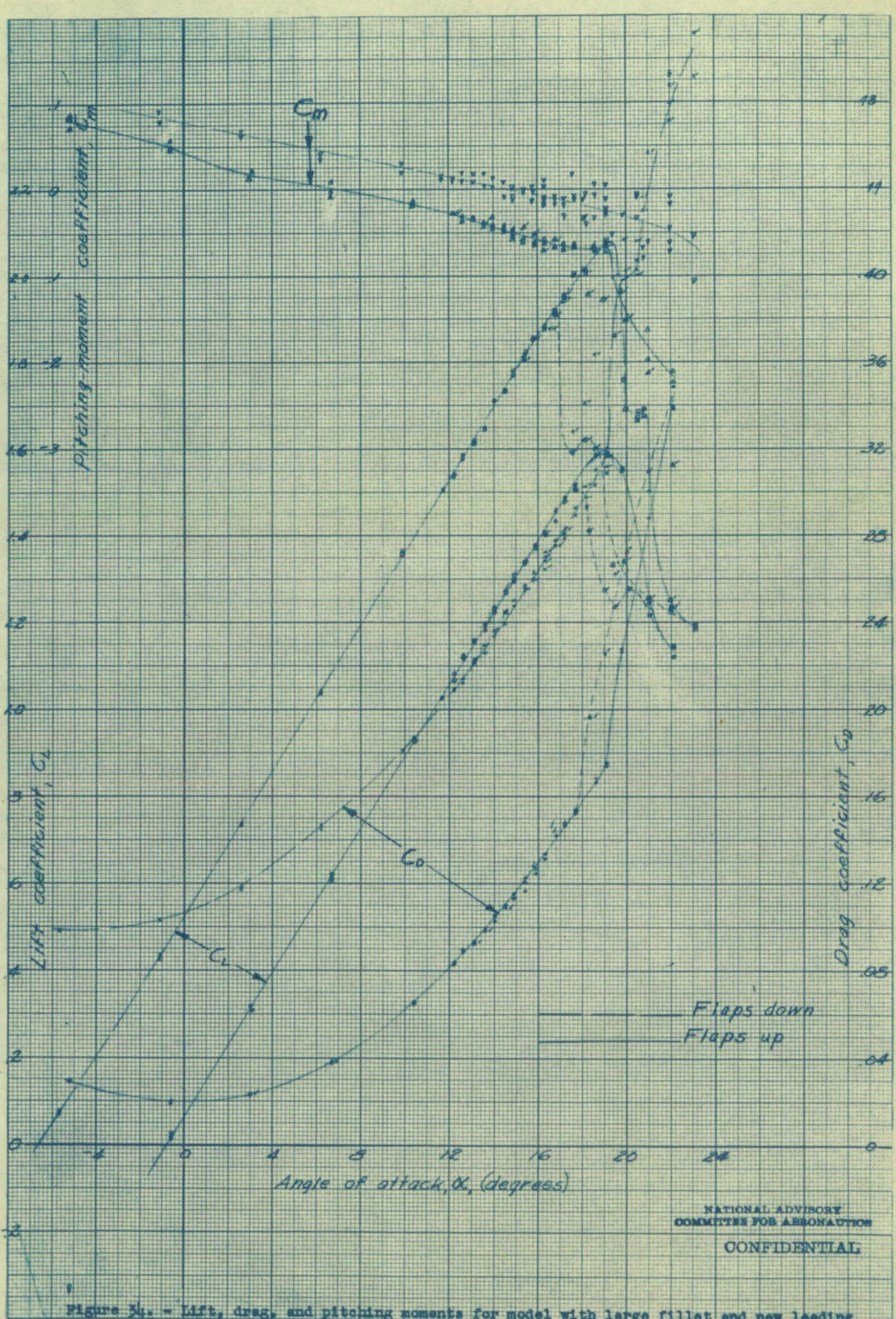

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Figure 34. - Lift, drag, and pitching moments for model with large fillet and new leading edge in place. Flaps up and down, landing gear up. Revised forward carburetor scoop and exhaust stacks on. Test speed 58 miles per hour. Runs 39 and 40.

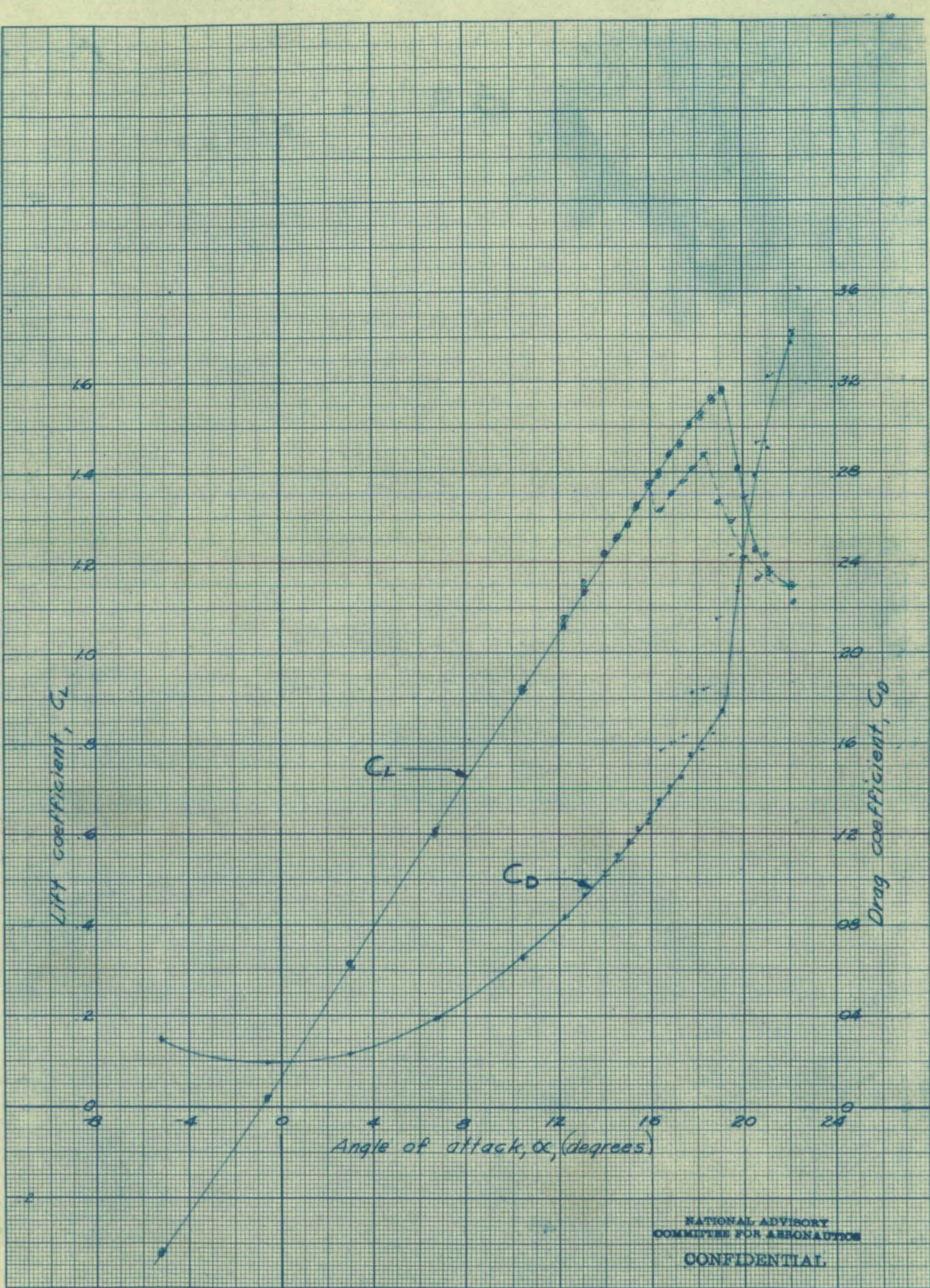

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Figure 35. - Lift and drag of model with original fillet and new leading edge in place. Flaps and landing gear up. Revised forward carburetor scoop and exhaust stacks on. Test speed 58 miles per hour. Run 47.

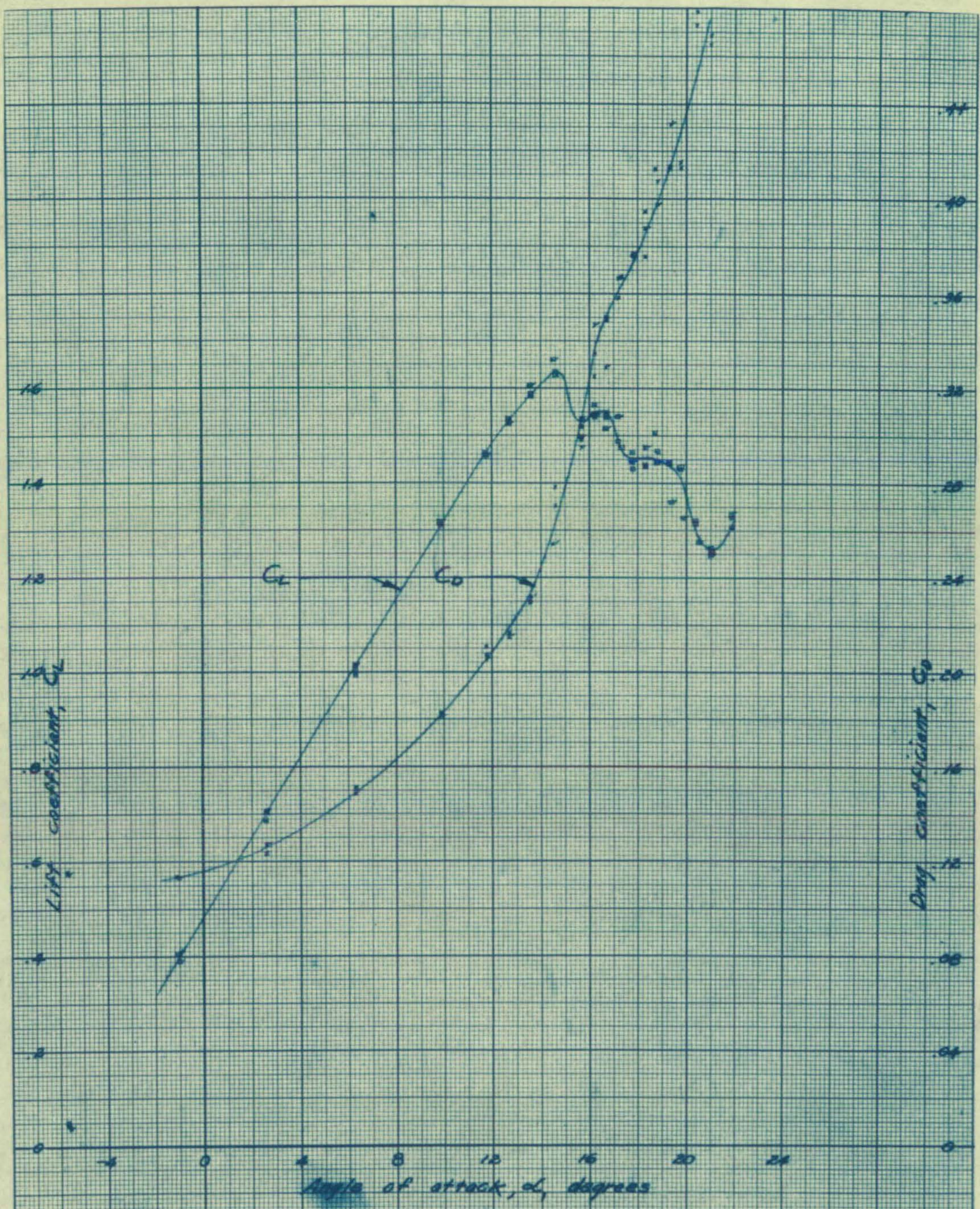

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Figure 36. - Lift and drag of model with large fillet in place and oil cooler wing ducts (2 percent c inlet, N. A. C. A. outlet) open. Flaps and landing gear down. Revised forward carburetor scoop and exhaust stacks on. Test speed 58 miles per hour. Run [illegible].

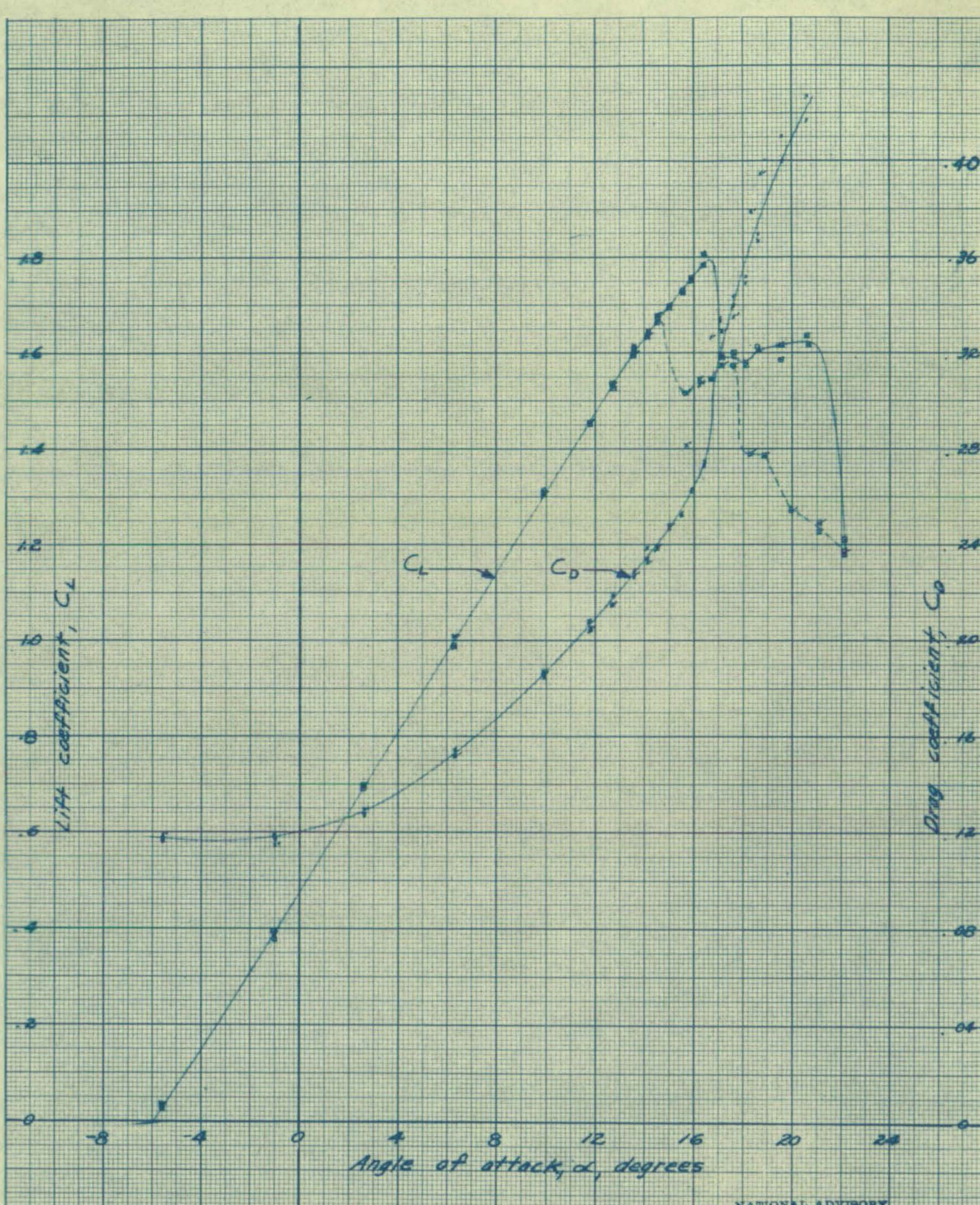

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Figure 37. - Lift and drag of model with large fillet in place and oil cooler wing ducts (1 percent c inlet, N. A. C. A. outlet) open. Flaps and landing gear down. Revised forward carburetor scoop and exhaust stacks on. Test speed 58 miles per hour. Run 45.

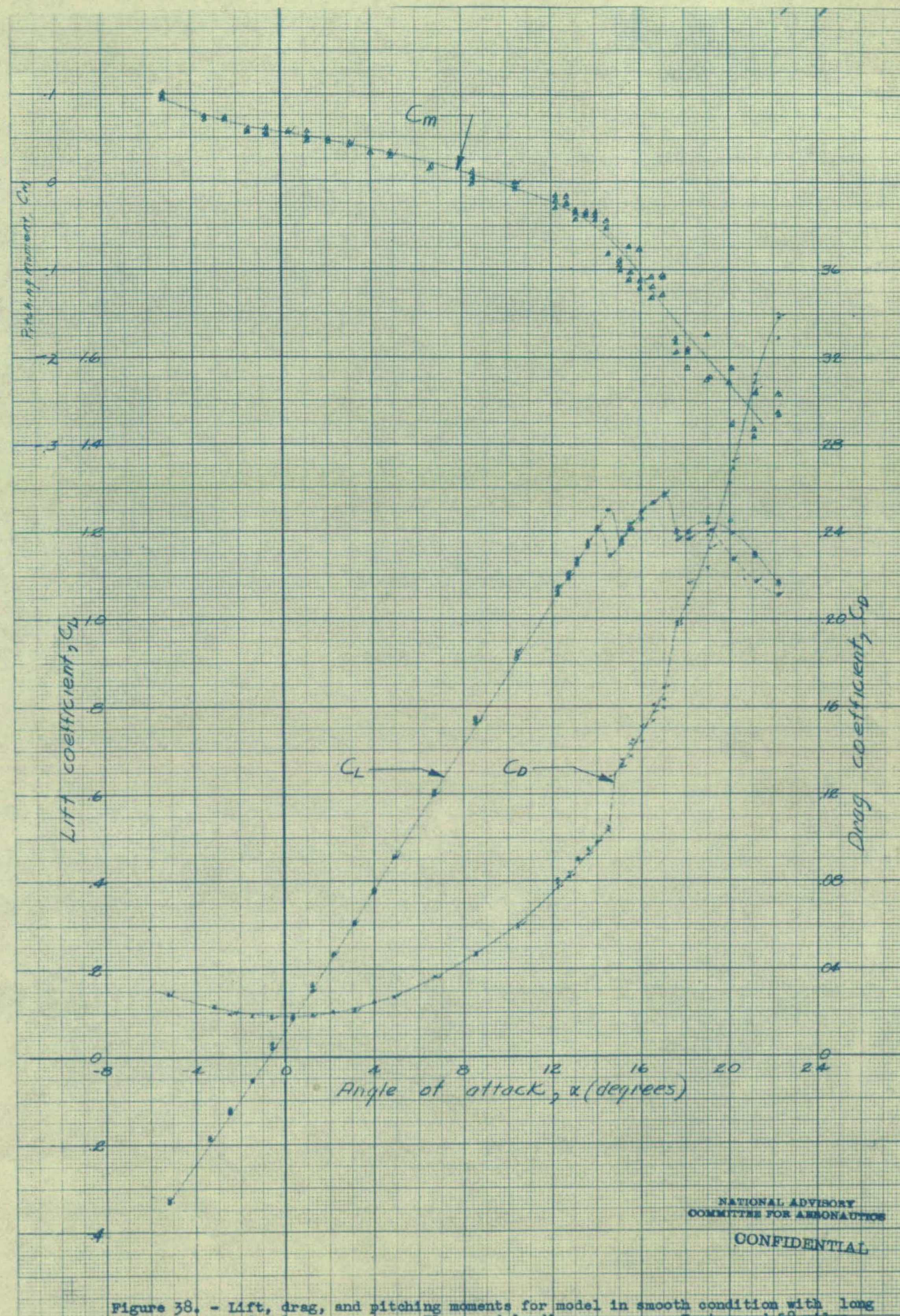

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Figure 38. - Lift, drag, and pitching moments for model in smooth condition with long fuselage nose on. Flaps and landing gear up. Test speed 58 miles per hour. Run 48.

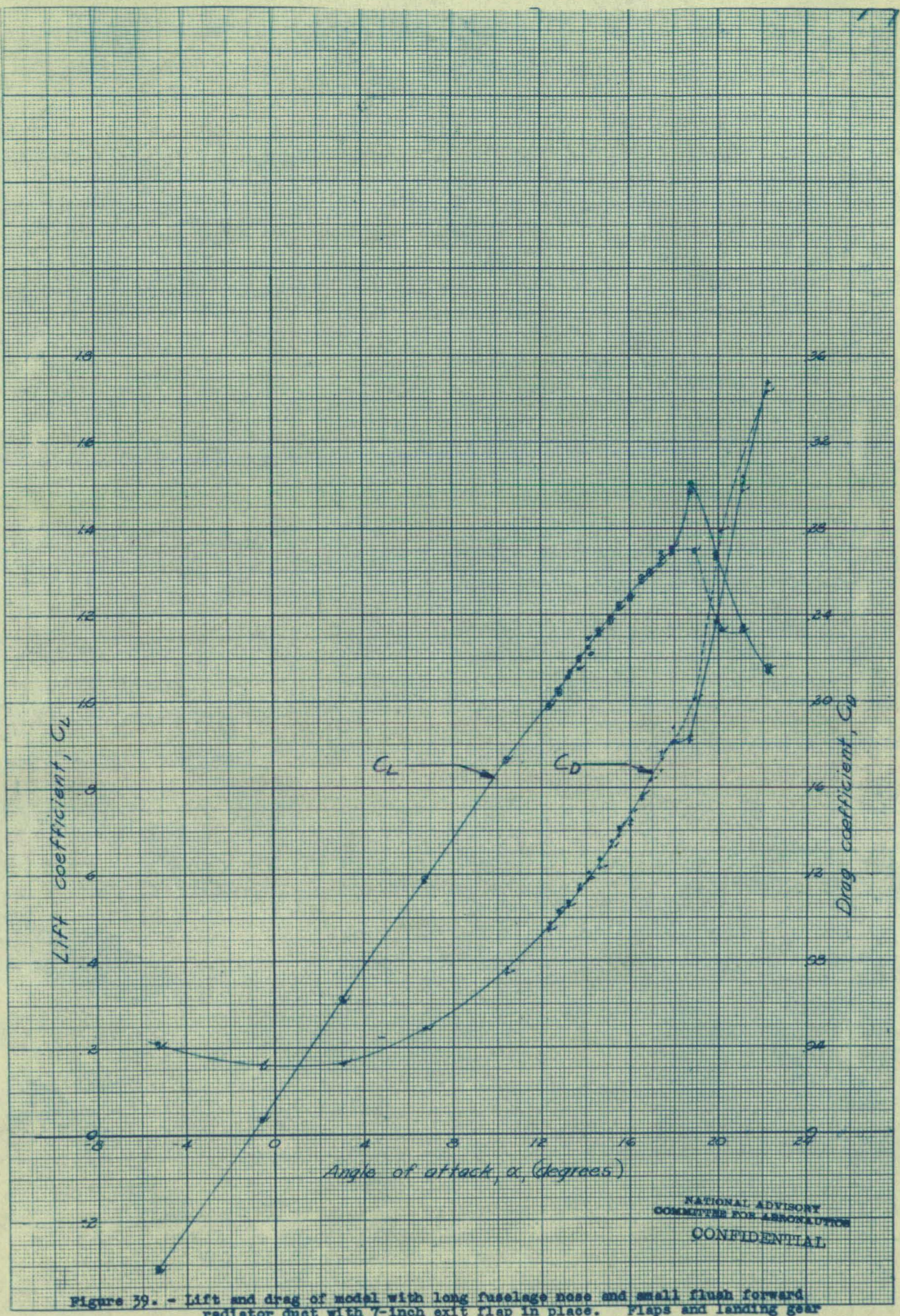

Figure 39. - Lift and drag of model with long fuselage nose and small flush forward radiator duct with 7-inch exit flap in place. Flaps and landing gear up. Test speed 58 miles per hour. Run 58.

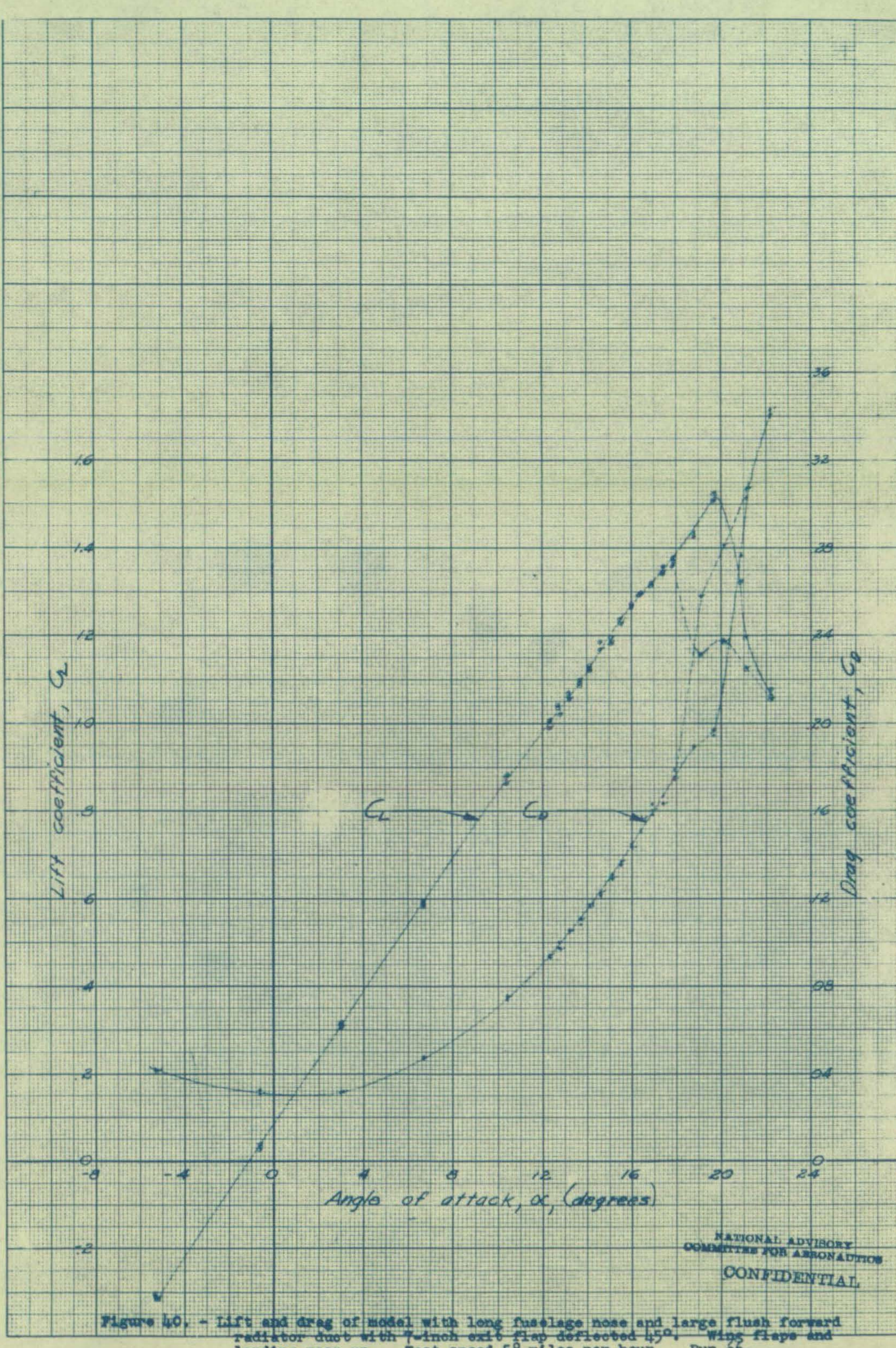

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Figure 40. - Lift and drag of model with long fuselage nose and large flush forward radiator duct with 7-inch exit flap deflected 45°. Wing flaps and landing gear up. Test speed 58 miles per hour. Run 66.

Figure 41. - Lift and drag in the region of the stall for the model with rear radiator duct in place. Duct inlet flap open 30°, outlet flap open 45°. Test speed 58 miles per hour. Run 74.