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MEMORANDUM REPORT

for

Army Air Corps

FULL-SCALE WIND-TUNNEL INVESTIGATION OF BUFFETING AND DIVING TENDENCIES OF THE YP-38 AIRPLANE

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INTRODUCTION

During the service tests on the YP-38 airplane, a violent tail shaking accompanied by a strong diving tendency was encountered in dives at speeds corresponding to Mach numbers of about 0.68 and above. At the request of the Army Air Corps, Materiel Division, an investigation has been conducted on the YP-38 airplane in the NACA full-scale wind tunnel to determine the cause of this tail buffeting and diving tendency of the airplane and to investigate airplane modifications to eliminate these undesirable characteristics. The conditions under which the phenomenon occurred (reference 1) led to the belief that the effects were due to compressibility and the tests consisted principally of pressure measurements in order to estimate the critical speed for the original and modified arrangements. Measurements were also made to determine the position of the wing and fuselage wake with respect to the tail for the dive attitude of the airplane.

Mar. 3 1942

AIRPLANE AND TEST APPARATUS

The YP-38 airplane is a single-place, twin-engine, low-wing monoplane with a 52-foot span and a wing area of 327.5 square feet. The gross weight of the airplane is 14,500 pounds. The 11.5-foot-diameter, three-blade Curtiss constant-speed propellers are driven through a 2:1 gear ratio by Allison V-1710-27 engines supercharged to a critical altitude of 25,000 feet.

The NACA full-scale wind tunnel and the balances used for these tests are described in reference 2. The method of mounting the airplane in the tunnel jet is shown in figure 1. The apparatus used for the wake-survey measurements is described in reference 3. Surface pressure measurements were made by means of 1/16-inch static-pressure tubes mounted about 1/16 inch from the surface.

RESULTS AND DISCUSSION

The results of the pressure-distribution measurements on the YP-38 airplane in its original and modified conditions are summarized in table I and sample pressure-distribution charts are shown in figures 2 and 3. The values of the peak negative pressures and their location are given from the test results and estimates are made of the critical Mach number and critical speed at 20,000 feet. The estimates of the critical Mach number are based on extrapolation of the pressure measurements made at low speeds (fig. 4) by the method of von Kármán (reference 4). The values of the critical speed estimated by this method have in general agreed with experiment. However, it may be expected that the method may be conservative for cases in which the shape of the pressure-distribution curve is extremely peaked at the forward part of the body.

The measurements show that the largest negative pressures occur in the wing-fuselage fillet, on the peak of the canopy, and on the wing between the fuselage and the booms. It is estimated in the dive condition ($C_L = 0.15$) that the local speed of sound will be reached in the wing-fuselage fillet at a speed of 404 miles per hour at 20,000 feet altitude. At speeds from 10 to 20 miles per hour above this, the entire region between the booms will reach the critical speed and be subject to the accompanying compressibility separation.

When the critical speed of a wing is reached and shock occurs on the upper wing surface, the flow separation which results is accompanied by a decrease in the wing lift, a sharp increase in the wing drag, and a strong diving tendency. In flight the pilot recognizes the phenomenon by the increased roughness of the airplane ride and by the necessity for applying large stick forces to avoid further nosing over. The diving tendency is contributed to both by the increase in negative moment of the wing and the decrease in lift. In order to increase the angle of attack of the airplane to compensate for the decrease in lift the pilot must exert a heavy pull on the stick. In the case of the P-38 airplane the required stick force was so high that it was necessary to use the elevator tab in the dive recovery.

The large drag increase resulting from flow separation at speeds above the critical effects a correspondingly large increase in the wake width and intensity since a correlation exists between the wake width and the drag. If this wake, which high-speed schlieren photographs have shown to possess an oscillating motion, passes over the tail surfaces it results in violent tail buffeting due in part to the changing angle of flow resulting from the oscillation and in part to the fluctuations in velocity of the wake vortices.

The joint occurrence of tail buffeting and the diving tendency on the P-38 airplane appears to be satisfactorily explained from analysis of the measurements as an effect produced by attainment of critical speed over the entire section of the airplane between the booms, which results in a sharp increase in the airplane diving moment and buffeting of the tail due to the wing wake. The methods of alleviating the difficulties which were possible in the full-scale-tunnel tests resolved themselves into investigations of means for increasing the critical speed and for lowering the wake at the tail.

Modification to Increase the Critical Speed

Wing. - The modifications that were applied to the section of the wing between the booms to reduce the peak pressure and to increase the critical speed consisted of 0.10c and 0.20c leading-edge extensions (figs. 5 and 6) and a glove of NACA 66-115 section (figs. 7 and 8). The pressure distributions in the critical regions for these modifications are compared in figures 9, 10, and 11 with those of the original airplane, from which it may be summarized (table I and fig. 4) that the maximum increase in critical speed of 64 miles per hour is effected by the 0.20c leading edge. The increases with the 0.10c leading-edge extension and NACA 66-115 glove under comparable test conditions were 34 and 48 miles per hour, respectively. The 0.20c leading-edge extension also had the largest unfavorable effect on the static stability of the airplane (figure 12) which corresponded to a forward shift of approximately 9 percent in the aerodynamic center.

To counteract the undesirable forward shift of the center of pressure resulting from the addition of the 0.20c leading-edge extension recommendations have been made (reference 5) that the Prestone and oil radiator installations be located in the extended leading edge (fig. 13). The shift in the center of gravity accompanying this modification balances the change in center of pressure, so that the static stability is not affected (fig. 14).

The relocation of the Prestone radiator in the 0.20c leading edge serves the double purpose of increasing the critical speed and reducing the drag (reference 6).

If modifications are applied to the wing between the booms, a leading-edge fillet may also be desirable at the outboard wing-boom juncture. This should be designed to increase the chord ahead of the maximum thickness of the wing and can taper out into the usual wing section in a spanwise distance of about 0.3c.

Canopy. - The revisions applied to the original canopy (figs. 15, 16, and 17) were designed to increase the radius of curvature over the canopy peak and eliminate the larger negative pressures occurring there. The second canopy revision which provided the longest nose length and the largest radius of curvature reduced the pressure from $-0.92q_o$ to $-0.68q_o$ (fig. 18) corresponding to an increase in critical speed of 44 miles per hour at 20,000 feet altitude. Lengthening the fuselage about 3 feet and fairing into this revised canopy did not further reduce the peak pressures but provided somewhat more gradual pressure recovery in the region in which separation might occur at high Mach numbers. The second revision of the canopy is an excellent companion modification for the 0.20c leading-edge extension since their critical speeds are about the same, i. e., 461 and 468 miles per hour, respectively.

Wing Wake Deflection

As a possible solution for overcoming the tail-buffeting tendencies, it has been suggested that the wing flaps be lowered during the dive. It was hoped that this would serve the double purpose of reducing the negative pressures on the wing and of deflecting the wake of the fuselage and wing below the horizontal tail surfaces. Tests were made with the flaps deflected one-sixth, one-third, and one-half of full deflection, corresponding to flap angles of 7°50', 14°20', and 18°35', respectively. Figures 19, 20, and 21 indicate that there was a general tendency for the wake to move downward with flap deflection; however, the wake also spread so that there was only a slight beneficial effect. The full-scale-tunnel measurements indicate that the horizontal tail was slightly above the edge of the wake. Near the critical speed when the wake widens, the tail will be immersed.

Only a small reduction of the negative pressures on the wing was effected by means of flap deflection, as shown in figure 22. At an airplane lift coefficient of 0.15 the minimum pressures were obtained with approximately one-third full flap deflection, in which case the negative pressures in the fuselage fillet were reduced from $-1.07q_o$ to $-0.92q_o$. A larger reduction than this would probably have been effected were it not for the fact that the angle-of-attack reduction required to obtain the lift coefficient of 0.15 with flap deflected tended to unload the outer sections of the wing and correspondingly increase the operating lift coefficient of the wing center section.

In order to determine the change in airplane trim due to flap deflection, measurements of the pitching moment were made with the wing flap deflected one-sixth, one-third, and one-half (fig. 23). In order to estimate the elevator deflection required to balance this change in trim, measurements of the elevator effectiveness were made and are given in figure 24. From these data it may be calculated that the elevator deflection required to trim the airplane for a change in flap angle of $18^\circ35'$ is about 3.6°. The additional stick force required to deflect the elevator 3.6° will depend on the initial elevator setting for the flap-up condition. Measurements of pressures over the tail surface and tail-surface fillets are given in figures 25, 26, and 27. It will be noted that with the elevator deflected 4° a maximum negative pressure value of -0.6q was measured on the upper surface of the stabilizer. This corresponds to a critical speed of 475 miles per hour, which is higher than that expected from the best wing-fuselage fillet and canopy modifications. Critical speeds for all sections of the tail and tail fillets are higher for the case of the undeflected elevator. Serious difficulties due to the direct effect of the attainment of critical speed on the tail are therefore not predicted from the full-scale-tunnel tests on the original airplane; however, if the wing and canopy modifications are made or if flaps are used for deflecting the wake in the dive, further consideration should be given to reducing the pressures on the tail.

Incidental to the study of the flow at the tail of the YP-38 airplane, measurements of the downwash were made ahead of the stabilizer for the case of the original wing and the NACA 66-115 wing glove in the dive condition. The average downwash across the tail span was 1.2° for the original wing and 1.8° for the 66-115 wing glove.

SUMMARY OF RESULTS

1. The buffeting and diving tendency of the YP-38 airplane is due to compressibility effects on the wing center section and canopy which produce a decrease in the airplane lift, an increase in the airplane diving moment, and a strong wake over the tail.

2. The critical speed at which the compressibility effects become important may be delayed from 50 to 60 miles per hour by extending the wing leading edge about 0.20c, by rounding over the canopy peak, and refairing the boom fillets. The moment changes due to the leading-edge modification can be counteracted by relocating the Prestone and oil radiators in the extended leading edge.

3. Deflecting the wing flaps in the dive will slightly improve the tail buffeting but will increase the elevator deflections required for trim.

4. Raising the tail above the wake will eliminate the tail buffeting but will not decrease the diving tendency.

5. Reduction of stick forces in the dive pull-out may necessitate an auxiliary elevator balancing device.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 31, 1942.

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REFERENCES

1. Johnson, C. L.: Investigation of Tail Buffeting Conditions on Lockheed P-38 Airplane and Appendix I. Lockheed Airc. Corp., Sept. 1941.

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

3. Goett, Harry J.: Experimental Investigation of the Momentum Method for Determining Profile Drag. T. R. No. 660, NACA, 1939.

4. von Karman, Th.: Compressibility Effects in Aerodynamics. Jour. Aero. Sci., July 1941.

5. Preliminary Analysis for Army Air Corps: Recommendations for Modifications to P-38 Airplane to Reduce the Tail Buffeting and to Increase the High Speed. NACA, March 18, 1942.

6. Preston, G. Merritt, and Guryansky, Eugene R.: Drag Analysis for Lockheed YP-38 Airplane. Memo. Report, NACA, March 27, 1942.

TABLE I. - Critical Mach Numbers of P-38 Airplane

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	$\left(-\frac{p}{q_0}\right)_{max}$	Location	Critical Mach No.	Critical speed 20,000 ft (mph)
CANOPY				
Original	0.92	39 in	0.59	417
Original, 66-115 wing glove	.95	39	.60	425
First revision, 66-115 wing glove	.84	43.5	.62	440
Second revision, 66-115 wing glove	.68	42	.65	461
Second revision, 0.10c L.E. extension	.68	42	.65	461
Second revision, 0.20c L.E. extension	.70	42	.65	461
Second revision extended, 66-115 wing glove	.68	41	.65	461
FUSELAGE FILLET				
Original	1.07	0.13c	.57	404
66-115 wing glove, original canopy	.72	.28	.64	452
66-115 wing glove, first canopy revision	.73	.27	.64	452
66-115 wing glove, second canopy revision	.72	.26	.64	452
66-115 wing glove, second canopy revision ext.	.68	.25	.65	461
0.10c L.E. extension, second canopy revision	.80	.24	.62	438
0.20c L.E. extension, second canopy revision	.65	.28	.66	468
Original, $\delta_f = 7°50'$	.94	.12	.60	425
Original, $\delta_f = 14°20'$	.92	.12	.60	425
Original, $\delta_f = 18°35'$	.99	.12	.59	417
WING, MIDWAY BETWEEN FUSELAGE AND NACELLE				
Original	.96	.11	.60	425
66-115 wing glove	.56	.25	.68	482
0.10c L.E. extension	.60	.25	.67	475
0.20c L.E. extension	.50	.25	.70	490
INBOARD NACELLE FILLET				
Original	.68	.30	.64	452
66-115 wing glove	.46	.31	.71	503
0.20c L.E. extension	.53	.05	.69	488
OUTBOARD NACELLE FILLET				
Original	.82	.29	.62	438
WING, BETWEEN TIP AND NACELLE				
Original	.74	.12	.63	447
WING TIP				
Original	.64	.26	.65	461
STABILIZER, CENTER SECTION				
Original, upper surface	.21	.15	.83	588
Original, upper surface, $\delta_e = -1.9°$	.18	.18	.84	596
Original, lower surface, $\delta_e = -1.9°$	.50	.02	.70	496
Original, lower surface, $\delta_e = -4.0°$	.60	.02	.67	475
Original, upper surface, $\delta_e = -4.0°$	.12	.20	.89	631
STABILIZER - FIN FILLETS				
Original, upper inboard	.21	.30	.83	588
Original, lower inboard	.32	.13	.79	561
Original, upper outboard	.26	.35	.80	568
Original, lower outboard	.08	.20	.88	625
Original, lower inboard, $\delta_e = -1.9°$	.15	.23	.87	616
Original, upper inboard, $\delta_e = -1.9°$	.13	.24	.88	625
Original, lower inboard, $\delta_e = -4.0°$	.19	.05	.84	596
Original, upper inboard, $\delta_e = -4.0°$	.13	.30	.88	625

Figure 1. - The P-38 airplane mounted in the NACA full-scale wind tunnel.

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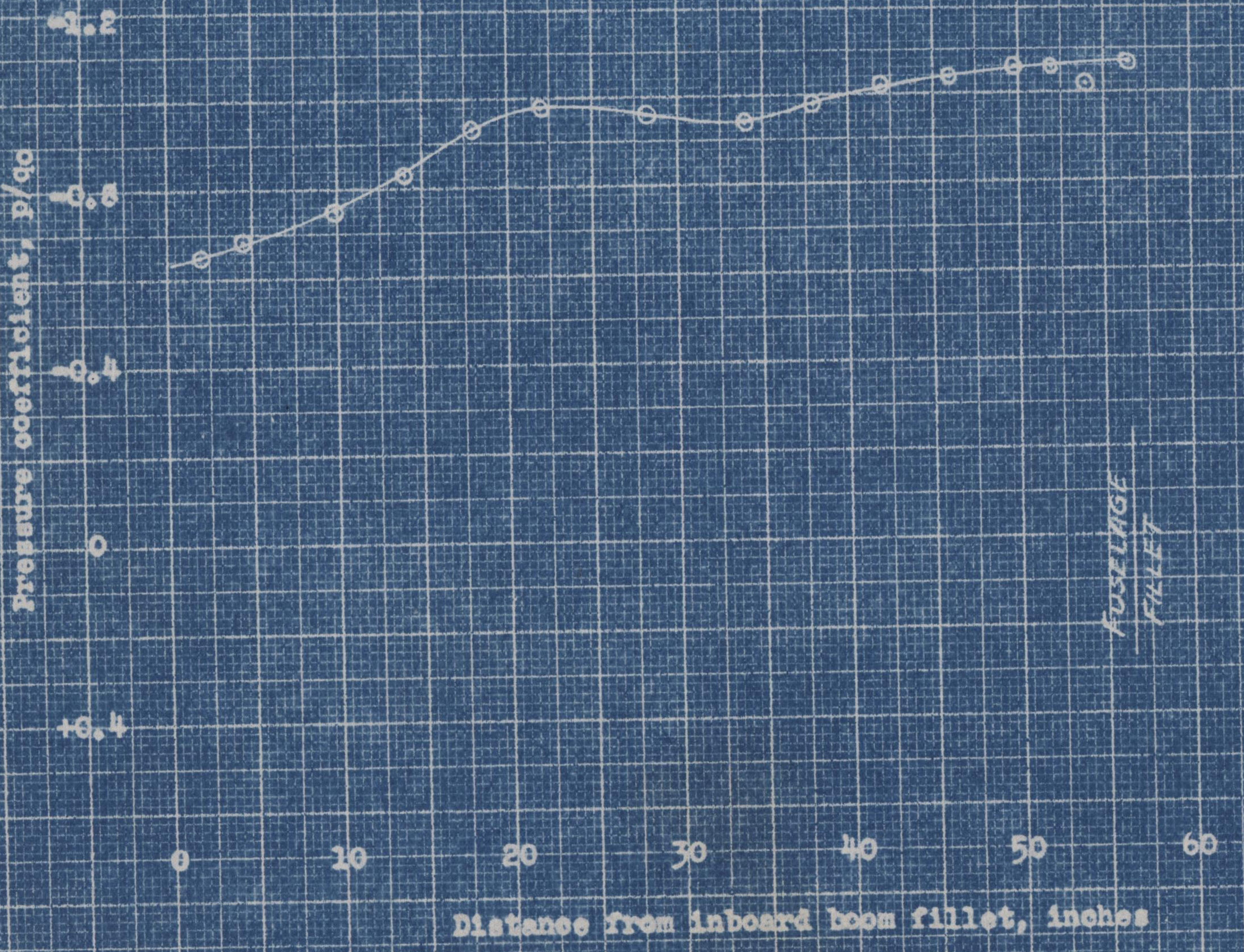

Figure 2.- Lateral survey of peak pressures of wing between nacelle and fuselage; C_L= 0.15 ; original condition.

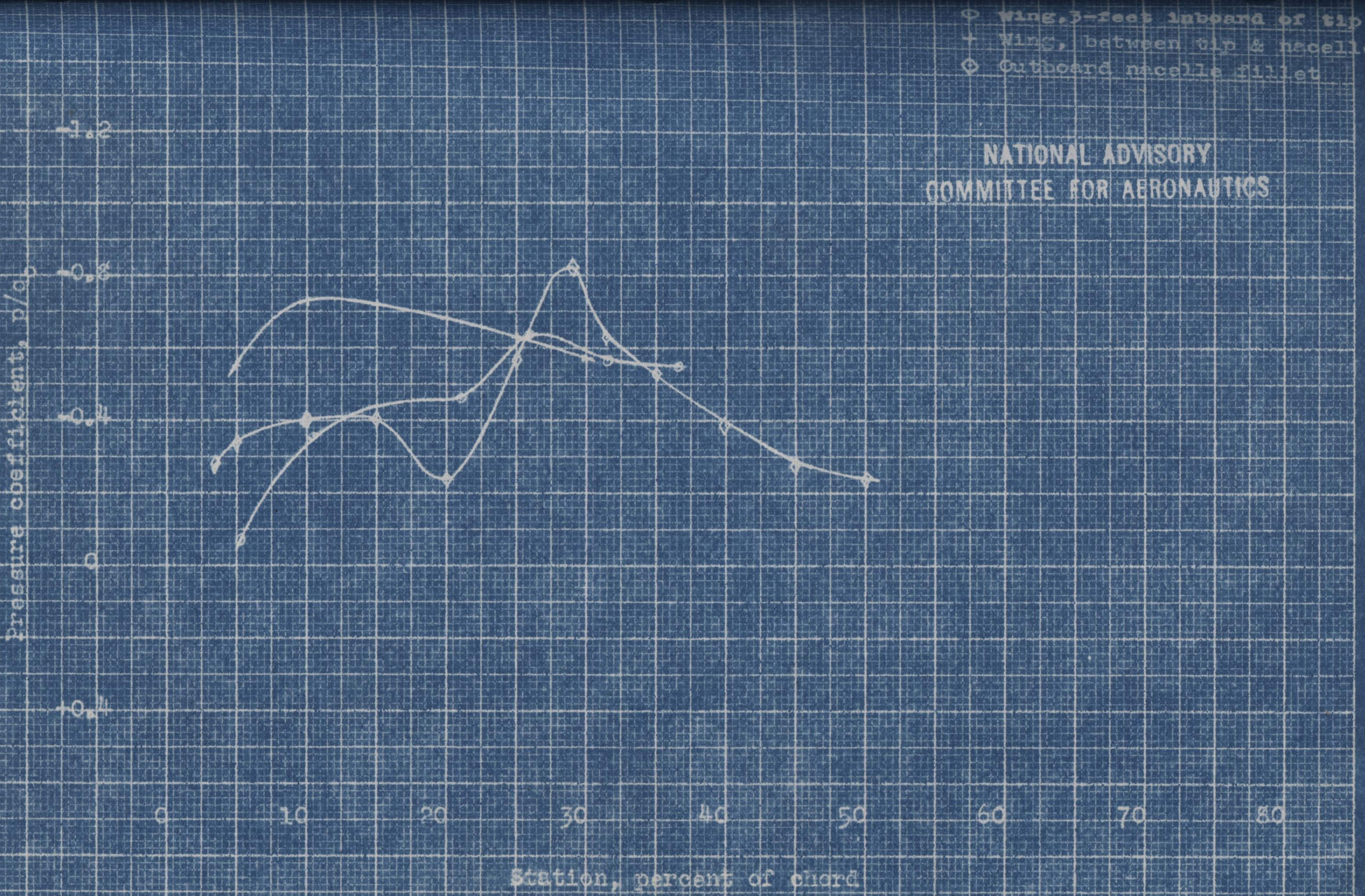

Figure 3.- Pressure distribution of outboard nacelle fillet and two wing stations; C_L = 0.15 ; original condition.

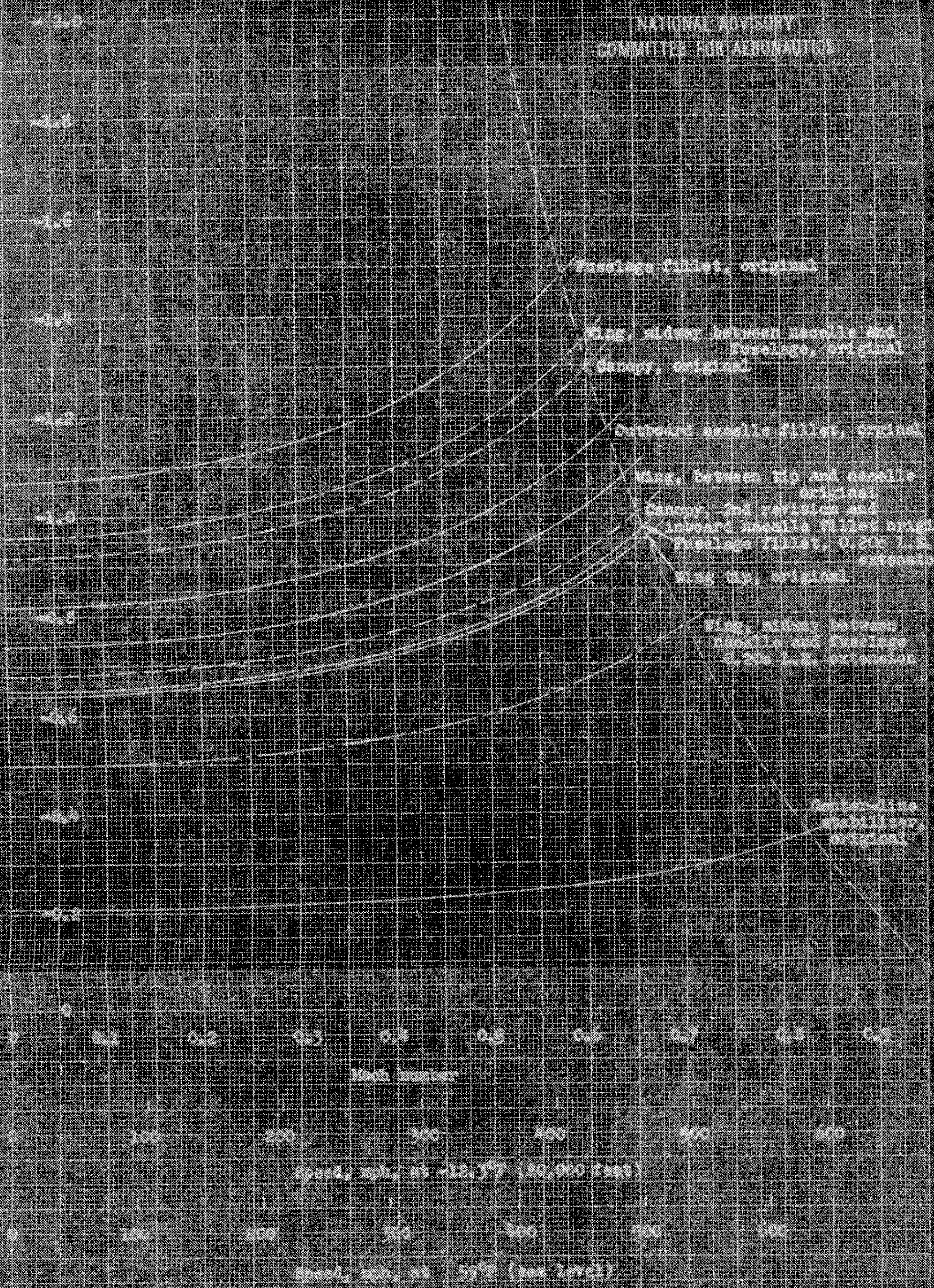

Figure 4.- Critical Mach numbers and compressibility speeds for P-38 airplane.

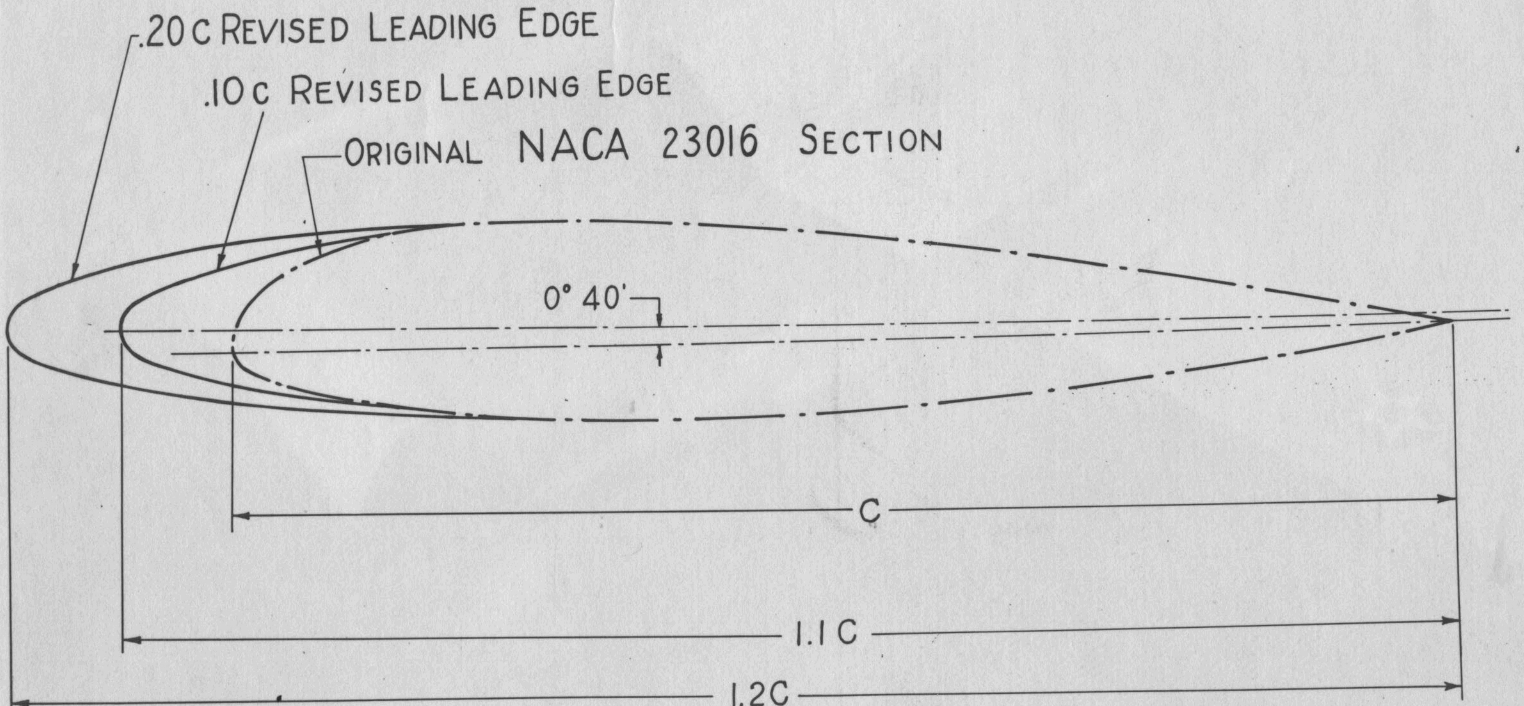

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Figure 5,– Leading Edge Modification

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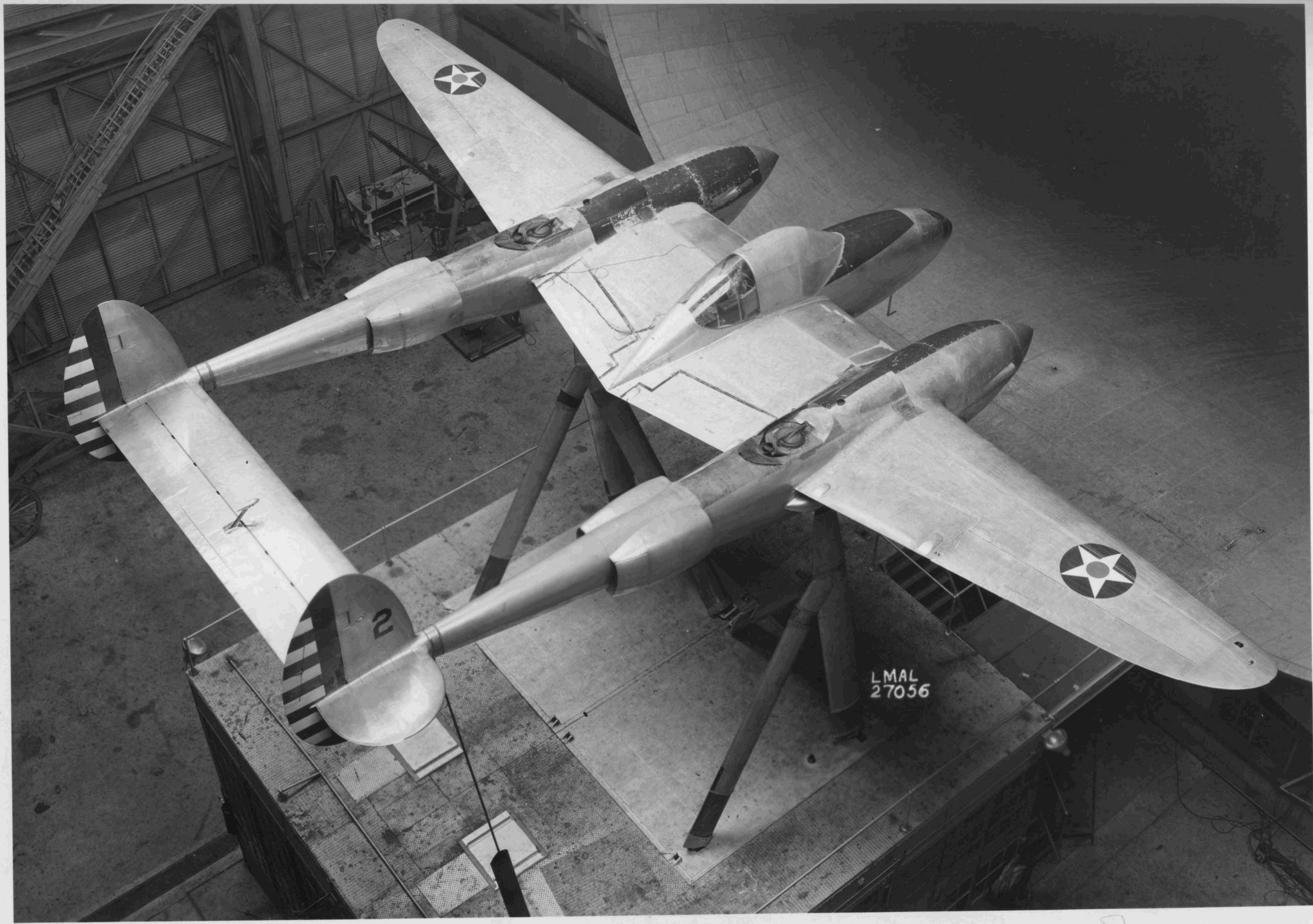

Figure 6. - Modified P-38 airplane with 0.10c leading-edge extension and second canopy revision.

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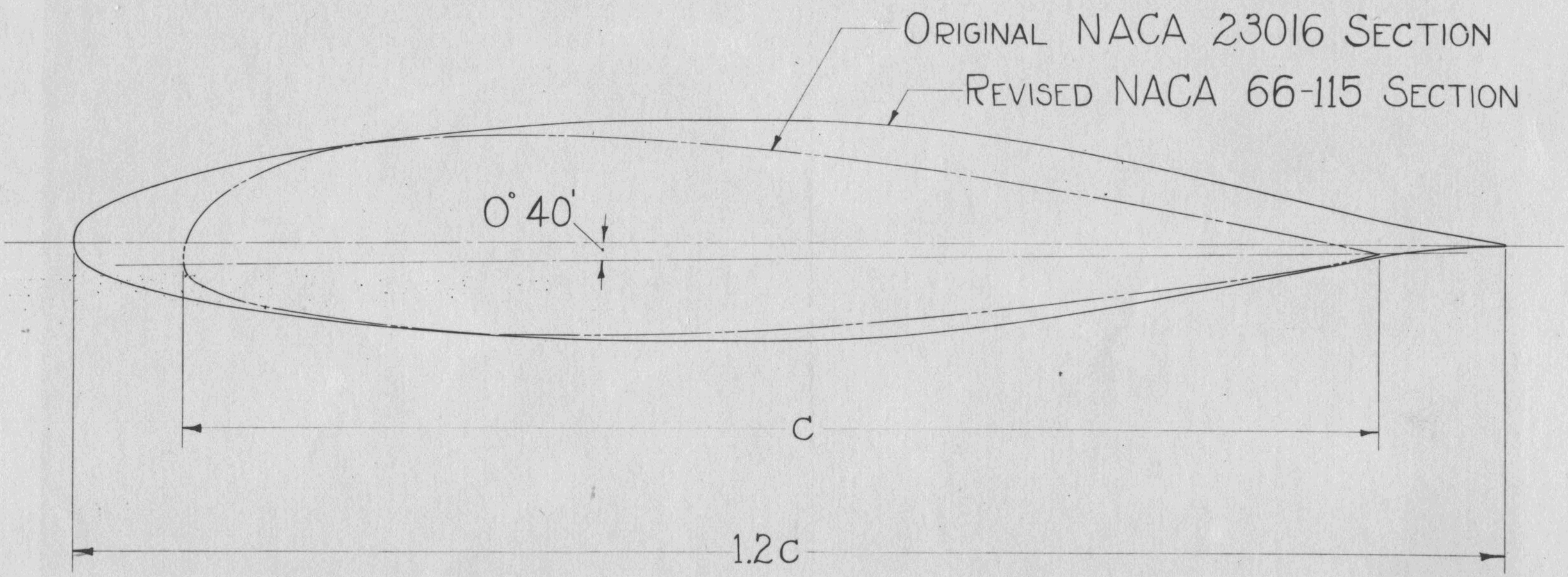

FIGURE 7 - WING MODIFICATIONS.

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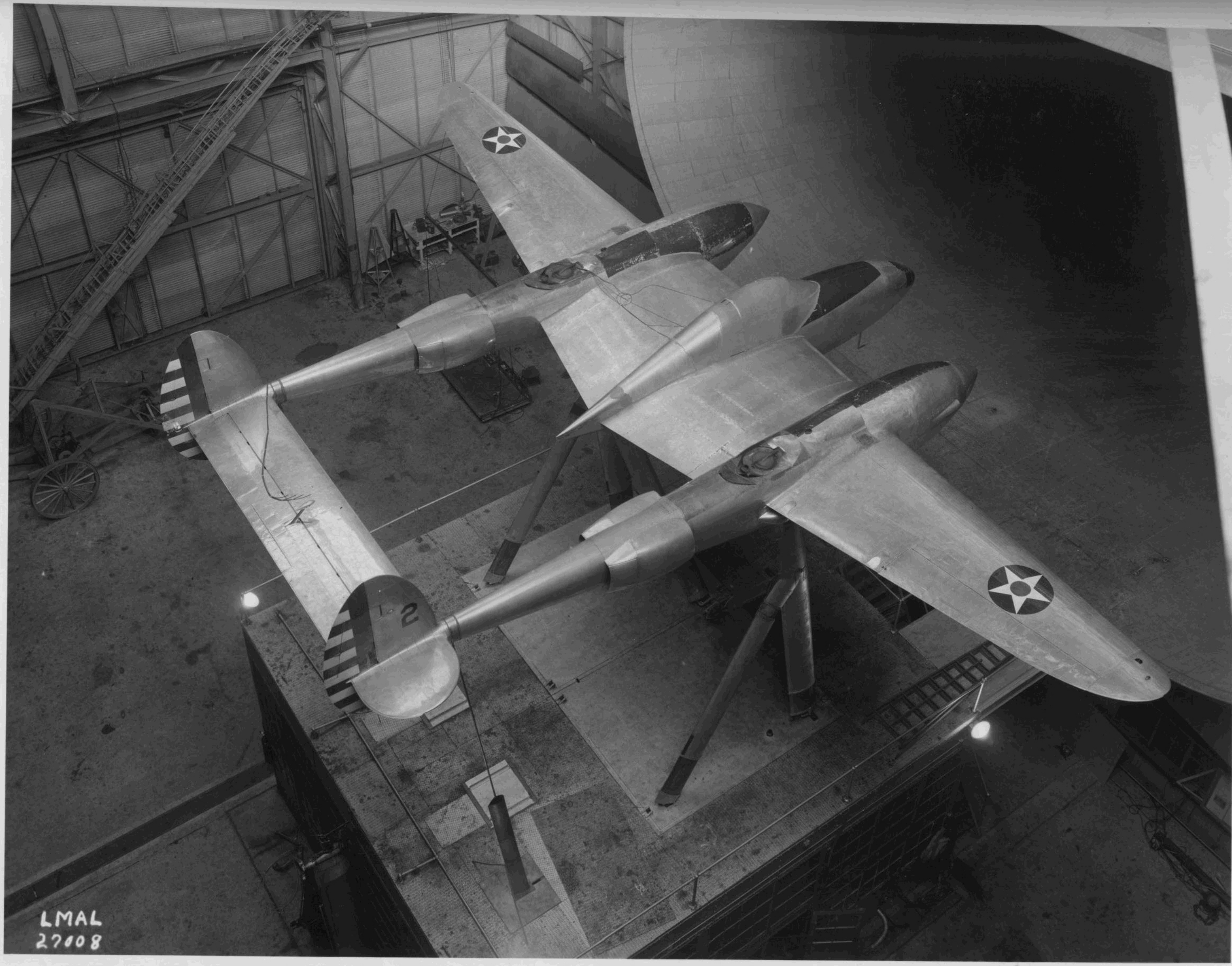

Figure 8. - Modified P-38 airplane with 66-115 wing glove and second canopy revision extended.

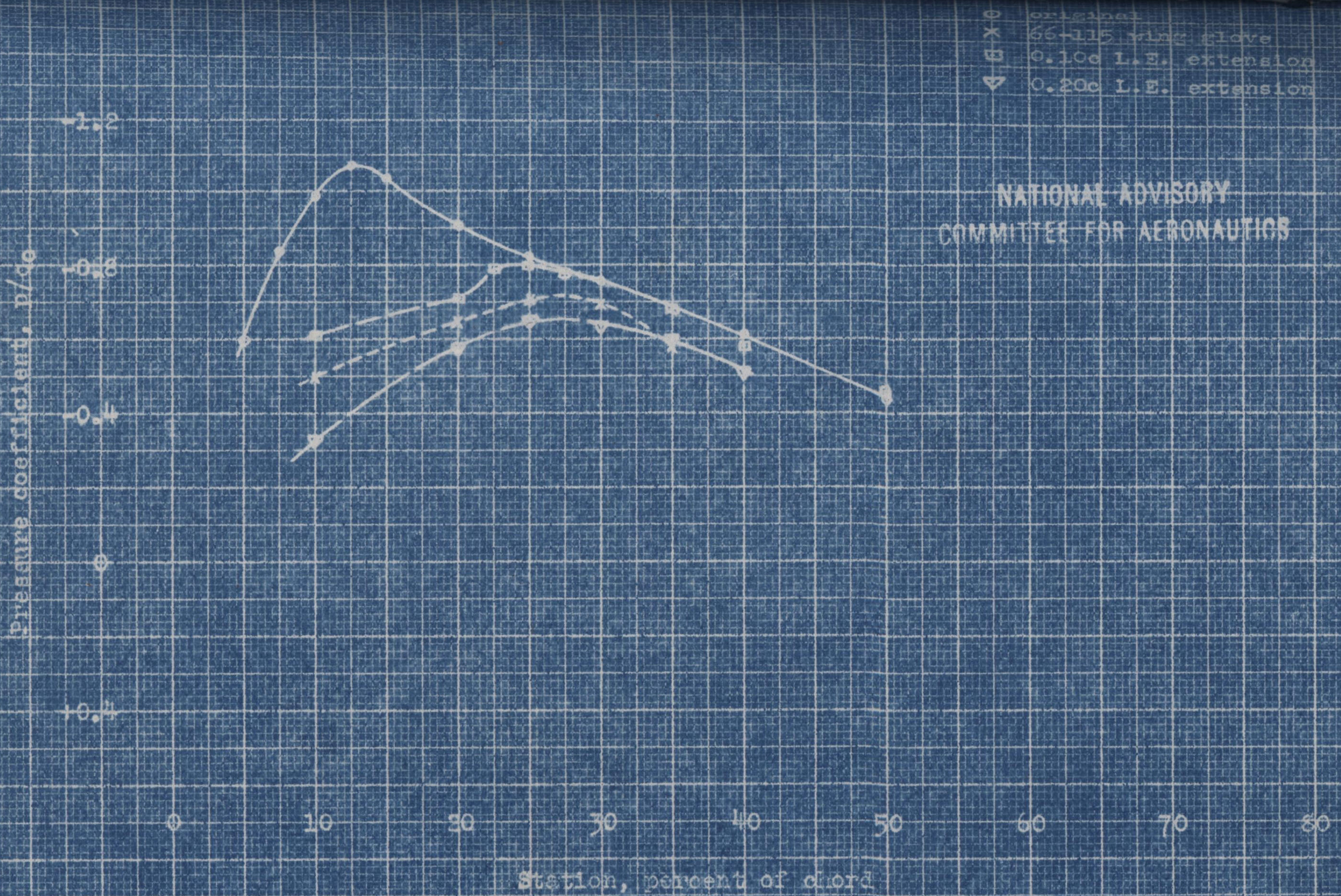

Figure 9. - Pressure distribution of fuselage fillet; $C_L = 0.15$.

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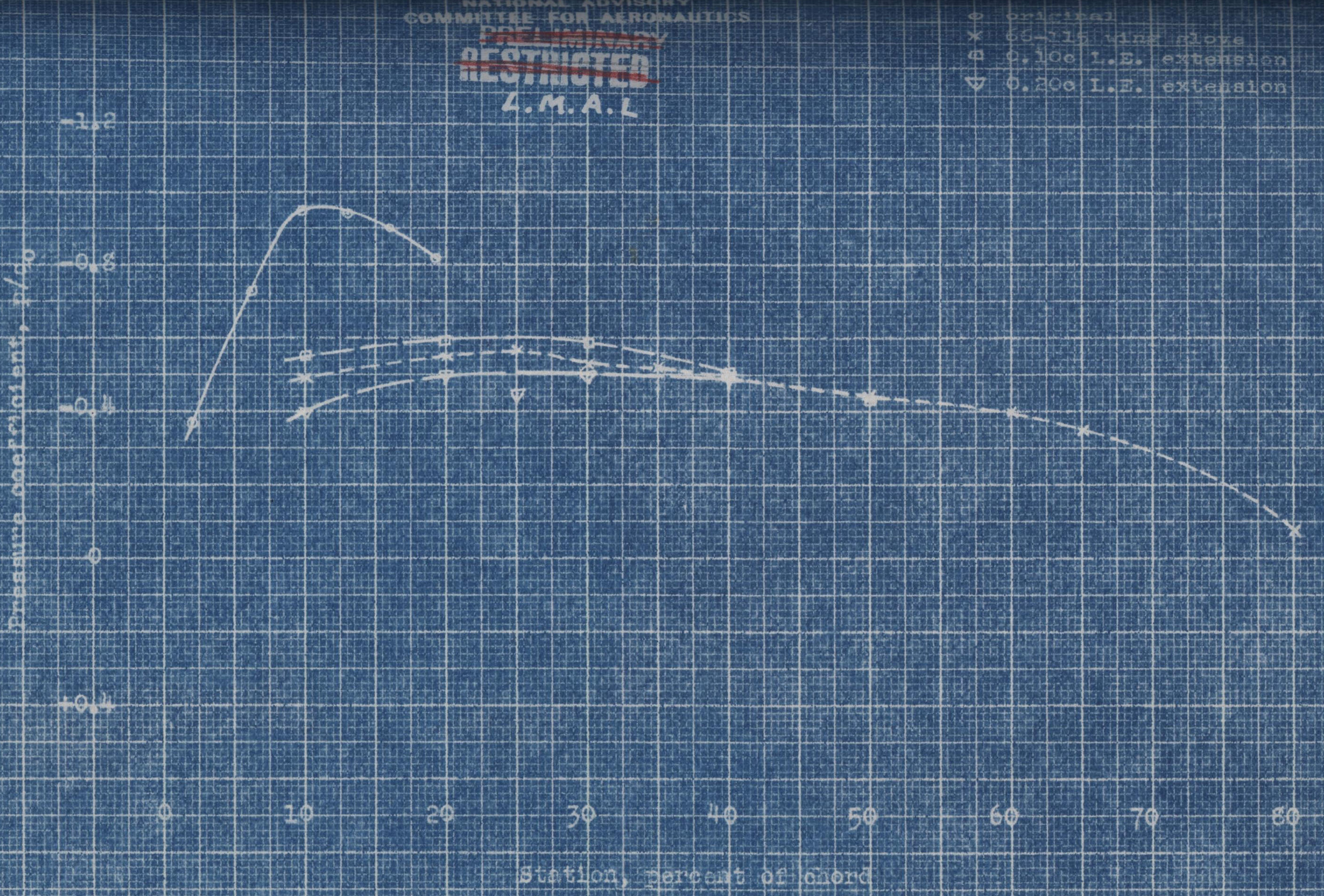

Figure 10.- Pressure distribution of the upper surface of wing midway between fuselage and nacelle; C_L = 0.15.

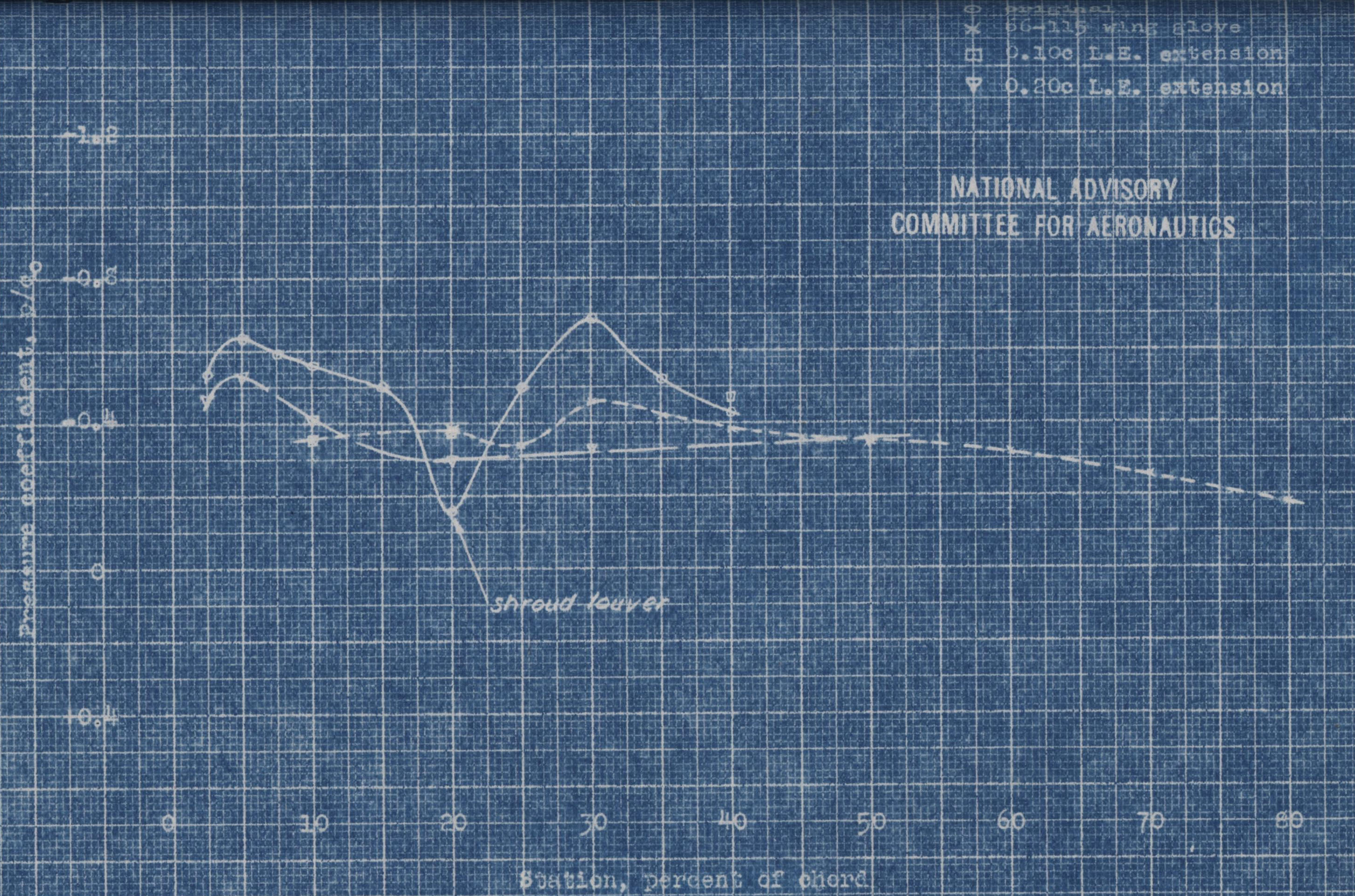

Figure 11. - Pressure distribution of inboard nacelle fillet; C_L = 0.15 .

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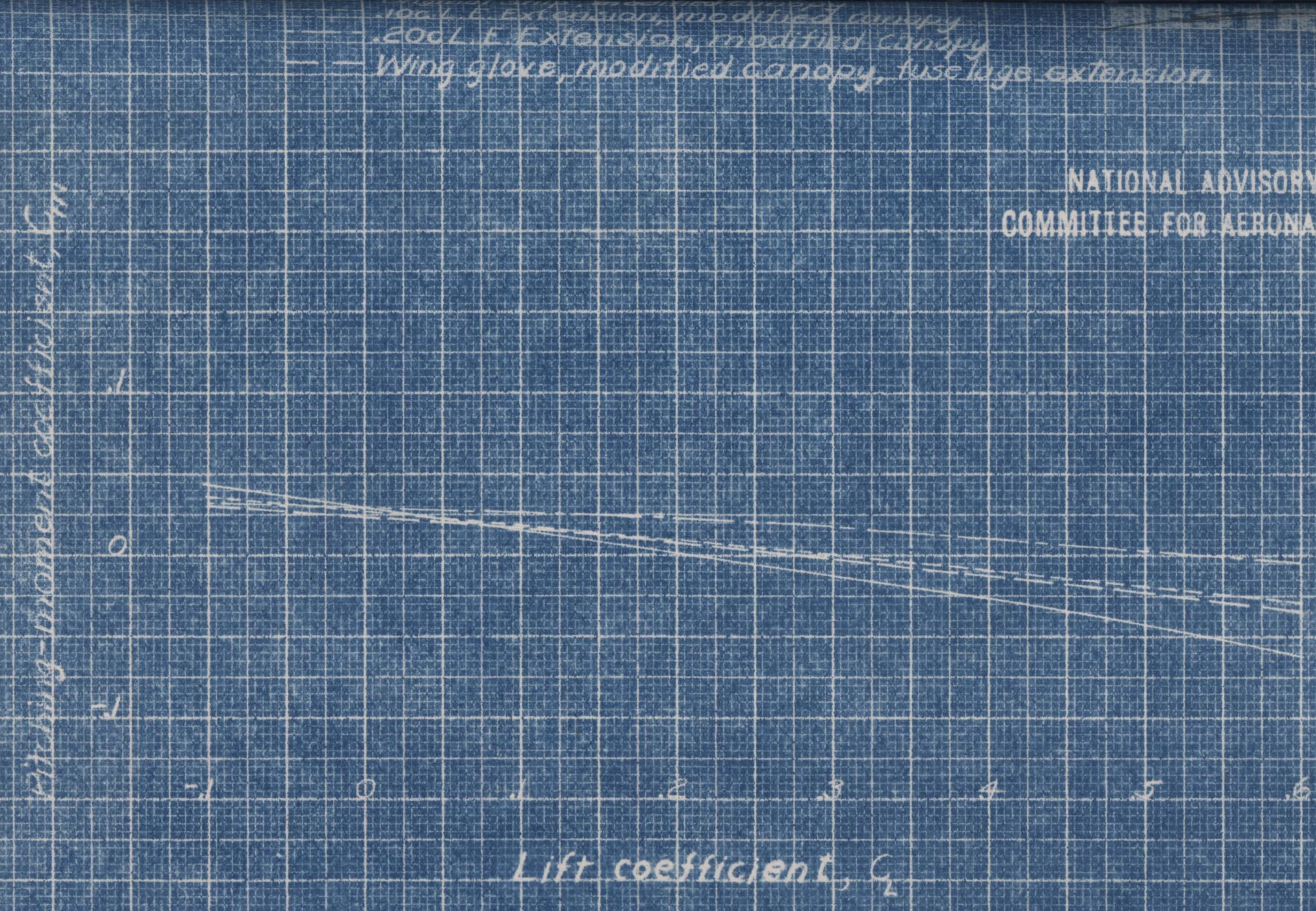

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Figure 12.- Pitching-moment coefficients for various airplane modifications.

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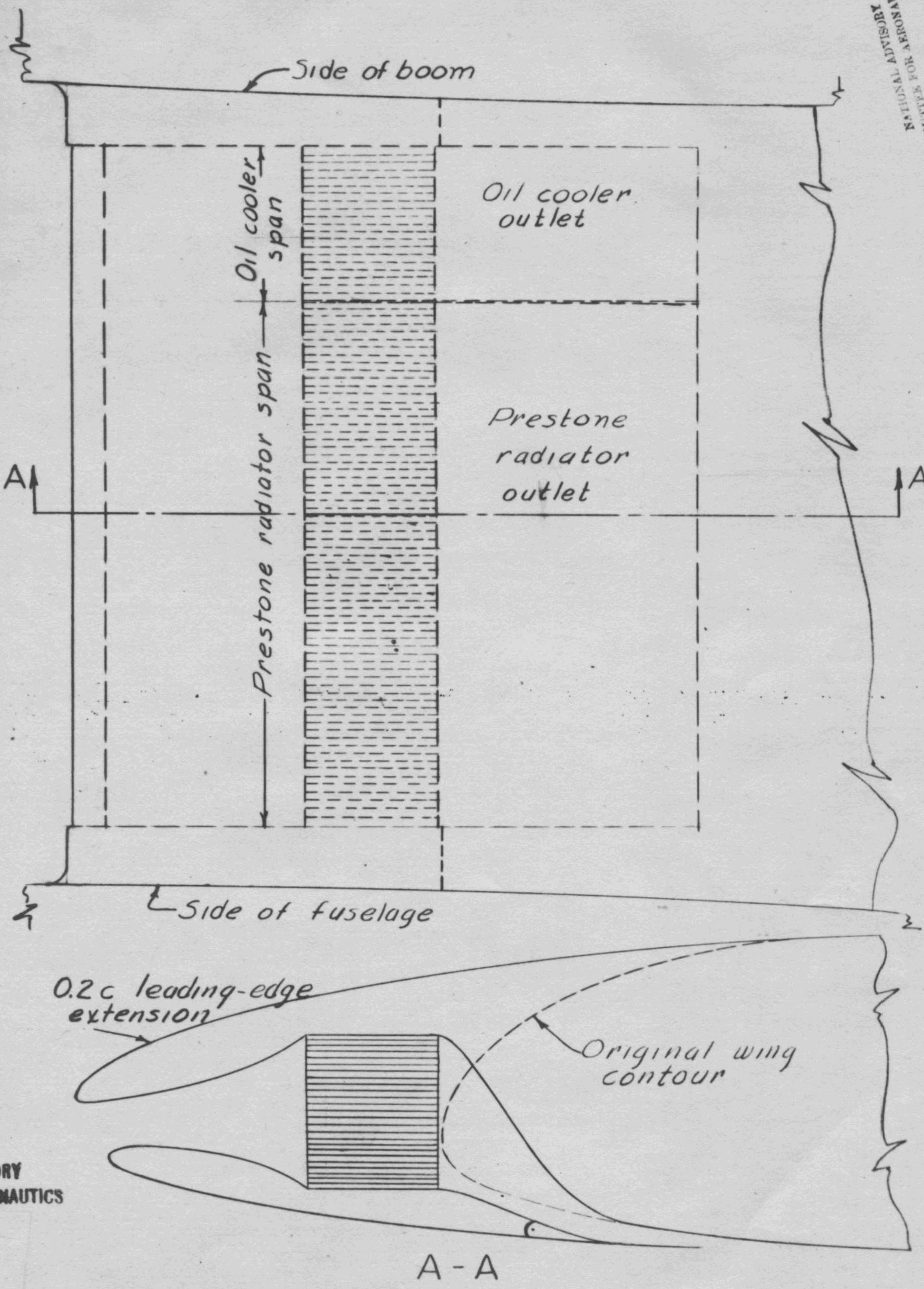

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Figure 13.– Recommended radiator and oil-cooler installation for YP-38 airplane

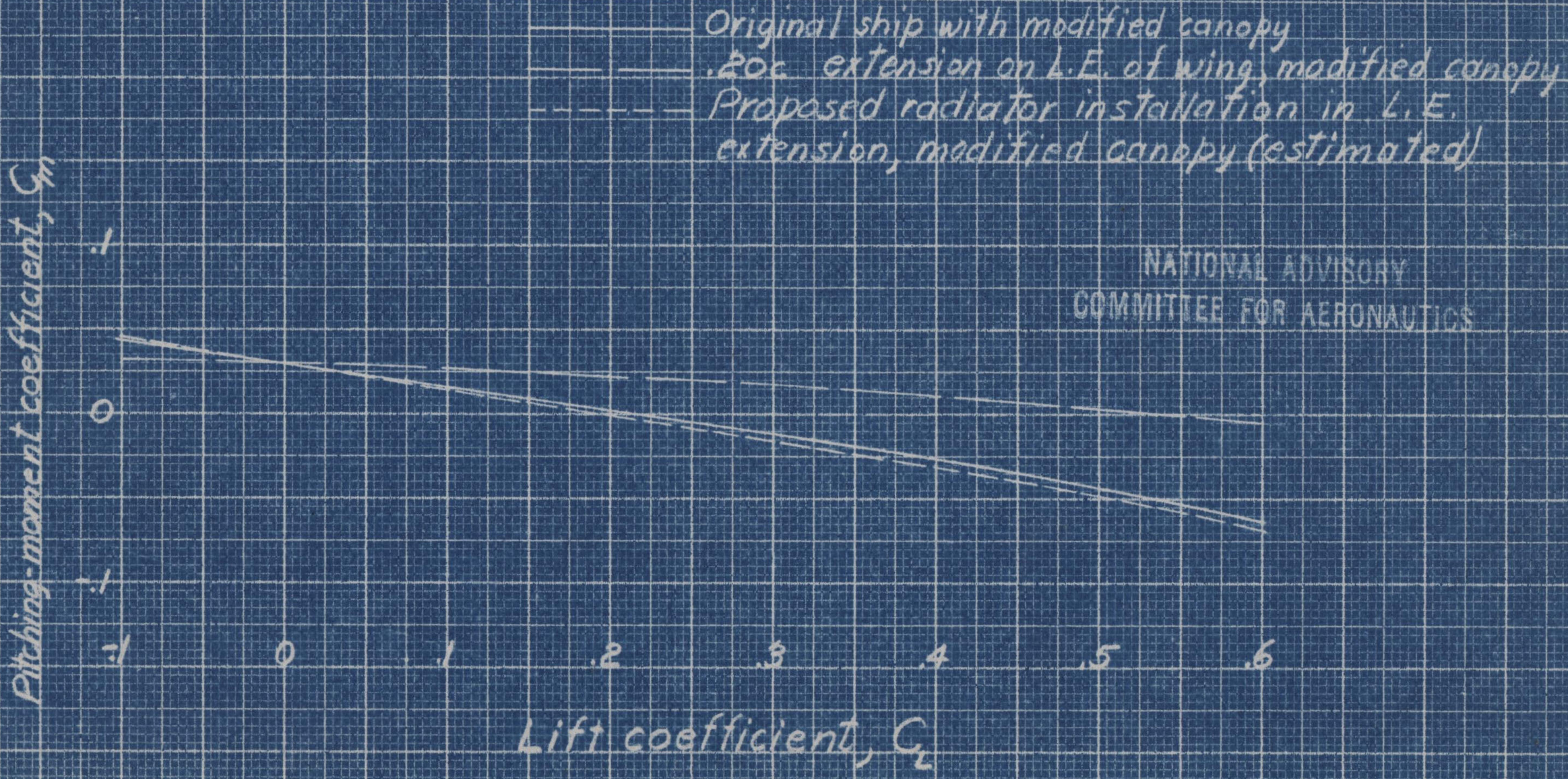

Figure 14.- Pitching-moment coefficients for P-38 airplane with original and recommended radiator installations.

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Figure 15 Canopy & Fuselage Modifications

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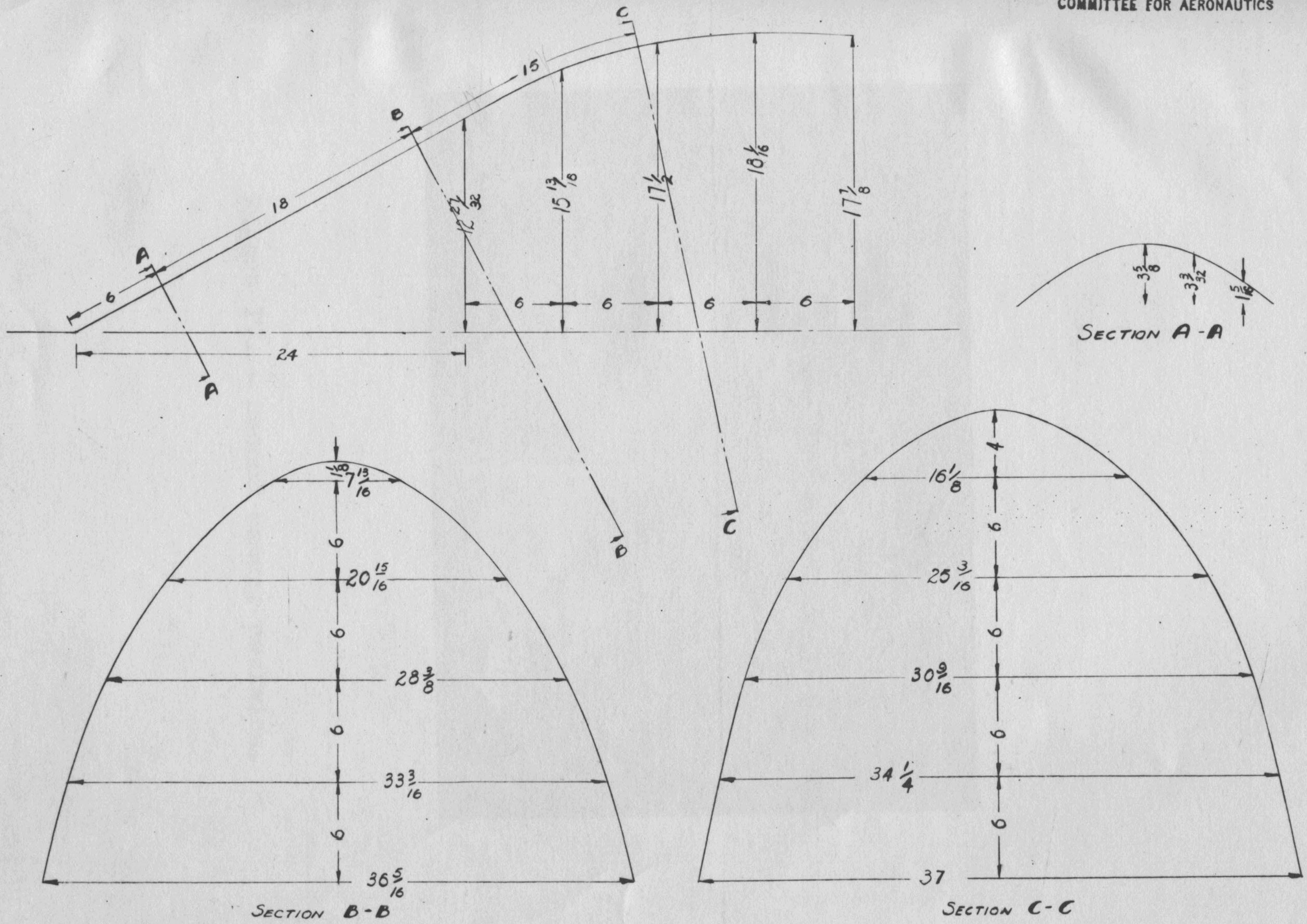

Figure 16 Second revision of canopy

Figure 17. - Second canopy revision.

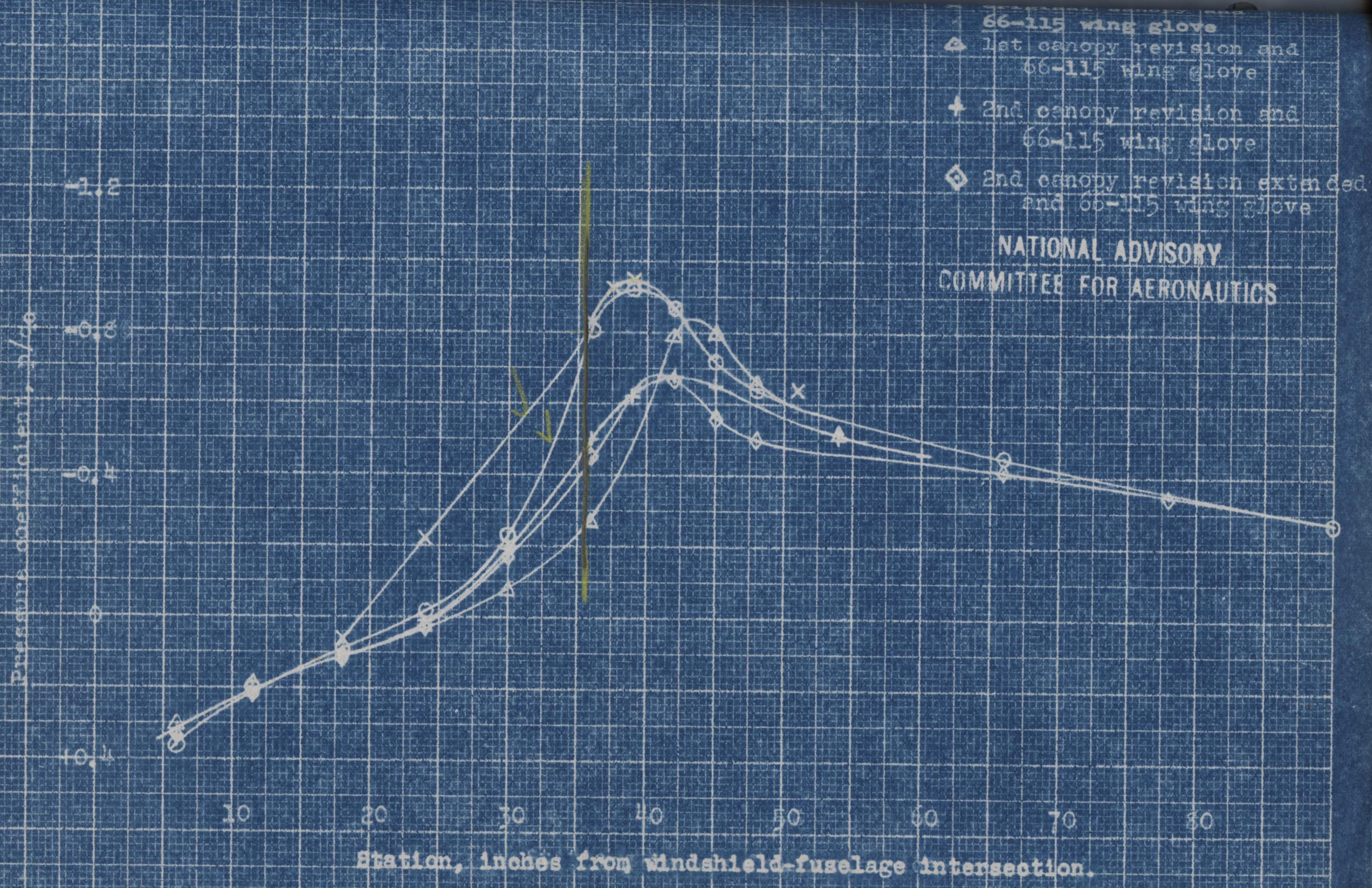

Figure 18- Pressure distribution over canopy; C_L= 0.15 .

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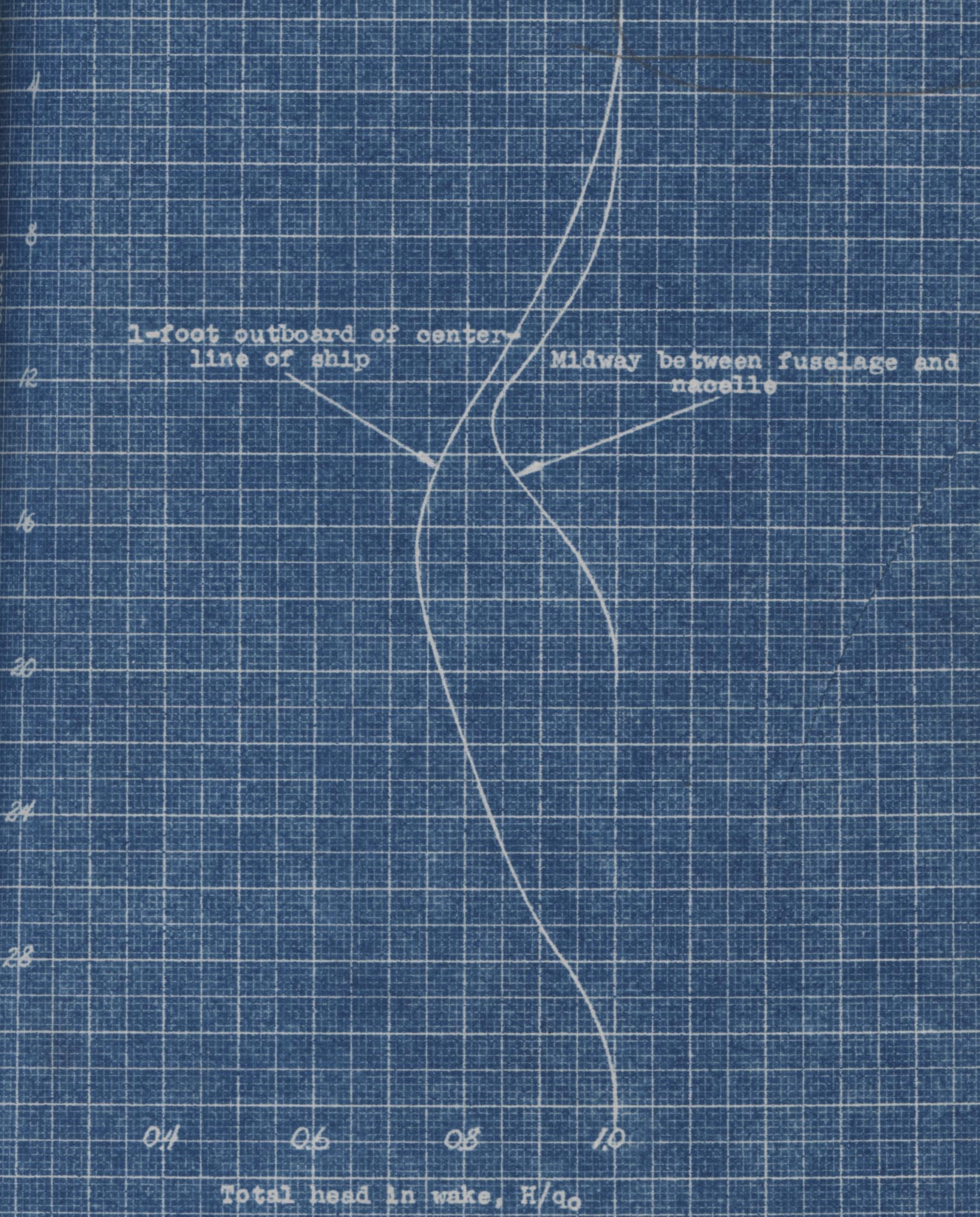

Figure 19.- Wing wake total-head distribution at stabilizer; C_L= 0.15

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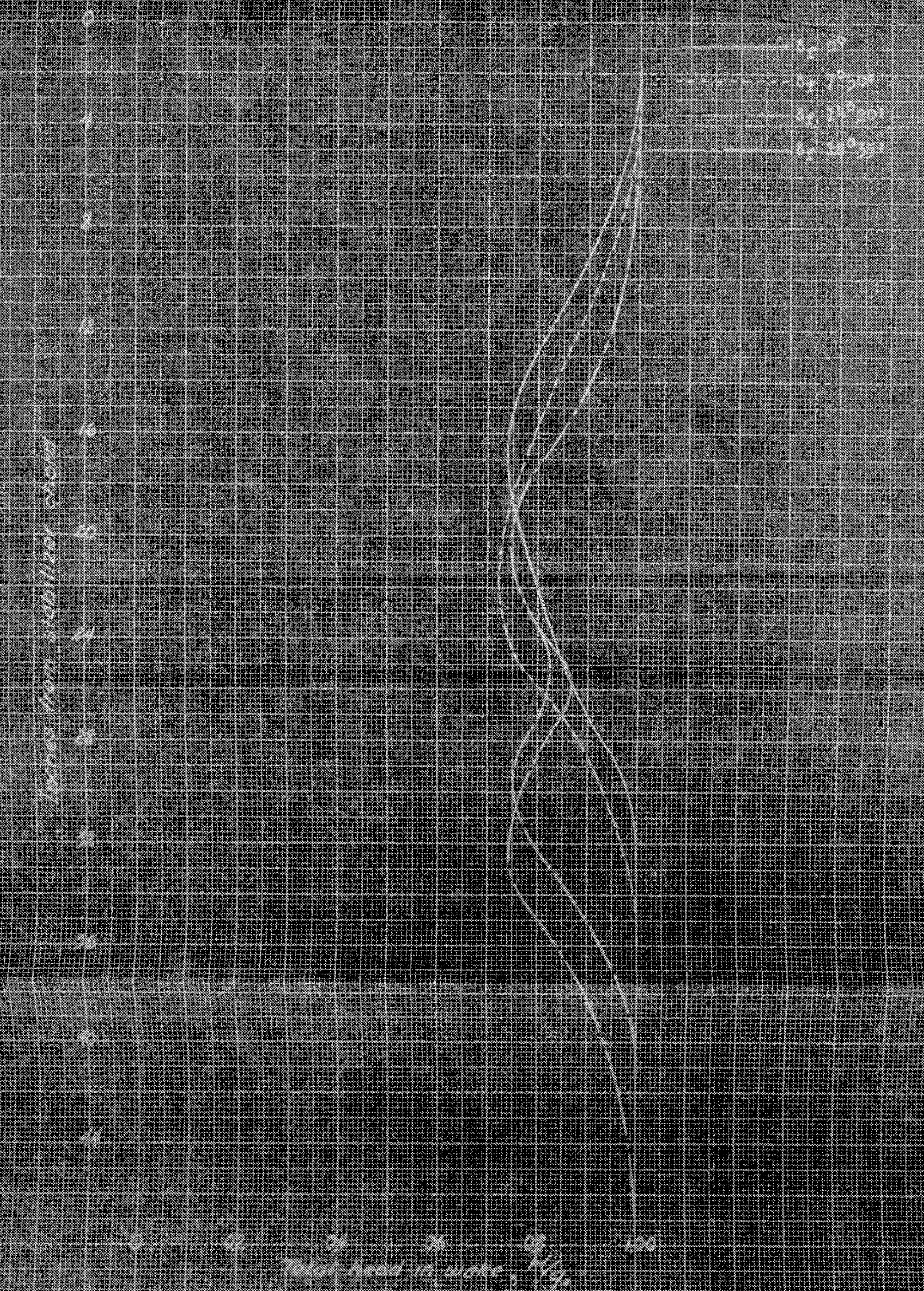

Figure [illegible].- Wake distribution at stabilizer of wing 1-foot outboard of center line of ship; [redacted]; C_L 0.15.

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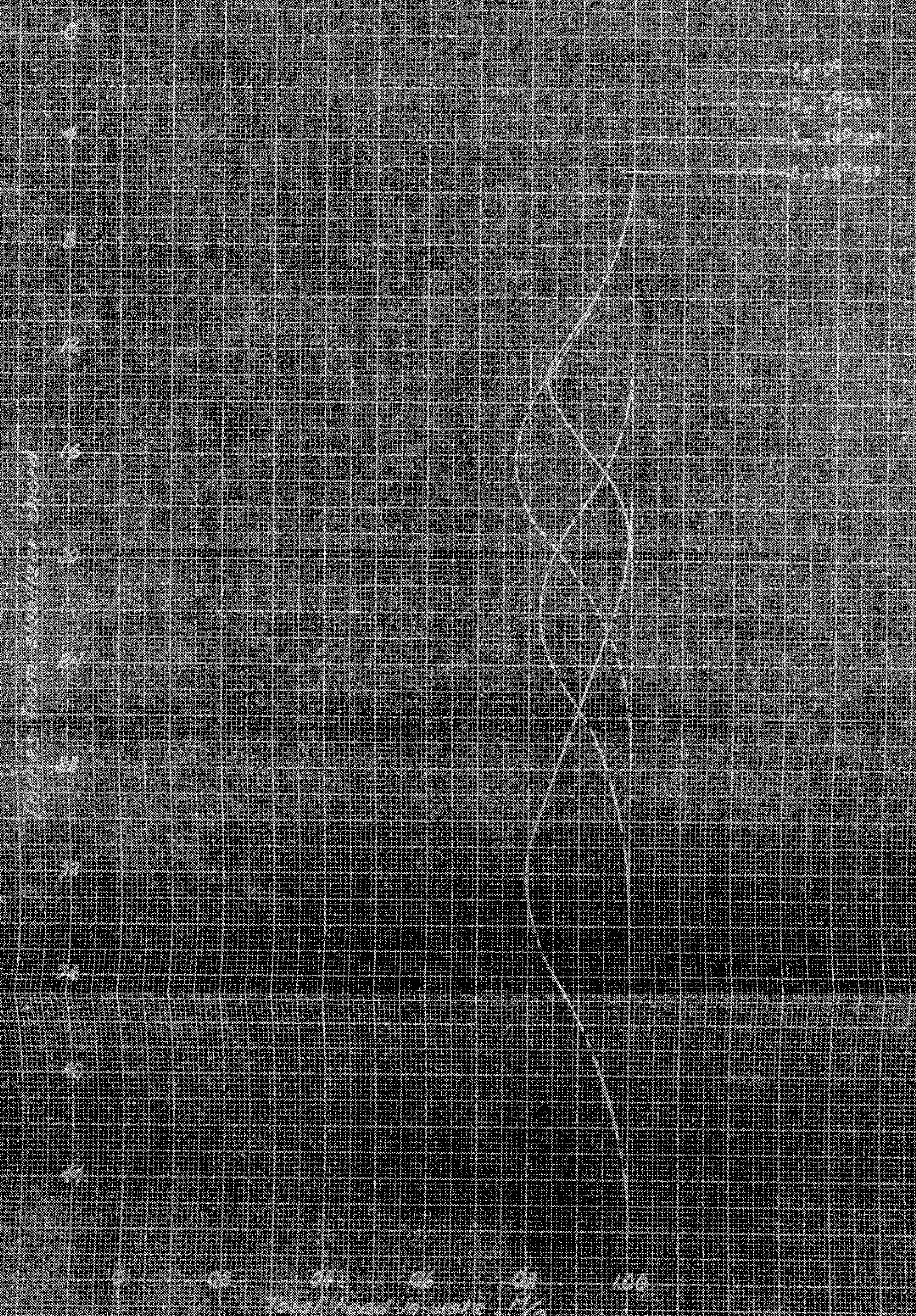

Figure 21.- Wake distribution at stabilizer of wing gap between fuselage and nacelle; [redacted]; 0.1 0.12.

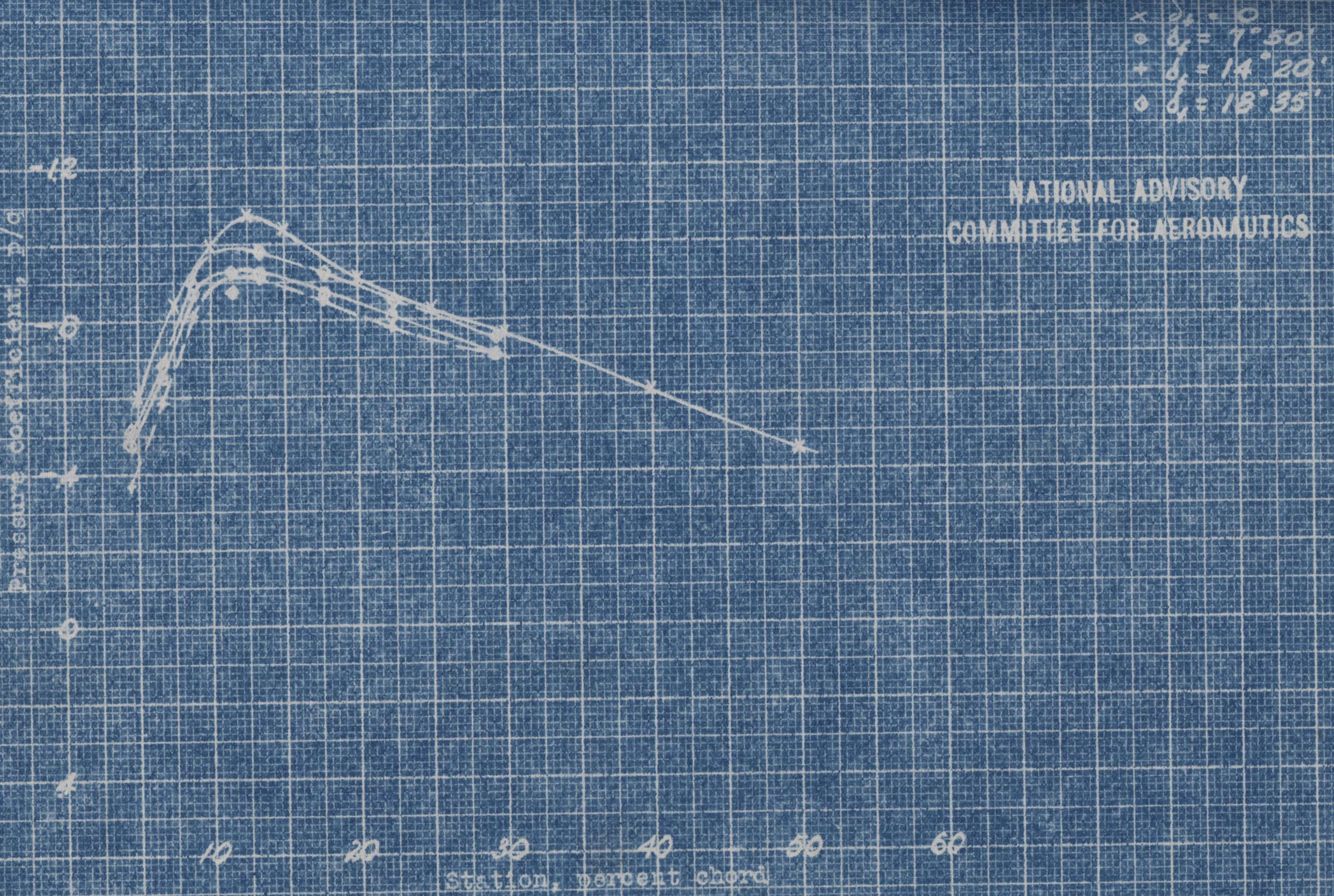

Figure 22.- Pressure distribution in fuselage fillet with flaps deflected; C_l = 0.15, original wing.

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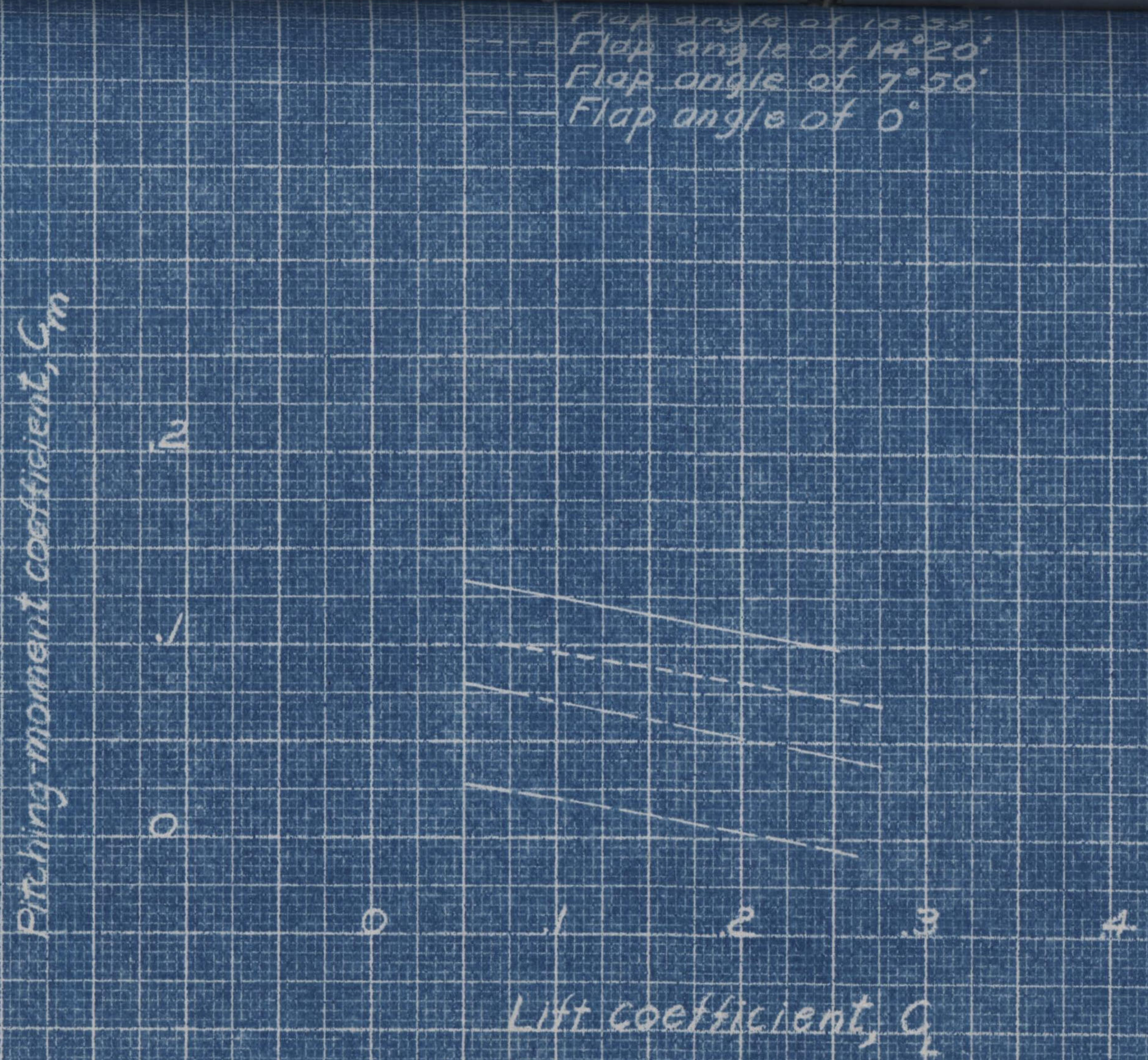

Figure 23.- Effect of flap deflections on pitching-moment coefficients for the airplane in the original condition with modified canopy.

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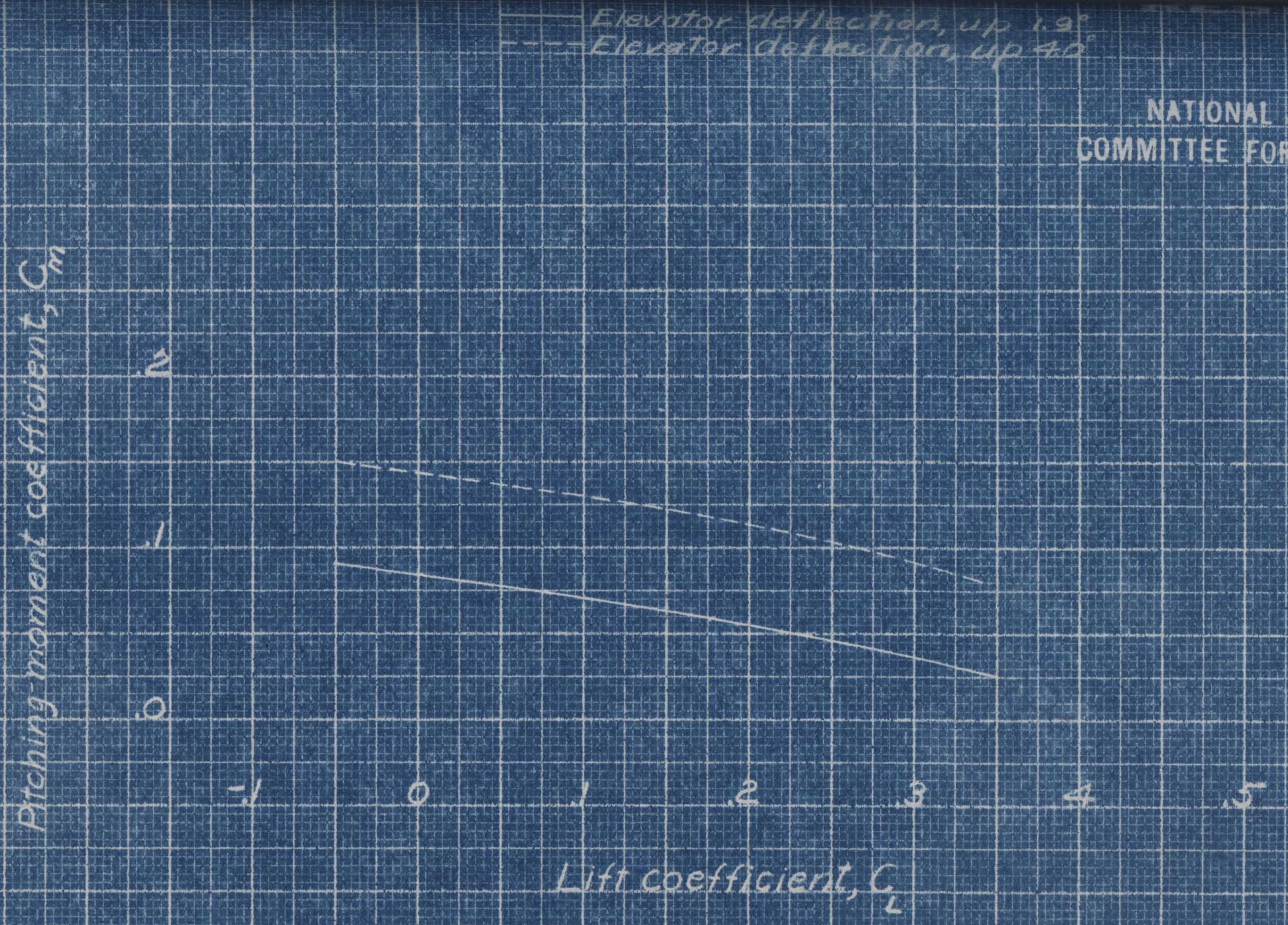

Figure 24.- Effect of elevator deflections on pitching-moment coefficients for the airplane in the original condition with modified canopy.

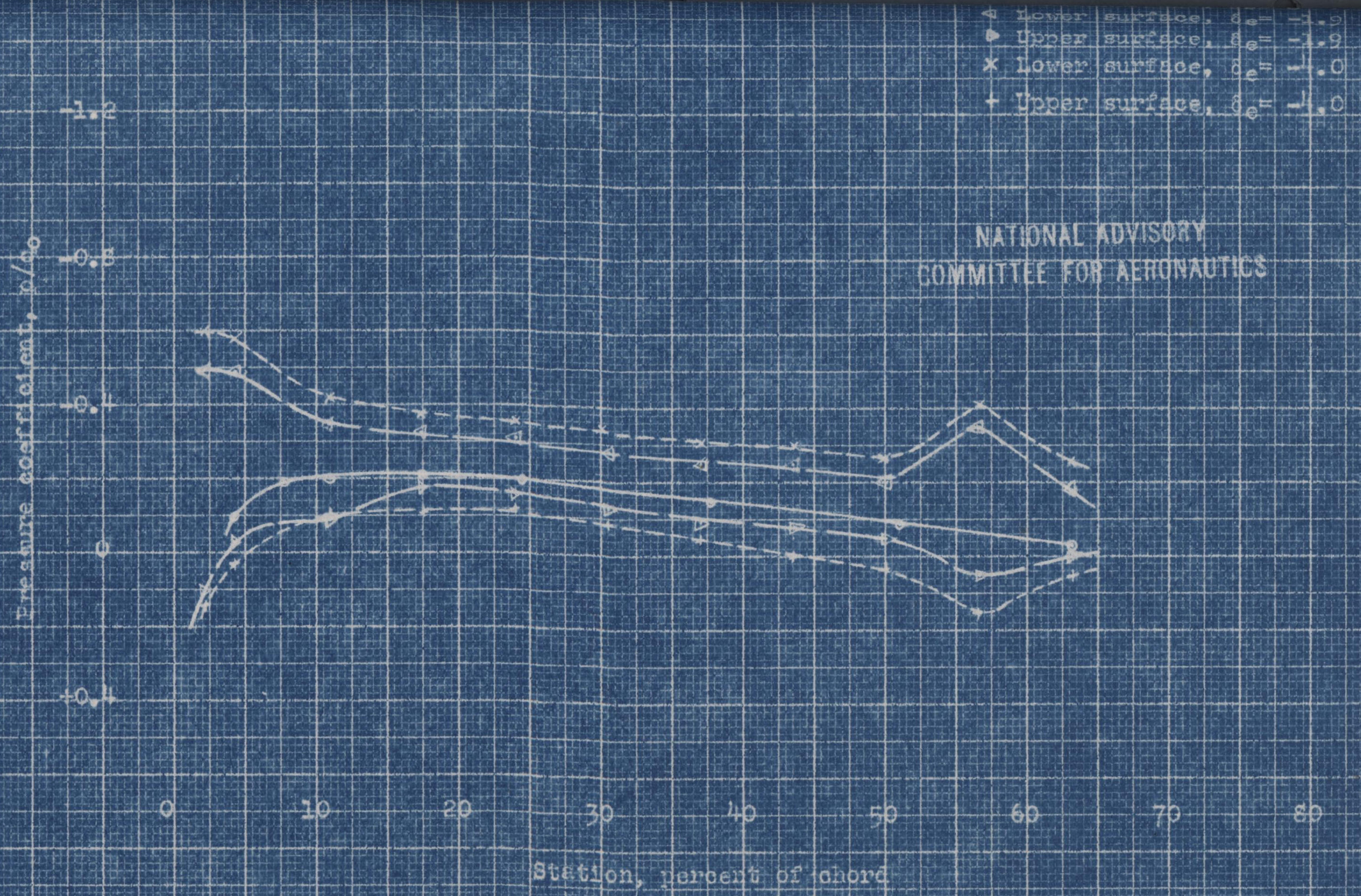

Figure 25- Pressure distribution of stabilizer 1-foot outboard of center line for various flap deflections; C_L= 0.15 ; original condition.

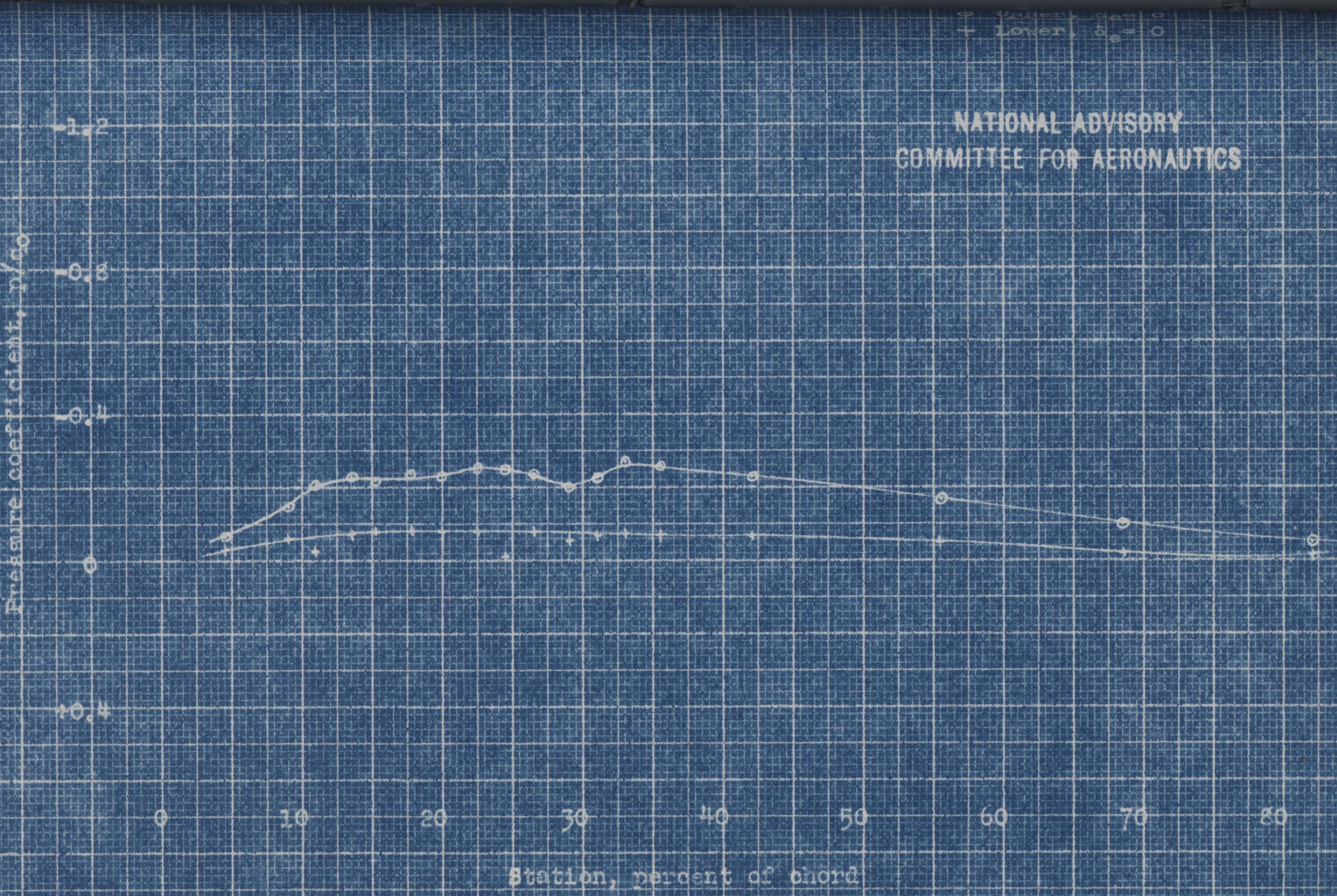

Figure 26.- Pressure distributions of the outboard stabilizer-fin fillets; $C_L = 0.15$; original condition.

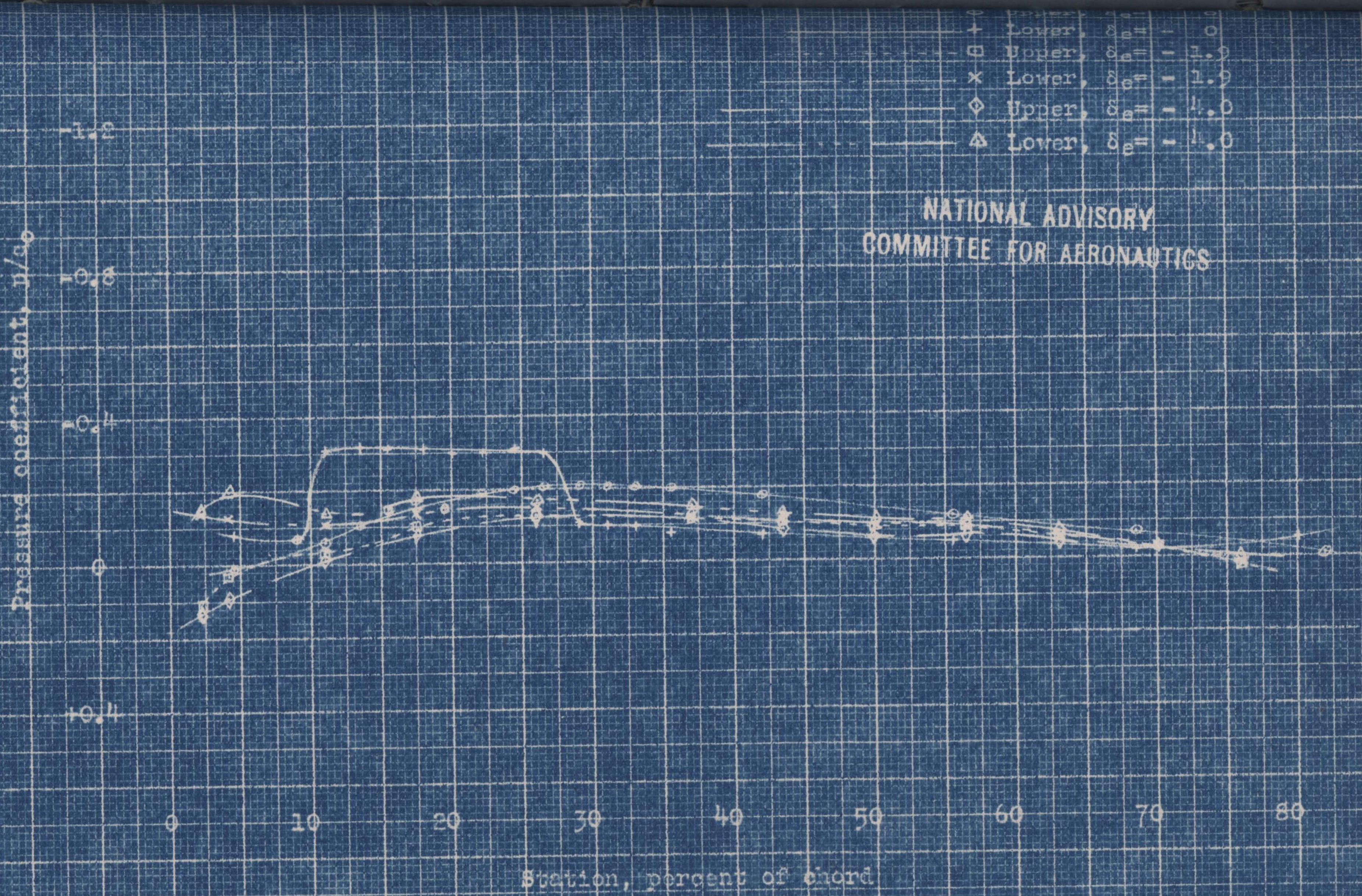

Figure 27.- Pressure distribution of the inboard stabilizer-fin fillets for various elevator deflections; C_L = 0.15 ; original condition.