NACA

RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION OF A WING-FUSELAGE COMBINATION WITH EXTERNAL STORES

By

H. Norman Silvers and Kenneth P. Spreemann

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

July 9, 1948
Declassified August 18, 1954

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION OF A WING-FUSELAGE COMBINATION WITH EXTERNAL STORES

By H. Norman Silvers and Kenneth P. Spreemann

SUMMARY

An investigation was conducted in the Langley high-speed 7- by 10-foot tunnel on a basic wing-fuselage combination with several types of external-store installations specifically designed to delay the advent of airplane buffet caused by external stores. Buffeting has been recognized in wind-tunnel data as a sharp increase in the external-store drag coefficient as the Mach number is increased. Analysis of the results presented herein is made by a comparison of the store drag rise Mach number with the drag rise Mach number of the wing-fuselage combination.

The results of this investigation indicate that mounting the stores with their maximum thicknesses at large distances from the wing maximum thickness resulted in store drag rise Mach numbers in excess of the drag rise Mach number of the basic wing-fuselage combination. Eliminating the pylon suspension member typical of current external-store installations by flush attachment of the store to the wing furnishes a practical means of obtaining store drag rise Mach numbers at least as high as the drag rise Mach number of the basic wing-fuselage combination. Modifying a body of revolution by flattening and fanning out the tail cone and locating the pylon suspension member aft of the wing maximum thickness resulted in store drag rise Mach numbers about as high as the drag rise Mach number of the basic wing-fuselage combination. Modifying an external-store installation typical of current practice by adding a small auxiliary wing between the wing and the store resulted in no appreciable changes in the store drag rise Mach numbers.

INTRODUCTION

In the design of tactical aircraft, current practice is to attach auxiliary equipment to the exterior of the airplane. This has frequently resulted in an uncontrollable vibratory motion of the airplane, called buffeting, at high speeds. Consequently, a research program was undertaken to investigate the effects of external stores on the aerodynamic characteristics of airplanes in order to provide external-store installations that do not result in buffeting of the airplane. Included in the program was a résumé of the effects of external stores on the stability of models of military airplanes at low speeds (reference 1). A theoretical approach to the problem of buffet due to external stores (reference 2) was prepared in an attempt to establish the cause of buffet and to furnish an analytical approach to the design of external-store installations. It was concluded in reference 2 that the buffet experienced in flight with airplanes equipped with external stores may be caused by the phenomenon associated with the formation of a compression shock in the vicinity of the external store. In order to verify experimentally the conclusions of reference 2 and to establish a wind-tunnel method of predicting airplane buffet speeds, wind-tunnel tests on a model with external stores were made and correlated (reference 3) with the buffet speeds due to external stores determined in flight. It was shown in reference 3 that the tunnel Mach number corresponding to the rapid increase in magnitude of the external-store drag-coefficient curve may be used to estimate the maximum speed that an airplane with external stores may attain without encountering prohibitively severe buffet due to the stores.

The present paper presents the results of an investigation of the drag-coefficient variation with Mach number of several external-store installations designed specifically to delay the advent of buffet by delaying the formation of compression shock in the vicinity of the stores.

SYMBOLS

The coefficients and symbols referred to in this paper are defined as follows:

C_D drag coefficient $\left(\frac{D}{qs}\right)$

C_{D_s} drag coefficient of the external-store installations $\left(C_{D_{\text{model + store}}} - C_{D_{\text{model}}}\right)$

M stream Mach number $\left(\frac{V}{a}\right)$

q dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$

ρ mass density of air, slugs per cubic foot

V velocity of air, feet per second

a velocity of sound, feet per second

ϵ blockage correction at high speeds

$\beta = \sqrt{1 - M^2}$

S wing area (7.63 sq ft on model)

$\bar{c}$ mean aerodynamic chord (1.30 ft)

c chord, inches

α angle of attack of wing chord line, positive when nose of model is raised

α_t angle of inclination of center line of store with fan-shaped tail with respect to chord line of wing, positive when nose of store is raised

α_a angle of inclination of chord line of auxiliary wing with respect to chord line of wing, positive when leading edge of auxiliary wing is raised

ψ angle of yaw of model, positive when left wing is forward

x longitudinal location of maximum thickness of store with respect to maximum thickness of wing, percent $\bar{c}$; positive when maximum thickness of body is aft of wing maximum thickness

l/d fineness ratio of store

l length of store, inches

d maximum dimension of store in plane perpendicular to center line of store, inches

t/c thickness ratio

t thickness, inches

h minimum distance between lower surface of wing and upper surface of store, percent $\bar{c}$

Z spanwise location of store from center line of model to center line of store, percent $\bar{c}$; positive when store is mounted on right wing

Λ angle between leading edge of pylon and line perpendicular to chord line of wing section, positive when pylon is swept back

Subscripts:

s store

p pylon

w wing

m measured

c corrected

APPARATUS AND MODELS

The Langley high-speed 7- by 10-foot tunnel in which this investigation was conducted is a closed-return tunnel of rectangular cross section. The turbulence level of this tunnel, although somewhat higher than free air, is very low. The model used in this investigation consisted of a fuselage, a wing of NACA 66, 1.5-(1.5)14 airfoil section, and a vertical tail which was an integral part of the fuselage structure. A drawing of the model showing the method of mounting in the tunnel and a typical external-store installation is presented in figure 1.

The external stores used for the tandem-mounted arrangement (fig. 2) consisted of two streamline bodies of revolution suspended from the right wing of the model with their maximum thicknesses at large distances from the maximum thickness of the wing. The inboard store (see fig. 2) was located aft of the wing maximum thickness by a sweptback pylon and the outboard store was located ahead of the wing maximum thickness by a sweptforward pylon in such a manner as to counteract the center-of-gravity movement resulting from the aft external store.

The flush-mounted external store (fig. 3) had a mean line cambered 2 percent concavely with respect to the plane of symmetry of the model when the store was mounted on the left wing. By removing the store from the left wing and attaching it to the right wing, the camber of the store was changed 4 percent with respect to the plane of symmetry. An extension was provided for the flush-mounted arrangement in order to increase its effective capacity.

The external store with a fan-shaped tail consisted of a body of revolution whose tail cone was flattened and whose mean line was reflexed so that the upper surface of the store was parallel to the lower surface of the wing (fig. 4). The store was suspended from the right wing of the model by an unswept pylon located well aft of the maximum thickness of the wing.

The auxiliary wing arrangement utilized a model of a standard Navy auxiliary fuel tank suspended from the right wing of the model by an unswept pylon (fig. 5). The relative locations of store, pylon, and wing were made consistent with current practice; that is, the center of gravity of the tank was alined with the assumed center of gravity of the model and the maximum thickness of the pylon was made to coincide approximately with the assumed center of gravity of the model. A small auxiliary wing whose angle of inclination was adjustable was mounted between the lower surface of the wing and the external store at the trailing edge of the wing.

TEST AND RESULTS

Procedure

Drag measurements were obtained for the model without stores and with stores in place at several angles of attack and yaw at various Mach numbers. The angles of attack and yaw were held constant during these tests and the Mach number was varied by varying the speed of the tunnel. The Mach number range investigated generally extended from 0.2 to 0.825. Drag measurements were supplemented by tuft studies of the flow in the vicinity of the external store. Tuft observations were made simultaneously with each drag measurement throughout the Mach range. Because of vapor condensation in the tunnel at high Mach numbers in some instances, it was not possible to observe the behavior of tufts. In such cases, the analysis of the drag measurements was made without benefit of tuft observations.

Corrections

All Mach numbers and drag coefficients were corrected for blocking by the following equations obtained from reference 4:

$$C_{D_c} = C_{D_m}\left[1 - \epsilon\left(2 - M_m^2\right)\right]$$

and

$$M_c = M_m\left[1 - \epsilon\left(2 - M_m^2\right)\right]$$

$$\epsilon = \epsilon_{solid} + \epsilon_{wake}$$

$$\epsilon_{solid} = \frac{0.00546}{\beta^4}$$

$$\epsilon_{wake} = \frac{0.0465\ C_D}{\beta^2}$$

where the numerical constants apply to this particular model and tunnel and were determined for the model without external stores. Neglecting the external stores results in negligible errors in the corrections.

An increment in drag coefficient of 0.0022 has been added to the total drag coefficient to account for the horizontal buoyancy resulting from the longitudinal pressure gradient in the tunnel.

Accuracy of Results

Calculations show that mechanical friction in the balance system may cause a change in C_{D_s} of 0.0010 at a Mach number of 0.2. The error decreases as the Mach number increases and becomes negligible at a Mach number of 0.4.

Additional errors are probably introduced into the data by such factors as the model size relative to size of the test section, the physical characteristics of the air passing over the model, and the surface conditions of the model. It is not possible to estimate the extent to which these factors influence the data. Because of this fact, analysis of the data is confined to evaluating qualitative trends and approximate merits of the various installations with respect to the drag rise Mach number of the wing-fuselage combination.

The choking Mach number of the tunnel with this model in place is about 0.83 based on one-dimensional flow theory. In general, data are assumed to be quantitatively reliable to a Mach number within 0.03 of the estimated choking Mach number. Data are presented above a Mach number of 0.80, however, in order to permit a qualitative comparison of the behavior of these installations at Mach numbers greater than 0.80.

Presentation of Results

The effect of angles of attack and yaw on the variation of the drag coefficient of the basic wing-fuselage combination is presented in figures 6 and 7. The drag rise Mach number of the wing-fuselage combination was determined by the British method of tangents. This method describes the drag rise Mach number as the Mach number at which a tangent to the drag-coefficient curve prior to the break intersects a tangent to the drag-coefficient curve after the break.

The results of the measurements of the external-store drag coefficient are presented as variations in external-store drag coefficient with Mach number for several angles of attack and yaw of the model in figures 8 to 19. The store drag coefficient includes the drag of the various members of the installation and the drag created by mutual interference effects. Store drag coefficients were obtained by a graphical subtraction of the total drag coefficients of the model without stores (figs. 6 and 7) from the total drag coefficients of the model with stores in place. The ticks on the external-store drag-coefficient curves represent the drag rise Mach number of the drag coefficient of the basic wing-fuselage combination.

The results of the tuft observation are presented in figures 20 to 29. Since it was not possible to observe the flow over either the pylons or the part of the stores adjacent to the wing because of the location of the model in the tunnel, the tuft observations presented herein are confined to the lower surface of the wing for all but one configuration and that is the store with a fan-shaped tail. For this installation, studies of the flow over the lower surface of the store are also included.

The degree of turbulence of the air passing over the wing was determined by the motions of the tufts. The flow disturbances were separated into four general types: unsteady, rough, separated, and reversed, in the order of increasing severity. The nomenclature chosen is descriptive of the flow patterns involved.

DISCUSSION

General

The results of the investigation are presented as the variation of the drag coefficient of the external-store installations with Mach number. The significance of the force break indicated by this coefficient in terms of airplane buffet was established in reference 3 for the case in which the store drag rise Mach number occurred at Mach numbers less than the drag rise Mach number of the basic model. The store drag rise Mach number was obtained simply by inspection of the data as the Mach number at which the store drag coefficient begins to increase rapidly in a positive direction. Attempting to extend the method of estimating buffet

Mach numbers of reference 3 to the data presented herein, where the store drag rise Mach number generally occurs at Mach numbers higher than the drag rise of the basic model, may, however, result in erroneous conceptions of the buffet characteristics of the installations investigated. The analysis of the results presented herein are confined, therefore, to simply pointing out the relative difference in Mach number between the drag rise Mach number of the wing-fuselage combination and the store drag rise Mach number.

It should be pointed out that because the external-store drag coefficients presented herein were obtained with the various external-store arrangements on only one wing of the model, these data are not expected to represent installations that are symmetrically arranged about the plane of symmetry of the model.

Tandem-Mounted Arrangement

The tandem-mounted arrangement was designed to minimize the adverse aerodynamic interference between the pressure field of the external store and the pressure field over the lower surface of the wing by locating the maximum thicknesses of the stores at large chordwise distances from the maximum thickness of the wing.

The variation of store drag coefficient with Mach number for the tandem-mounted arrangement for several angles of attack of the model is shown in figure 8. These data indicate that the lowest store drag rise Mach number is considerably higher than the drag rise Mach number of the basic wing-fuselage combination and that increasing the angle of attack from -1.25° to -0.25° increases the Mach number at which C_{D_s} breaks. The negative values of store drag coefficient characteristic of this installation may be attributed to beneficial interference effects. A study of the tuft observations for this arrangement (fig. 22) and those of the basic wing-fuselage combination (fig. 20) indicates that the inboard store delays considerably the onset of flow disturbances at the wing-fuselage juncture.

The effect of angle of yaw on the variation of store drag coefficient with Mach number for this installation is presented in figure 9. It appears from these data and from tuft studies (fig. 23) that yawing the model has negligible effect upon the store drag rise Mach number and the character of the flow over the lower surface of the wing.

Flush-Mounted Arrangement

Theoretical calculations indicate that the relatively thick pylon suspension member of current external-store installations operating in the high-velocity region of the wing causes marked reductions in critical speeds. The flush-mounted arrangement was designed to eliminate the pylon by attaching the store flush to the lower surface of the wing. Fairing blocks were fitted to the store so that no air was allowed to flow between the lower surface of the wing and the external store. An attempt was made to alleviate the resulting venturi effect between the inboard side of the store and the fuselage by cambering the mean line of the store 2 percent. An extension was provided for the store in order to increase its effective capacity.

The variation of drag coefficient with Mach number for the store installation mounted on the left wing with extension in place is shown in figure 10 for several angles of attack of the model. These data show that the store drag rise Mach number is at least as high as that of the basic wing-fuselage combination and is essentially unaffected by changes in the attitude of the model in pitch. Tuft studies presented in figure 24 for $\alpha = -0.75^{\circ}$ show that the flow first becomes rough over the wing on the outboard side of the store at a Mach number of about 0.714. This Mach number is found to correspond approximately with the store drag rise Mach number at $\alpha = -0.75^{\circ}$.

It is apparent that yawing the model from -2° to 2° increases the store drag rise Mach number (fig. 11). At the largest positive angle of yaw investigated, the store drag rise Mach number compares favorably with those of the structurally complicated tandem-mounted arrangement. Consideration of the tuft studies (fig. 25) indicates that the marked increase in store drag rise Mach number when the model is yawed may be attributed to the clearing up of the unsteady flow over the wing outboard of the store previously noted on the unyawed model (fig. 24).

The effect of removing the extension on the store drag characteristics in pitch may be determined by comparing the data of figure 12 with those of figure 10. As might be expected, the store drag coefficient was reduced through the Mach number range. Although the store drag rise Mach number was not materially changed by removing the extension at the higher angle of attack (-0.75°), at -1.25° angle of attack the store drag rise Mach number was increased about 0.05.

The effect of camber on the drag characteristics of the flush-mounted installation without extension may be obtained by comparison of figure 13 (store on the right wing of the model) with figure 12 (store on the left wing of the model). These data indicate that the resulting increase in the venturi effect between store and fuselage caused by a change in camber of 4 percent decreases the store drag rise Mach number by about 0.08.

Store with a Fan-Shaped Tail

In an attempt to alleviate the unsteady flow conditions over the aft part of the lower surface of the wing with a pylon suspended store, an example of which is shown in figure 28, the aft part of a body of revolution was flattened and fanned out. The upper surface contour of this part of the store conformed to the contour of the lower surface of the wing (see fig. 4). Further efforts to delay onset of adverse compressibility effects over a pylon suspension system were made by moving the pylon as far aft as was considered feasible.

The effect of yaw on the variation of store drag coefficient with Mach number at $\alpha_t = 0^\circ$ is shown in figure 14. The store drag coefficient of this installation is relatively high at the lower Mach numbers and is increased with angle of yaw. It also appears that regardless of the angle of yaw the store drag rise Mach number is about the same as that of the basic wing-fuselage combination. Tuft studies at $\alpha = -0.75^\circ$ (fig. 26) indicate that flow over the wing is satisfactory to Mach numbers higher than the drag rise Mach number of the wing-fuselage combination. The flow over the lower surface of the store, however, becomes objectionably rough at much lower Mach numbers.

The effect of changing the angular position of the store is shown in figure 15. At an angle of attack of -0.75° the store drag rise Mach number was increased about 0.03 for a change in α_t of $-2\frac{1}{2}^\circ$. Tuft studies show a marked improvement in the flow over the lower surface of the store as evidenced by a comparison of figure 27 with figure 26.

The effect of angle of attack on the variation of store drag coefficient with Mach number at $\alpha_t = -2\frac{1}{2}^\circ$ is presented in figure 16. It is apparent that the store drag rise Mach number remains unchanged for the angles of attack investigated.

Auxiliary Airfoil Arrangement

An external store typical of current arrangement was modified by placing a small auxiliary wing between the wing and the afterbody of the store in an attempt to control the flow conditions over the lower surface of the wing aft of the external store.

The variation of store drag coefficient with Mach number for the installation without the auxiliary wing and with the auxiliary wing at several angles of inclination is presented in figure 17. It is evident from these data that, although the drag characteristics after the drag rise Mach number of the basic model are altered by the auxiliary wing, the store drag rise Mach number is not greatly altered by the addition of the auxiliary wing regardless of its angular position. Analysis of tuft studies (figs. 28 and 29) of the flow over the lower surface of the wing with and without the auxiliary wing indicates that the auxiliary airfoil primarily influences the flow at Mach numbers higher than the store drag rise Mach number and these Mach numbers apparently correspond to the flat spots in the store drag coefficient curves.

The effect of angle of attack on the store drag coefficient is shown in figure 18 for $\alpha_a = -15^{\circ}$. These data indicate that variations in angle of attack of the model had considerable effect upon the drag characteristics of the installation at Mach numbers greater than the drag rise Mach number of the basic model; and that, as the angle of attack was increased, the influence of the auxiliary wing was apparently increased. At the highest angle of attack investigated (-0.25°) the external-store drag coefficient variation showed a tendency to decrease at Mach numbers slightly higher than the drag rise Mach number of the basic model. Although this particular variation of C_{D_s} with Mach number is somewhat unique, it is felt that at $\alpha = -0.25^{\circ}$ the auxiliary wing results in noticeable increases in the store drag rise Mach number and that the store drag rise Mach number is higher than the drag rise Mach number of the basic model.

The variation of drag coefficient of the store with Mach number for the model unyawed and yawed 2° is shown in figure 19. It appears that yawing the model from 0° to 2° primarily causes a large increase in the rate of increase of C_{D_s} with Mach number at the higher Mach numbers.

CONCLUSIONS

It is concluded from an analysis of the results of wind-tunnel tests of a basic wing-fuselage combination equipped with several types of external-store installations listed in the order of aerodynamic preference that:

1. A tandem-mounted arrangement which utilized two stores with the maximum thicknesses located at large chordwise distances from the maximum thickness of the wing had a store drag rise Mach number in excess of the drag rise Mach number of the basic wing-fuselage combination.

2. A flush-mounted external store which eliminated the pylon suspension member typical of current store arrangements had a store drag rise Mach number at least as high as the drag rise Mach number of the basic wing-fuselage combination.

3. An external store with a fan-shaped afterbody mounted on a pylon located aft of the maximum thickness of the wing had a store drag rise Mach number about as high as the drag rise Mach number of the wing-fuselage combination.

4. Modification of a typical external-store installation by the addition of a small auxiliary wing between the wing and the store resulted in no appreciable changes in the store drag rise Mach number.

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

REFERENCES

1. Silvers, H. Norman, and Vogler, Raymond D.: Résumé of Wind-Tunnel Data on the Effect of External Stores on Stability of Models of Military Airplanes. NACA RM No. L6K08, 1946.

2. Katzoff, S., and Finn, Robert S.: Effects of External Fuel Tanks and Bombs on Critical Speeds of Aircraft. NACA CB No. L5H27, 1946.

3. Silvers, H. Norman, and Spreemann, Kenneth P.: Correlation of Wind-Tunnel and Flight Determinations of the Buffet Speed of an Airplane Equipped with External Stores. NACA RM No. L7E20, 1947.

4. Thom, A.: Blockage Corrections in a Closed High-Speed Tunnel. R. & M. No. 2033, British A.R.C., 1943.

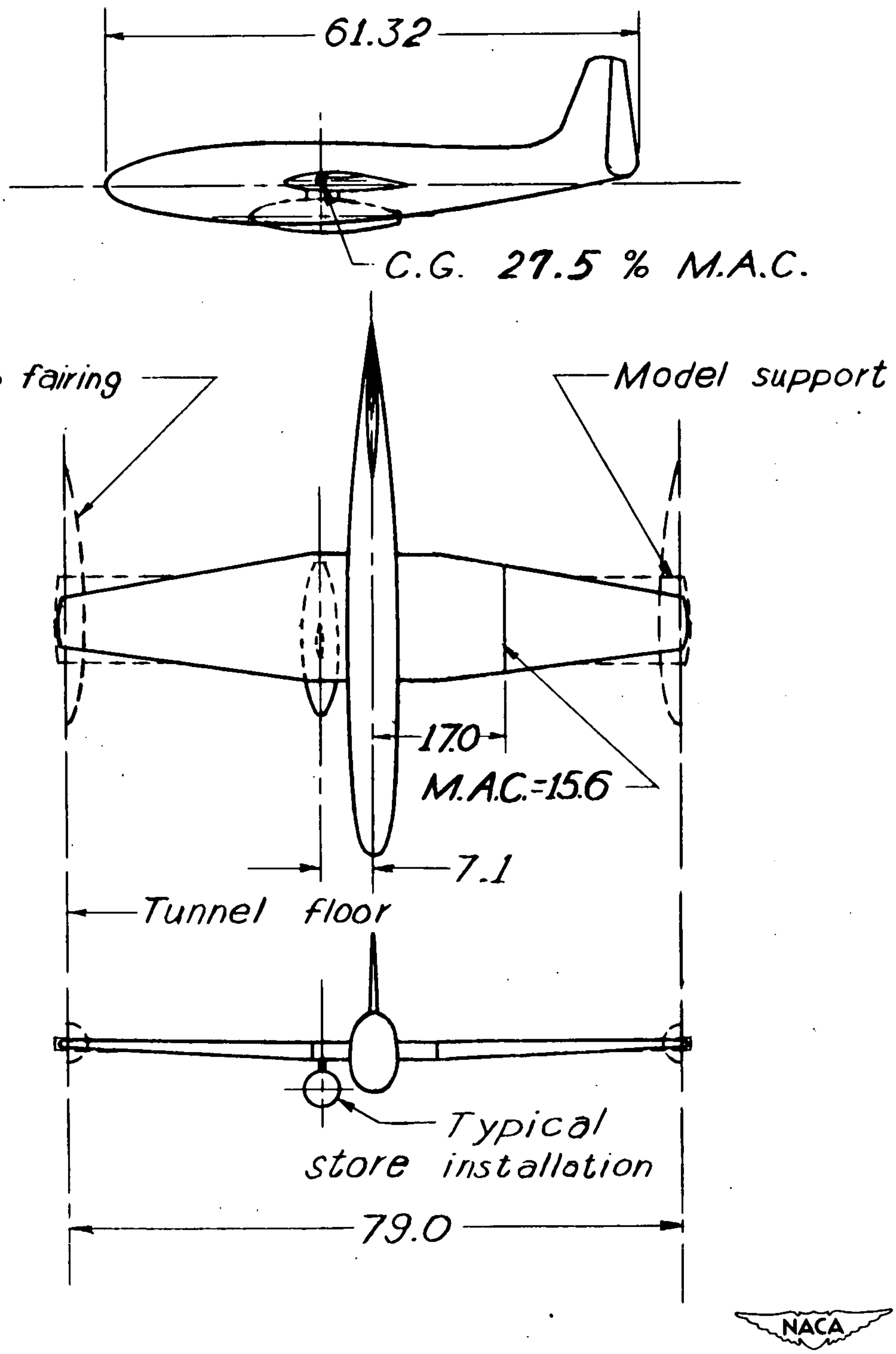
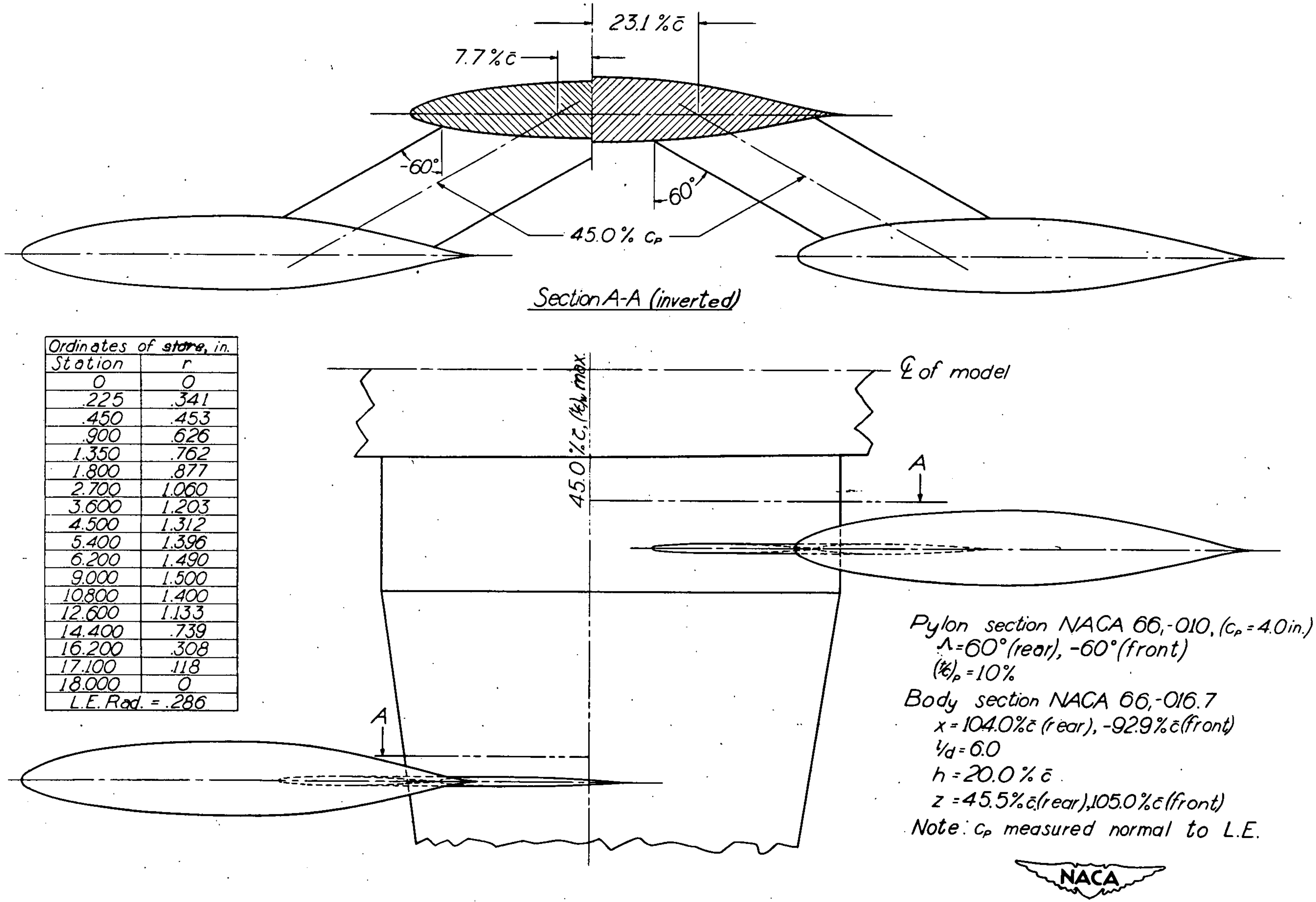
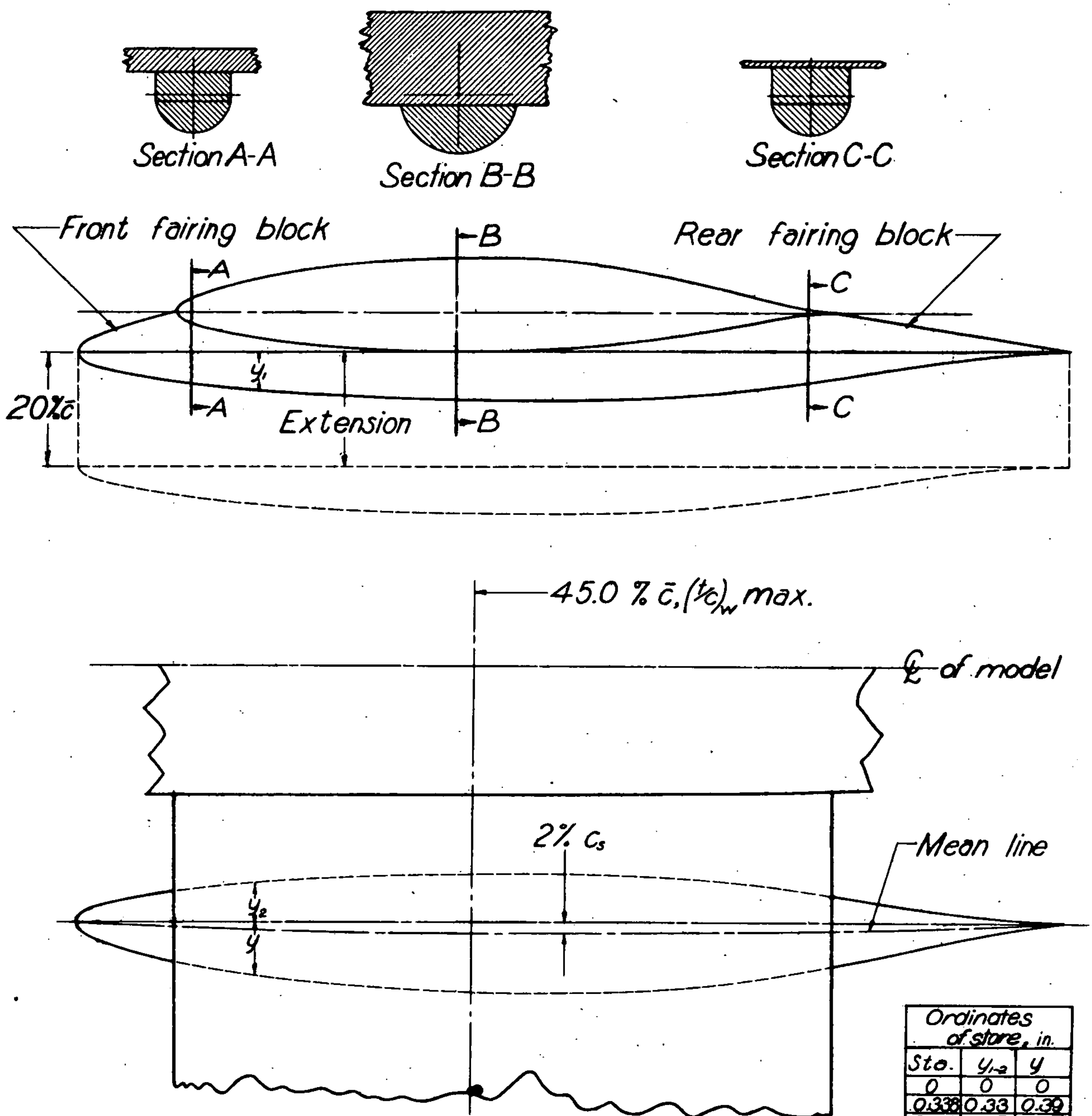


Figure 1.- Three-view drawing of the wing-fuselage combination mounted in the Langley high-speed 7-by 10-foot tunnel.



Ordinates of store, in.	
Station	r
0	0
.225	.341
.450	.453
.900	.626
1.350	.762
1.800	.877
2.700	1.060
3.600	1.203
4.500	1.312
5.400	1.396
6.200	1.490
9.000	1.500
10.800	1.400
12.600	1.133
14.400	.739
16.200	.308
17.100	.118
18.000	0
L.E. Rad. = .286	

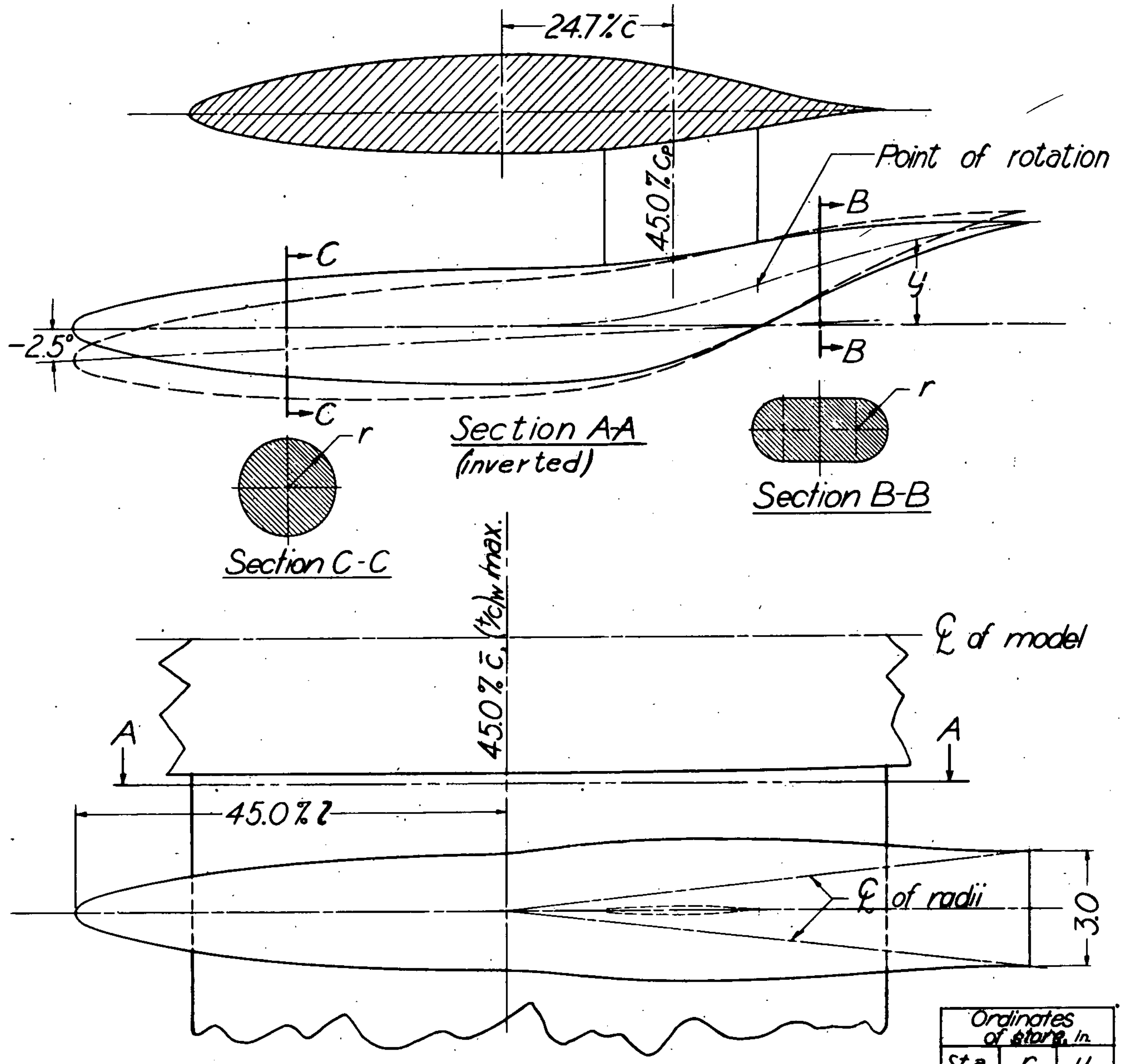
Figure 2.- Drawing of the tandem mounted arrangement as tested on the right wing of a wing-fuselage combination.



Body section NACA 66,-212 (approximate)
$x = 8.2\% \bar{c}$
$l/d = 8.33$ unextended, 5.82 extended
$h = 0$
$z = -45.5 \% \bar{c}$

Ordinates of store, in.		
Sta.	y_{1-2}	y
0	0	0
0.338	0.33	0.39
0.676	0.45	0.56
1.350	0.61	0.77
2.03	0.74	0.97
2.70	0.84	1.10
4.05	0.98	1.34
5.40	1.08	1.51
6.76	1.17	1.64
8.10	1.23	1.74
10.80	1.29	1.86
13.50	1.30	1.88
16.20	1.21	1.78
18.90	0.94	1.44
21.60	0.58	0.96
24.30	0.19	0.41
25.70	0.06	0.18
27.00	0	0
L.E. radius = 0.267		
Slope of radius thru L.E. = 0.084		

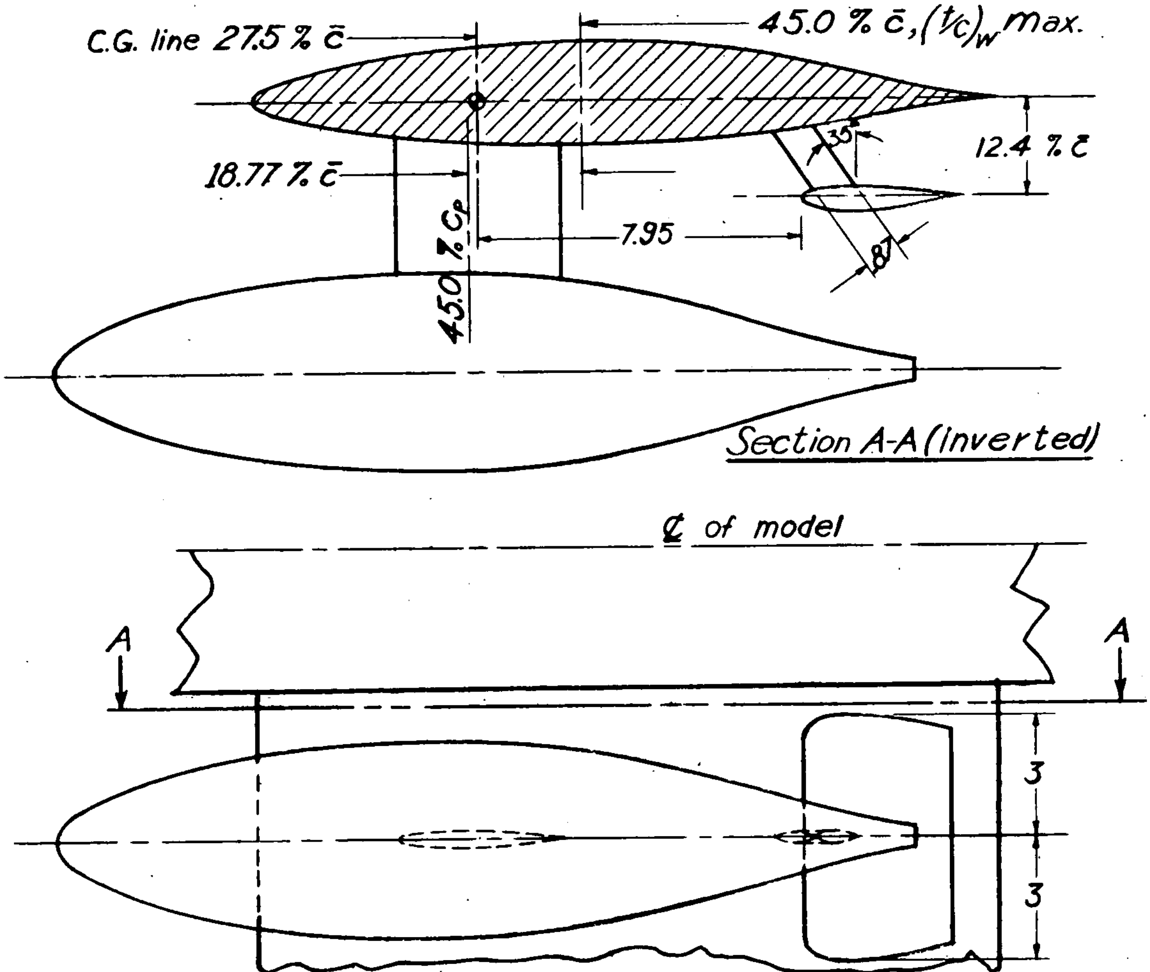
Figure 3.- Drawing of the flush-mounted arrangement as tested on the left wing of a wing-fuselage combination.



Pylon section NACA 66,-010, (c_p = 4.0 in.)
$\Lambda = 0°$
Body section NACA 66,-012
$x = 0\% \bar{c}$
$l/d = 6.75$
$h = 20\% \bar{c}$
$z = -45.5\% \bar{c}$

Ordinates of store, in.		
Sta.	r	y
0	0	0
0.313	0.339	0
0.625	0.452	0
1.250	0.625	0
1.875	0.760	0
2.50	0.875	0
3.75	1.058	0
5.00	1.200	0
6.25	1.310	0
7.50	1.391	0
8.75	1.490	0
10.00	1.500	0
12.50	1.491	0.02
15.00	1.397	0.29
17.50	1.130	0.95
20.00	0.735	1.73
22.50	0.309	2.23
23.75	0.119	2.53
25.00	0	2.62
L.E. radius = .238		

Figure 4.- Drawing of a body with a fan-shaped tail as tested on the right wing of a wing-fuselage combination.



Navy tank ordinates, in.	
Station	r
0	0
.262	.517
.525	.714
1.050	.939
1.575	1.258
2.100	1.437
3.150	1.760
4.200	1.989
6.300	2.272
8.400	2.419
10.500	2.407
12.600	2.186
14.700	1.781
16.800	1.228
18.900	.695
19.950	.445
21.000	.227
L.E.R. = .639	

Pylon section NACA 66,-010
($c_p = 4.0$ in.)
$\Lambda = 0°$
$(t/c)_p = 10$ %
Tank :-
$x = -25.8$ % $\bar{c}$
$l/d = 4.34$
$h = 20$ % $\bar{c}$
$z = 45.5$ % $\bar{c}$

Auxiliary wing ordinates, in.		
Station	ordinates	
	Lower	Upper
0	0	0
.046	.149	.067
.091	.193	.099
.182	.252	.138
.273	.292	.167
.364	.321	.190
.546	.359	.225
.728	.377	.250
.910	.384	.265
1.092	.384	.272
1.456	.365	.268
1.820	.329	.248
2.184	.282	.216
2.548	.225	.175
2.912	.160	.127
3.276	.087	.071
3.458	.048	.040
3.640	0	0
L.E. radius = .1295		

Note: All dimensions in inches, unless otherwise stated.

Figure 5.- Drawing of auxiliary wing arrangement as tested on the right wing of a wing-fuselage combination.

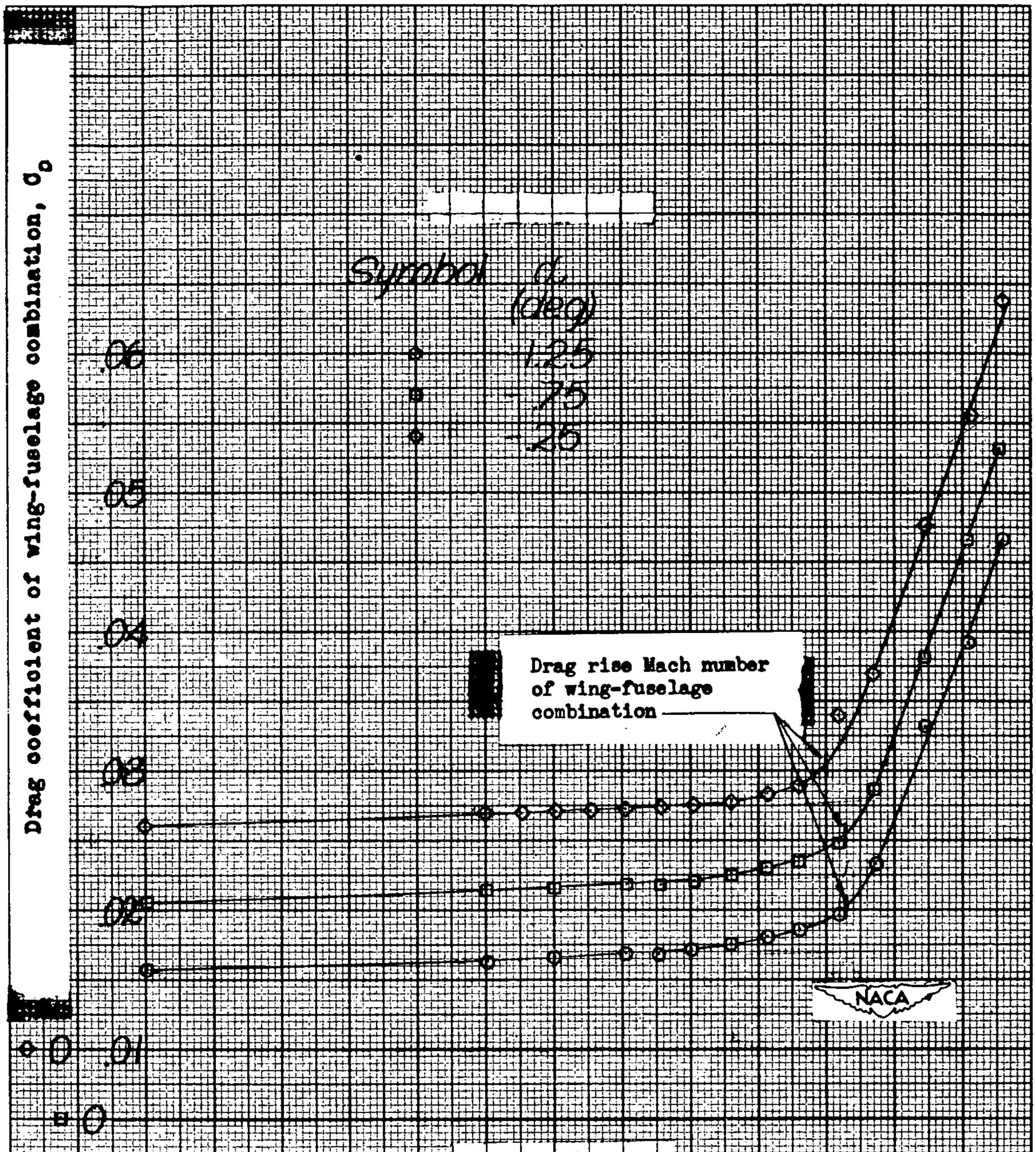


Figure 6.- Variation of the drag coefficient with Mach number of the wing-fuselage combination at various angles of attack, $\Psi = 0°$.

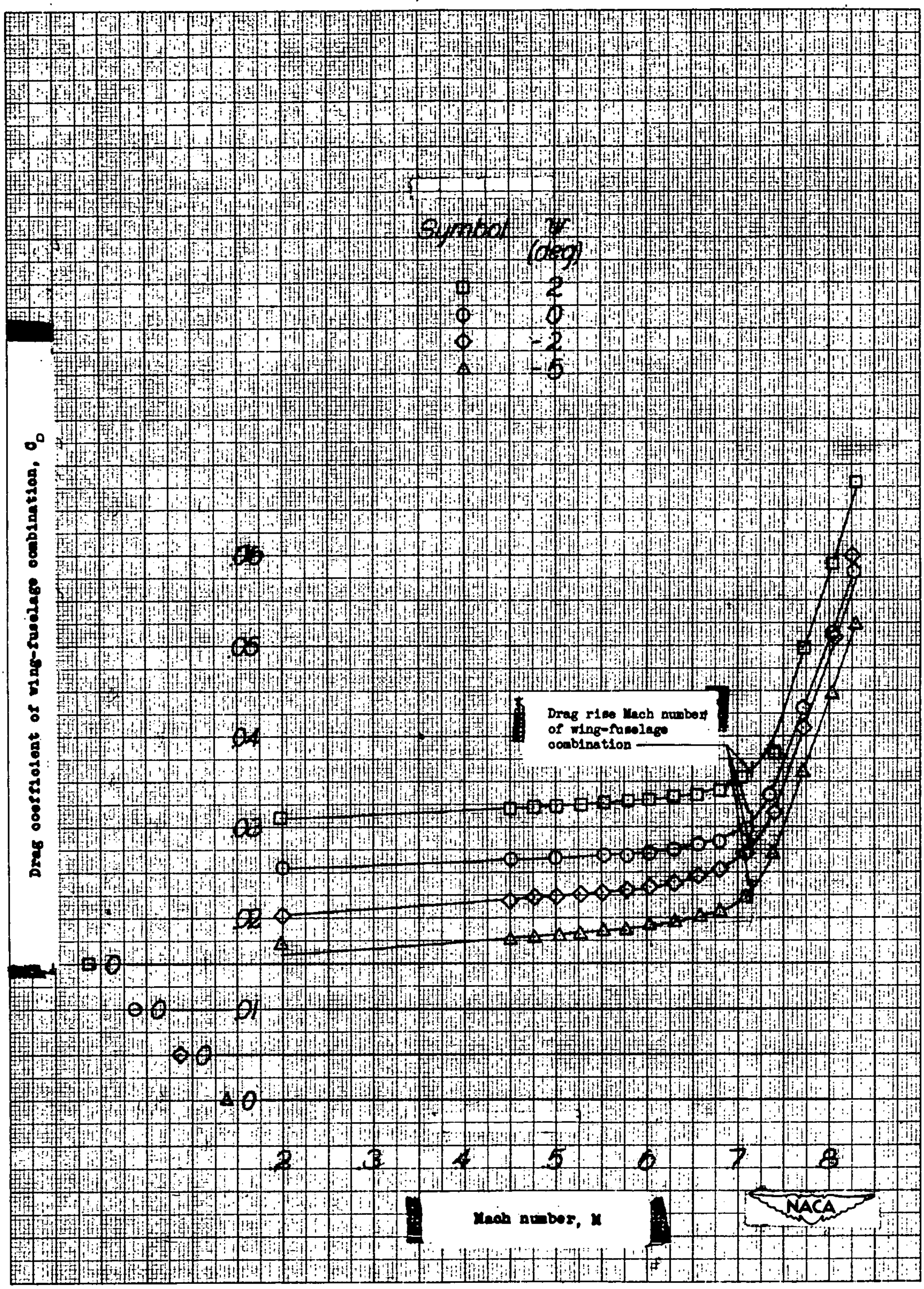


Figure 7.- Variation of the drag coefficient with Mach number of the wing-fuselage combination at various angles of yaw, α = -.75°.

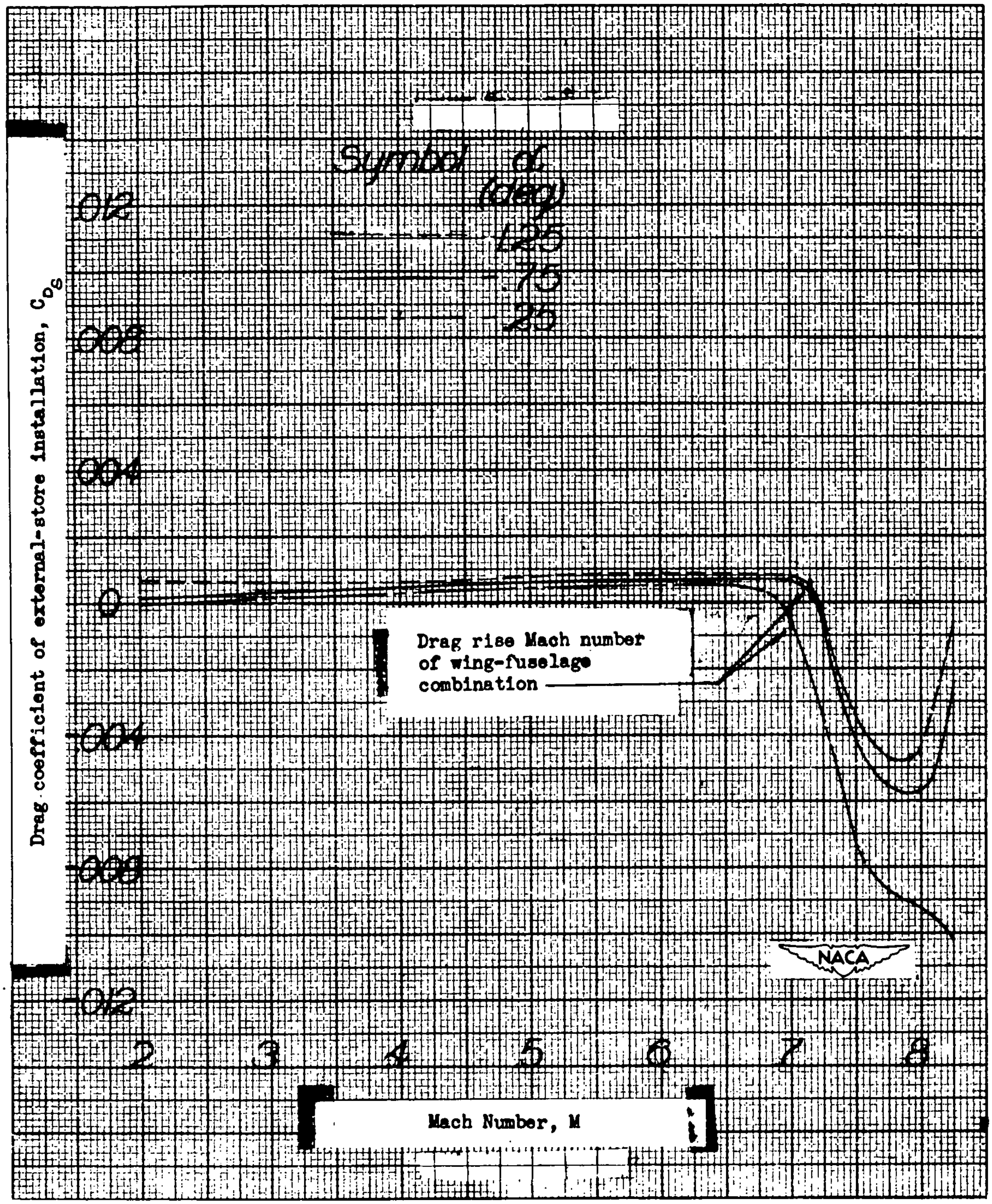


Figure 8.- Variation of the drag coefficient of the external-store installation with Mach number for the tandem external-store arrangement mounted on the right wing of a wing-fuselage combination at various angles of attack, Ψ = 0°.

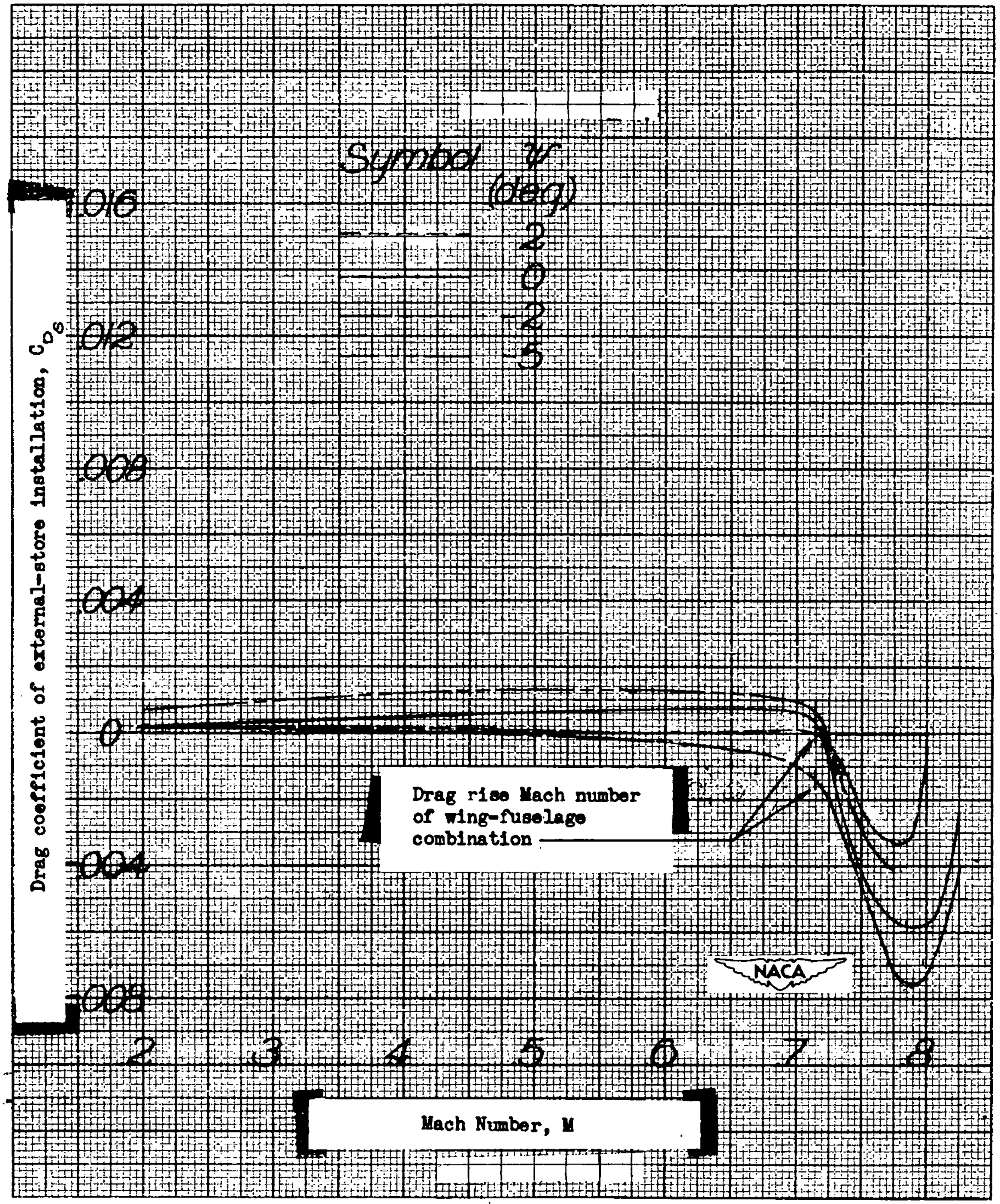


Figure 9.- Variation of the drag coefficient of the external-store installation with Mach number for the tandem external-store arrangement mounted on the right wing of a wing-fuselage combination at various angles of yaw, $\alpha = -.75^{\circ}$.

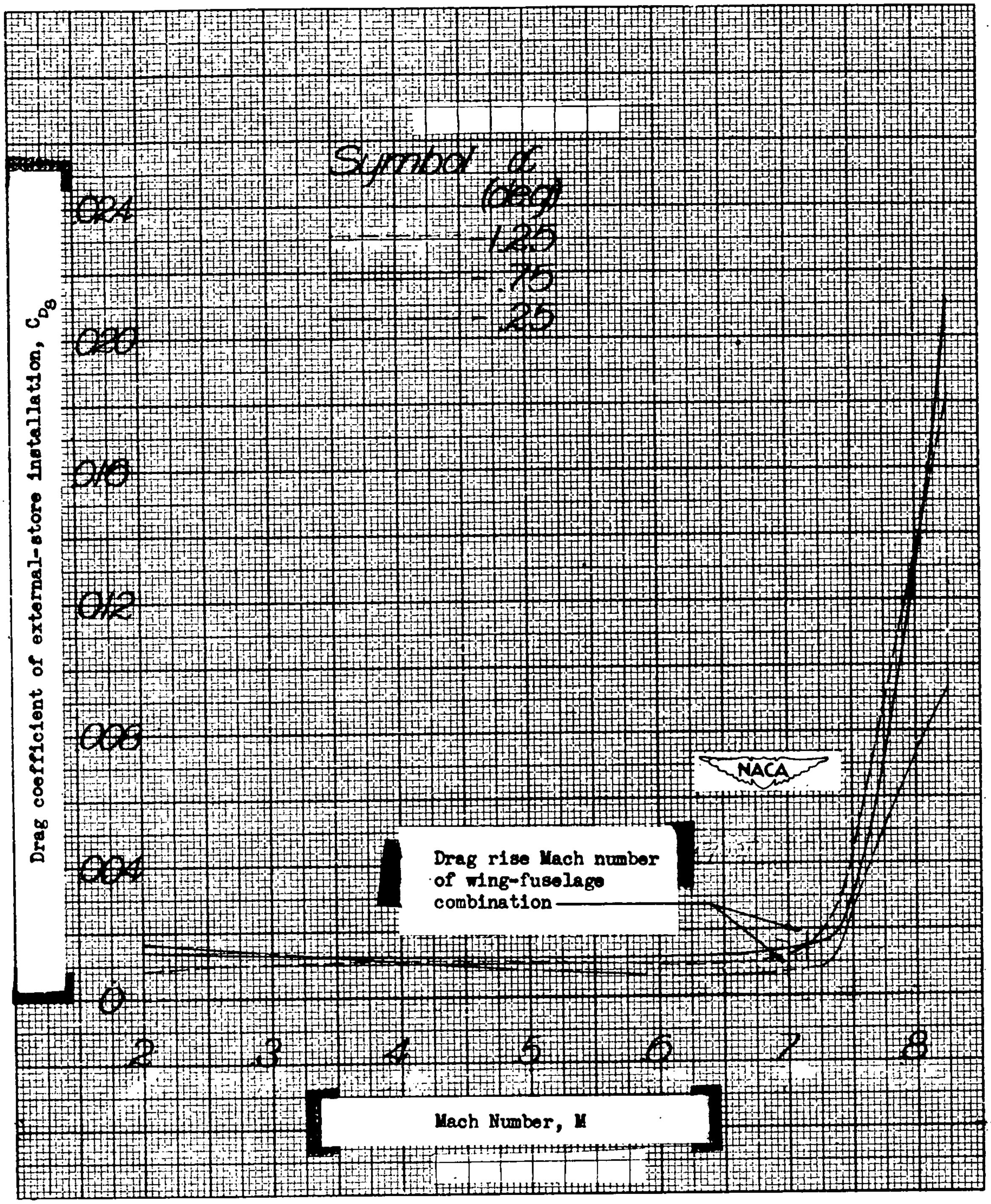


Figure 10.- Variation of the drag coefficient of the external-store installation with Mach number for the flush-mounted external-store arrangement mounted on the left wing of a wing-fuselage combination at various angles of attack, extension attached, $\Psi = 0^{\circ}$.

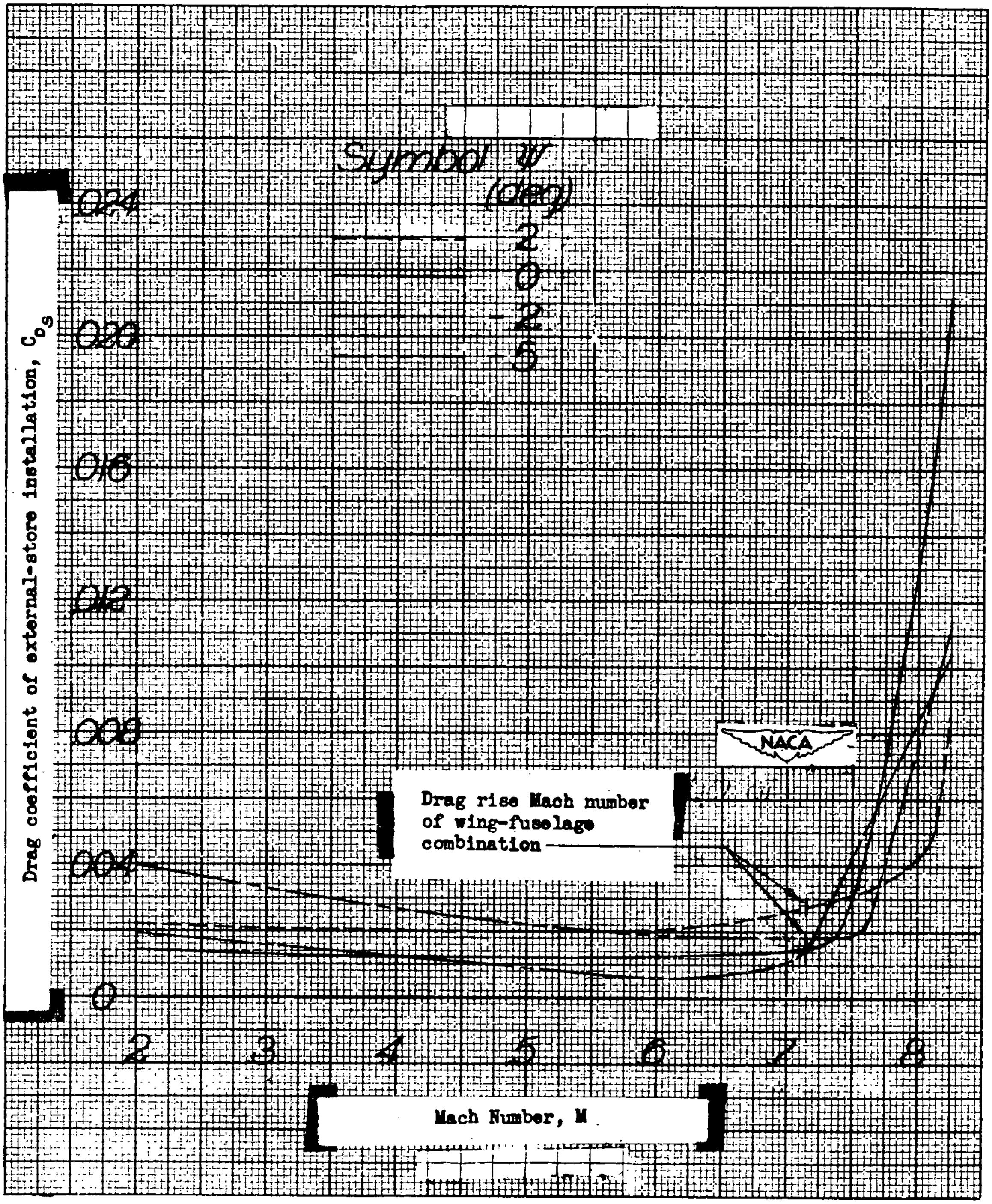


Figure 11.- Variation of the drag coefficient of the external-store installation with Mach number for the flush-mounted external-store arrangement mounted on the left wing of a wing-fuselage combination at various angles of yaw, extension attached, $\alpha = -.75^{\circ}$.

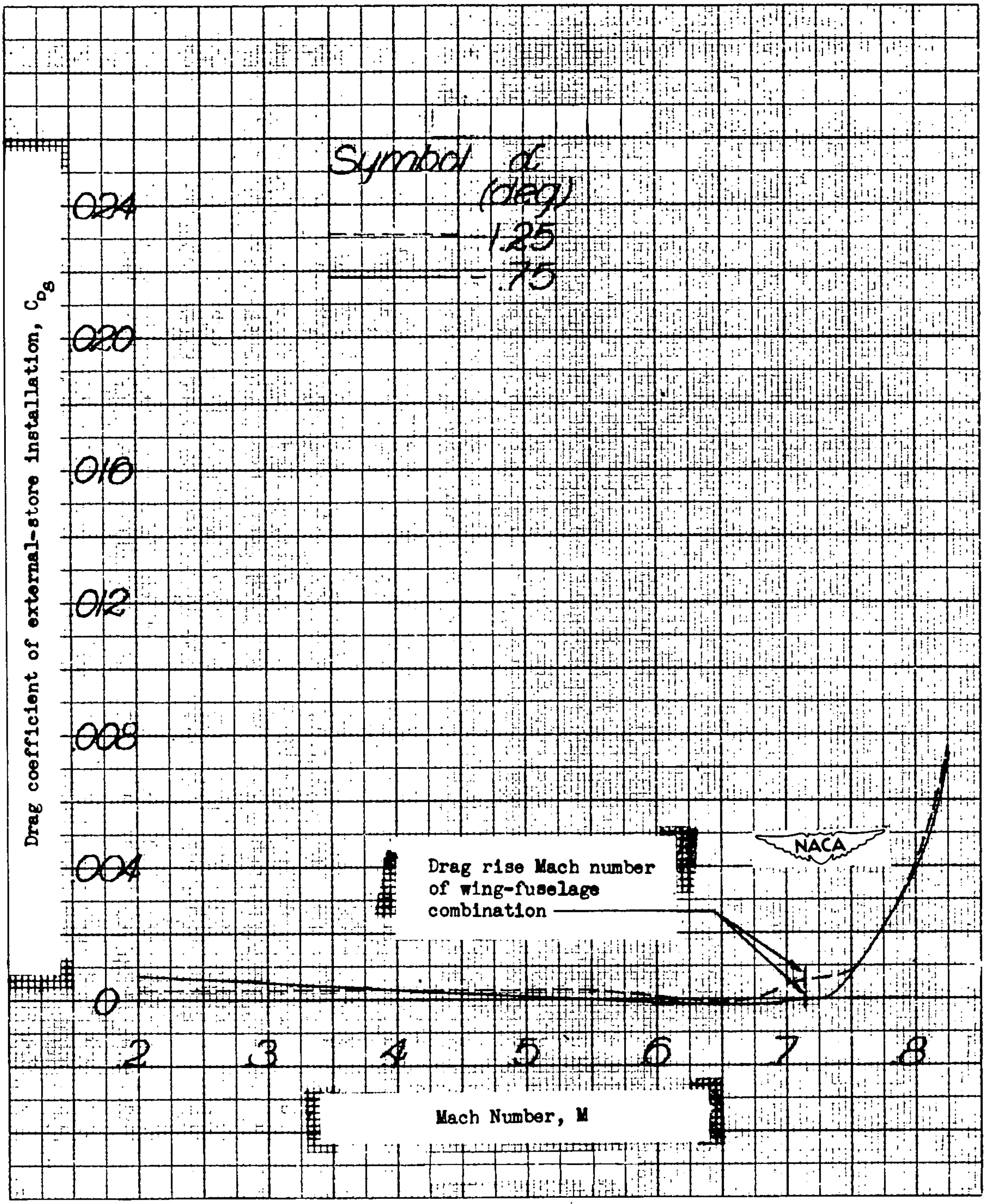


Figure 12.- Variation of the drag coefficient of the external-store installation with Mach number for the flush-mounted external-store arrangement mounted on the left wing of a wing-fuselage combination at two angles of attack, $\psi = 0°$.

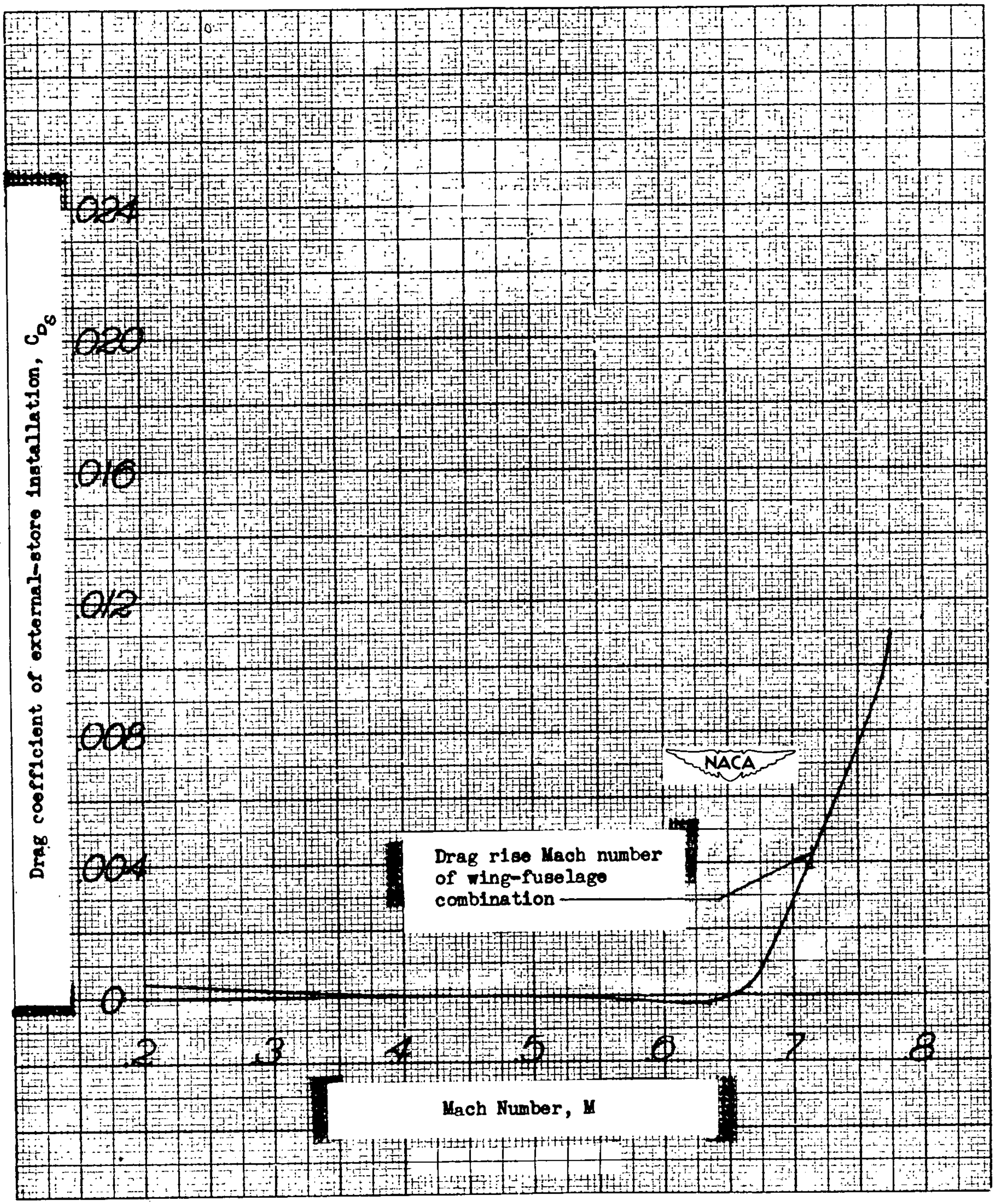


Figure 13.- Variation of the drag coefficient of the external-store installation with Mach number for the flush-mounted external-store arrangement mounted on the right wing of a wing-fuselage combination, $\alpha = -.75^{\circ}$, $\Psi = 0^{\circ}$.

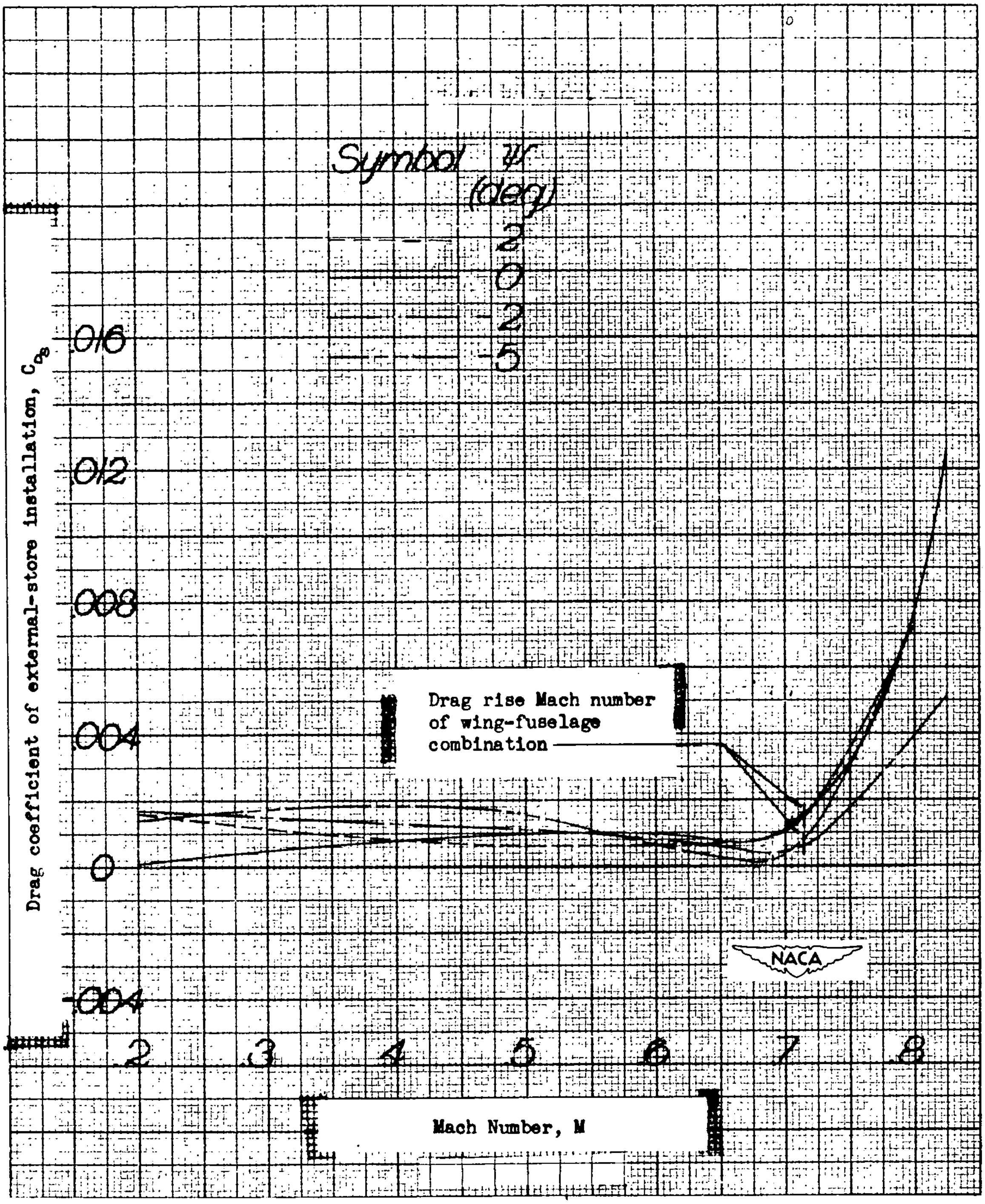


Figure 14.- Variation of the drag coefficient of the external-store installation with Mach number for the external store with a fan-shaped tail mounted on the right wing of a wing-fuselage combination at various angles of yaw, $\alpha = -.75^{\circ}$, $\alpha_t = 0^{\circ}$.

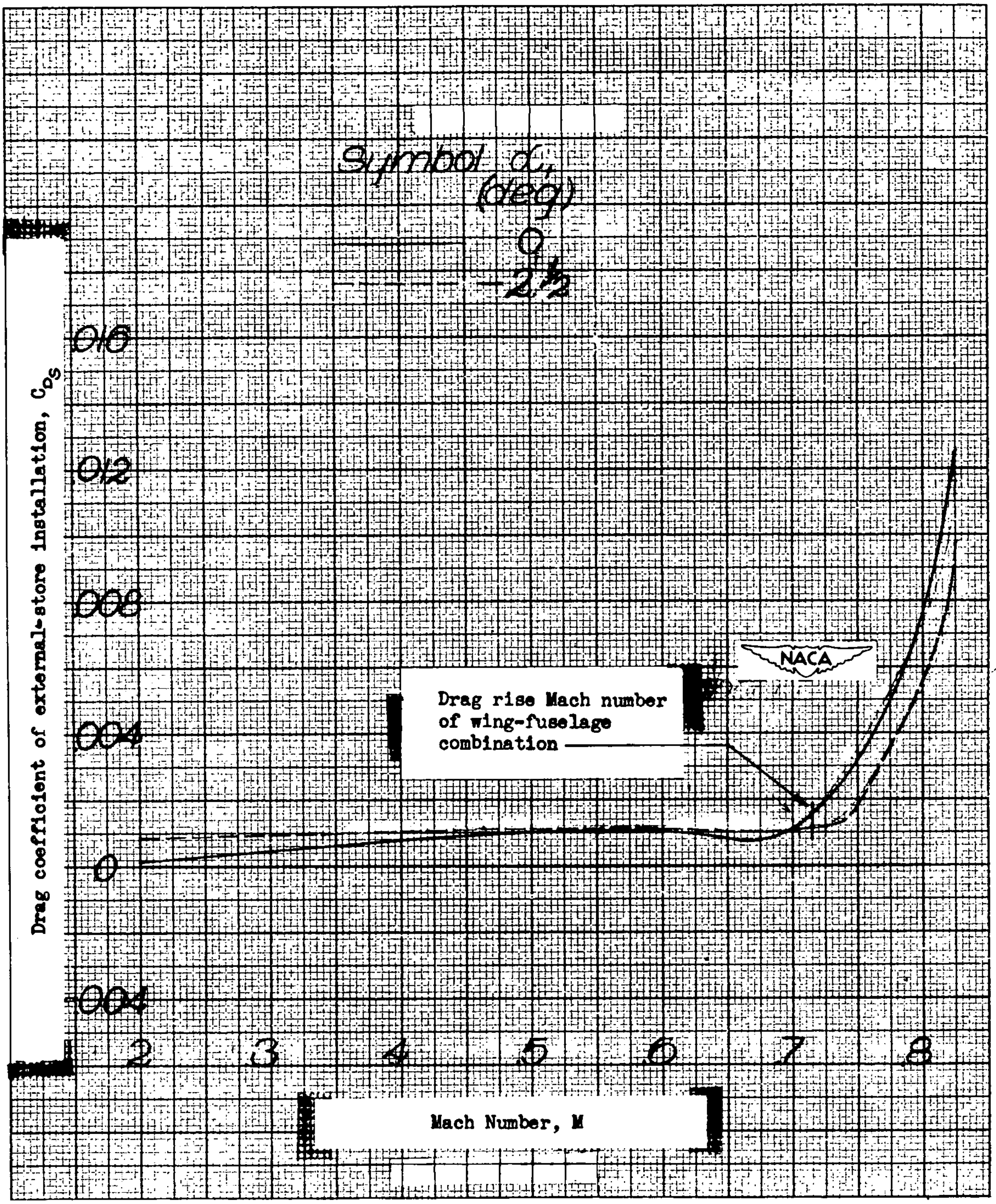


Figure 15.- Effect of the angular position of the external store with a fan-shaped tail mounted on the right wing of a wing-fuselage combination on the variation of the drag coefficient of the external-store installation with Mach number, $\alpha = -.75^{\circ}$, $\Psi = 0^{\circ}$.

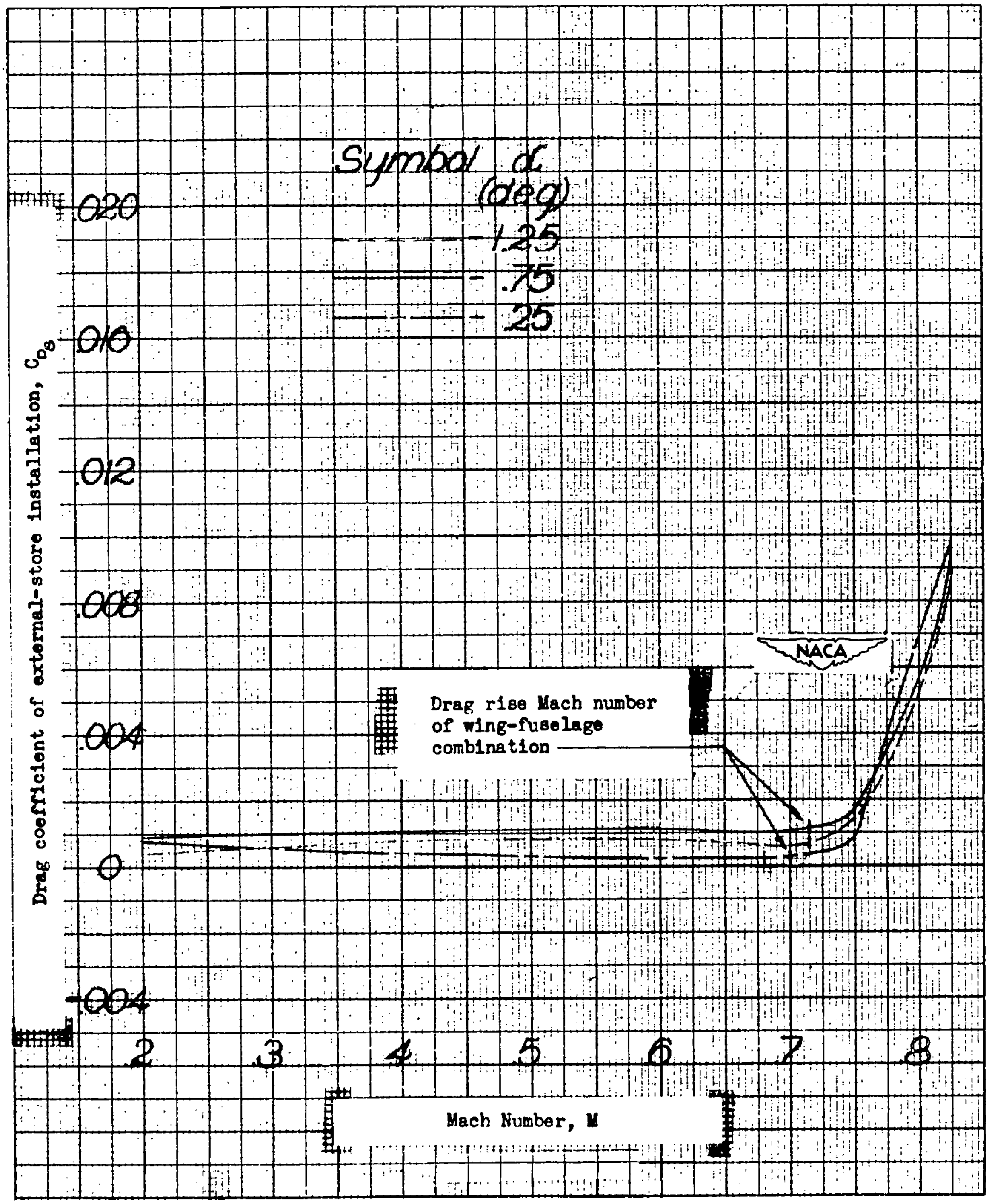


Figure 16.- Variation of the drag coefficient of the external-store installation with Mach number for the external store with a fan-shaped tail mounted on the right wing of a wing-fuselage combination at various angles of attack, $\Psi = 0^{\circ}$, $\alpha_t = -2\ 1/2^{\circ}$.

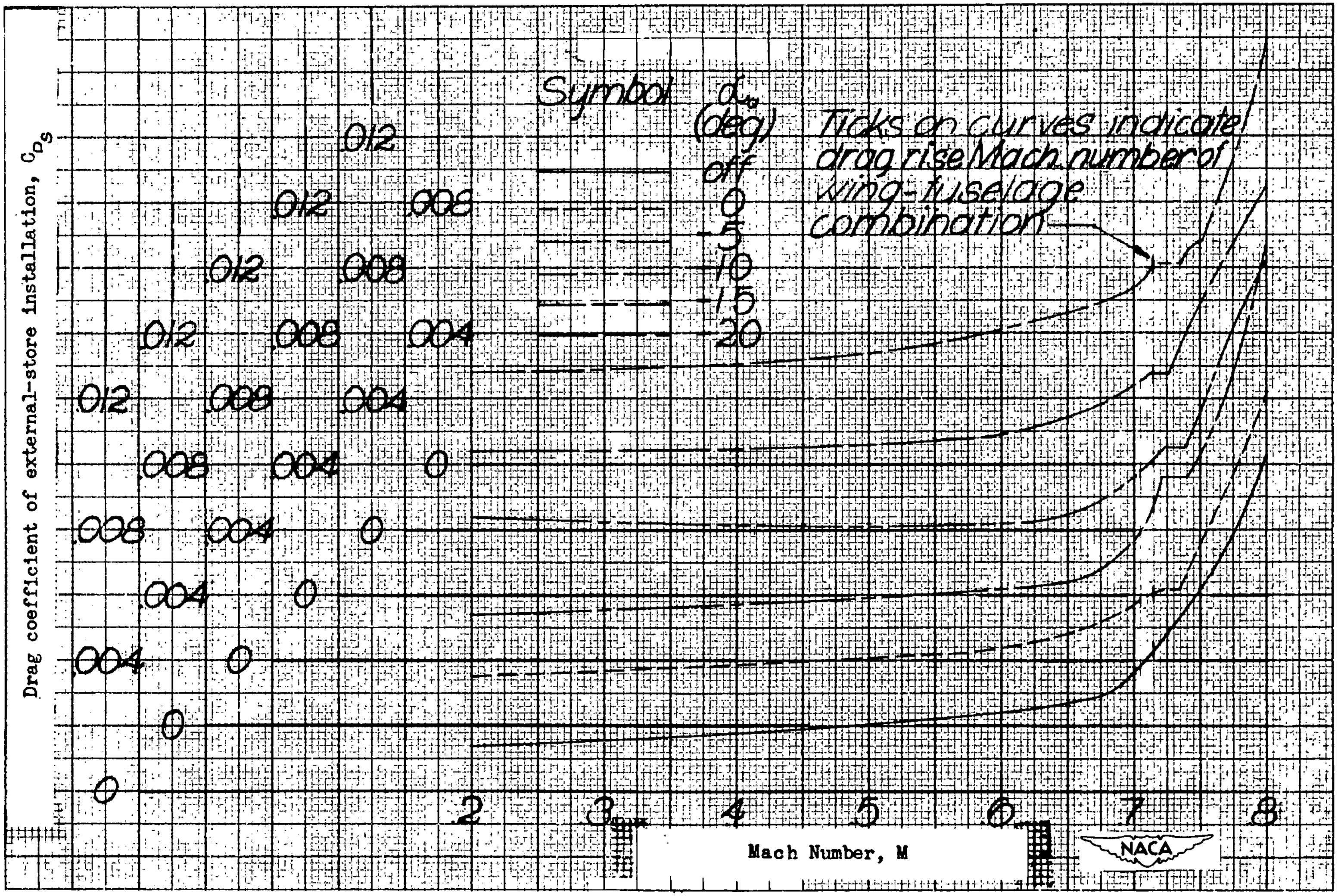


Figure 17.- Effect of the angular position of the auxiliary wing on the variation of the drag coefficient of the external-store installation with Mach number for the auxiliary wing arrangement mounted on the right wing of a wing-fuselage combination, $\alpha = -.75^{\circ}$, $\Psi = 0^{\circ}$.

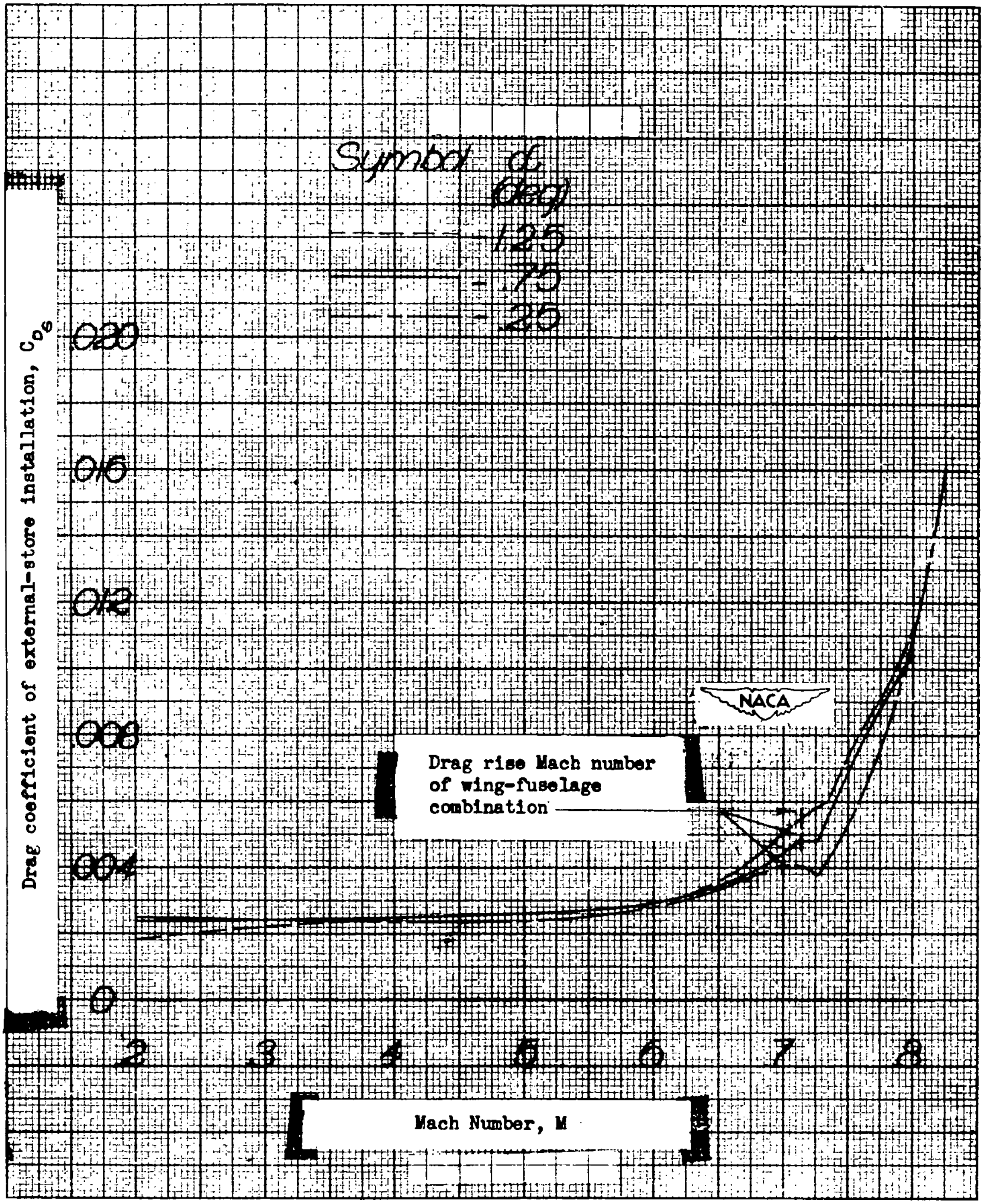


Figure 15.- Variation of the drag coefficient of the external-store installation with Mach number for the auxiliary wing arrangement mounted on the right wing of a wing-fuselage combination at various angles of attack, $\Psi = 0^{\circ}$, $\alpha_a = -15^{\circ}$.

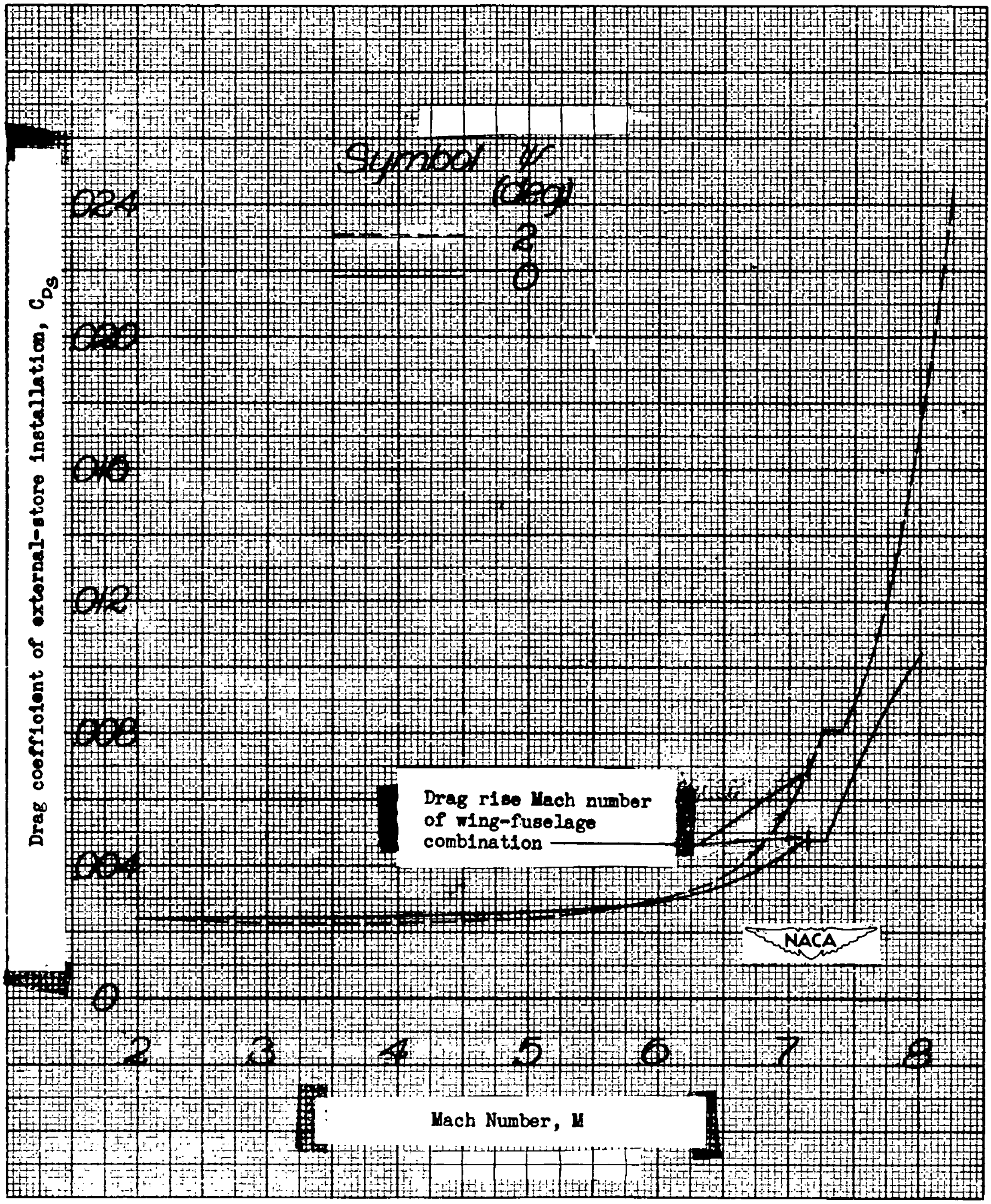
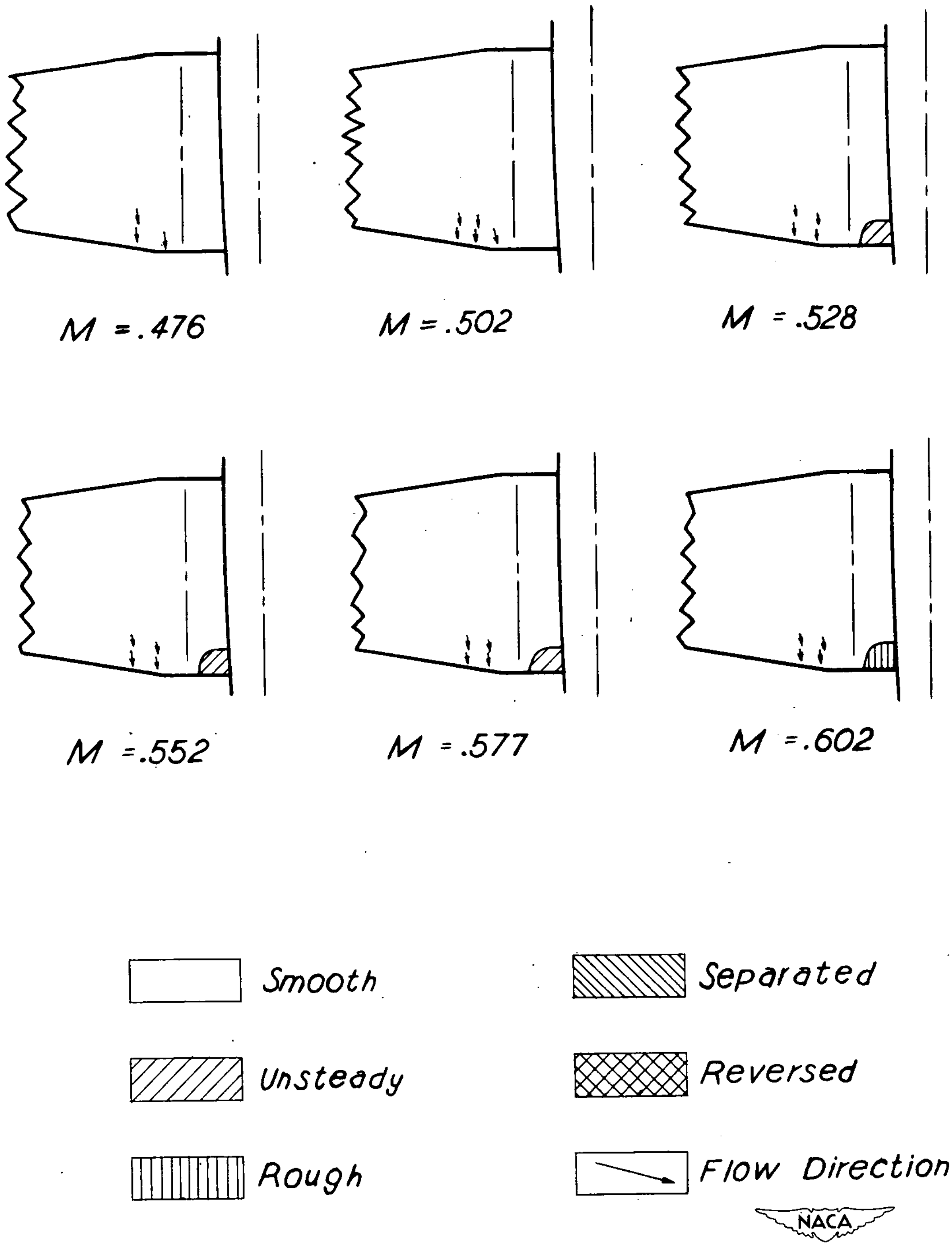
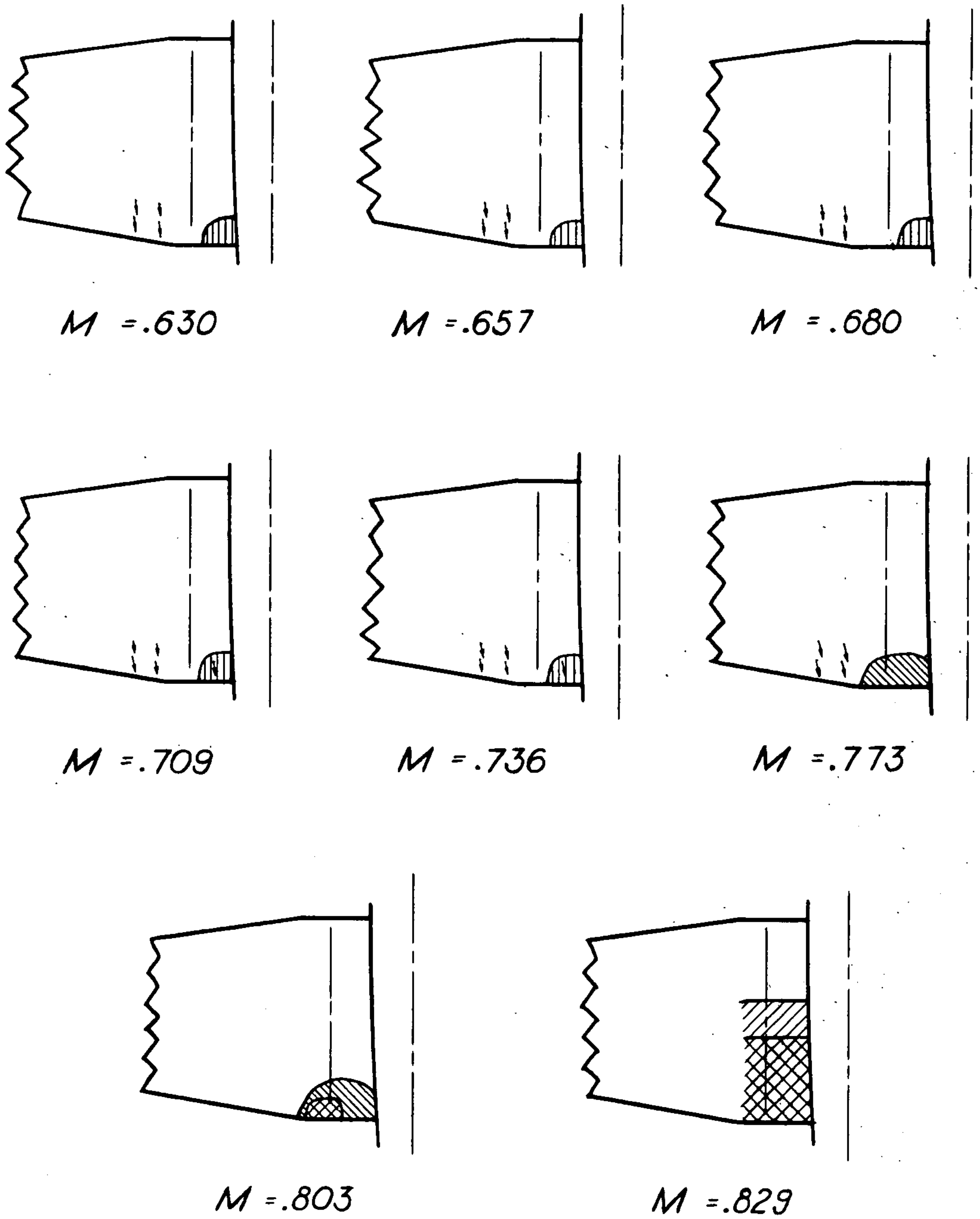


Figure 19.- Variation of the drag coefficient of the external-store installation with Mach number for the auxiliary wing arrangement mounted on the right wing of a wing-fuselage combination at two angles of yaw, $\alpha = -.75^{\circ}$, $\alpha_a = -15^{\circ}$.



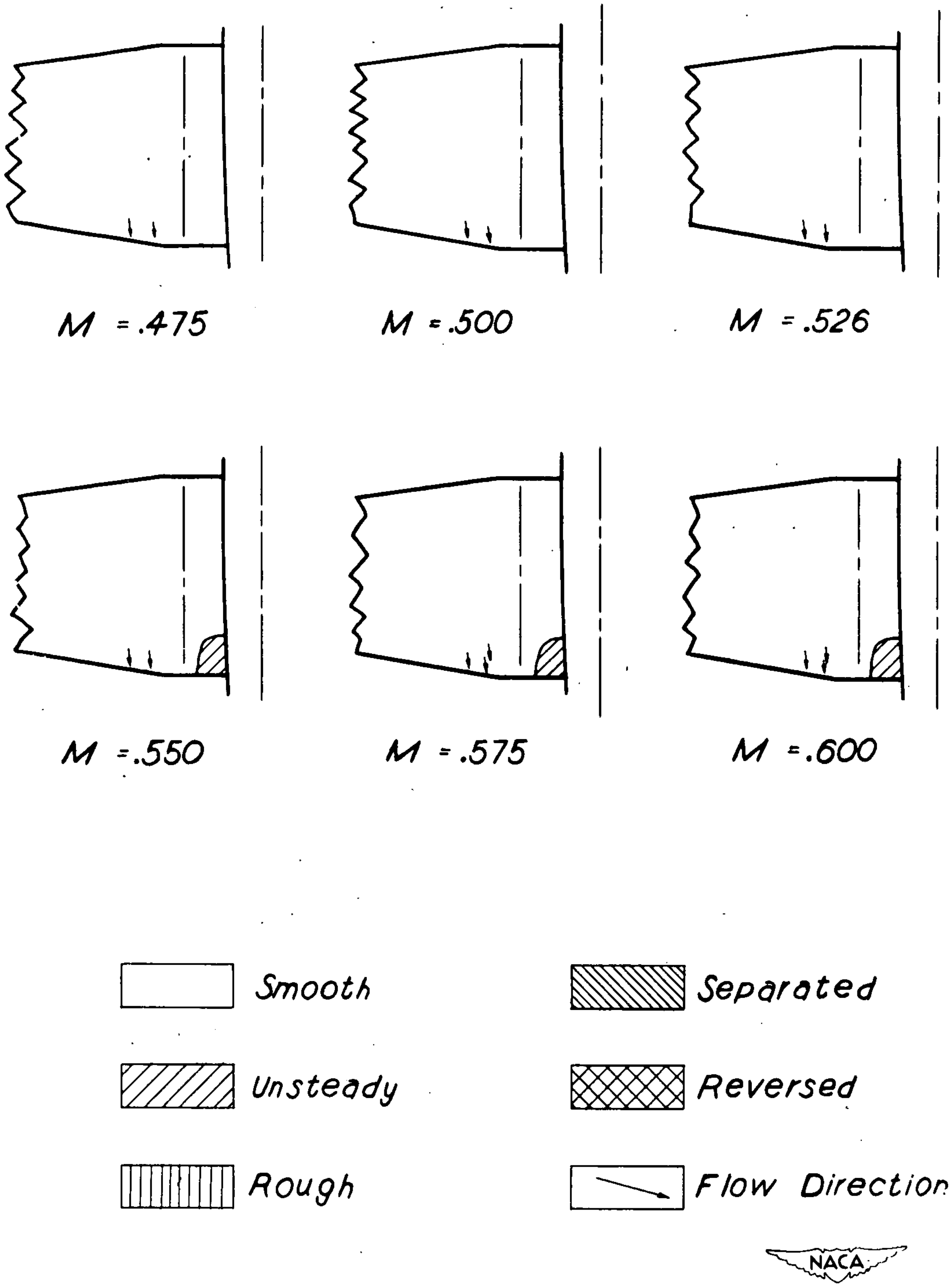
(a) $\alpha = -1.25^{\circ}$.

Figure 20.- Tuft studies of the lower surface of the right wing of a wing-fuselage combination at various angles of attack and Mach numbers, $\Psi = 0^{\circ}$.



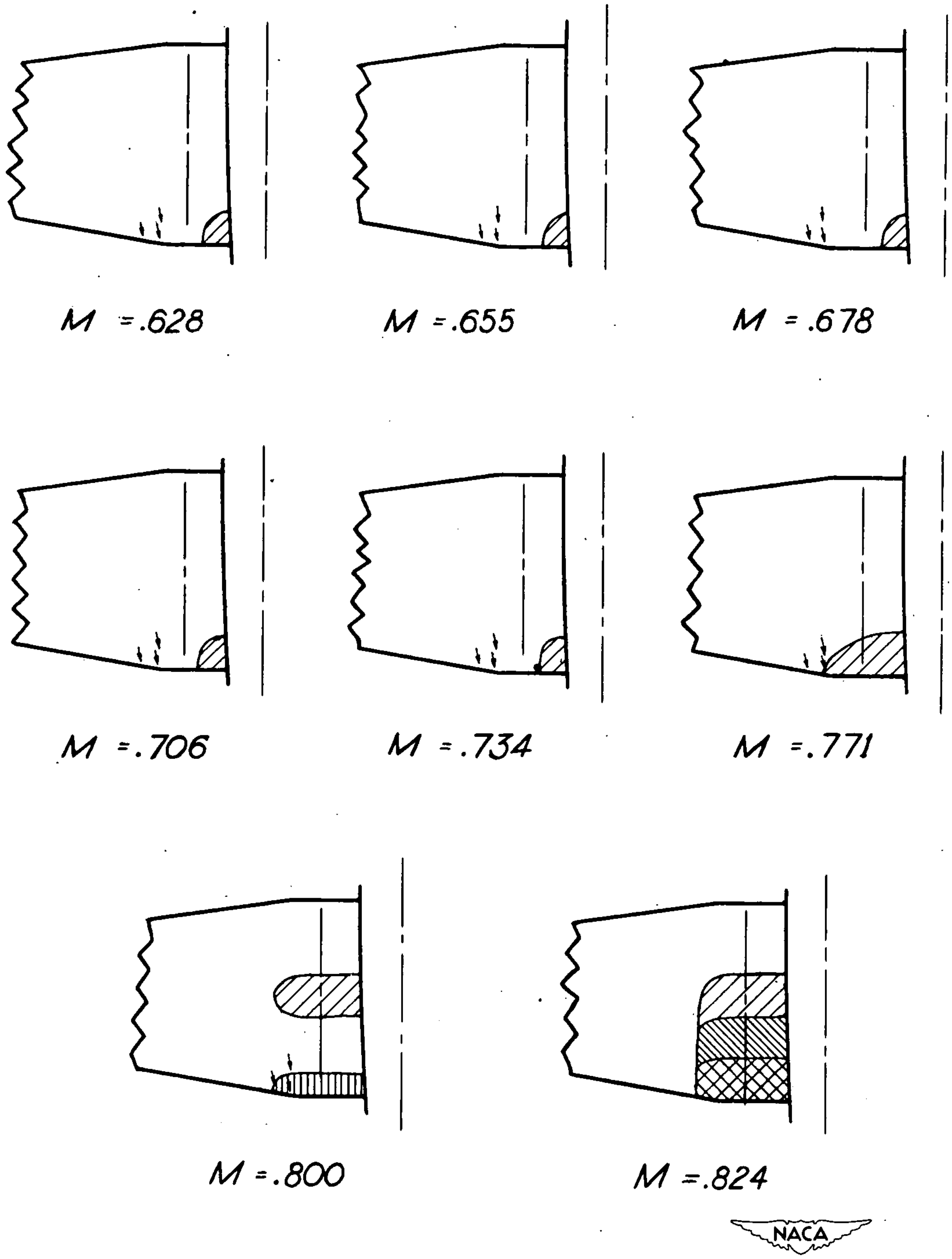
(a) Concluded.

Figure 20.- Continued.



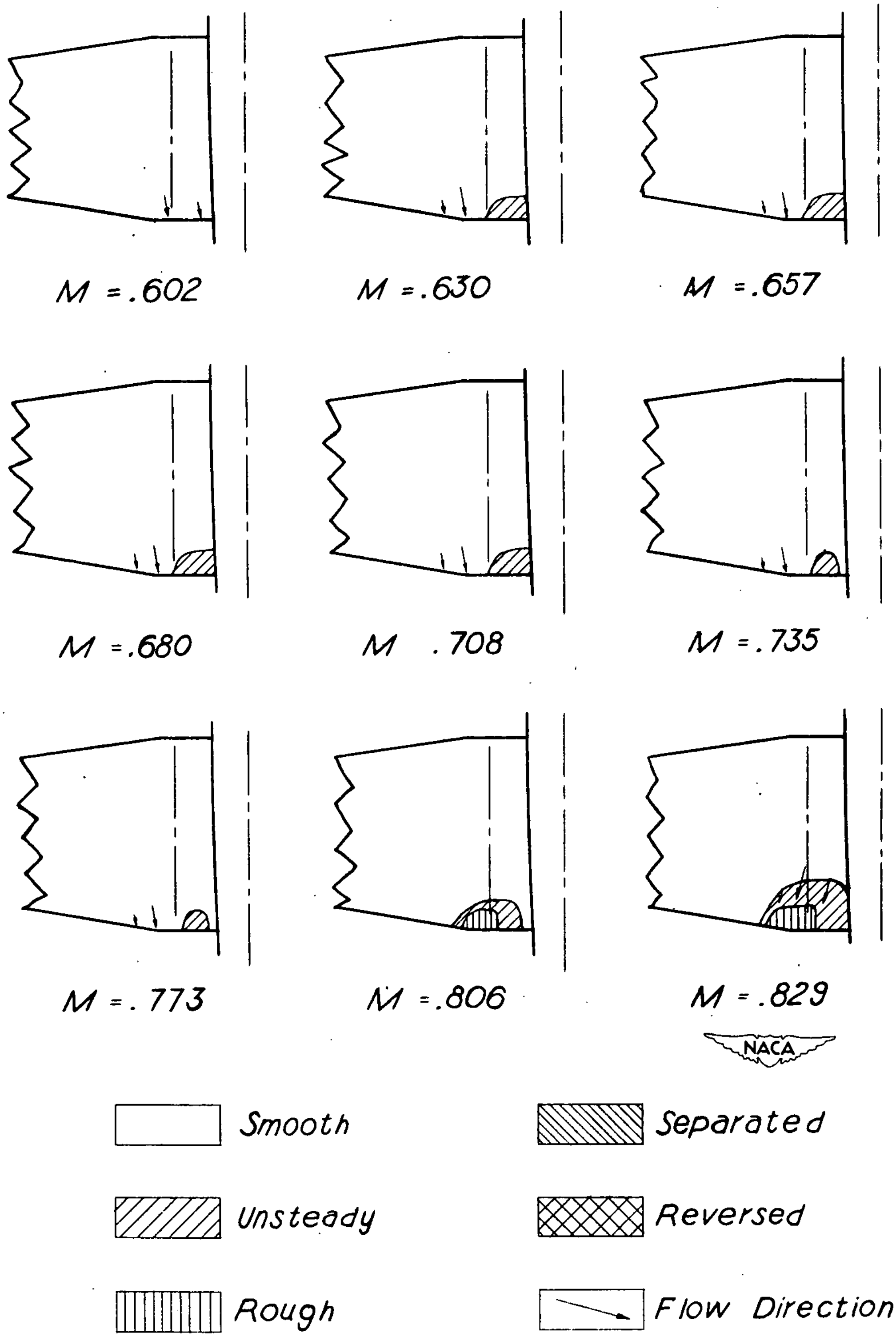
(b) $\alpha = -.75°$.

Figure 20.- Continued.



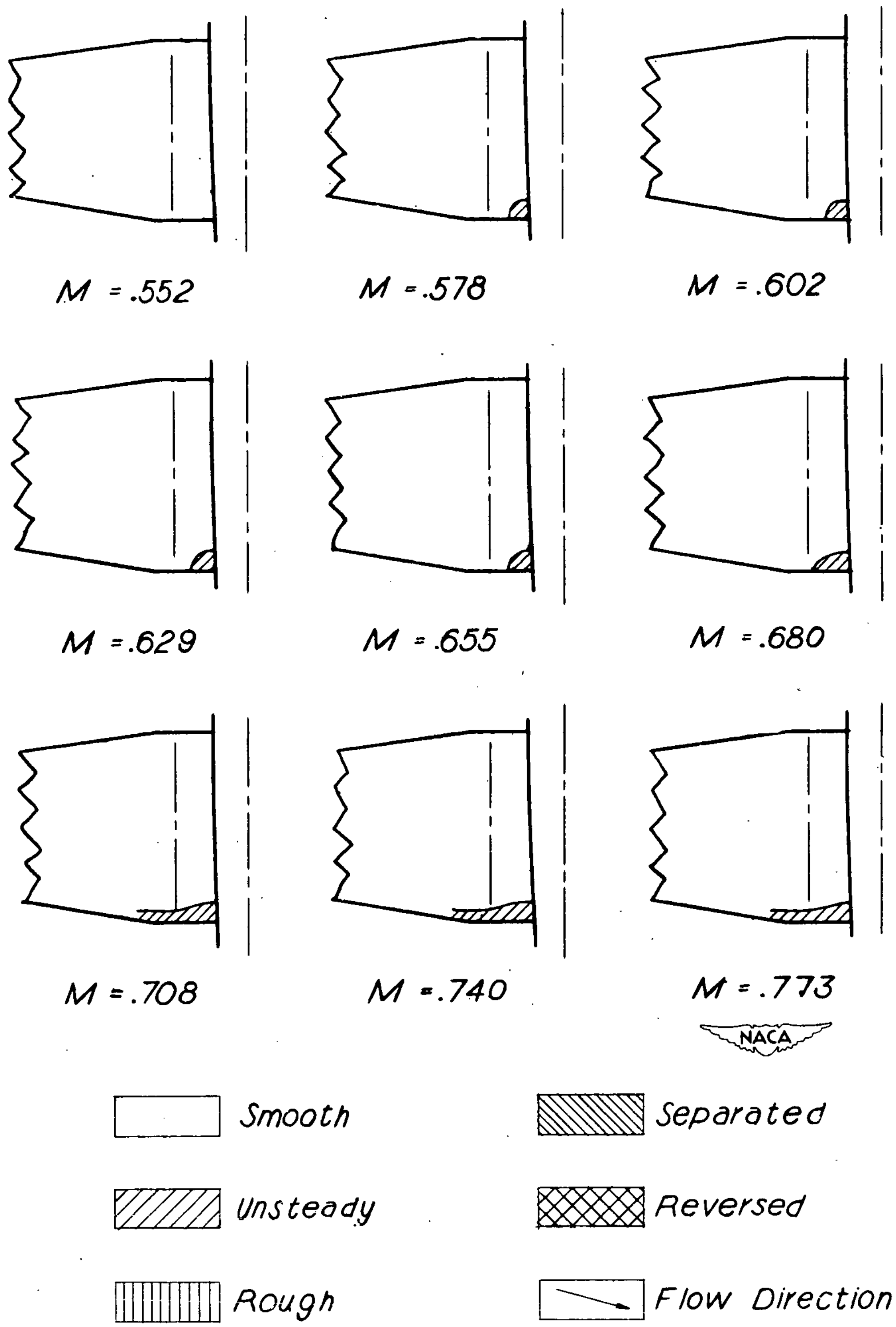
(b) Concluded.

Figure 20.- Continued.



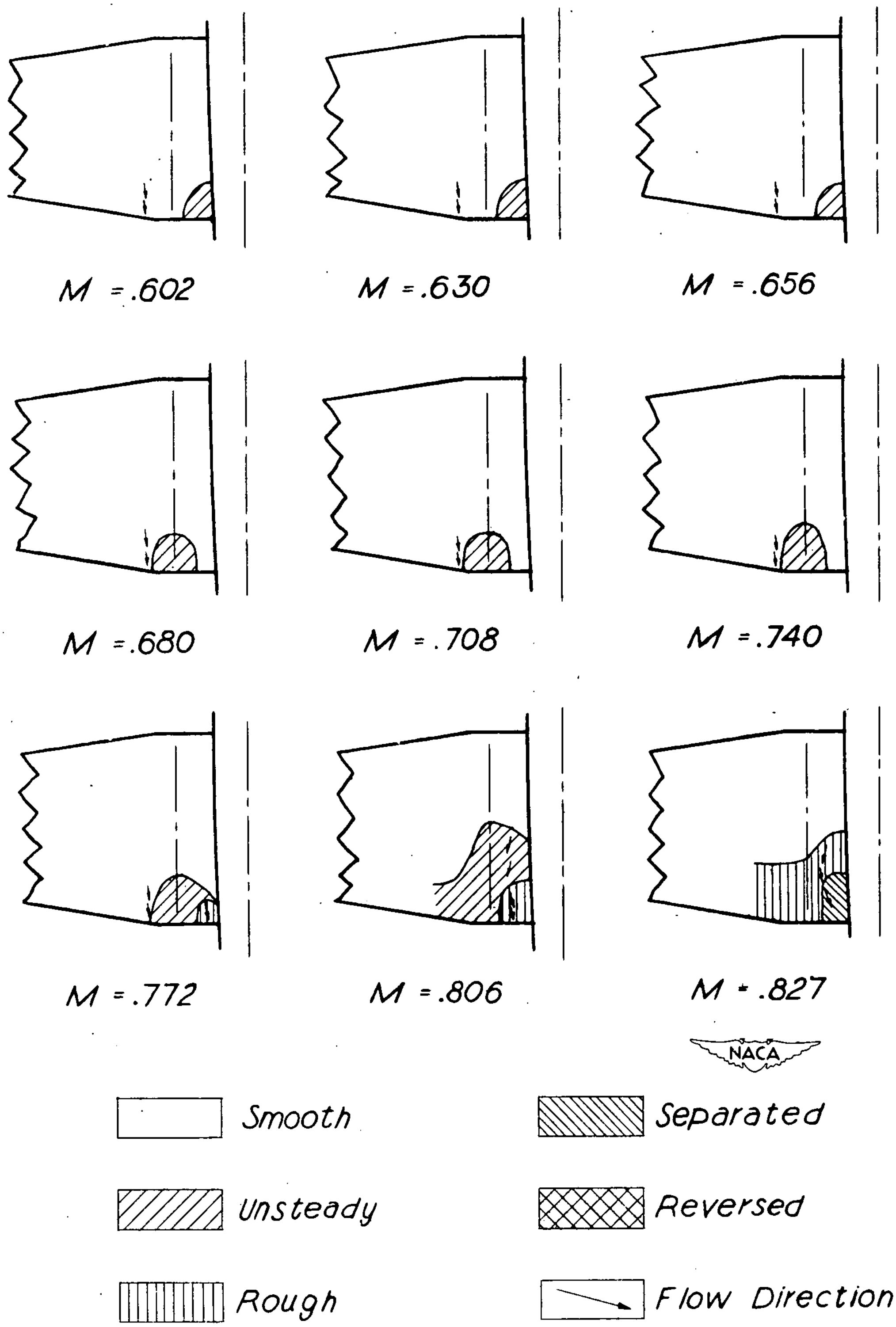
(c) $\alpha = -.25°$.

Figure 20.- Concluded.



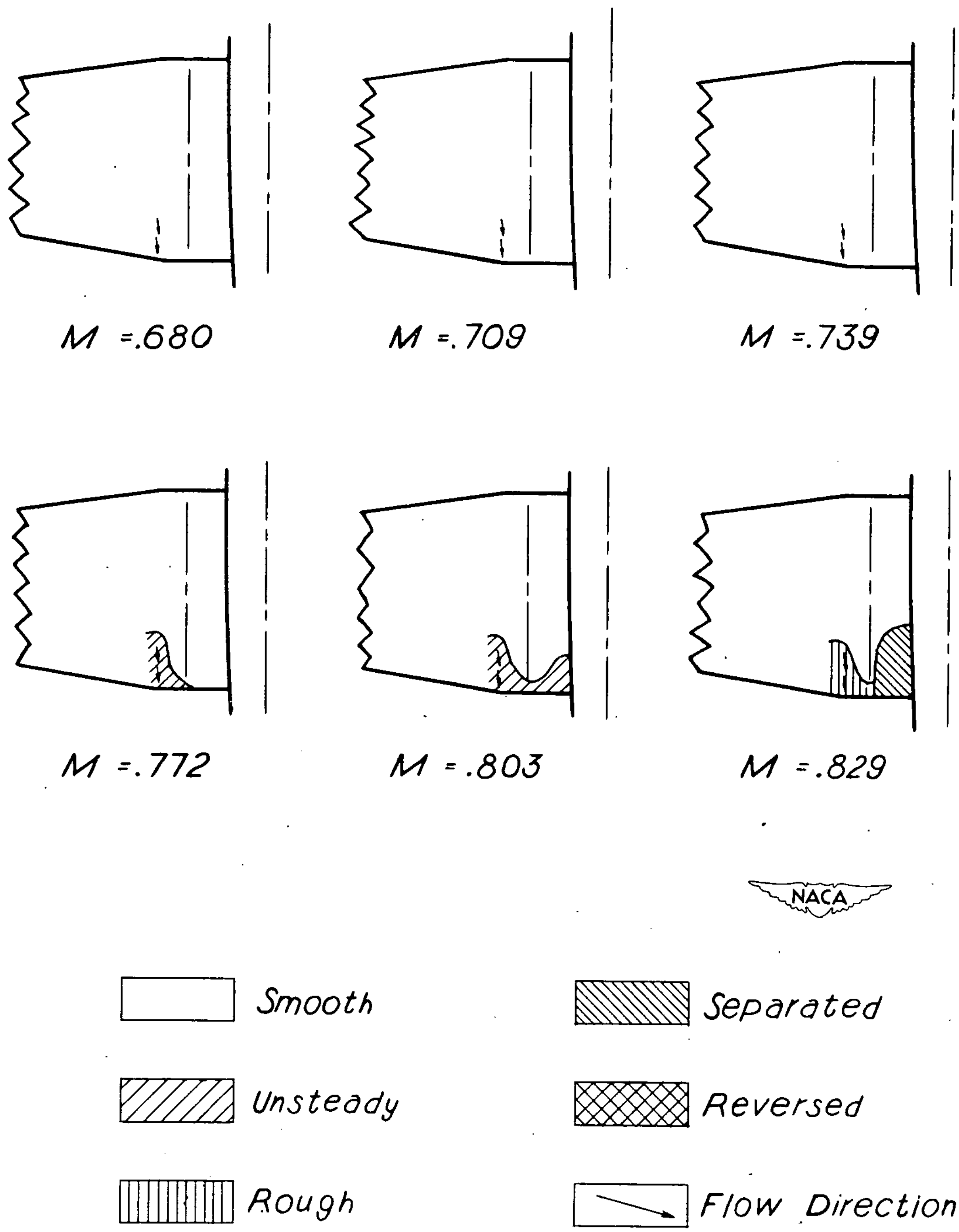
(a) $\psi = 2^{\circ}$.

Figure 21.- Tuft studies of the lower surface of the right wing of a wing-fuselage combination at various angles of yaw and Mach numbers, $\alpha = -.75^{\circ}$.



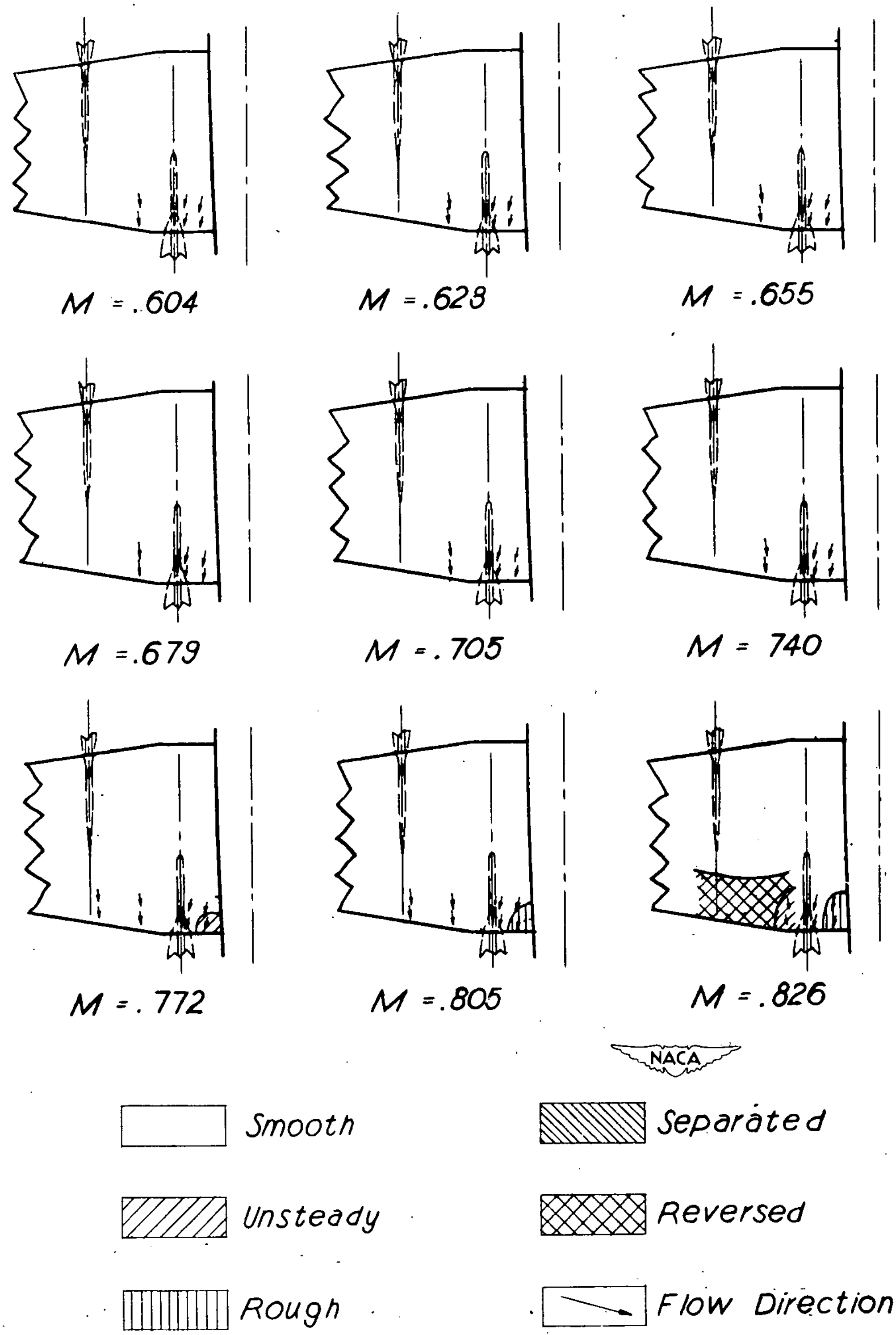
(b) $\gamma = -2^{\circ}$.

Figure 21.- Continued.



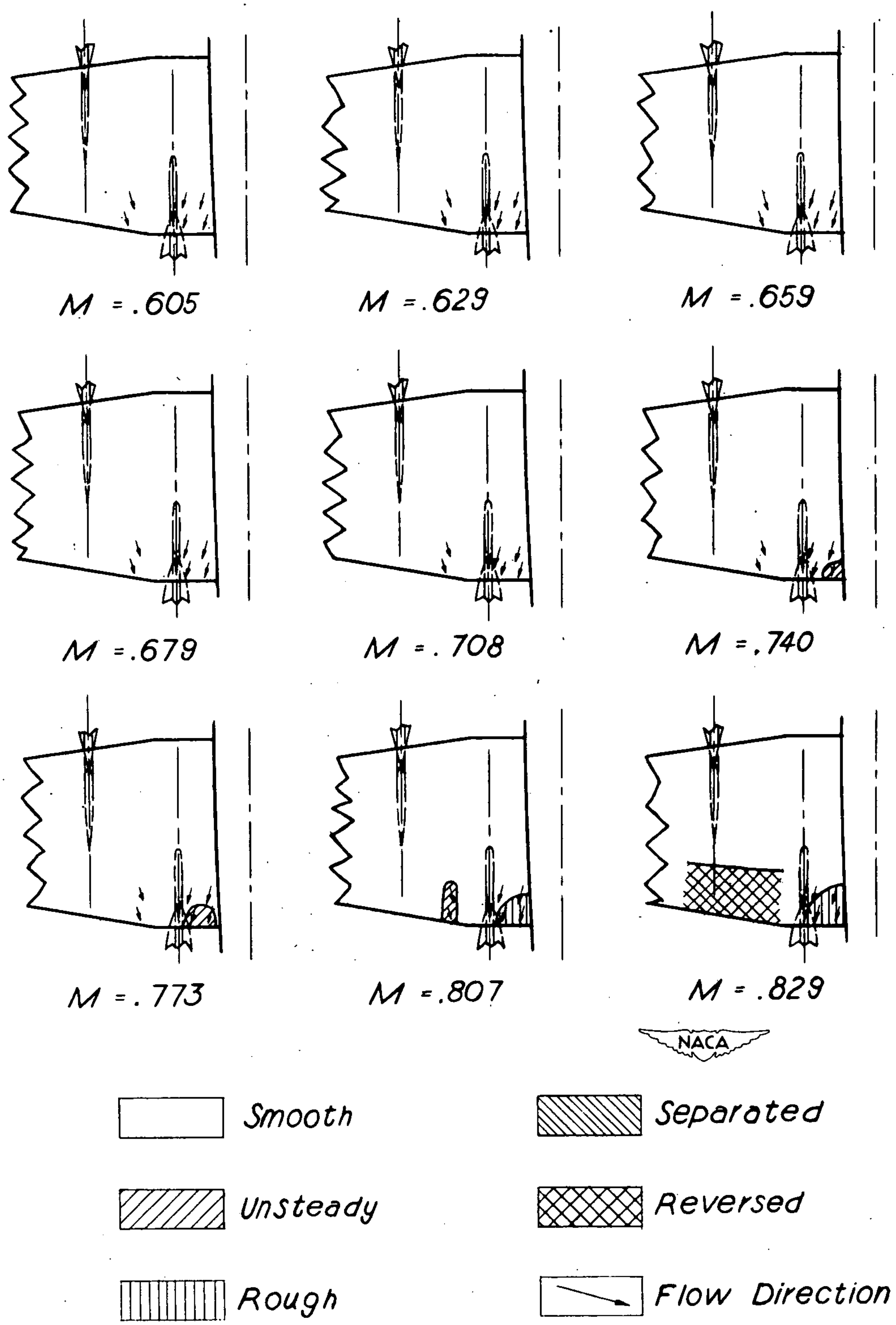
(c) $\Psi = -5^{\circ}$.

Figure 21.- Concluded.



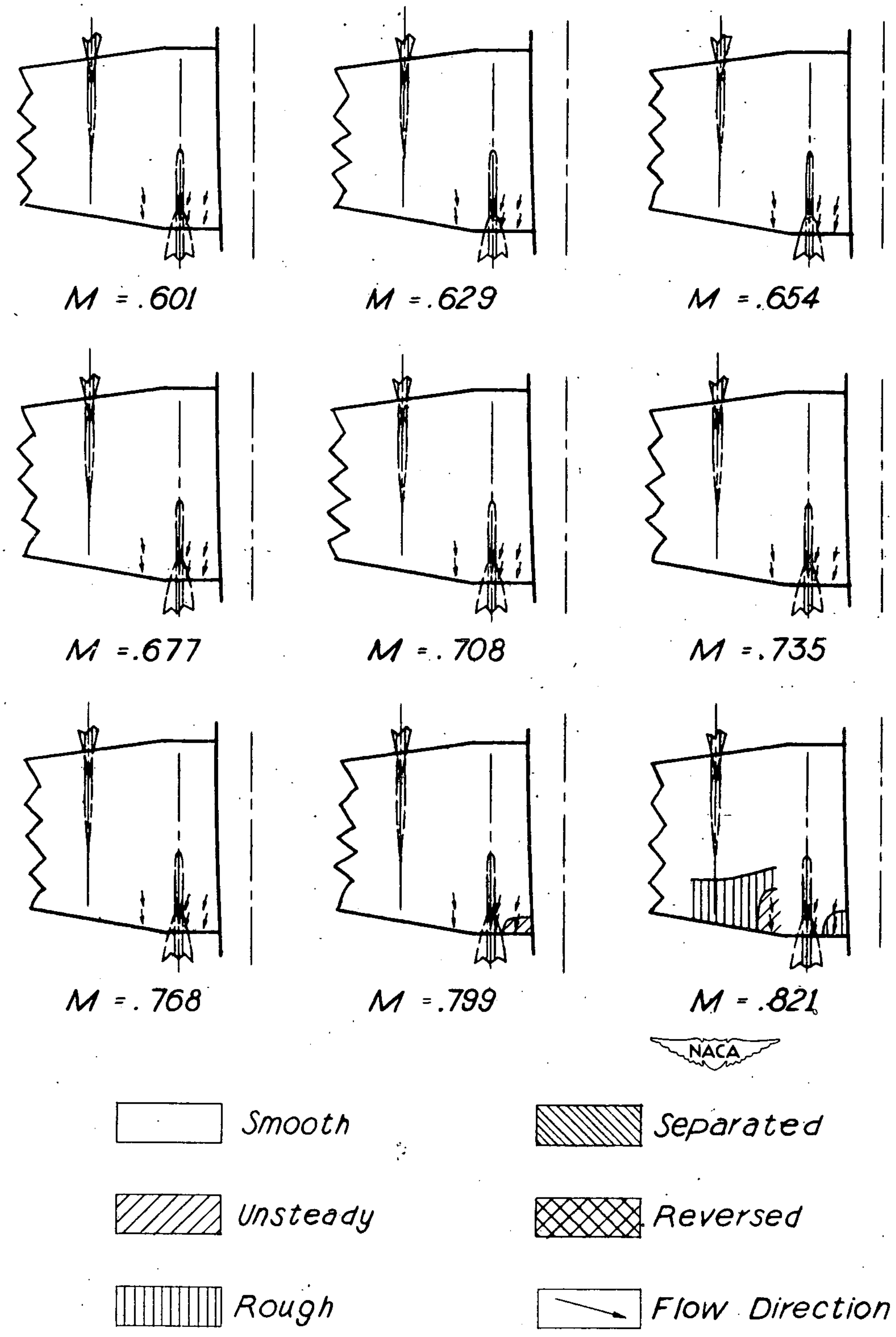
(a) α = -1.25°.

Figure 22.- Tuft studies of the lower surface of the right wing of a wing-fuselage combination at various angles of attack and Mach numbers with the tandem mounted external-store arrangement in place, ψ = 0°.



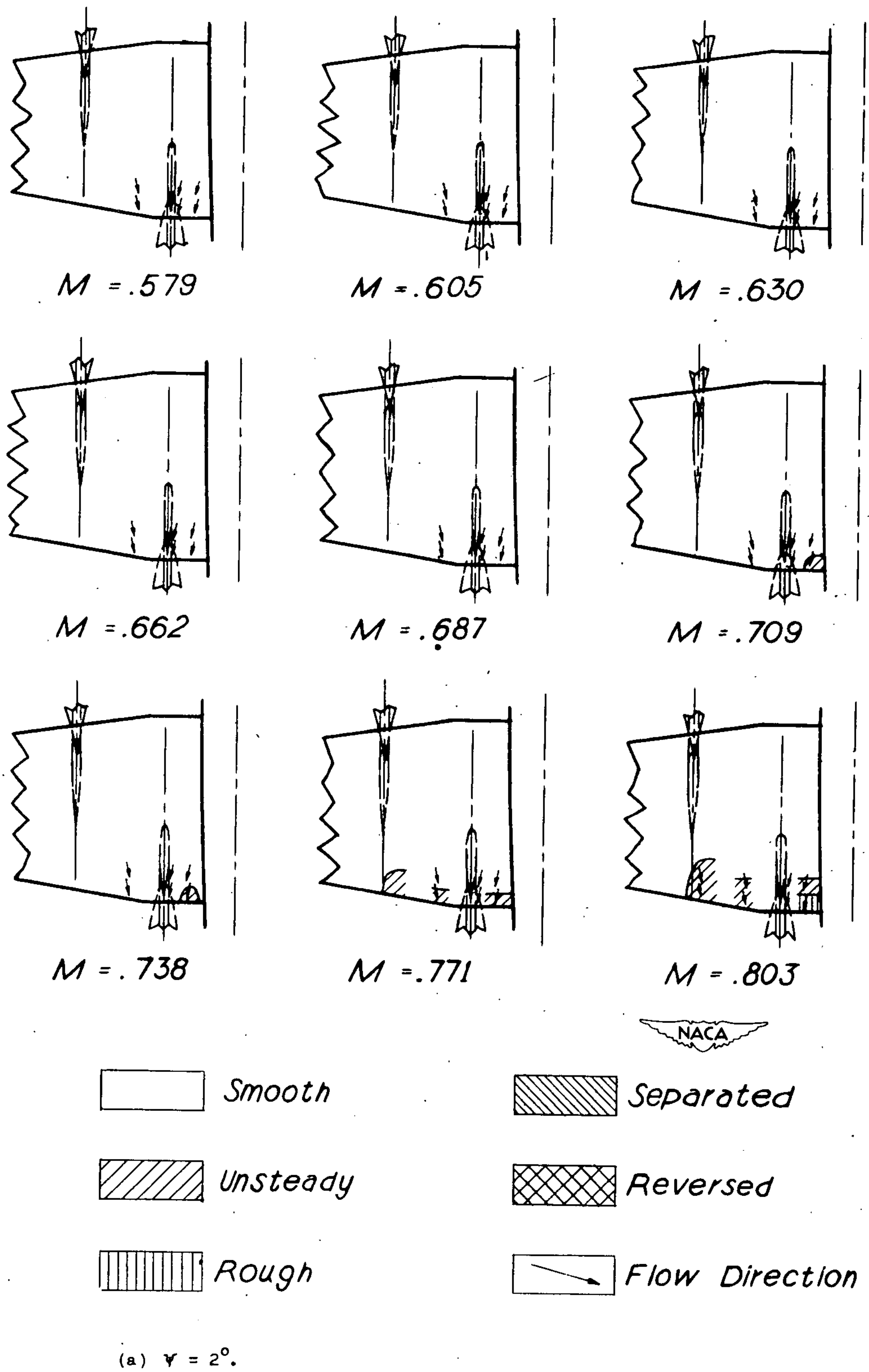
(b) $\alpha = -.75^{\circ}$.

Figure 22.- Continued.



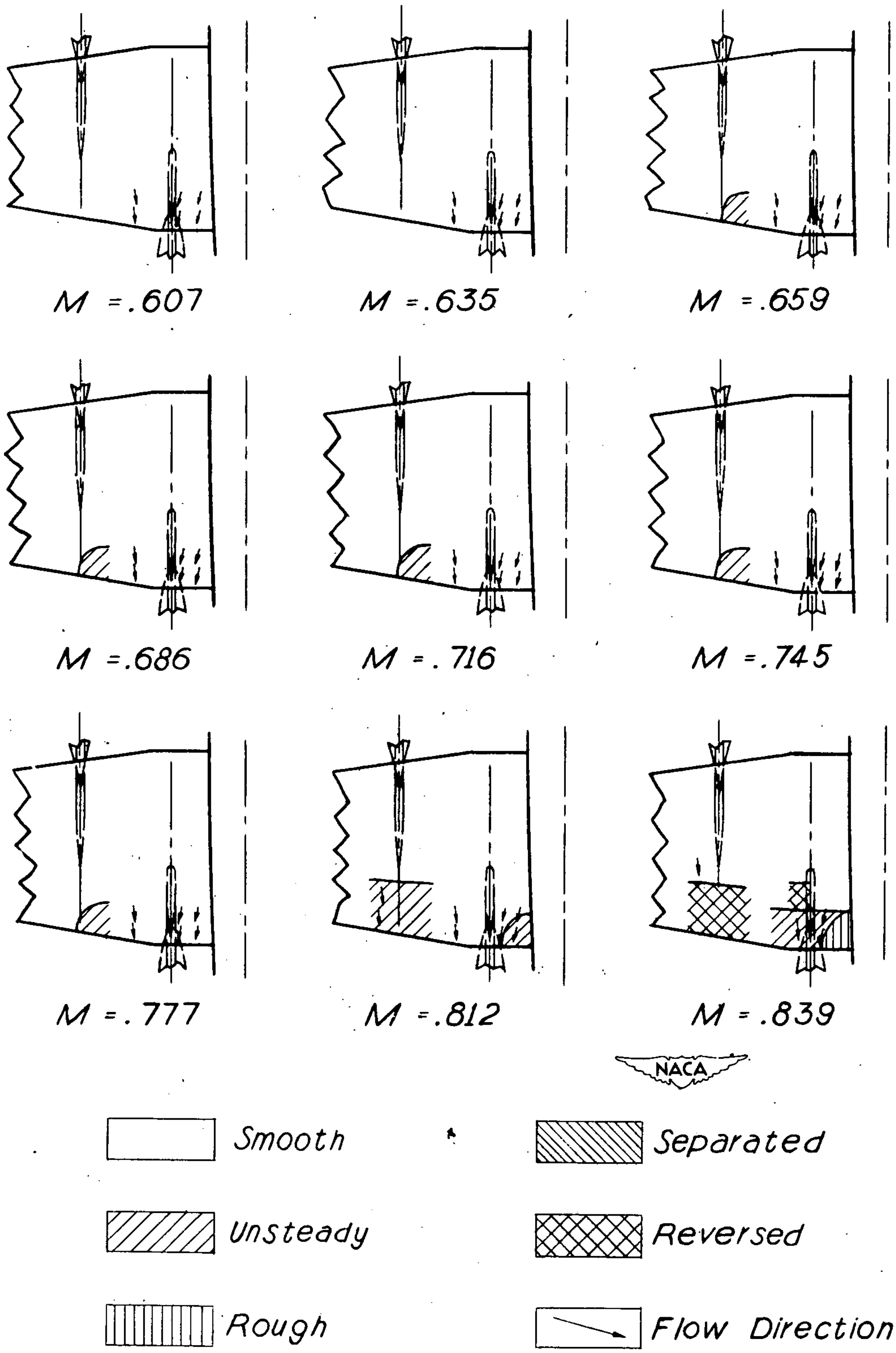
(c) $\alpha = -.25^{\circ}$.

Figure 22.- Concluded.



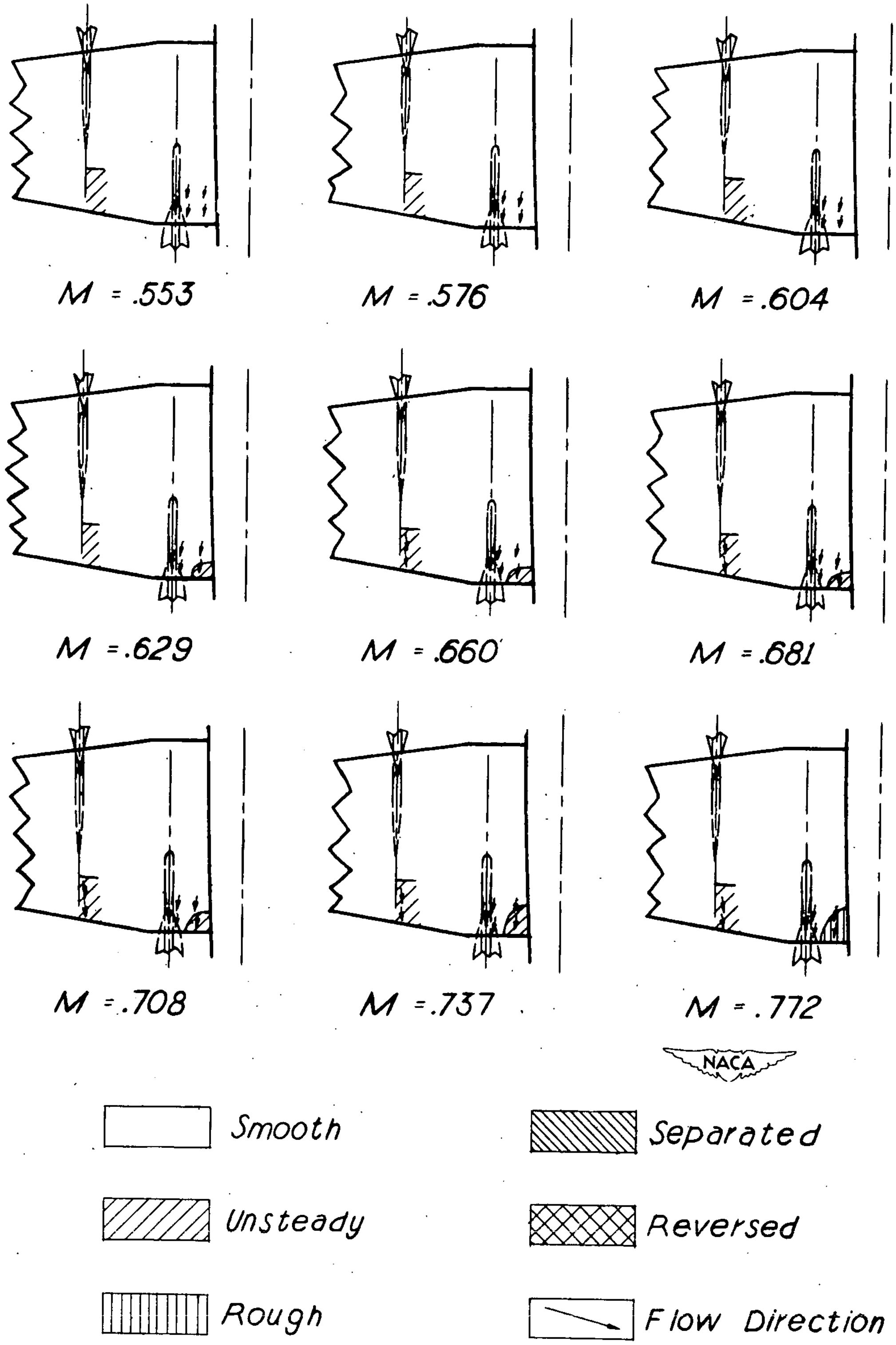
(a) $\psi = 2^{\circ}$.

Figure 23.- Tuft studies of the lower surface of the right wing of a wing-fuselage combination at various angles of yaw and Mach numbers with the tandem-mounted external-store arrangement in place, $\alpha = -.75^{\circ}$.



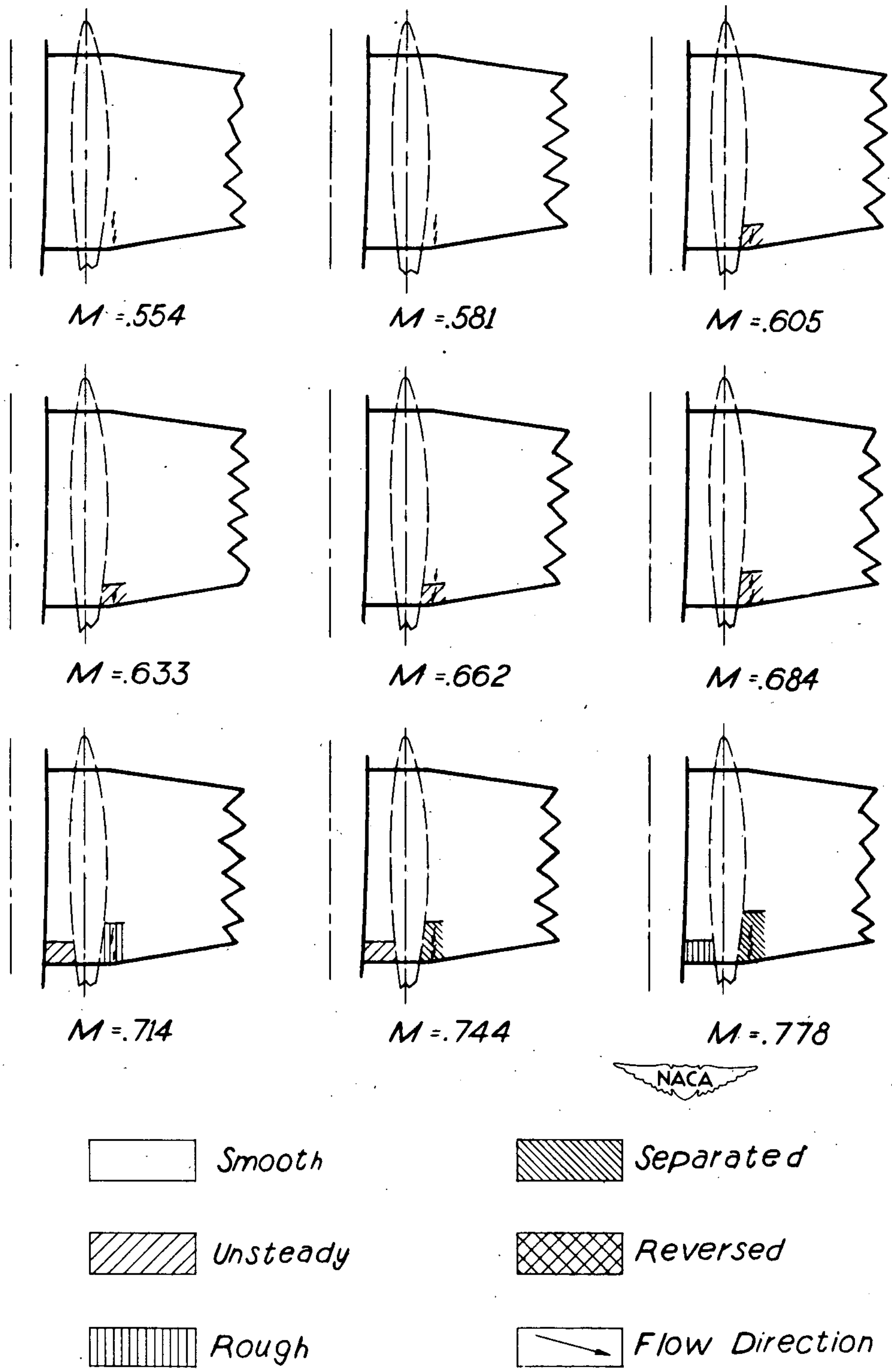
(b) $\gamma = -2^{\circ}$.

Figure 23.- Continued.



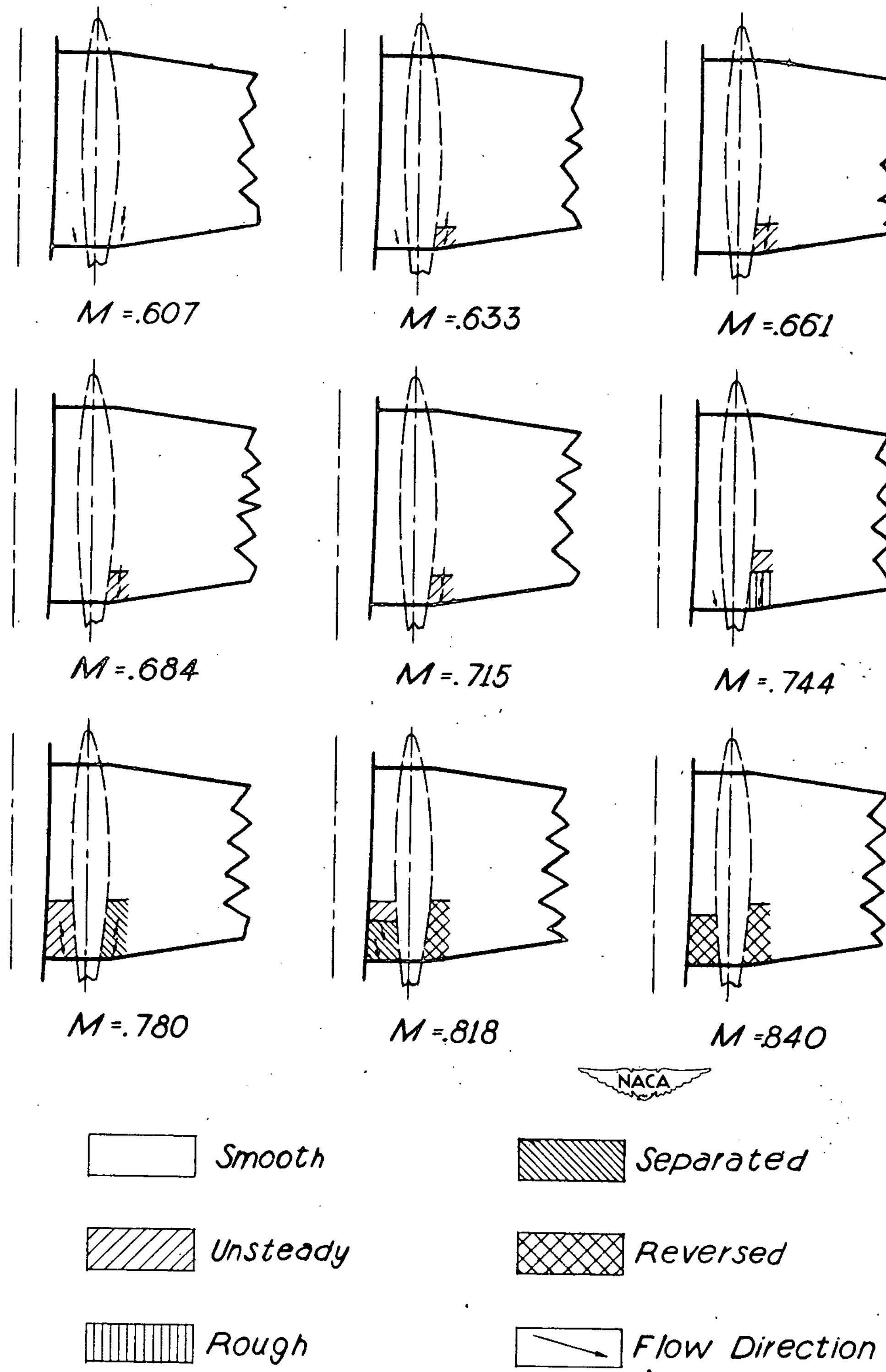
(c) $\psi = -5^{\circ}$.

Figure 23.- Concluded.



(a) $\alpha = -.75^{\circ}$

Figure 24.- Tuft studies of the lower surface of the left wing of a wing-fuselage combination at various angles of attack and Mach numbers with the flush-mounted external-store arrangement in place, extension attached, $\Psi = 0^{\circ}$.



(b) $\alpha = -.25^{\circ}$.

Figure 24.- Concluded.

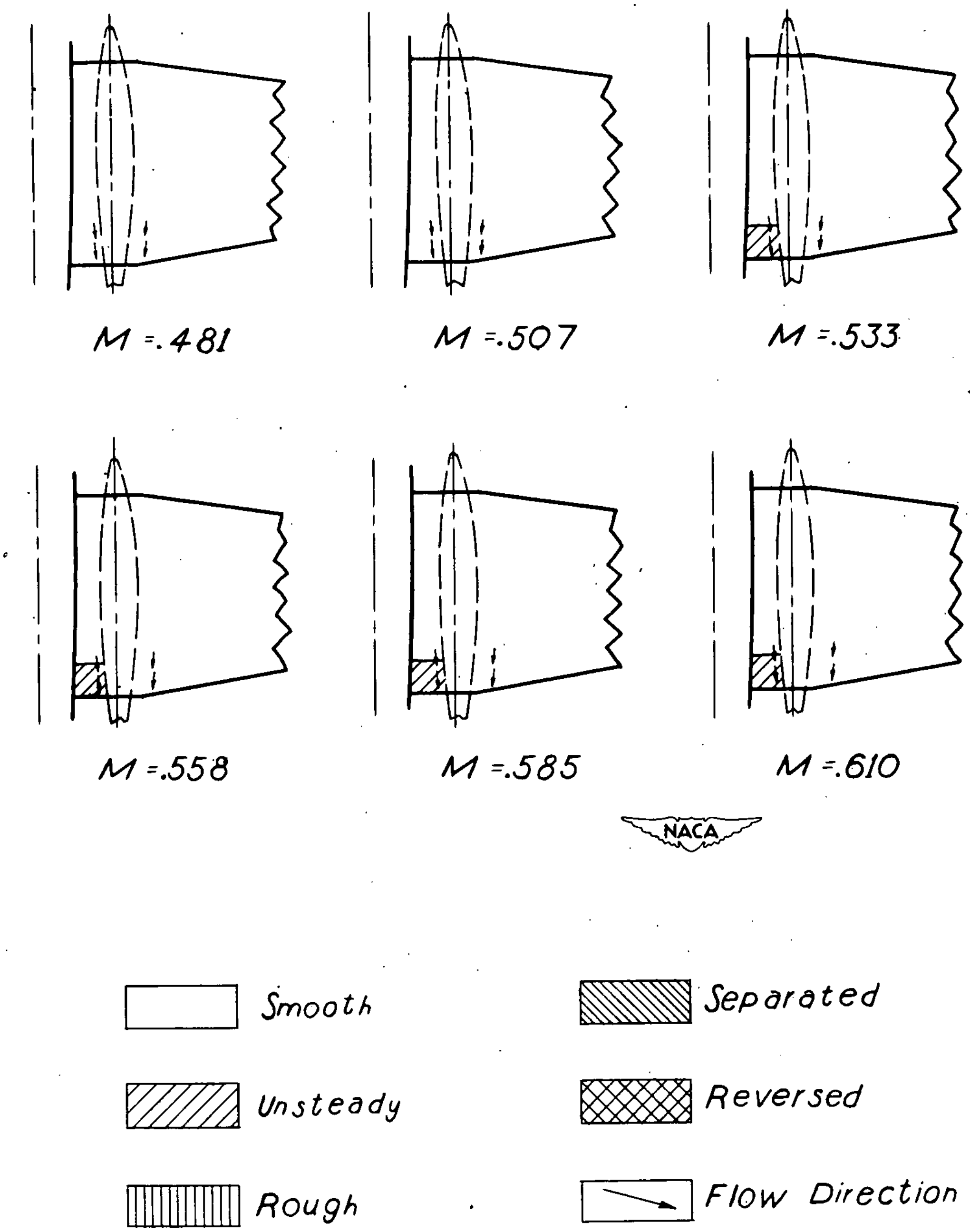


Figure 25.- Tuft studies of the lower surface of the left wing of a wing-fuselage combination at various Mach numbers with the flush-mounted external-store arrangement in place, extension attached, $\alpha = -.75^{\circ}$, $\Psi = 2^{\circ}$.

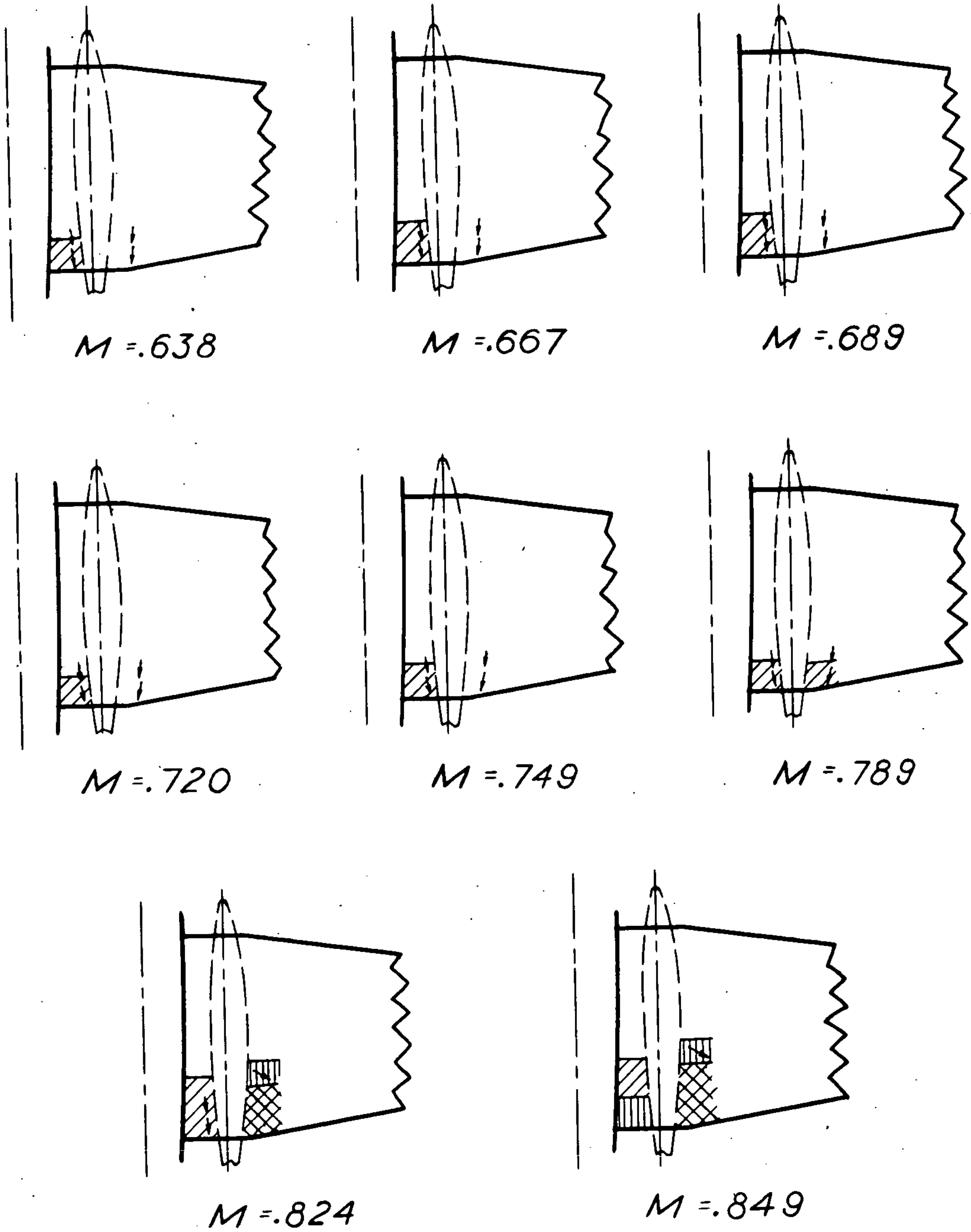


Figure 25.- Concluded.

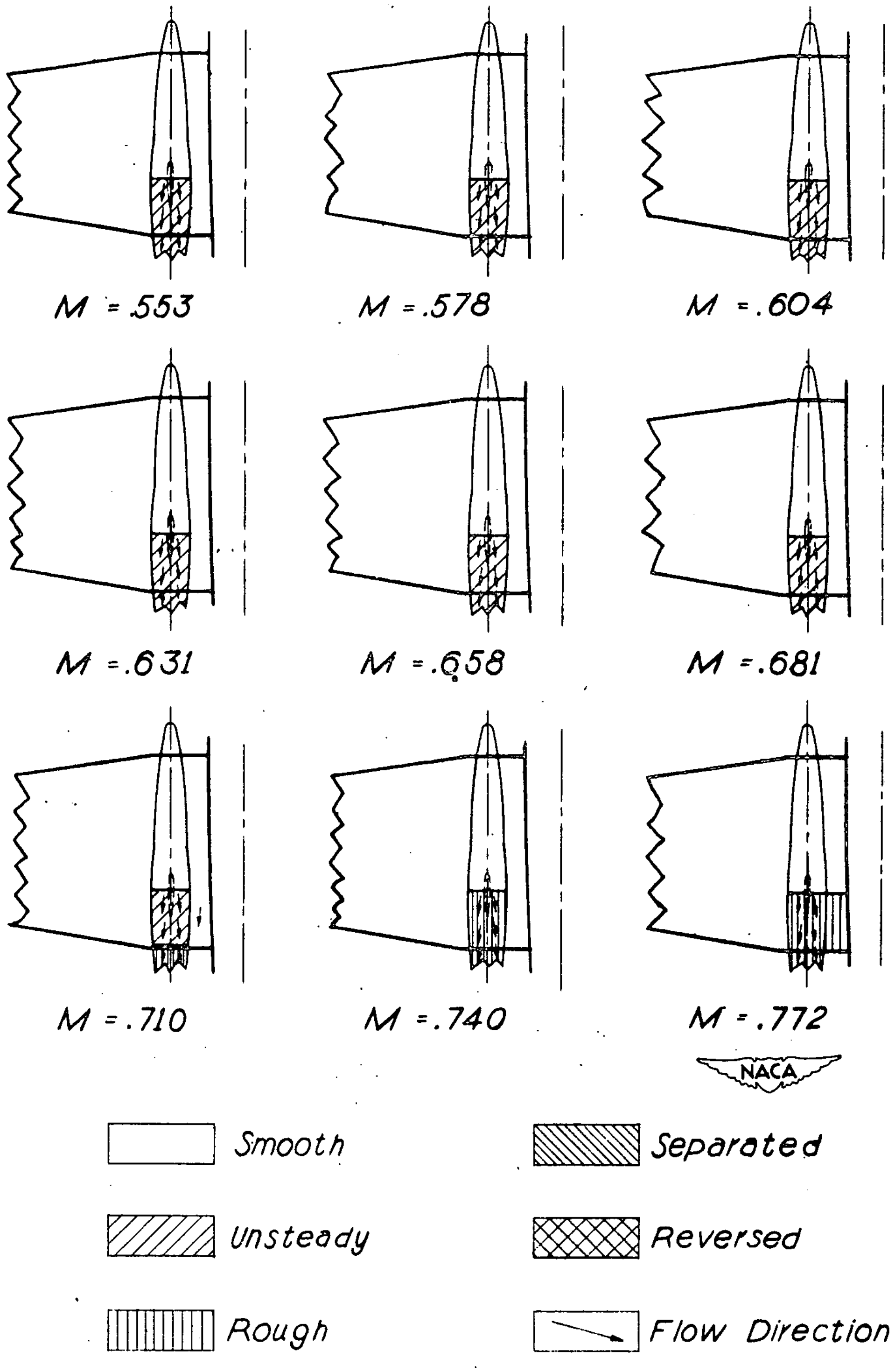


Figure 26.- Tuft studies of the lower surface of the store and the lower surface of the right wing of a wing-fuselage combination at various Mach numbers with the external store with a fan-shaped tail in place, $\alpha = -.75^{\circ}$, $\psi = 0^{\circ}$, $\alpha_t = 0^{\circ}$.

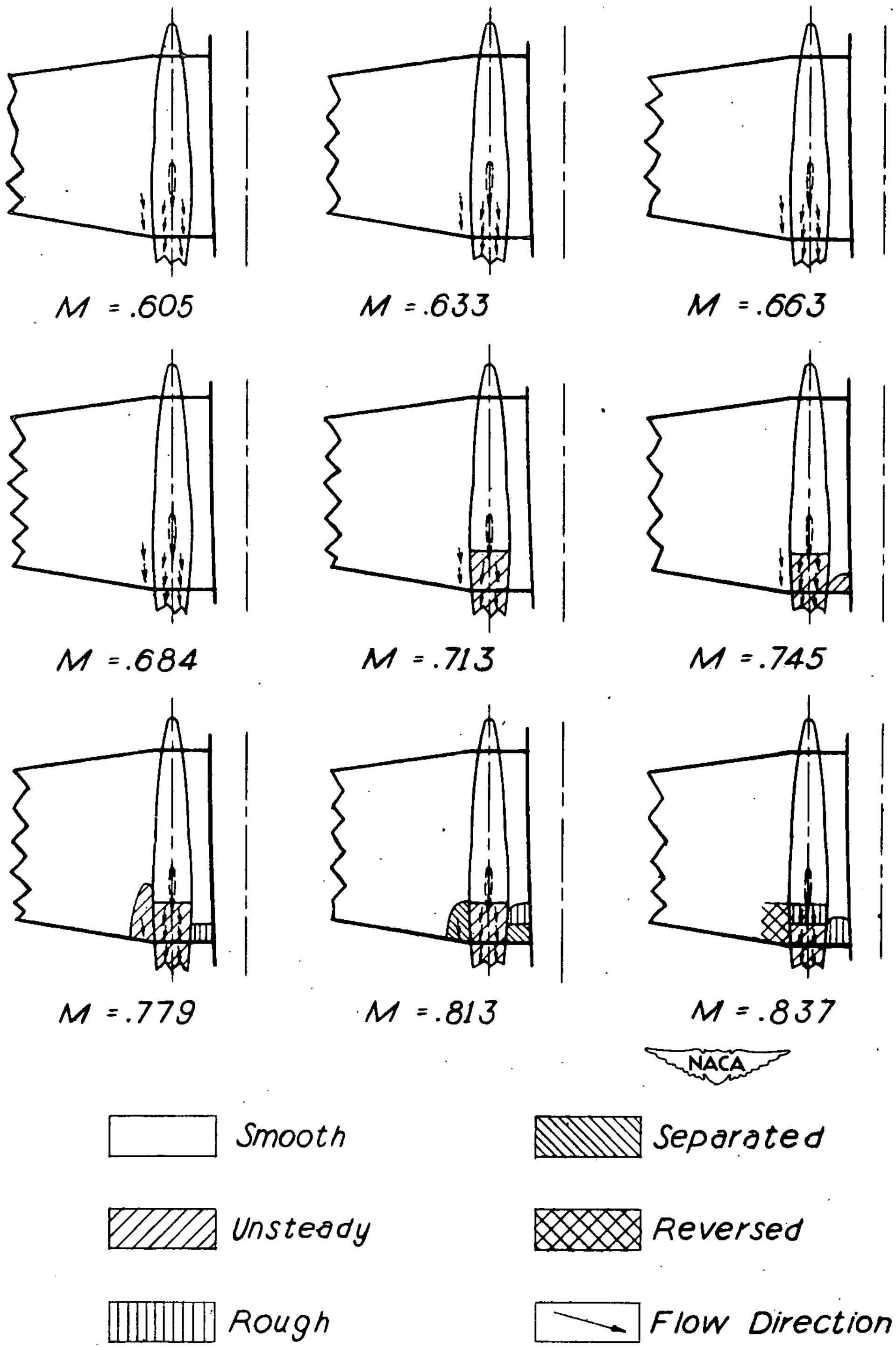


Figure 27.- Tuft studies of the lower surface of the store and the lower surface of the right wing of a wing-fuselage combination at various Mach numbers with the external store with a fan-shaped tail in place, $\alpha = -.75^{\circ}$, $\Psi = 0^{\circ}$, $\alpha_t = -2\ 1/2^{\circ}$.

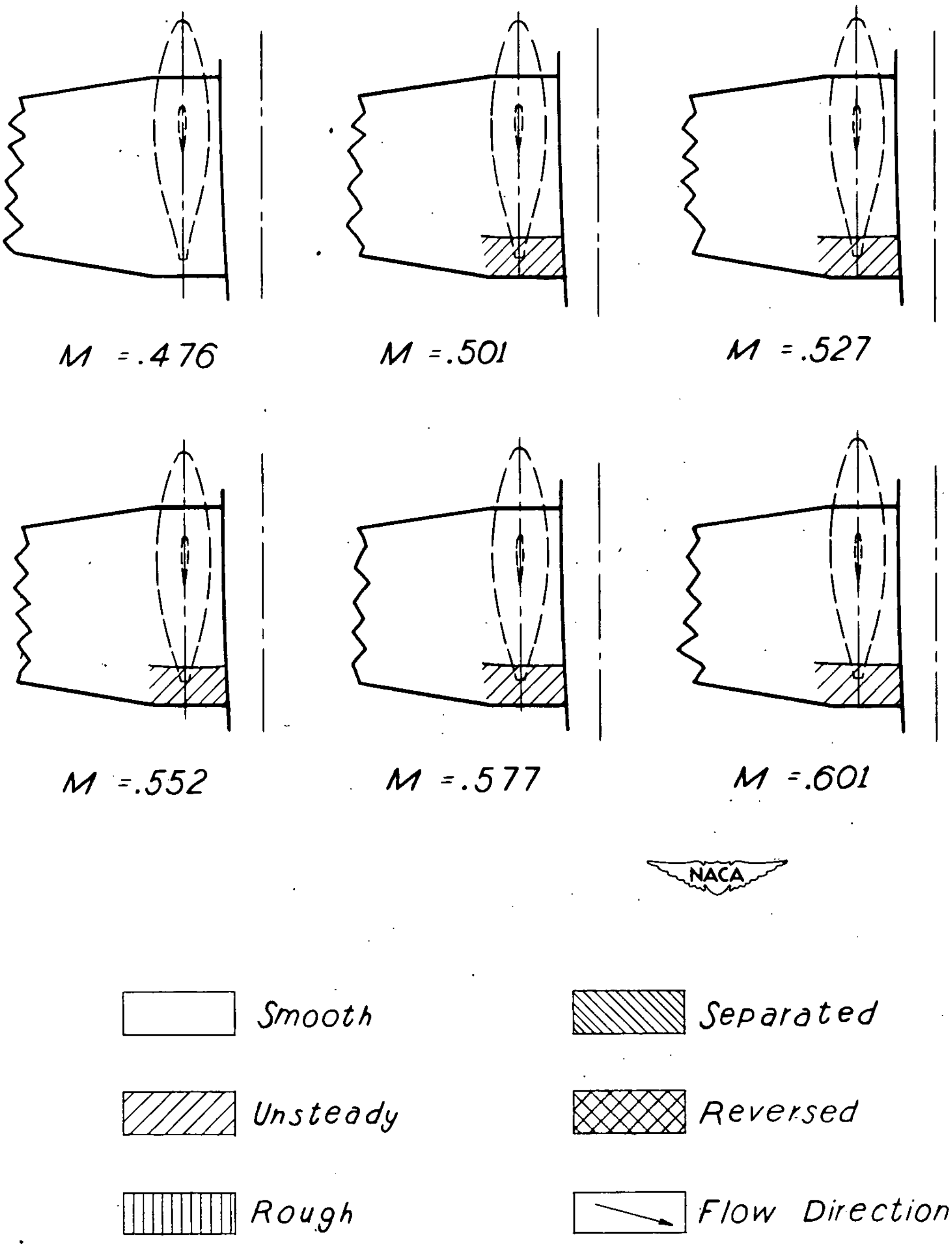


Figure 28.- Tuft studies of the lower surface of the right wing of a wing-fuselage combination at various Mach numbers with a standard Navy drop tank in place, $\alpha = -.75^{\circ}$, $\Psi = 0^{\circ}$.

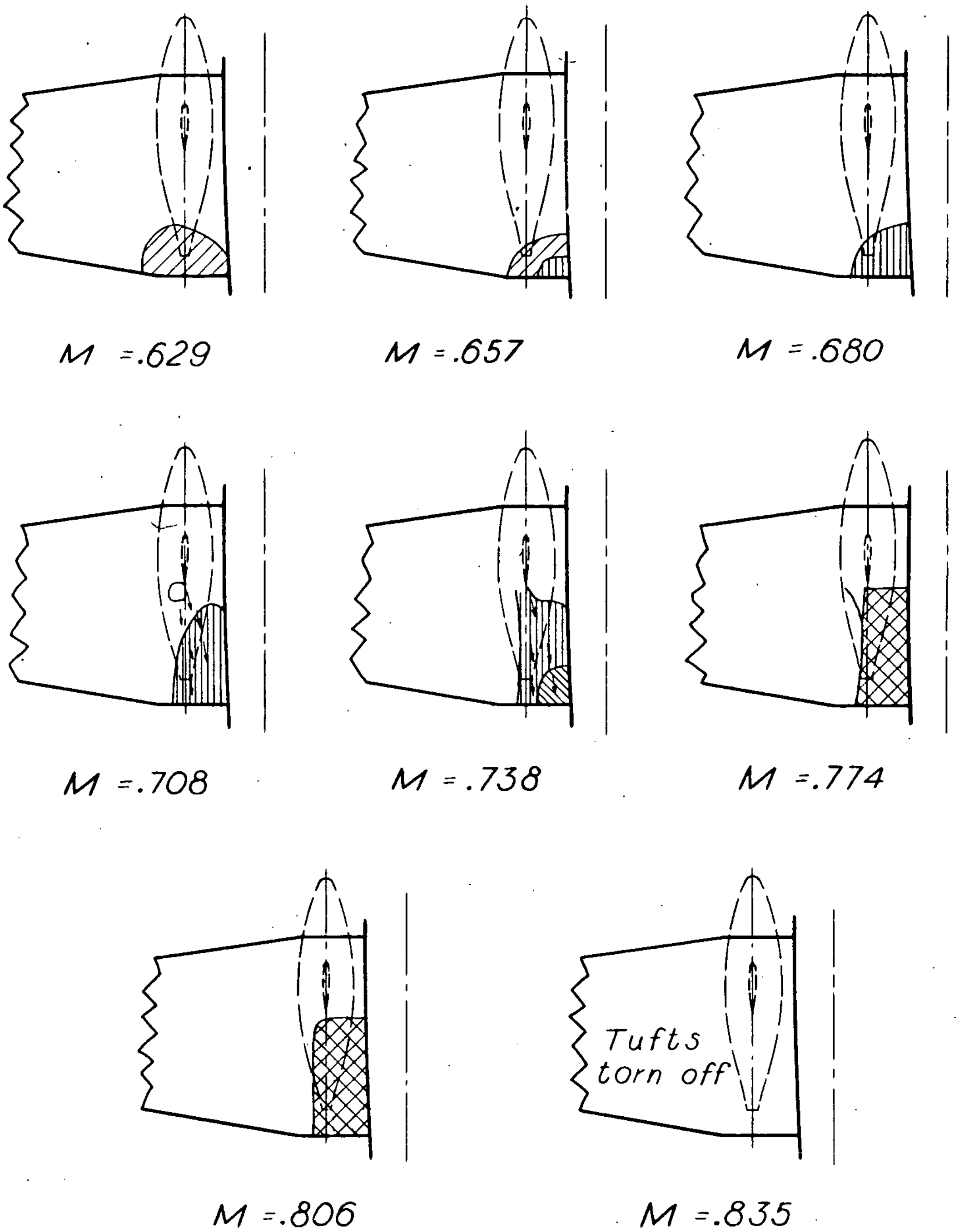
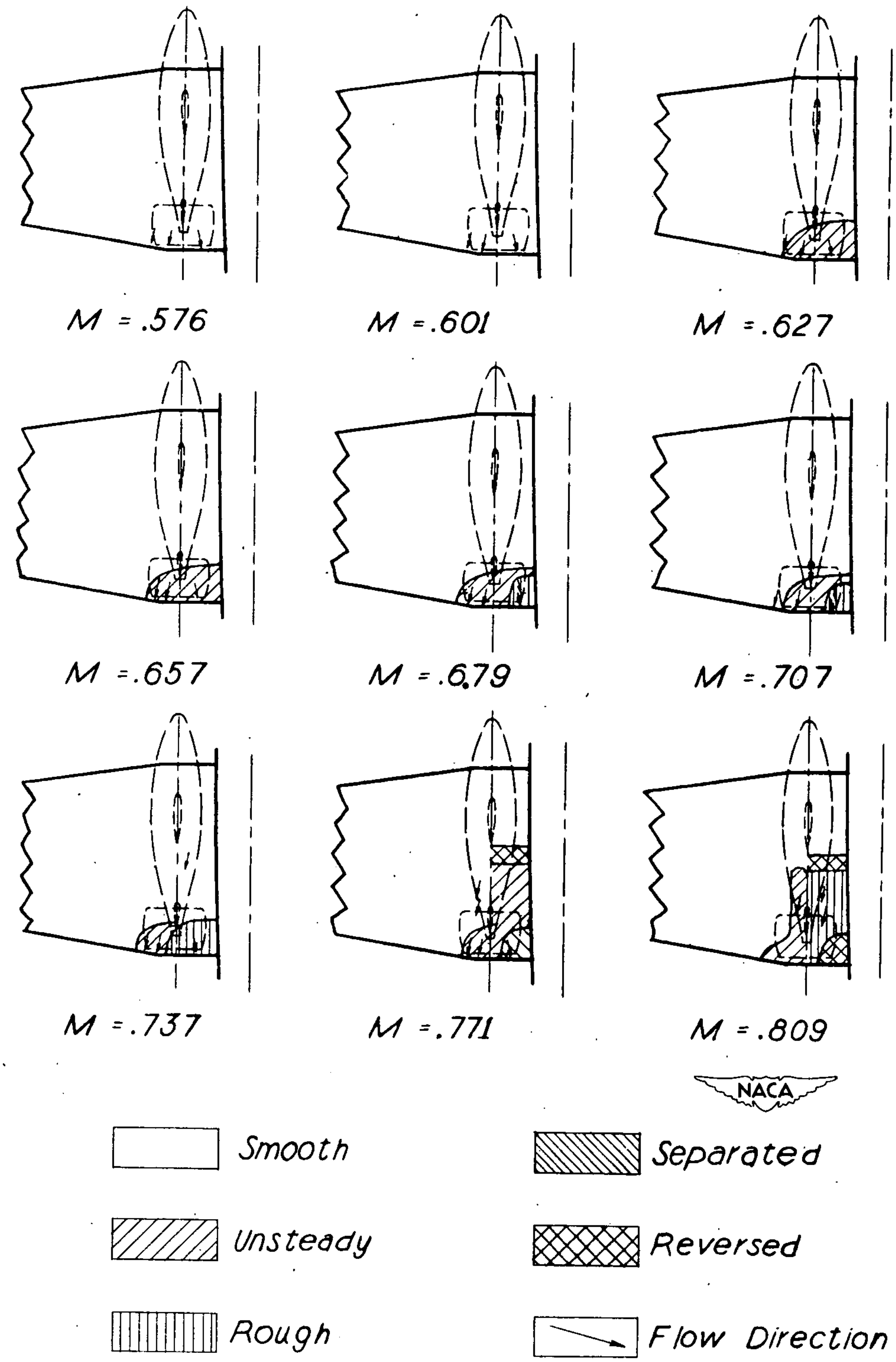
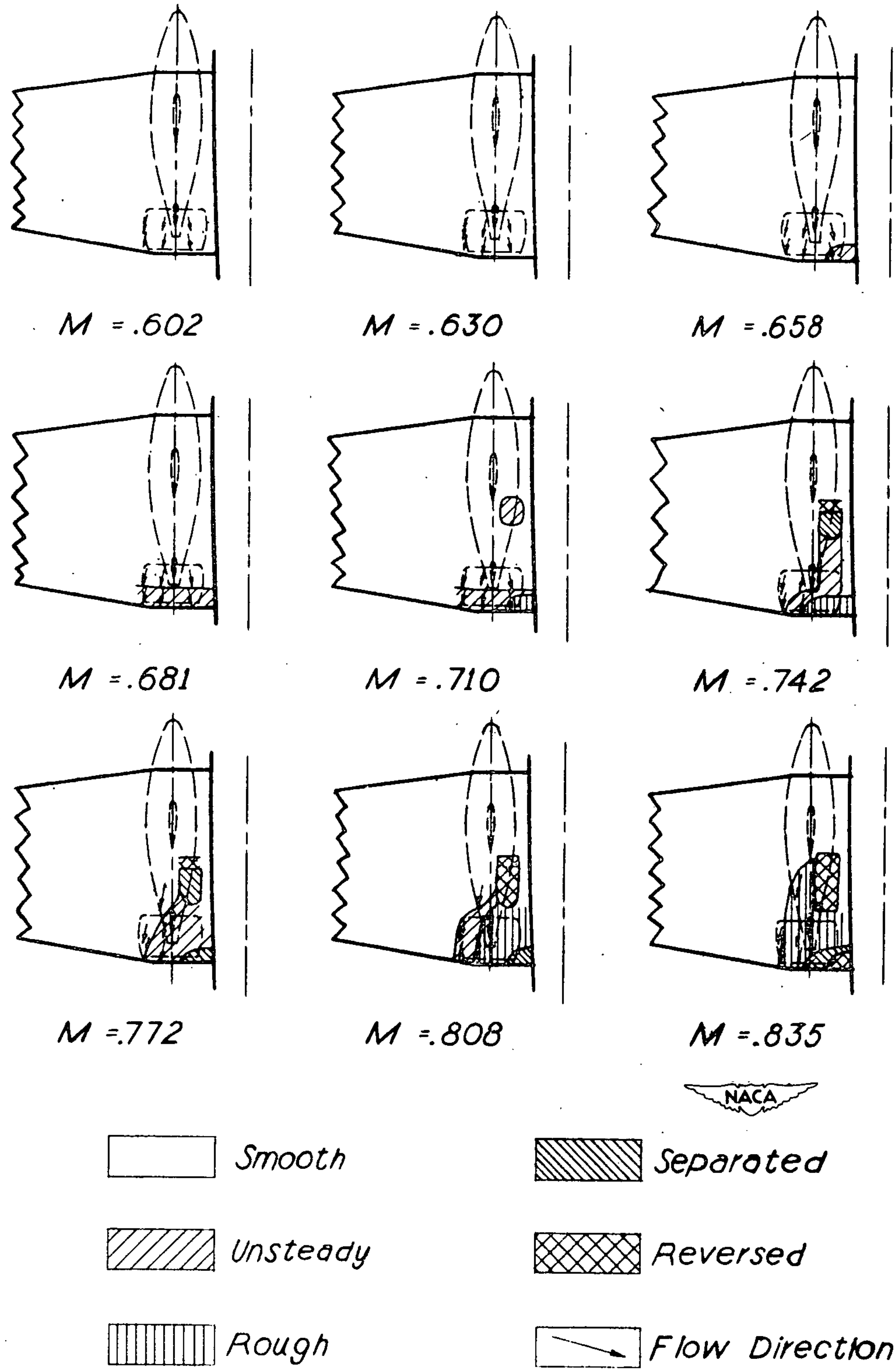


Figure 28.- Concluded.



(a) $\alpha = -.75^{\circ}$.

Figure 29.- Tuft studies of the lower surface of the right wing of a wing-fuselage combination at two angles of attack and various Mach numbers with the auxiliary wing external-store arrangement in place, $\Psi = 0^{\circ}$, $\alpha_a = -15^{\circ}$.



(b) $\alpha = -.25^\circ$.

Figure 29.- Concluded.