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WIND-TUNNEL INVESTIGATION OF A REVISED HORIZONTAL TAIL SURFACE FOR THE GRUMMAN TBF-1 AIRPLANE

By John W. McKee and Robert B. Liddell

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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WASHINGTON

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

WIND-TUNNEL INVESTIGATION OF A REVISED HORIZONTAL TAIL SURFACE FOR THE GRUMMAN TBF-1 AIRPLANE

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INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department, an investigation was made in the LMAL 7- by 10-foot tunnel of the aerodynamic characteristics of a revised 0.5-scale model of the Grumman TBF-1 left horizontal tail surface. The investigation was undertaken to determine if a horizontal tail surface with a large overhang would reduce the high stick forces in maneuvers that the airplane had with the original horn-balanced elevator, without appreciably affecting the longitudinal stability characteristics of the airplane.

Preliminary flight tests of the XTBF-1 airplane and wind-tunnel tests of a 0.5-scale model of the left horizontal tail surface with various amounts of horn balance (reference 1) had previously been made. For the present investigation the model of reference 1 was modified by moving the elevator-hinge axis rearward, by increasing the percentage of aerodynamic nose balance, by eliminating the horn balance, and by adding a full-span leading tab. The effects of tab-elevator deflection ratio, tab-elevator nose seal, elevator hinge cut-out seals, and elevator rudder cut-out were determined.

The results of the wind-tunnel tests, parameters estimated from section data, and estimated control forces for the various arrangements are presented in this report.

METHODS AND APPARATUS

The test setup is shown schematically in figure 1 and by the photographs of figure 2. The semispan model was mounted vertically in the LMAL 7- by 10-foot tunnel (reference 2) with the inboard end adjacent to the floor of the tunnel, which thereby acted as a reflection plane. The model was supported entirely by the balance frame with a small clearance at the tunnel floor so that all the forces and moments acting on the model could be measured. The flow over the model simulated the flow over the left semispan of a complete horizontal tail consisting of the test panel joined to its reflection and mounted in a 10- by 14-foot tunnel.

Provisions were made for changing the angle of attack of the model and the deflection of the elevator while the tunnel was in operation. The elevator hinge moments were measured by means of an electrical strain gage mounted within the elevator.

The 0.5-scale model was a revision of the model of the TBF-1 left horizontal tail surface described in reference 1. The revised model had the same root and tip airfoil section and chord and the same tip shape as the model of reference 1. The model represented the portion of the airplane cross-hatched in figure 3. The model was tested with modifications 2a and 2b as shown in figure 4 and had the geometric characteristics of table I. The inboard end of the elevator of modification 2a (fig. 4(a)) was cut out to allow for rudder deflection and was made similar to that of the original model (reference 1). The elevator of modification 2b (fig. 4(b)) extended the full span of the model with no cut-out to allow for rudder deflection.

The elevator of modification 2a was the type of control surface suggested in reference 3, having a large aerodynamic balance and a leading tab. The elevator of modification 2a had a blunt-nose balance of approximately 50 percent of the elevator area. The balance was designed to have the center of the nose reach the stabilizer surface (unport) along its full length at an elevator deflection of approximately 12°. The blunt-nose balance shape was used because section data (references 3, 4, and 5) indicated that a blunt nose added less drag than other nose shapes. The elevator was designed, as suggested in reference 3, to have enough balance or overhang to give modification 2a a positive value of C_{h_α} in order that the airplane longitudinal stability with controls free would exceed that with controls fixed. A full-span leading tab of approximately 10 percent of the total tail area was provided on modification 2a to overcome the overbalance of the elevator when deflected. The linkage of the tab is shown schematically in figure 5 and the calibrations for the various tab-elevator deflection ratios are shown in figure 6. The elevator hinge-moment coefficients include the effect of the tab and linkage loads on the elevator. A reduction in elevator area was permissable due to the increase in elevator effectiveness caused by the leading tab, so the elevator-hinge axis was 5.10 inches (model dimensions) nearer the elevator trailing edge than the hinge axis of the original model (reference 1).

The model was tested with various elevator and tab gap conditions. The dimensions "a" and "b" (fig. 4) of the gap at the elevator nose were varied. For some of the tests the gap was sealed with a sheet rubber seal that allowed an elevator deflection of only ±12°. The tab was tested with a small gap at the nose and with a grease nose seal. Both elevator modifications had four cut-outs in the nose balance for the elevator hinges and the elevator-deflecting link (fig. 4). Each cut-out was 1/2-inch wide and extended back to the hinge axis. Most tests were run with these cut-outs unsealed. For some tests they were sealed with sheet rubber. It is believed that these cut-out seals had some small leaks at large negative elevator deflections but the cut-outs may be considered completely sealed for all practical purposes.

All tests were made at a dynamic pressure of 16.37 pounds per square foot which corresponds to a velocity of approximately 80 miles per hour. The test Reynolds number based on the model mean chord was 1,980,000 for modification 2a and 2,090,000 for modification 2b.

RESULTS

Coefficients and Corrections

The coefficients used in this report are defined as follows:

C_L lift coefficient (L/qS)

C_D drag coefficient (D/qS)

C_m pitching-moment coefficient (m/qSc)

Ch_e elevator hinge-moment coefficient $(H_e/qb_e\overline{c}_e{}^2)$

where

L twice the lift of the semispan model

D twice the drag of the semispan model

m twice the pitching moment about the mounting axis of the semispan model

H_e twice the elevator moment of the semispan model about the elevator hinge axis, positive when it tends to depress the elevator trailing edge

q dynamic pressure $(\frac{1}{2}\rho V^2)$

S twice the area of the semispan model

b twice the span of the semispan model

c mean chord of horizontal tail (S/b)

b_e twice the elevator span of the semispan model

$\overline{c}_e$ root-mean-square chord of the elevator

α angle of attack, degrees

ϵ	angle of downwash, degrees
A	aspect ratio of complete tail (b^2/S)
δ_e	elevator deflection relative to the stabilizer, degrees; positive when the trailing edge is deflected downward
δ_t	tab deflection relative to the elevator, degrees; positive when trailing edge is deflected downward
$\frac{\delta_t}{\delta_e}$	ratio of tab deflection to elevator deflection
δ_s	stick deflection, degrees
F_s	stick force, pounds, pull is positive force
a'	change in airplane normal acceleration due to maneuver, feet per second per second
g	acceleration of gravity, feet per second per second

and

$$C_{L_\alpha} = \left(\frac{\partial C_L}{\partial \alpha}\right)_{\delta_e,\ \delta_t}$$

$$C_{L_\delta} = \left(\frac{\partial C_L}{\partial \delta_e}\right)_{\alpha}$$

$$C_{h_\alpha} = \left(\frac{\partial C_h}{\partial \alpha}\right)_{\delta_e,\ \delta_t} \qquad (\text{at } \alpha = 0^\circ)$$

$$C_{h_\delta} = \left(\frac{\partial C_h}{\partial \delta_e}\right)_{\alpha} \qquad (\text{at } \delta_e = 0^\circ)$$

$$\alpha_{\delta_e} = \left(\frac{\partial \alpha}{\partial \delta_e}\right)_{C_L}$$

The results have been corrected for jet-boundary effects. The corrections which were applied (by addition) to the angle of attack and the lift, drag, pitching-moment, and hinge-moment coefficients were:

$$\Delta\alpha = 1.48 \times C_L \quad \text{(in degrees)}$$

$$\Delta C_L = -0.016 \times C_L$$

$$\Delta C_{D_i} = 0.00235 \times C_L^2$$

$$\Delta C_m = 0.0069\ C_L$$

$$\Delta C_h = 0.0046 \times C_L$$

The method of determining the corrections is presented in reference 6. No corrections have been made for the effect of the gap between the root section and the floor or leakage around the support strut.

For convenience in locating the results a résumé of the tests is given in the following table:

Test no.	α_T, deg	δ_e, deg	$\frac{\delta_t}{\delta_e}$	Elevator gap	Tab gap	Modification	Figure no.
109	-4	20 to -20	No tab	a = 0.22	No tab	2b	17
110	-2			b = 0.67			
111	0			No seal			
112	2						
113	4						
114	8						
115	12						
116	16						
117	-4		0		Unsealed	2a	7
118	-2						
119	0						
120	2						
121	4						
122	8						
123	12						
124	16						
117a	-4				Sealed		12
119a	0						
121a	4						
122a	8						
125	-4		1		Unsealed		9
126	-2						
127	0						
128	2						
129	4						
130	8						
131	12						
132	16						
133	-4		2				10
134	-2						
135	0						
136	2						
137	4						
138	8						
139	12						
140	16						
141	-4	12 to -12	0.5	a = 0.06	Sealed		13
142	-2			b = 0.06			
143	0			Nose			
144	2			sealed			
145	4						
146	8						
147	12						
148	16						

Test no.	α_T, deg	δ_e, deg	$\frac{\delta_t}{\delta_e}$	Elevator gap	Tab gap	Modification	Figure no.
141a	-4	12 to -12	0.5	(a = 0.06, b = 0.06, Nose sealed, Cut-outs sealed)	Sealed	2a	15
142a	-2						
143a	0						
144a	2						
145a	4						
146a	8						
147a	12						
148a	16						
149	-4		1				16
150	-2						
151	0						
152	2						
153	4						
154	8						
155	12						
156	16						
157	-4		0				14
158	-2						
159	0						
160	2						
161	4						
162	8						
163	12						
164	16						
173	-4	20 to -20	0.5	(a = 0.22, b = 0.67, No seal)	Unsealed		8
174	-2						
175	0						
176	2						
177	4						
178	8						
179	12						
180	16						
181	-4			(a = 0.06, b = 0.67, No seal)			11
182	-2						
183	0						
184	2						
185	4						
186	8						
187	12						
188	16						

α_T is angle of attack of model in tunnel, uncorrected

DISCUSSION

Modification 2a, unsealed. - The results of the tests of modification 2a with the elevator and tab nose gaps unsealed and with several values of δ_t/δ_e are shown in figures 7 to 11. With $\delta_t/\delta_e = 0$ (fig. 7) the elevator had a positive value of C_{h_α} and was overbalanced over most of its deflection range. Table II shows that for $\delta_t/\delta_e = 0.5$ the elevator was no longer overbalanced and as δ_t/δ_e was increased C_{h_δ} became more negative. As δ_t/δ_e was increased C_{L_δ} progressively increased and C_{h_α} decreased, becoming 0 for $\delta_t/\delta_e = 2$. The values of C_{h_α} and C_{h_δ} ($\delta = 0$) of table II are in general valid for only small changes near zero angle of attack and zero elevator deflection. Comparison of figures 8 and 11 shows that reducing the elevator nose gap "a" from 0.22 inch to 0.06 inch gave some increase in C_{L_α} but did not increase C_{L_δ}. This modification also reduced C_{h_α} and did not change C_{h_δ}.

Modification 2a, tab sealed. - Sealing the tab gap ($\delta_t/\delta_e = 0$, fig. 12) slightly increased C_{L_δ} but did not change C_{L_α}. The hinge-moment curves were about the same except that C_{h_α} was less positive when the tab gap was sealed.

Modification 2a, tab and elevator nose sealed. - Comparison of figure 13 with figure 11 shows that sealing the tab and elevator nose gap slightly increased C_{L_α} but did not increase C_{L_δ} when $\delta_t/\delta_e = 0.5$. The seals added negative increments to both C_{h_α} and C_{h_δ}. The sheet seal used at the elevator nose restricted the elevator deflection to the unporting angle, 12°.

Modification 2a, complete seal. - The characteristics of the model with the tab and elevator nose and elevator balance cut-outs sealed are shown in figures 14 to 16 for several values of δ_t/δ_e. Sealing the elevator balance cut-outs had little effect on C_{h_δ} at small elevator deflections as shown by comparison of figures 13 and 15. Beyond 4° deflection the hinge cut-out seals added balance to the elevator. The hinge cut-out seals increased C_{L_δ}, made C_{h_α} more positive, and did not change C_{L_α}. Comparison of figures 14 to 16 with figures 7 to 9 shows that the complete seal increased C_{L_α} and C_{L_δ} and in general added balance to the elevator.

Modification 2b, unsealed. - The addition of the rudder cut-out area to the elevator area (modification 2b) with the elevator nose unsealed (fig. 17) increased C_{L_α} and greatly increased C_{L_δ}. For small elevator deflections, C_{h_δ} was negative, but the elevator was overbalanced at large deflections. C_{h_α} was reduced nearly to zero.

Computed tail surface parameters. - Table III lists the parameters calculated for modifications 2a and 2b. The section data from which these values were calculated were taken from references 3, 4, 5, 7, and 8. Considerable extrapolation of the data was necessary. No corrections were made for the hinge cut-outs and only approximate corrections were made for the elevator nose gap.

The formula,

$$C_{L_\alpha} = \frac{p\, c_{l_\alpha}}{1 + \frac{57.3\, r\, c_{l_\alpha}}{\pi A}} \qquad (1)$$

(reference 8) was used to find the lift-curve slopes where p is an aspect ratio correction and r is an end plate correction. A constant value of c_{l_α} (section lift-curve slope) across the span of 0.098 with unsealed gaps and 0.102 with sealed gaps was used. There is good agreement between the calculated and measured values of C_{L_α} for modification 2b but there appears to be a loss due to the rudder cut-out of modification 2a that the formula does not take into account.

The values of α_δ were obtained by the strip method (assuming no induction) of integrating the section α_δ across the span.

$$\alpha_\delta = \frac{2}{S} \int_0^{b/2} a_\delta \times c\, db \qquad (2)$$

For a given percent-chord flap, section α_δ has an only partially determined variation with overhang, gap, and elevator nose shape. This may explain most of the discrepancy between measured and calculated values of α_δ for the model. The section values of α_δ for the sealed tab were taken from reference 8. The unsealed tab was assumed to be 10 percent less effective.

The expression used to find C_{L_δ} was:

$$C_{L_\delta} = -\alpha_\delta \times C_{L_\alpha} \qquad (3)$$

The span load distribution should affect C_{h_α} and C_{h_δ}. In the following equation L_a is the span load factor:

$$C_{h_\alpha} = \frac{C_{L_\alpha} \times 2 \times S}{b_e \times b \times \bar{c}_e^2} \int_0^{b/2} \frac{c_{h_\alpha}}{c_{l_\alpha}} c_e^2 \frac{L_a}{c} db \qquad (4)$$

For modification 2b, C_{h_α} was determined using values of L_a obtained from reference 9 and for the case of $L_a = 1.0$. In both cases C_{h_α} was computed to be 0.0004. In the estimation of all other hinge-moment parameters, the span load factor was assumed to be unity. C_{h_δ} was determined from the equation:

$$C_{h_\delta} = \frac{2}{\bar{c}_e^2 b} \int_0^{b/2} \left(c_{h_\delta}\right)_{c_l} c_e^2 \, db + \frac{2C_{L_\delta}}{\bar{c}_e^2 b} \int_0^{b/2} \left(c_{h_{c_l}}\right)_\delta c_e^2 \, db \qquad (5)$$

A more convenient form is:

$$C_{h_\delta} = \frac{2}{\bar{c}_e^2 b} \int_0^{b/2} \left[\left(c_{h_\delta}\right)_\alpha + \left(c_{h_\alpha}\right)_\delta \alpha_\delta\right] c_e^2 \, db$$

$$+ \frac{2C_{L_\delta}}{\bar{c}_e^2 C_{L_\alpha} b} \times \int_0^{b/2} \left(c_{h_\alpha}\right)_\delta c_e^2 \, db \qquad (6)$$

Computed elevator control forces for the airplane.- Several control characteristics of the airplane were estimated for each of the configurations tested and are tabulated in table II. The control characteristics were estimated from the airplane characteristics shown in table I and the control-surface deflection determined from flight tests of the airplane, corrected to the elevator effectiveness $\left(C_{L_{\delta_e}}\right)$ of each modification. A constant value of maximum stick movement of 55° was used. The stick forces were calculated by the method of reference 1 for a center-of-gravity location of 25.5 percent of the mean aerodynamic chord point, approximately the normal center-of-gravity position. The values of $dF_s/d\frac{a}{g}'$, change in stick force per unit change in normal acceleration or load factor, are the values at a load factor of 3.5 at 217 miles per hour indicated airspeed. The stick forces required to land with power off were computed with the airplane trimmed at an indicated airspeed of 120 miles per hour with the flaps down.

From the requirements of reference 10 for this type of airplane it is believed that the stick force change per unit change in acceleration should be about 20 pounds and the forces to trim the change due to flaps or to land should be less than 35 pounds. It may be seen from table II that modification 2a with a = 0.22, b = 0.67, δ_t/δ_e = 0.5, and no seals gives a value of $dF_s/d\frac{a}{g}'$ of approximately 18 pounds, a force to trim the change due to flap deflection of -14 pounds, and a force to land of 7 pounds. Figure 18 shows the effect of tab-elevator deflection ratio on the forces for various flight conditions for modification 2a with no seals and with a complete seal. The forces were approximately the same with the gaps sealed or unsealed.

The model of the original tail surface (reference 1) had a large positive value of C_{h_α} which would give the airplane greater stability with controls free than with controls fixed. The revised model had smaller values of C_{h_α} but in no case was C_{h_α} negative at small angles of attack. The airplane with the revised tail would therefore also have as great or greater stability with controls free as with controls fixed. Stick forces against speed for two power conditions and two trim conditions were estimated (fig. 19) from the model data for modification 2a with no seals, with gap "a" = 0.22 inch, and with $\delta_t/\delta_e = 0.5$. The forces are low over the speed ranges investigated and in general have stable slopes.

CONCLUDING REMARKS

The results of the tests show that a satisfactory horizontal tail surface for the Grumman TBF-1 airplane could be built without the use of a horn balance. Such a tail surface should also be satisfactory on a high-performance high-speed airplane if the balance nose does not cause compressibility troubles when the elevator is deflected. The Grumman TBF-1 airplane with a tail similar to modification 2a with $\delta_t/\delta_e = 0.5$ with no seals would have satisfactory stick forces for turns, to land, and to trim the change due to flaps. The longitudinal stability characteristics of the airplane would not be seriously affected. Changing the elevator gap dimensions and sealing the tab and elevator gaps and balance cut-outs had only minor effects on the aerodynamic characteristics of the tail surface and on the estimated flight characteristics of the airplane. The tab-elevator deflection ratio had a large effect on the hinge moment due to elevator deflection and a small effect on the hinge moment due to angle of attack. More complete section data of flaps with large overhangs and the effect of balance and flap cut-outs are needed to make accurate estimations of the characteristics of tail surfaces with large amounts of balance.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 24, 1943.

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TABLE I

	XTBF-1 airplane	0.5-scale semi-span model of modified horizontal tail surface modification 2a	0.5-scale semi-span model of modified horizontal tail surface modification 2b
Gross weight, lbs	12,910	---------------	---------------
Wing area, sq ft	490	---------------	---------------
Stick length, ft	1.50	---------------	---------------
Stick movement, deg	55	---------------	---------------
Elevator movement, deg, (relative to stabilizer)	17.7 up, 11.0 down	variable	17.0 up, 10.6 down
Horizontal tail area, sq ft	111.50	14.12	14.88
Horizontal tail span, ft	20.83	5.20	5.20
Elevator span, ft	-------------	4.79	4.96
Elevator area behind hinge line, sq ft	48.00	4.21	4.96
Elevator root mean square chord, ft	2.536	.935	1.043
Slope of lift curve	.078	---------------	---------------
$\partial \epsilon / \partial \alpha$	.5	---------------	---------------

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TABLE II

SUMMARY OF TBF-1 REVISED HORIZONTAL TAIL CHARACTERISTICS

Figure	Modification	Elevator gap	Tab gap	δ_t/δ_e	C_{L_α}	C_{L_δ}	α_δ	C_{h_α}	C_{h_δ} ($\delta = 0$)	C_{h_δ} ($\delta = \pm 10$)	δ_e required to land (deg)	F_s to land (lb)	$\frac{dF_s}{d\frac{a'}{g}}$ (lb)	F_s to trim flaps at V_i=120 mph (lb)
7	2a	a = 0.22 b = 0.67 No seal	Unsealed	0	0.057	0.034	-0.60	0.0012	0.0021	0.0040	-20	-32	-9	-9
8				.5	.057	.042	-.74	.0010	-.0042	------	-17	7	18	-14
9				1.0	.057	.047	-.82	.0008	-.0107	------	-15	28	38	-18
10				2.0	.057	.055	-.96	.0000	-.0217	------	-13	53	58	-27
11	2a	a = 0.06 b = 0.67 No seal	Unsealed	.5	.058	.042	-.72	.0006	-.0042	------	-17	8	17	-12
12	2a	a = 0.22 b = 0.67 No seal	Sealed	0	.057	.035	-.61	.0009	.0020	.0040	-19	-34	-7	-6
13	2a	a = 0.06 b = 0.06 Nose sealed	Sealed	.5	.059	.042	-.71	.0003	-.0044	------	-17[a]	12	16	-9
14	2a	a = 0.06 b = 0.06 Nose sealed Cut-outs sealed	Sealed	0	.059	.035	-.59	.0013	⊕	.0057	-20[a]	-38	0	-1
15				.5	.059	.043	-.73	.0009	-.0043	------	-17[a]	2	17	-10
16				1.0	.060	.050	-.83	.0011	-.0110	------	-15[a]	27	39	-15
17	2b	a = 0.22 b = 0.67 No seal	No tab	No tab	.058	.042	-.72	.0002	-.0013	.0009	-17	-18	-4	2

[a]Hinge moments for elevator deflections greater than 12° are from extrapolated curves.

⊕ Indefinite at $\delta = 0$.

TABLE III

CALCULATED VALUES OF TBF-1 REVISED

HORIZONTAL TAIL PARAMETERS

Figure	C_{L_α}	C_{L_δ}	α_δ	C_{h_α}	C_{h_δ} ($\delta = \pm 10$)
7	0.060	0.034	-0.57	0.0007	0.0038
8	.060	.041	-.69	------	------
9	.060	.049	-.82	------	------
10	.060	.064	-1.06	------	------
11	.060	.041	-.69	------	------
12	.060	.034	-.57	.0007	.0038
13	.062	.044	-.71	------	------
14	.062	.035	-.57	-.0028	.0029
15	.062	.044	-.71	------	------
16	.062	.052	-.84	------	------
17	.058	.037	-.63	.0004	.0038

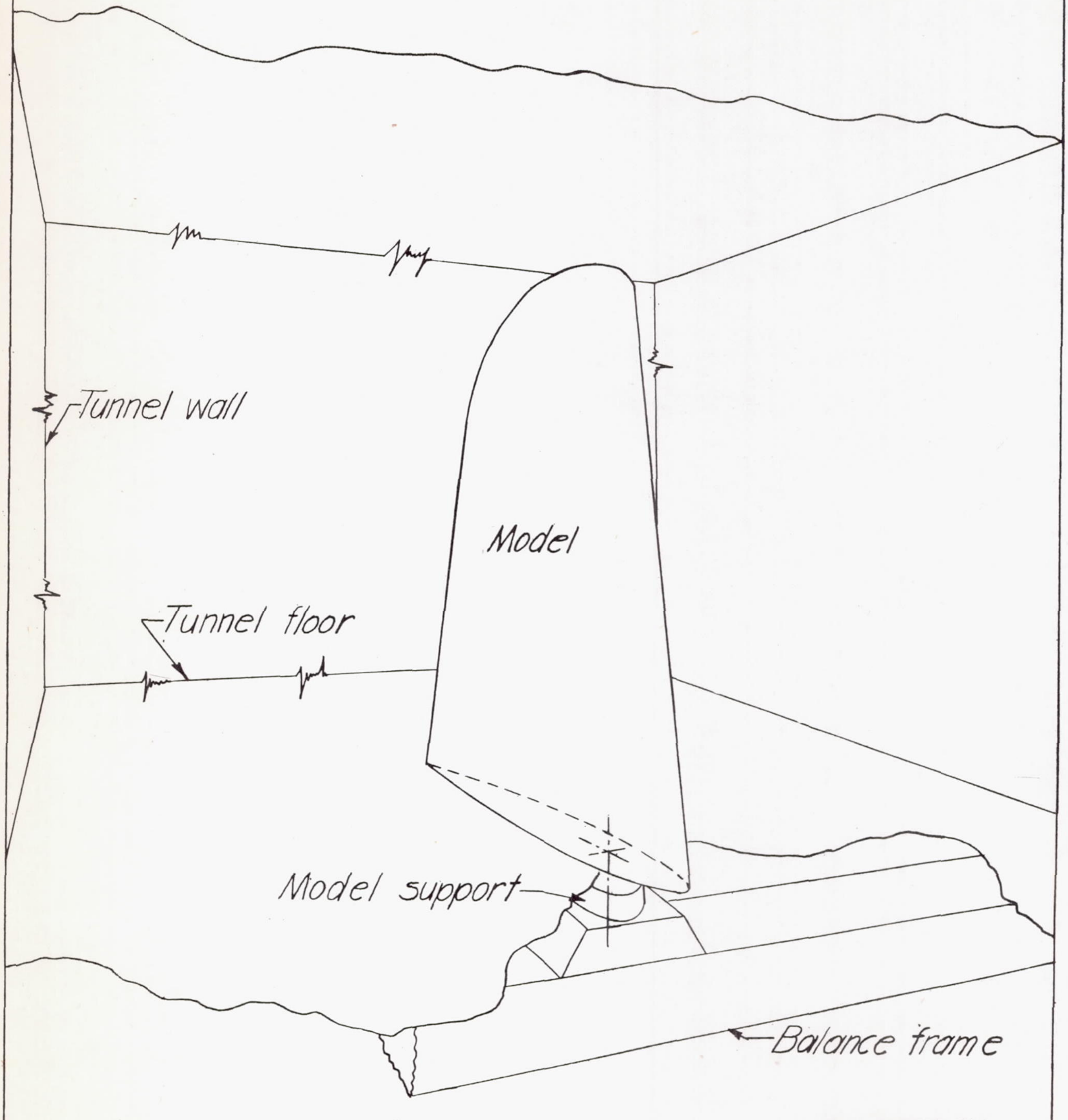

Figure 1.- Schematic diagram of test installation.

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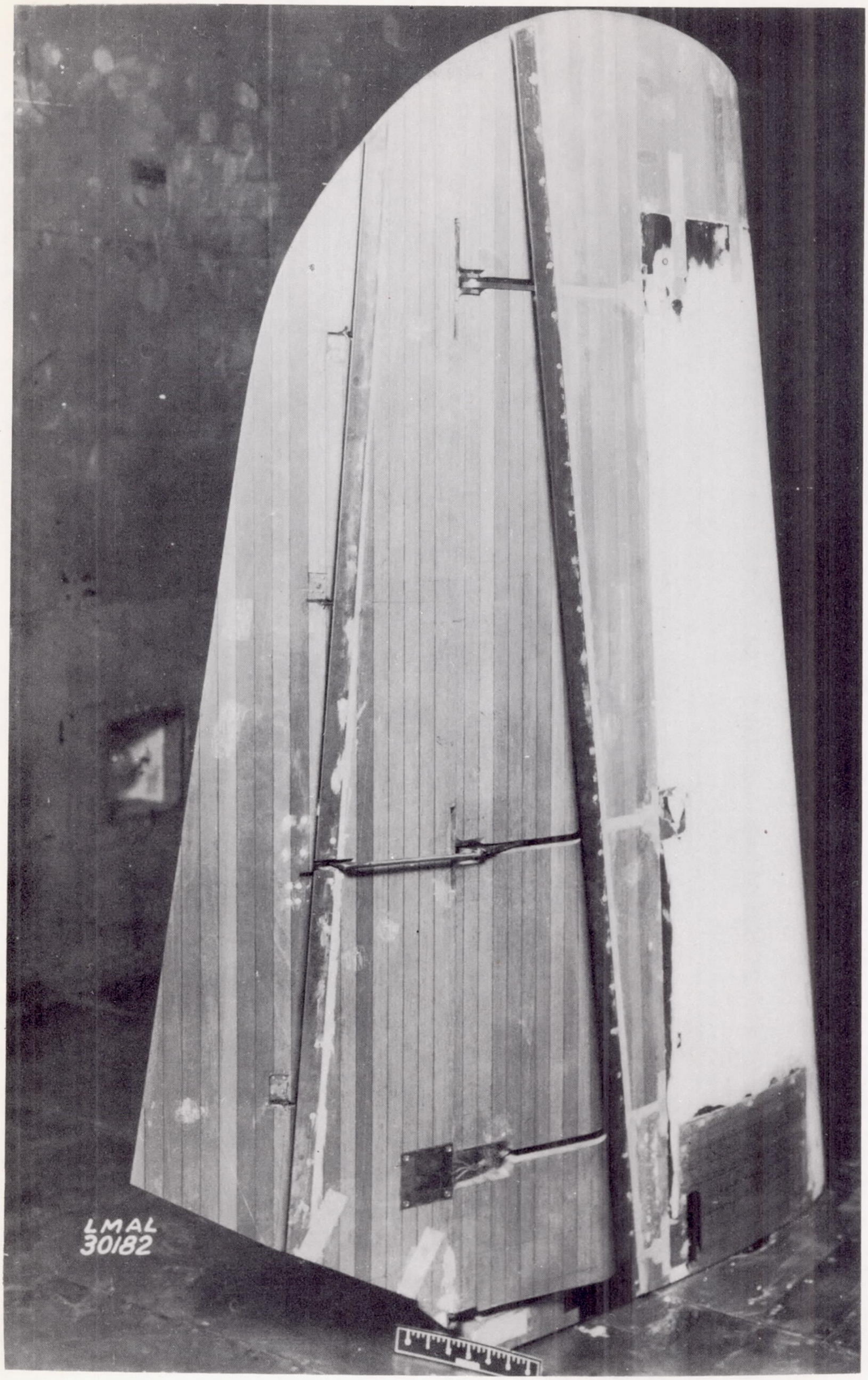
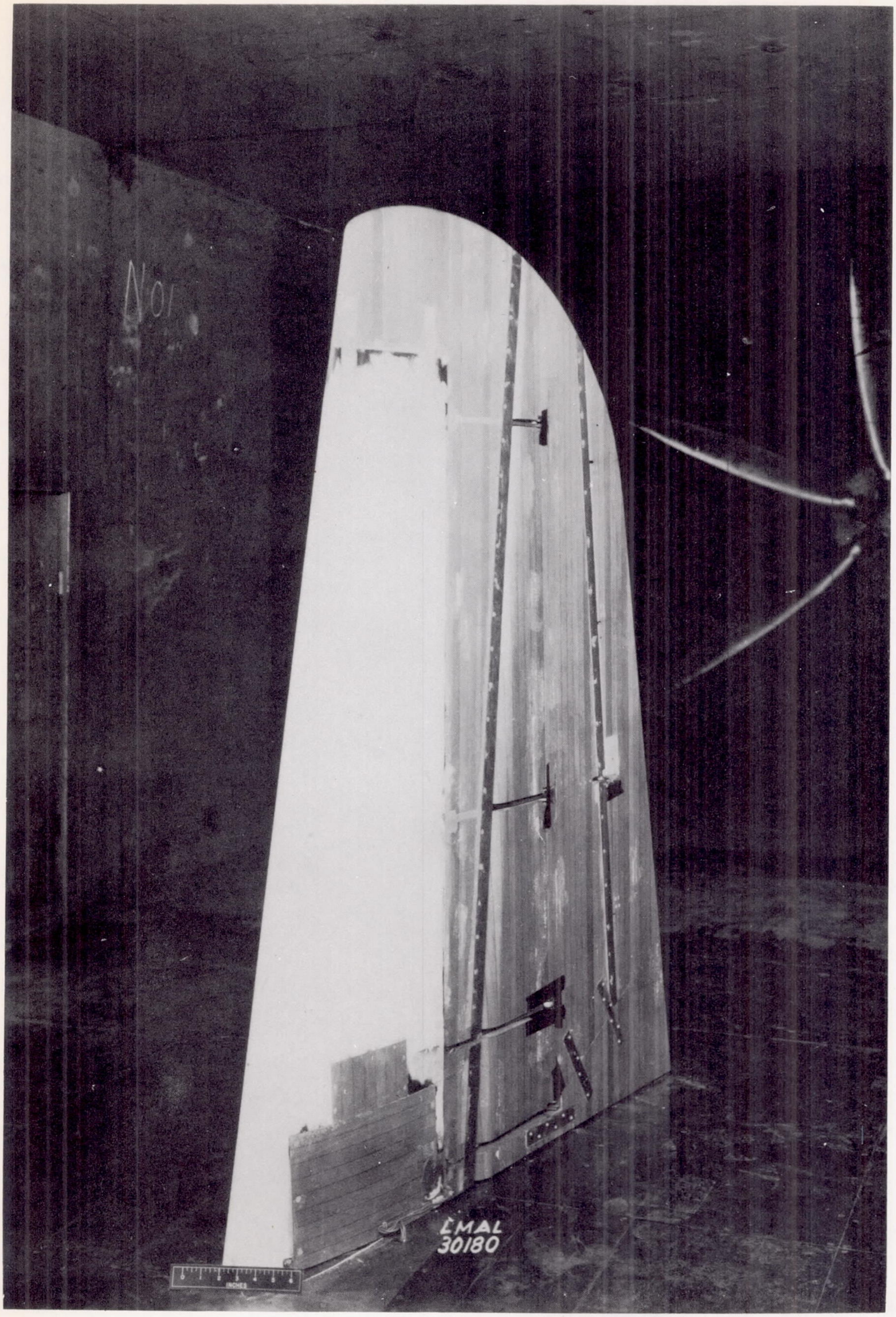


(a) Modification 2a, $\delta_e = 8.0^\circ$, $\delta_t/\delta_e = 1.0$.

Figure 2.- Revised 0.5-scale model of TBF-1 left horizontal tail surface.

L-702



(b) Modification 2b, $\delta_e = 0$.

Figure 2.- Concluded.

L-702

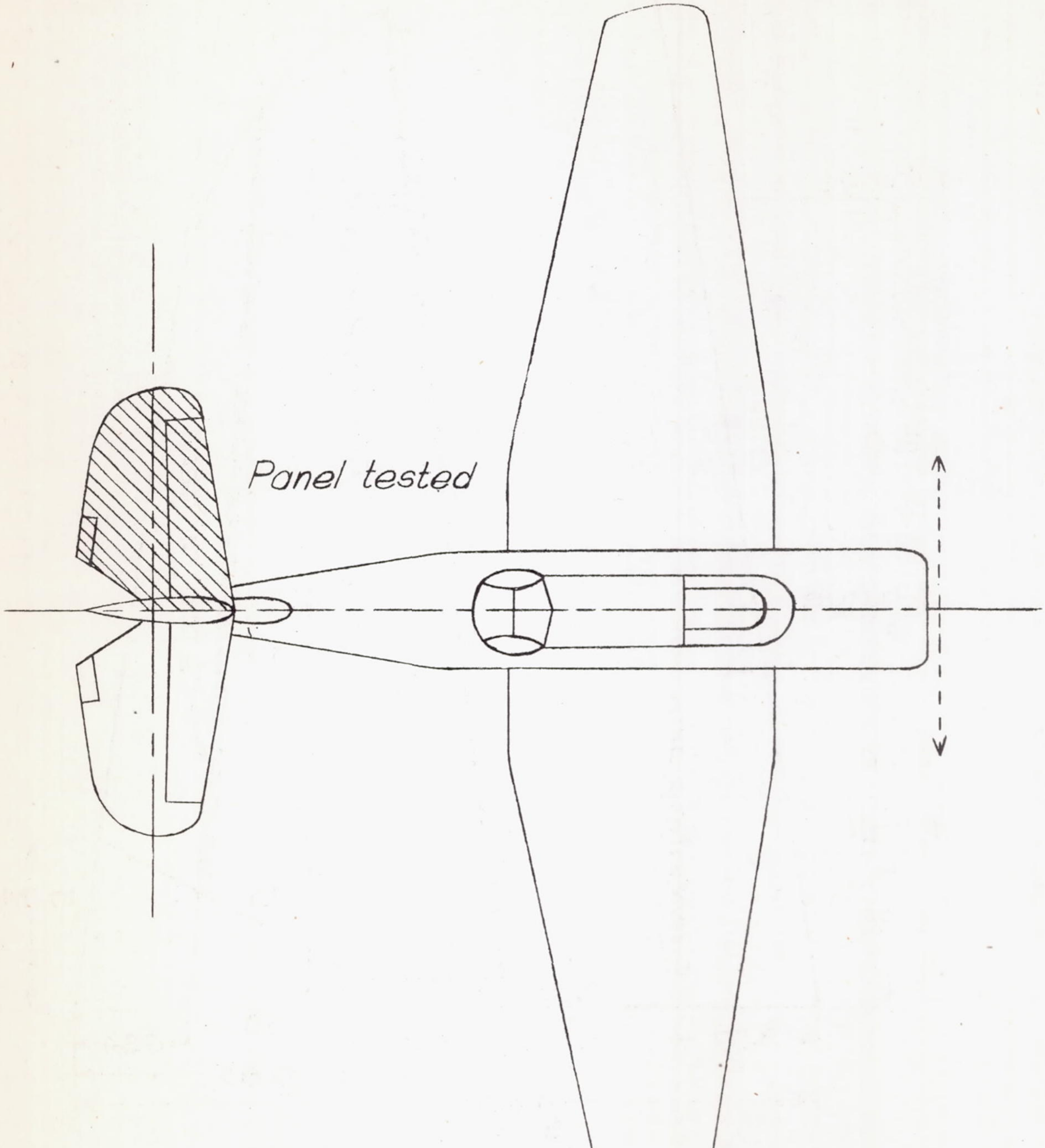


Figure 3.- Plan form of the Grumman TBF-1 airplane.

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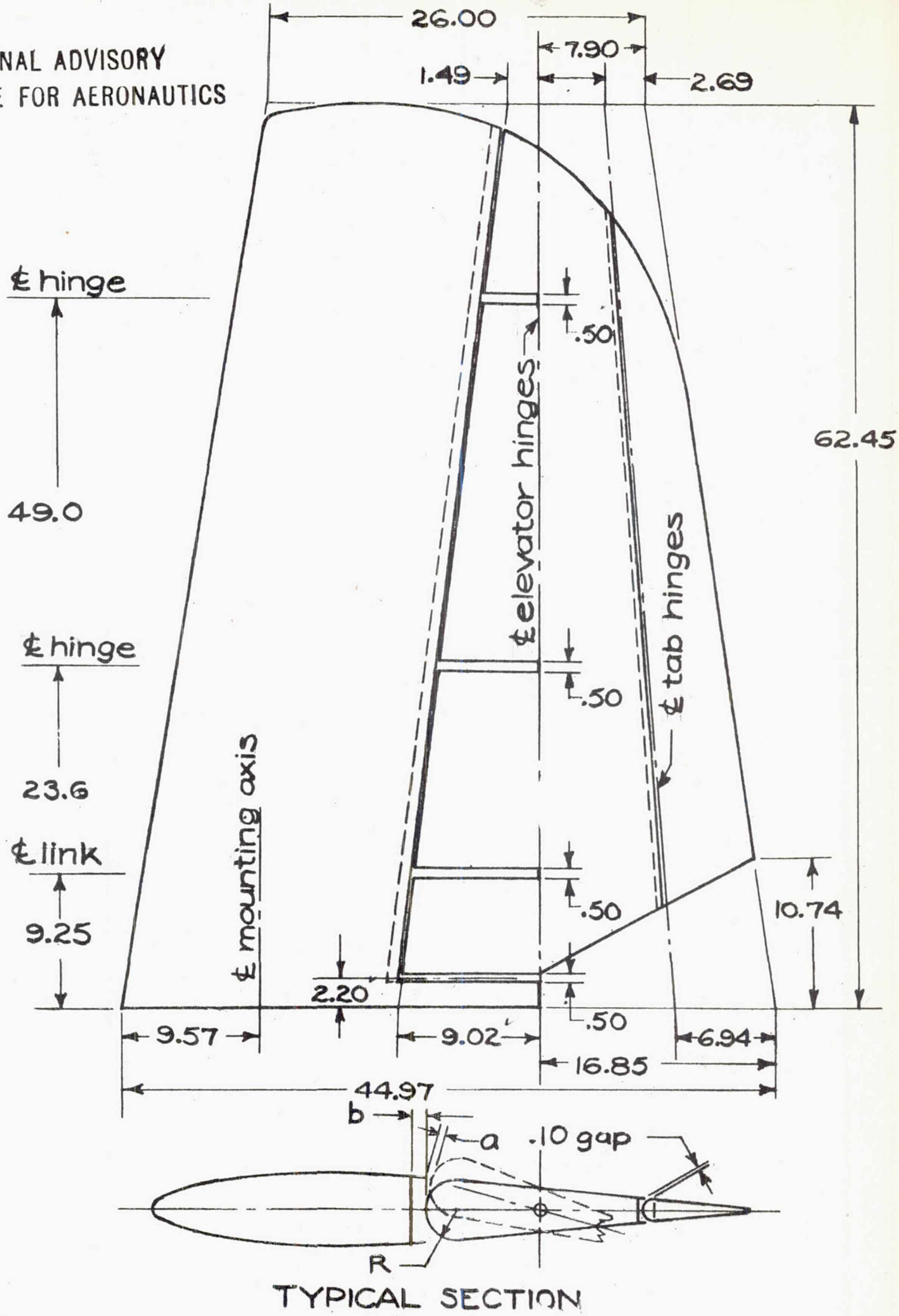
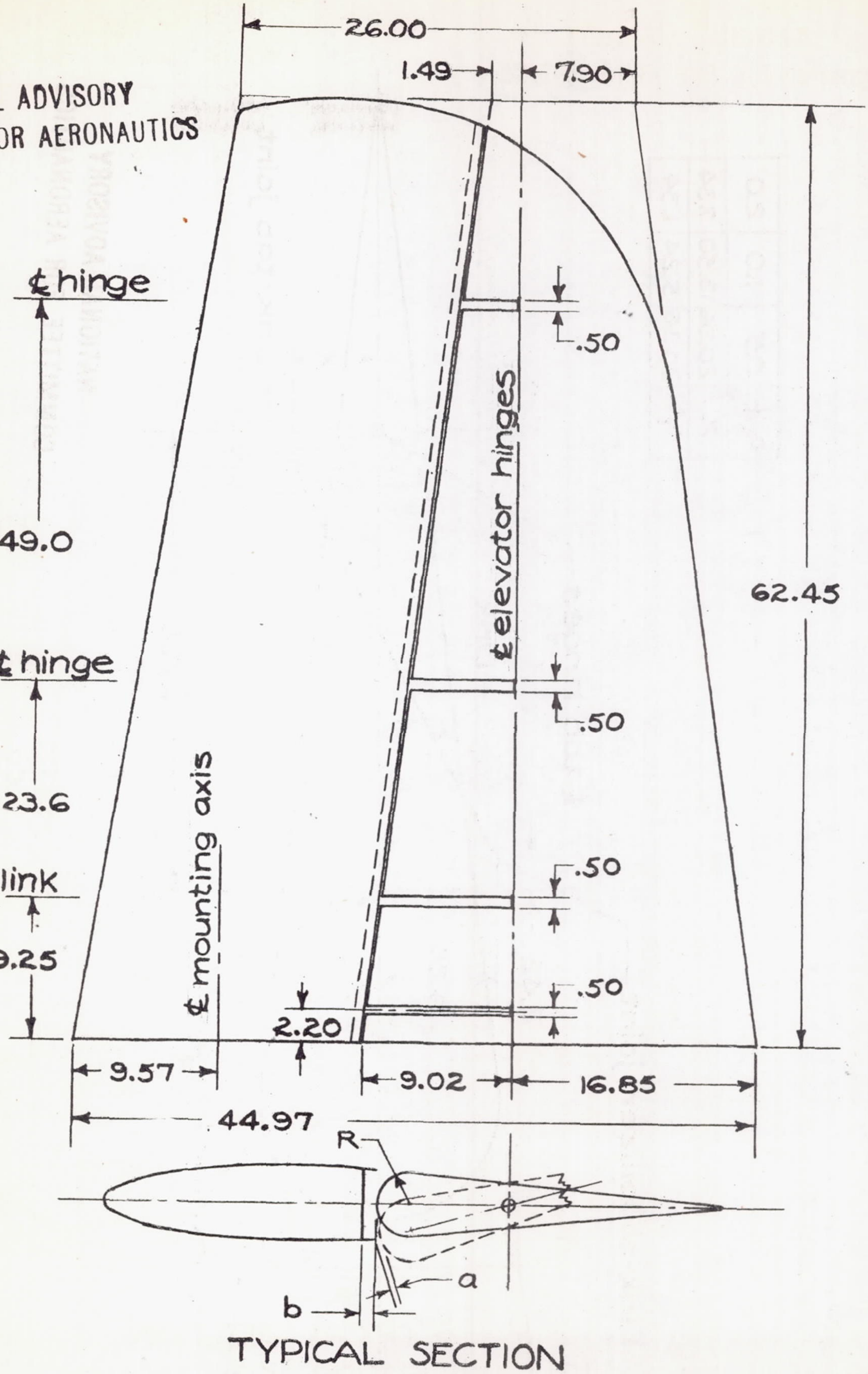


(a) Modification 2a.

Figure 4.- Revised 0.50-scale model of TBF-1 left horizontal tail surface.



(b) Modification 2b

Figure 4.- Concluded.

δ_t/δ_e	0.5	1.0	2.0
X	20.96	13.50	7.34
Y	20.36	5.24	1.34

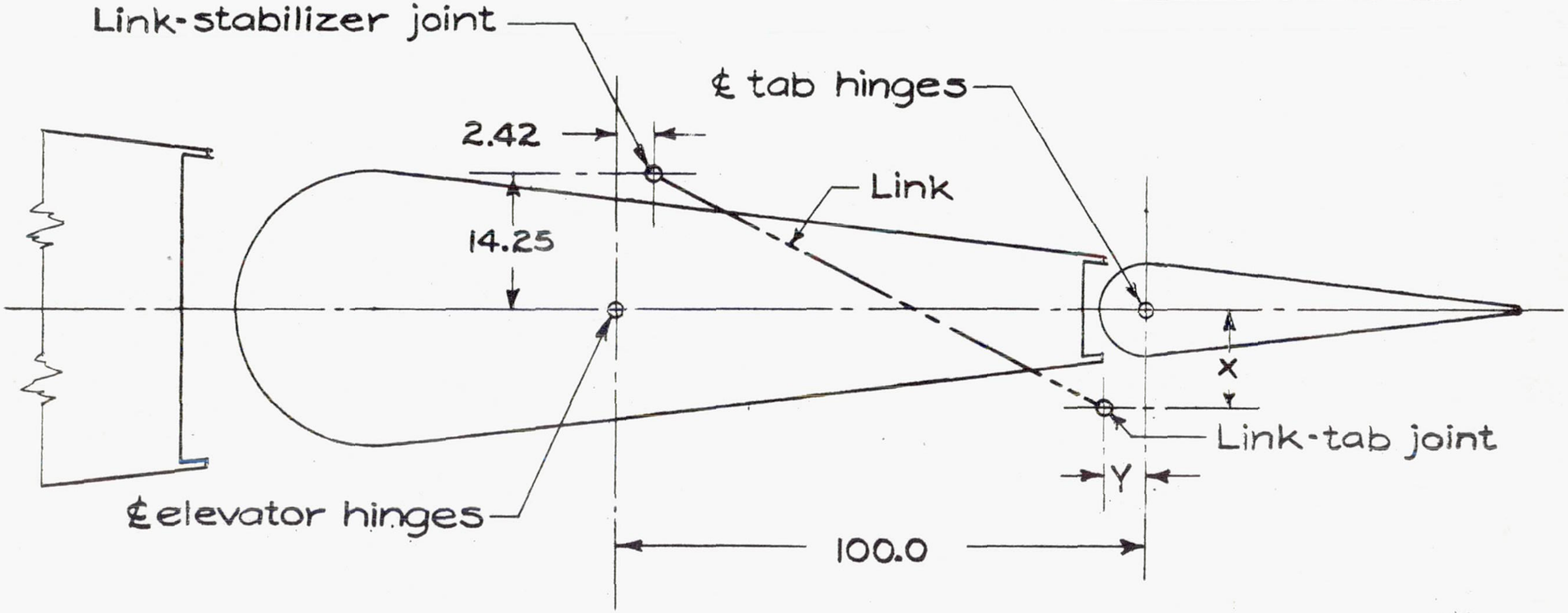


Figure 5 .- Schematic diagram of tab linkage.

L-702

L-702

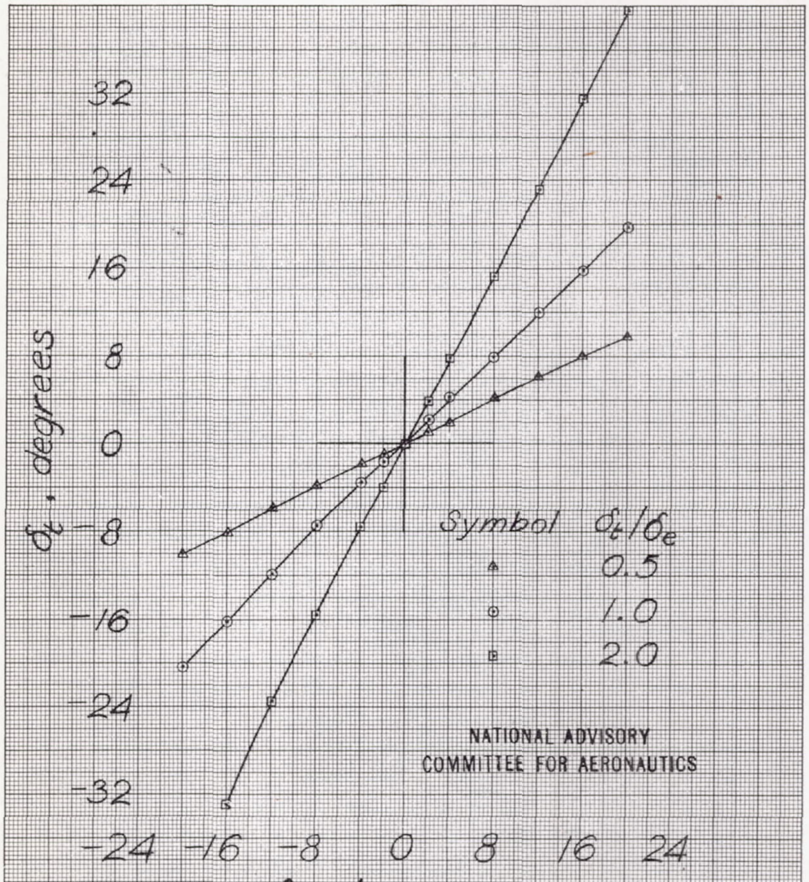


Figure 6.- Calibration of tab linkages.

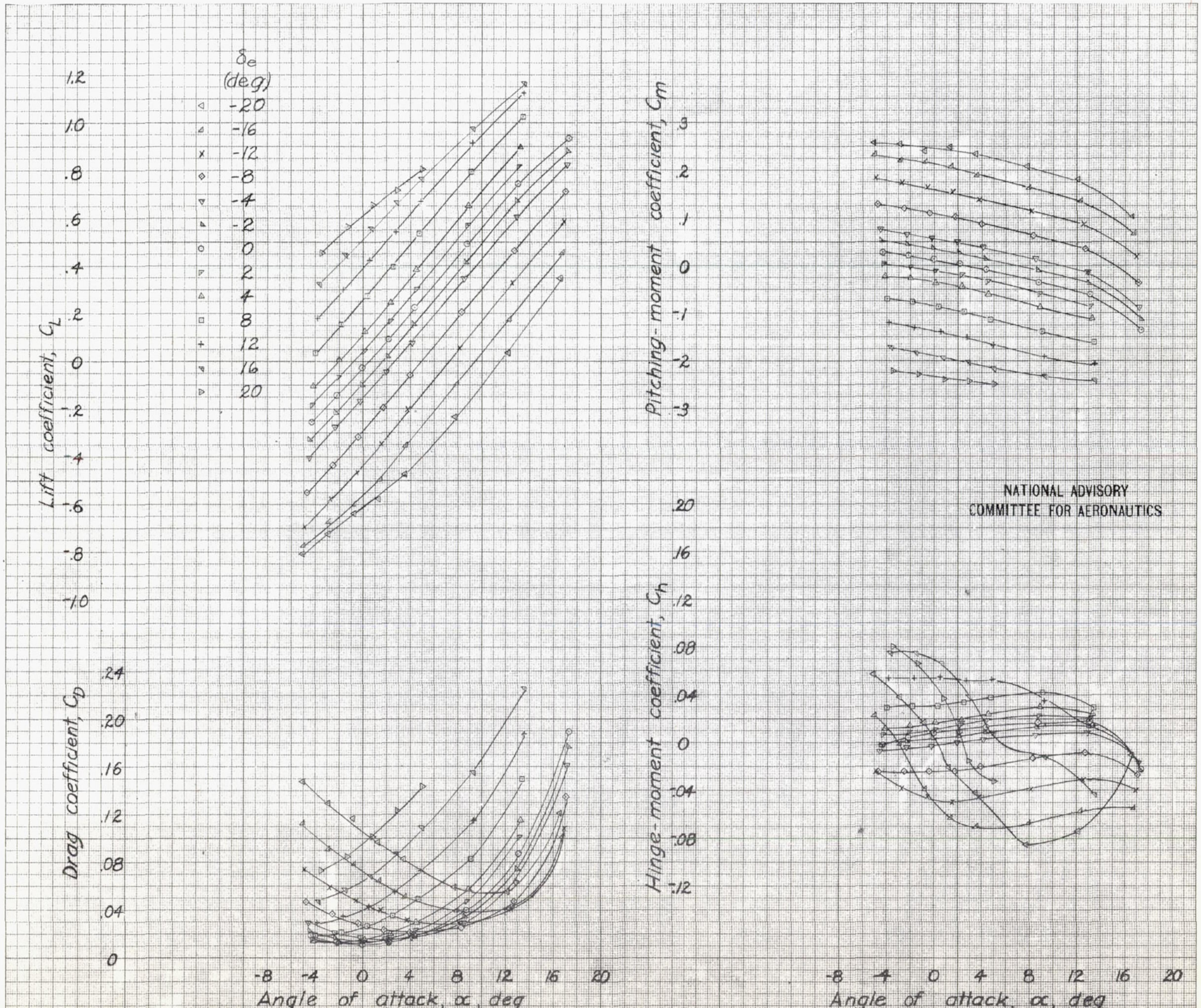


Figure 7.-Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2a, $\delta_t/\delta_e = 0$, elevator unsealed, $a = 0.22$, $b = 0.67$, tab unsealed.

L-702

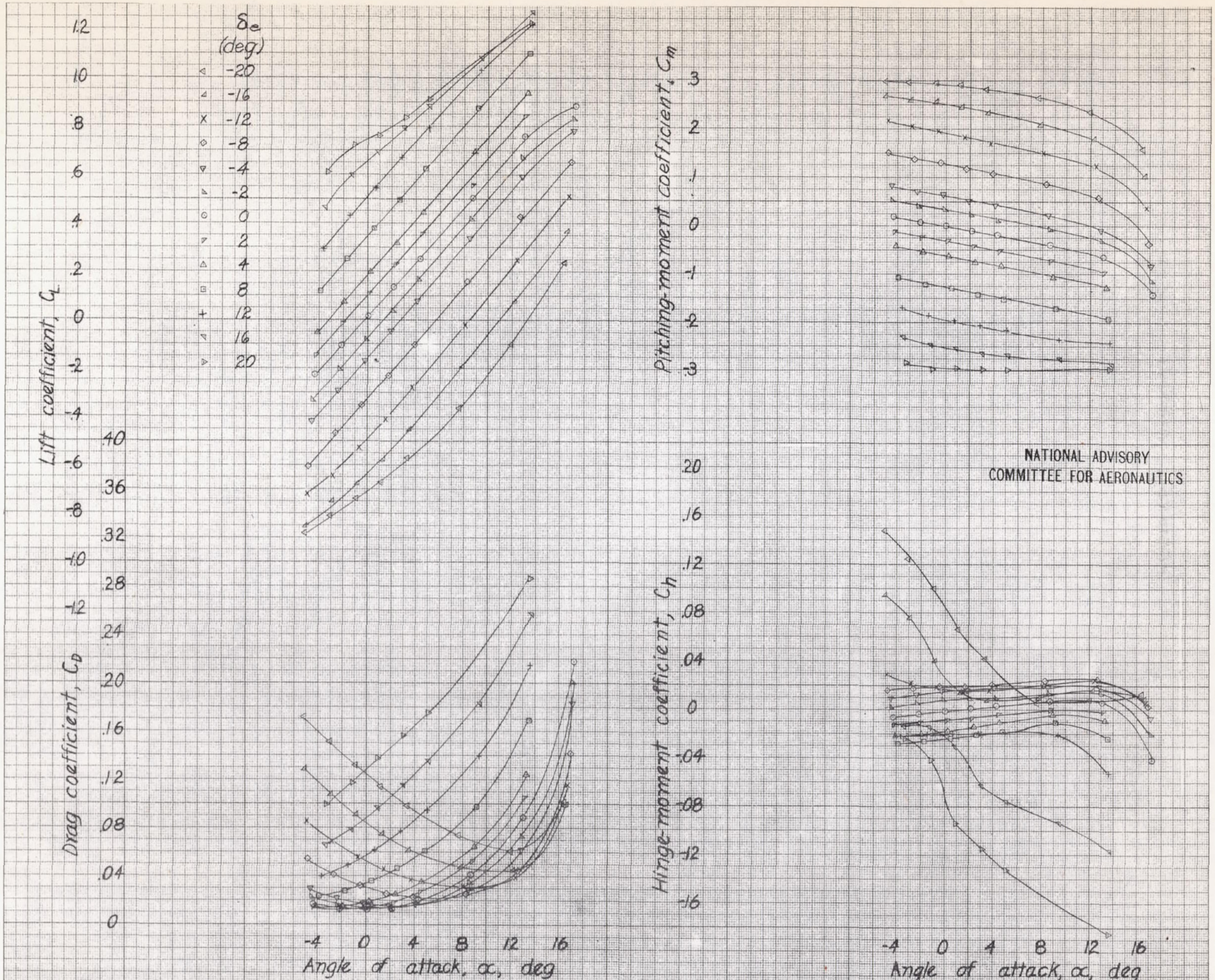


Figure 8.-Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2a, $\delta_t/\delta_e = 0.5$, elevator unsealed, a-0.22, b=0.67, tab unsealed.

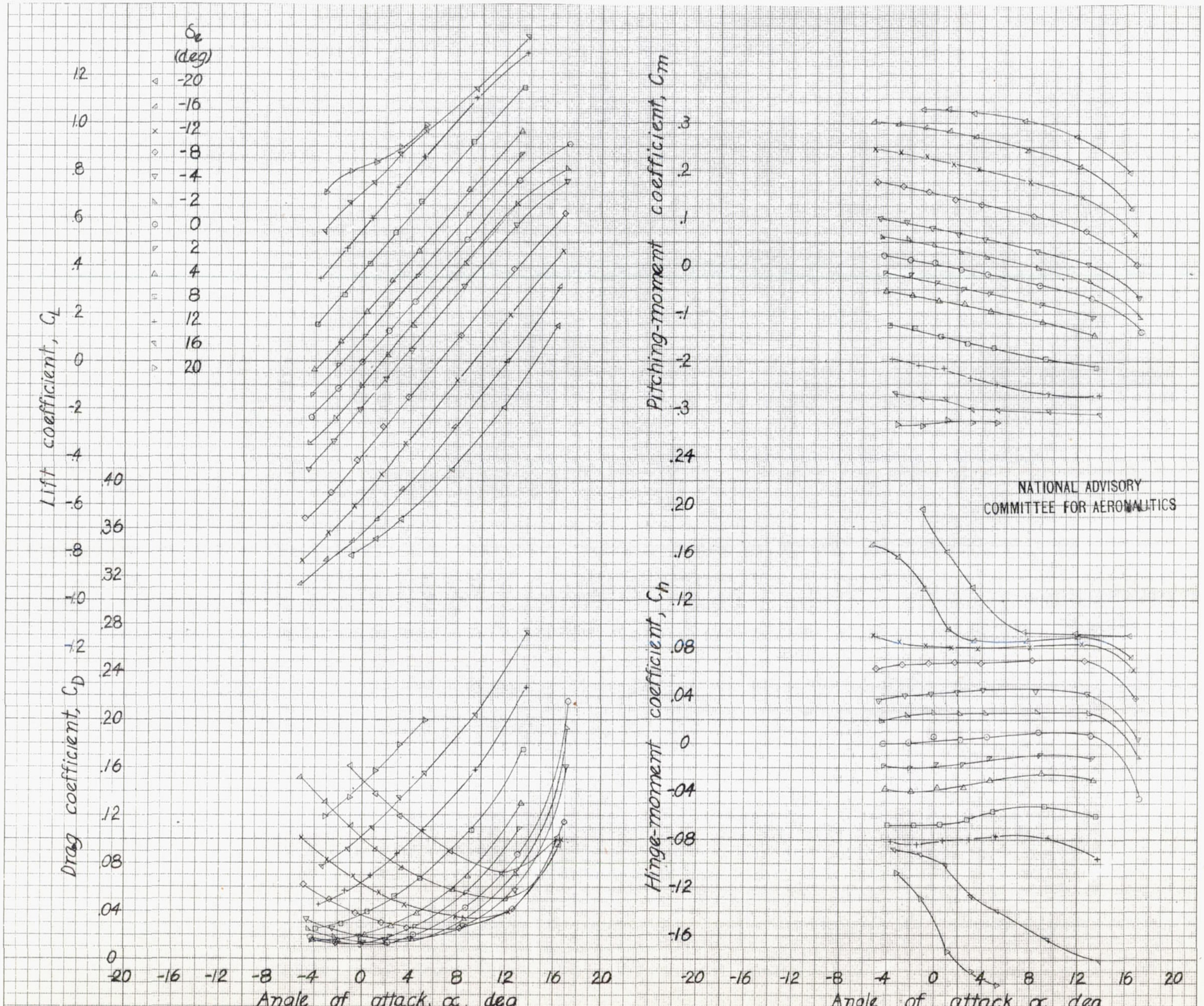


Figure 9.- Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2a, $\delta_t/\delta_e = 1.0$, elevator unsealed, $a = 0.22$, $b = 0.67$, tab unsealed.

L-702

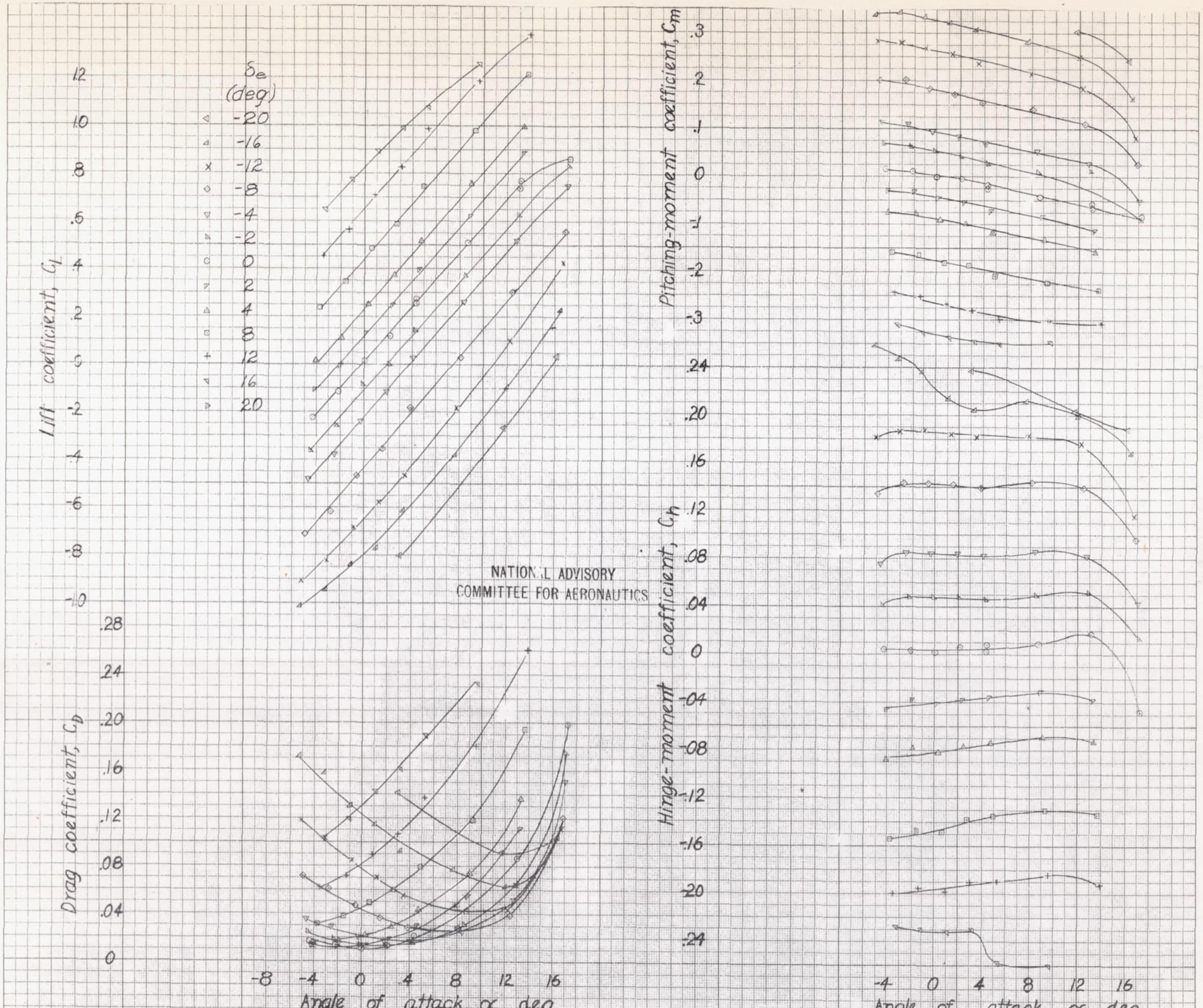


Figure 10.- Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2a, $\delta_t/\delta_e = 2$, elevator unsealed, a=0.22, b=0.67, tab unsealed.

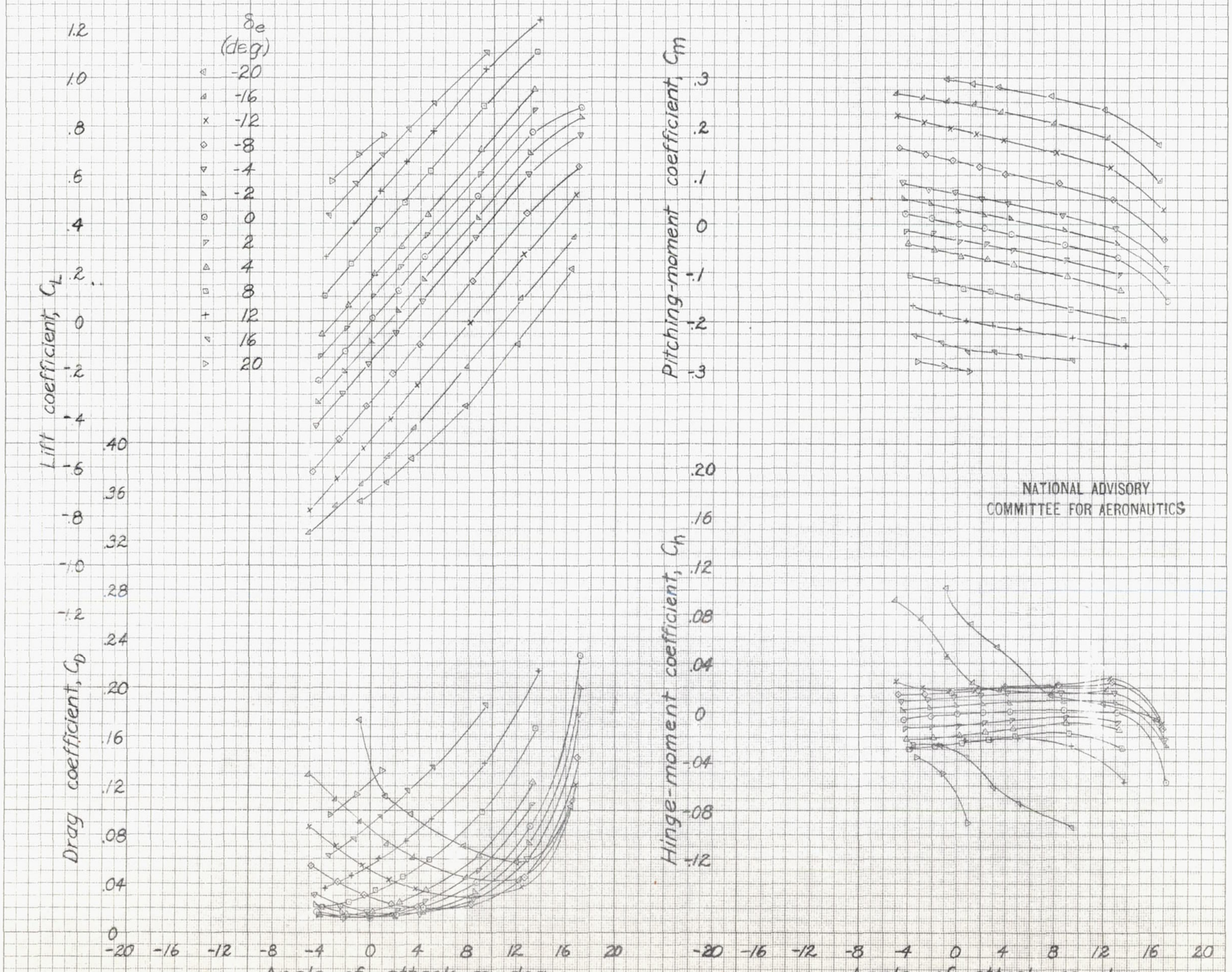


Figure 11.-Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2a, elevator unsealed, a=0.06, b=0.67, tab unsealed, $\delta_t/\delta_e = 0.5$.

L-702

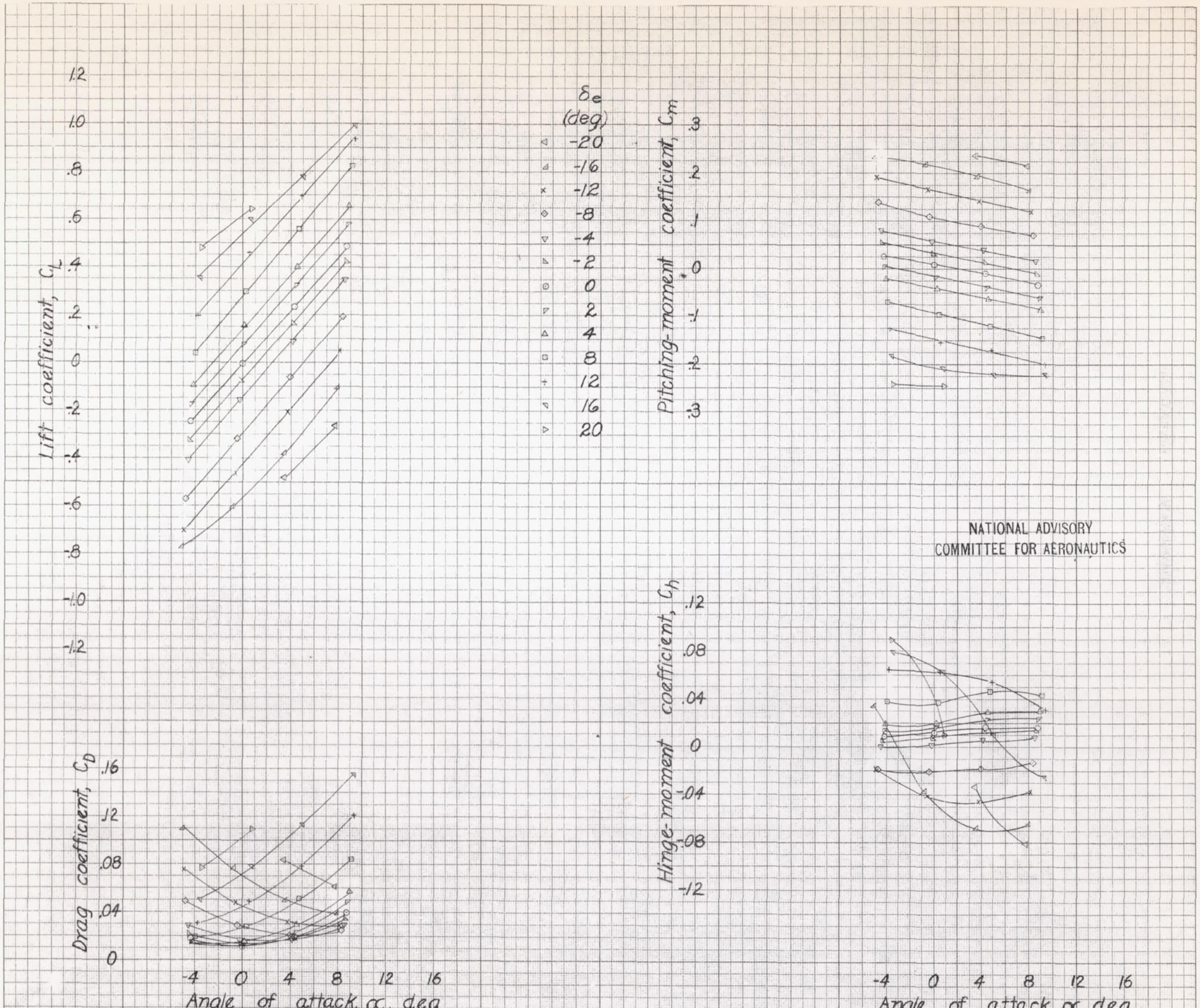


Figure 12.-Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2a, elevator unsealed, $a=0.22$, $b=0.67$, tab sealed, $\delta_t/\delta_e=0$.

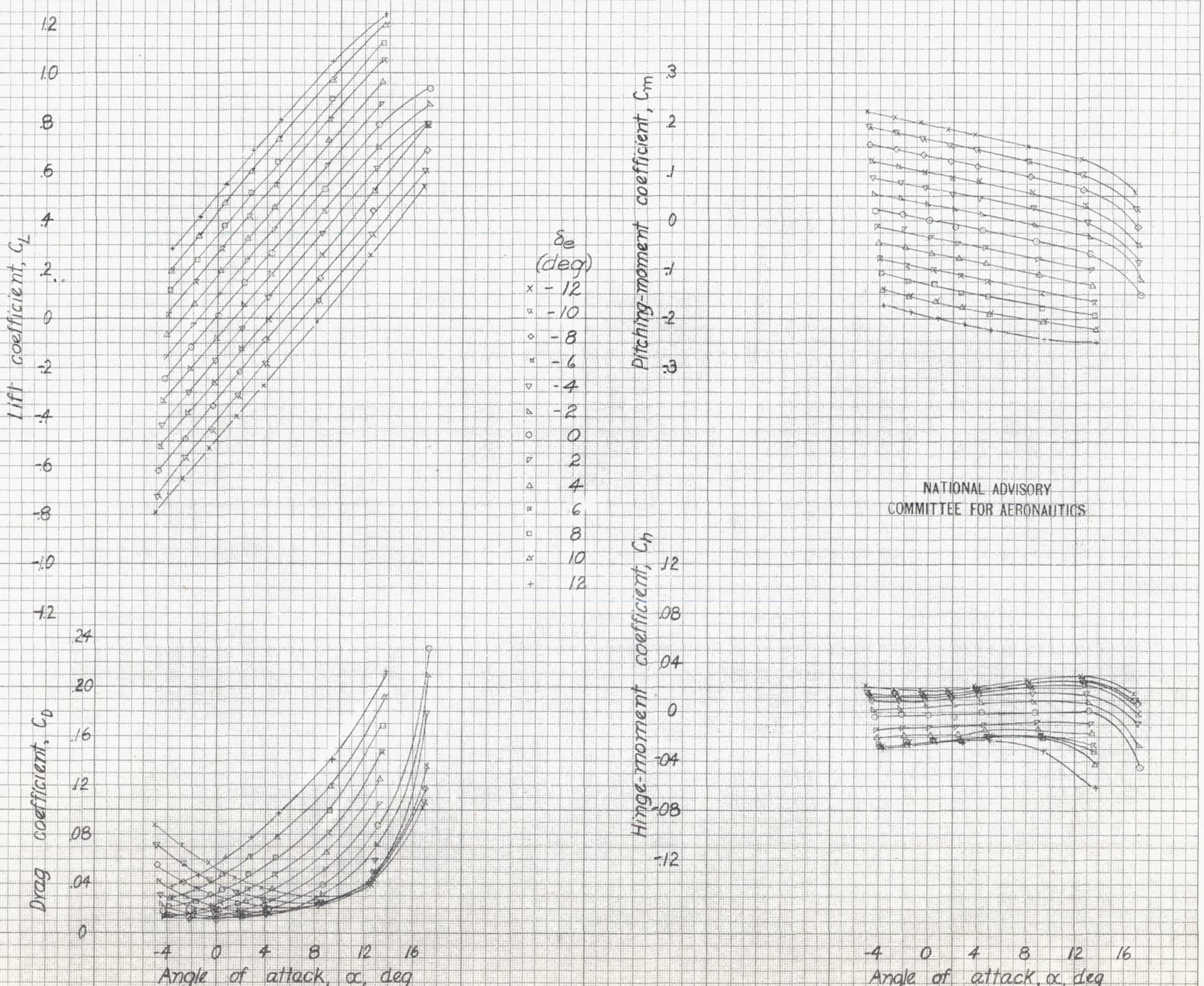


Figure 13.- Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2a, $\delta_t/\delta_e = 0.5$, elevator sealed, $a = 0.06$, $b = 0.06$, tab sealed.

L-702

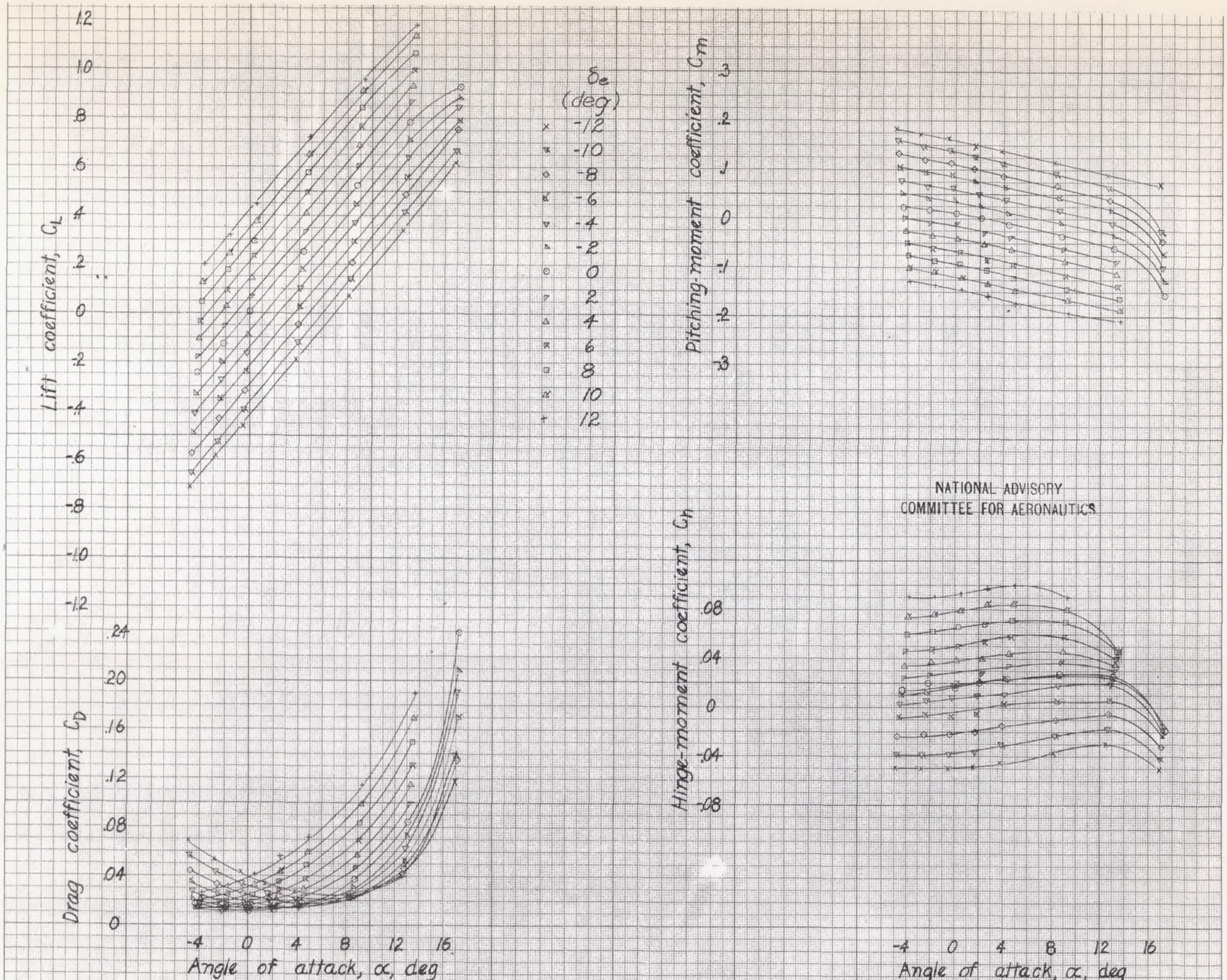


Figure 14.- Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2a, $\delta_t/\delta_e = 0$, elevator sealed, a=0.06, b=0.06, cutouts sealed, tab sealed.

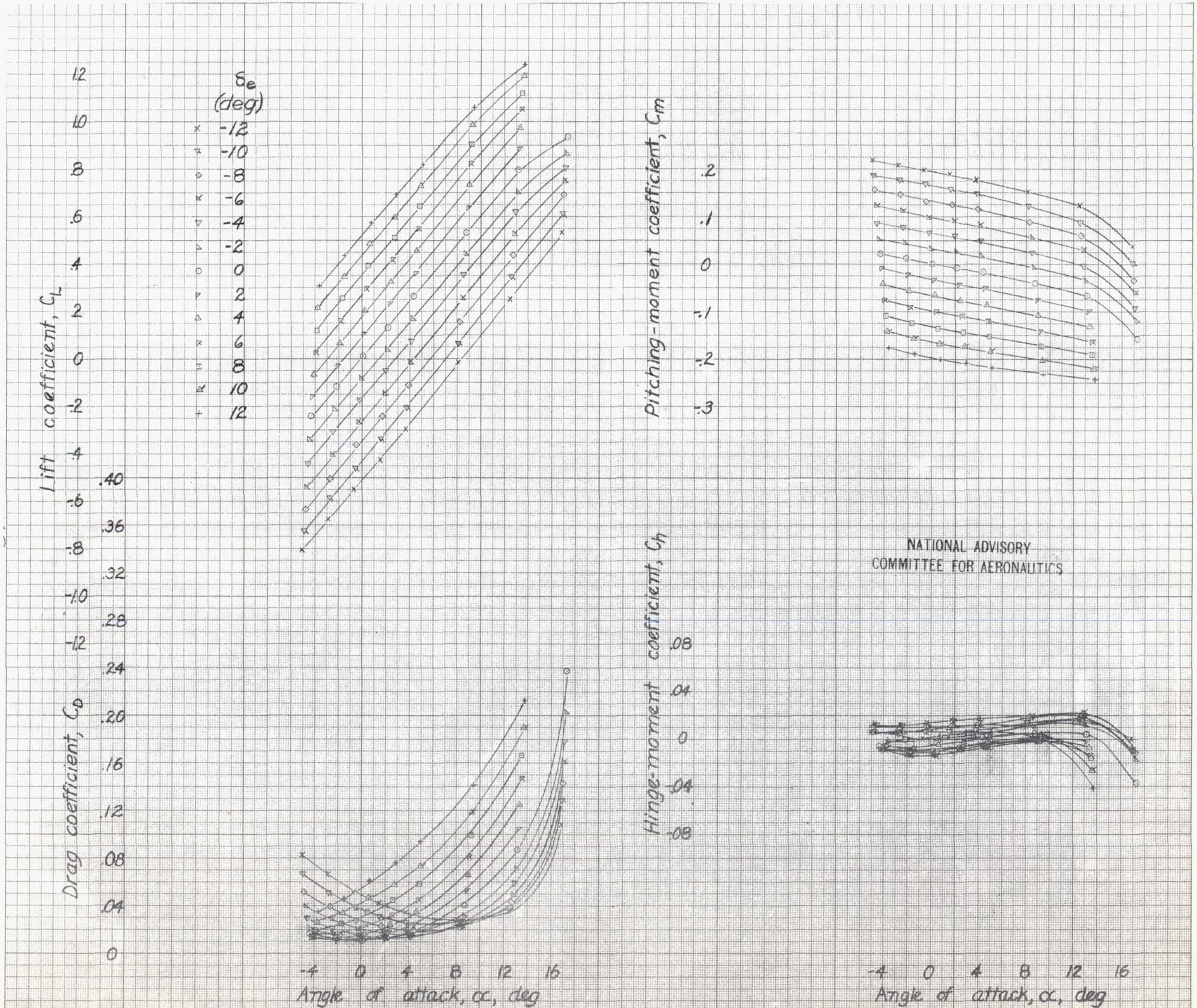


Figure 15.- Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2a, $\delta_t/\delta_e = 0.5$, elevator sealed, a=0.06, b=0.06, cutouts sealed, tab sealed.

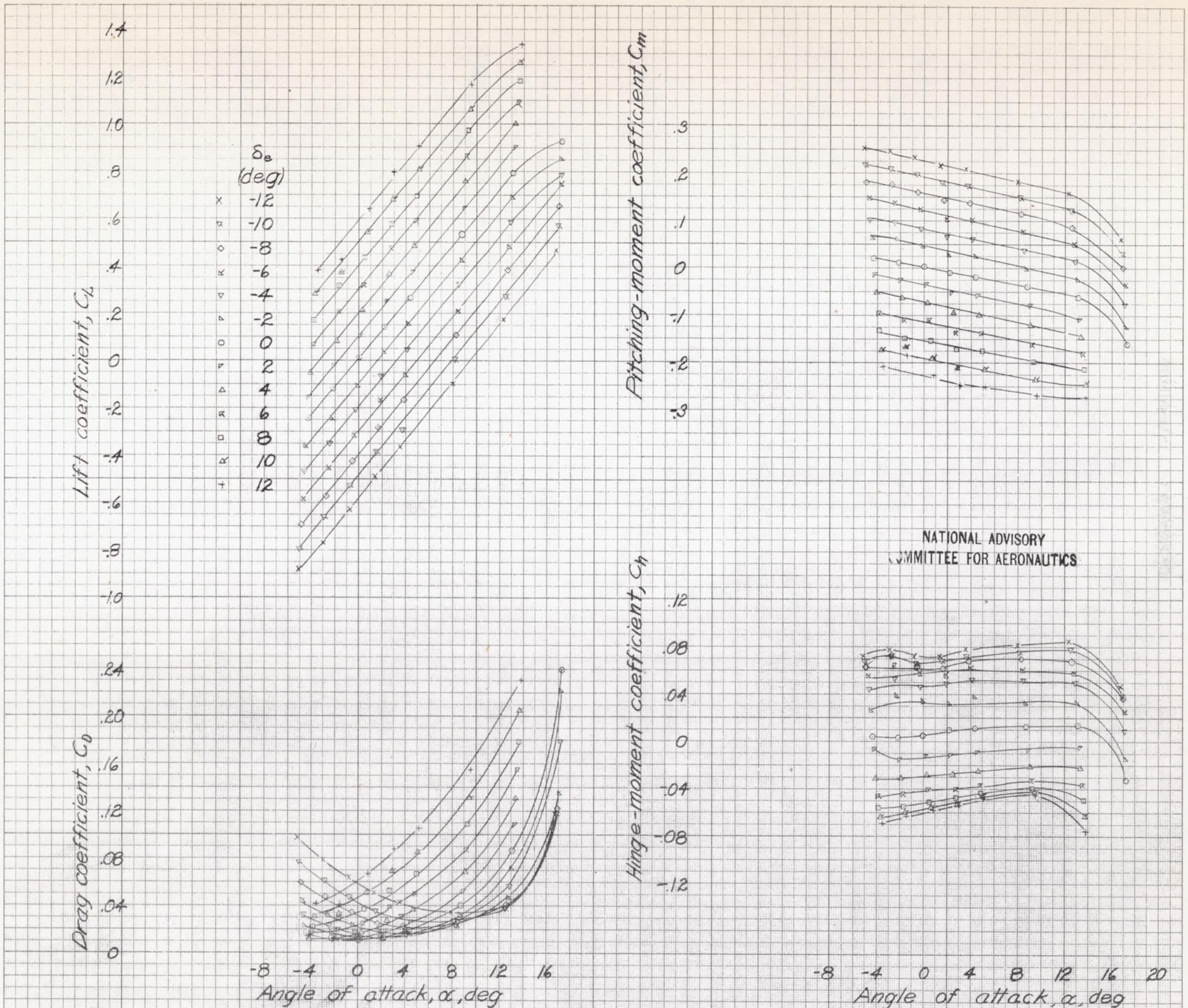


Figure 16.- Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2a, $\delta_t/\delta_e = 1.0$, elevator sealed, $a = 0.06$, $b = 0.06$, cutouts sealed, tab sealed.

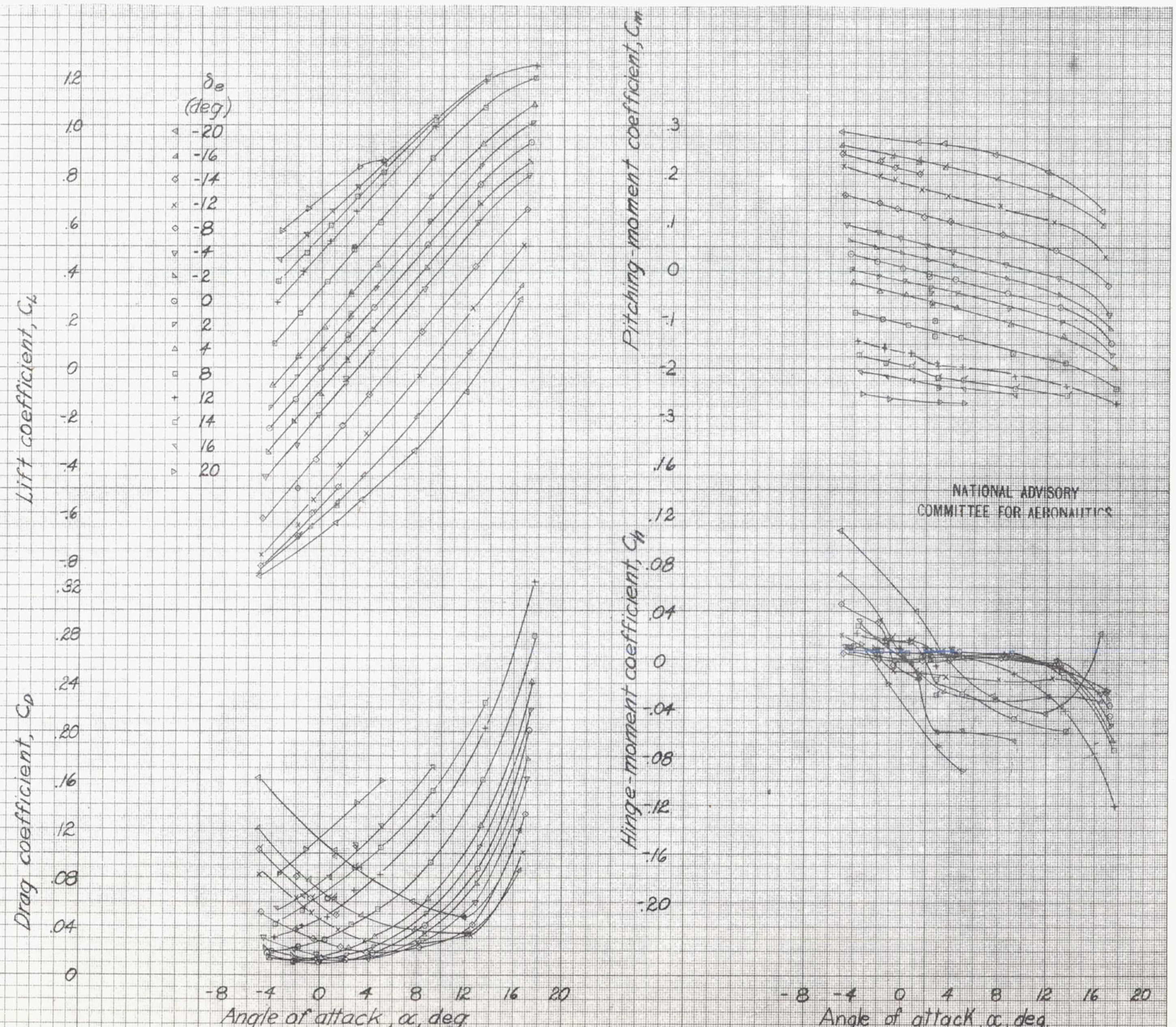


Figure 17.-Aerodynamic characteristics of the 0.5-scale model of the TBF-1 left horizontal tail surface. Modification 2b, elevator unsealed, a=0.22, b=0.67, no tab.

L-702

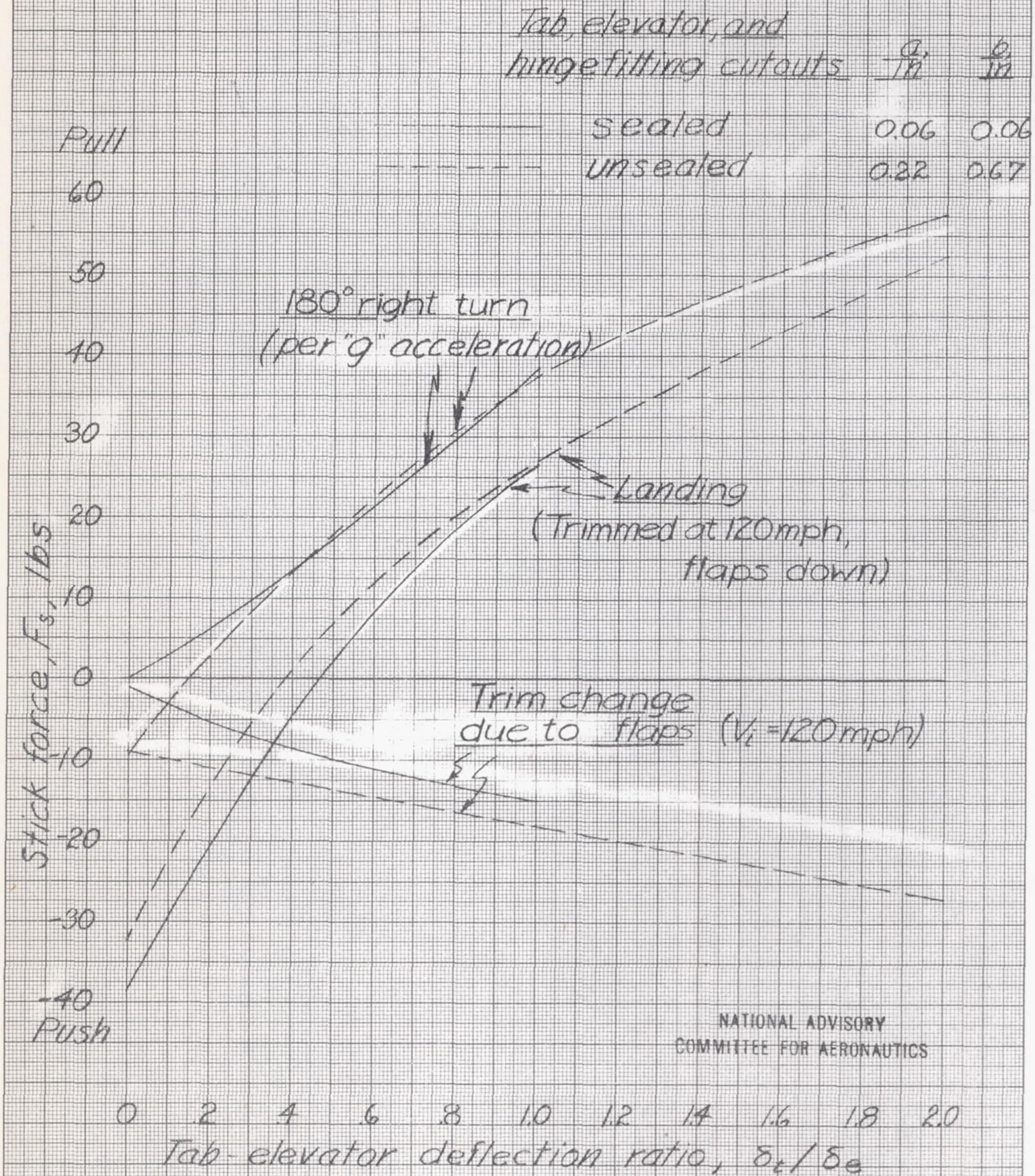


Figure 18.- Effect of δ_t/δ_e on the estimated stick forces required for various flight conditions of the TBF-1 airplane with revised horizontal tail surface; c.g. at 25.5 percent m.a.c.

L-702

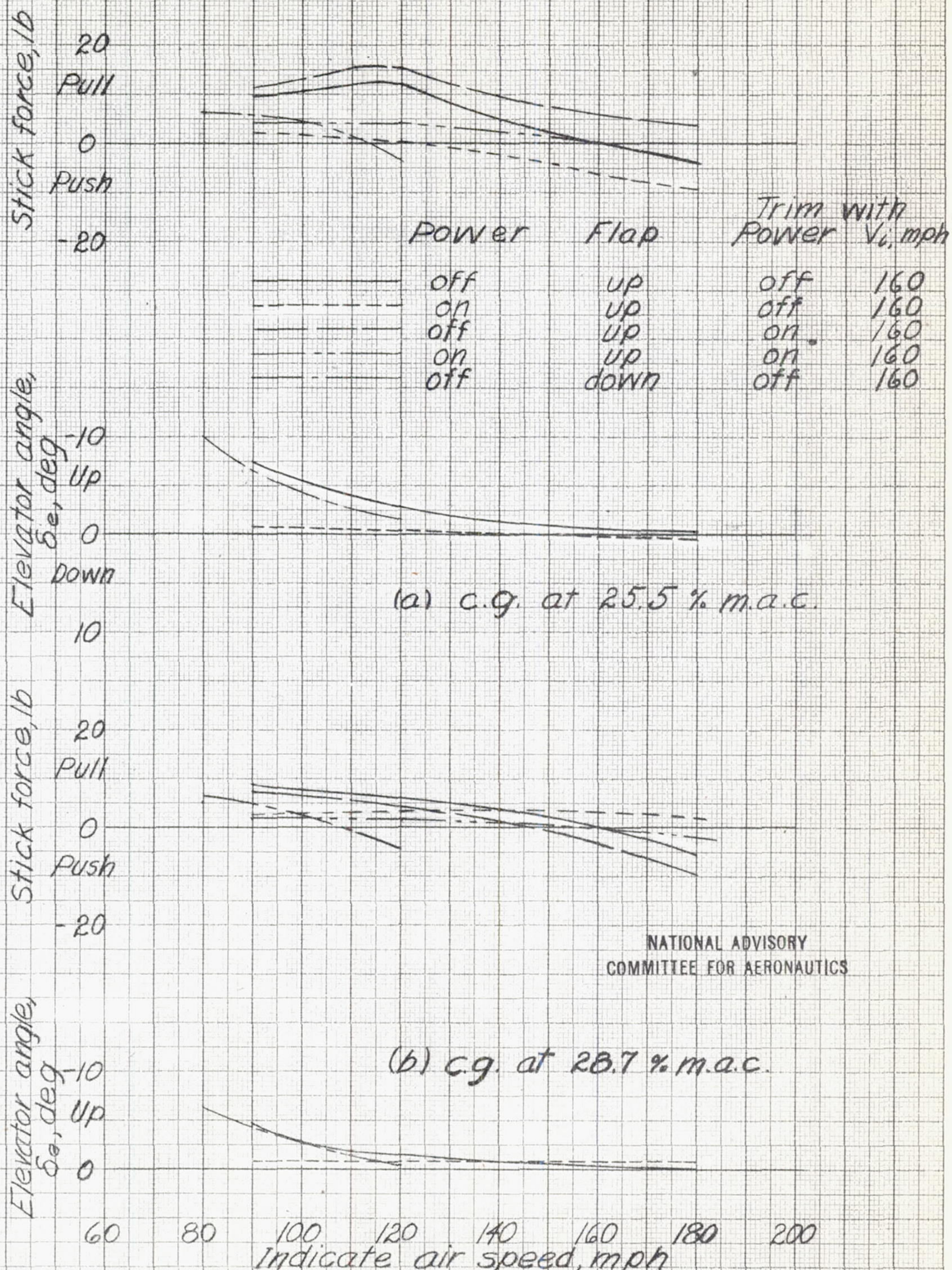


Figure 19.- Estimated longitudinal trim characteristics of TBF-1 airplane. Mod 2a, $\delta_t/\delta_e = 0.5$, no seals, a=0.22, b=0.67.