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SPACE SHUTTLE ORBITER TRIMMED CENTER-OF-GRAVITY EXTENSION STUDY

VOLUME IV - EFFECTS OF CONFIGURATION MODIFICATIONS ON THE AERODYNAMIC CHARACTERISTICS OF THE 139B ORBITER AT MACH 20.3

(NASA-TM-X-72661) SPACE SHUTTLE ORBITER TRIMMED CENTER-OF-GRAVITY EXTENSION STUDY. VOLUME 4: EFFECTS OF CONFIGURATION MODIFICATIONS ON THE AERODYNAMIC CHARACTERISTICS OF THE 139B ORBITER AT MACH G3/16

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William I. Scallion and David R. Stone

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National Aeronautics and
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Langley Research Center
Hampton, Virginia 23665

SUMMARY

As part of a study to extend the Space Shuttle Orbiter center-of-gravity envelope, tests were conducted at Mach 20.3 to determine the effect of several forebody, wing-fillet, and canard modifications on the orbiter longitudinal center-of-pressure locations. All of the modifications were designed to increase the forward planform area distribution in order to increase the hypersonic nose-up trim capability. Force and moment data were obtained at angles of attack of 18° to 54° at zero sideslip angle. The test Reynolds number was 1.95×10^{6} based on body length. The forward extended wing-body fillet modification produced the largest forward shift in center of pressure (3.0 percent of the body length) of any of the wing-fillet modifications tested. The large fillet-canard also produced a 3.0 percent forward center-of-pressure shift. The modified forebody produced a forward center-of-pressure shift of about 1.0 percent body length.

INTRODUCTION

The longitudinal center-of-gravity range of the Space Shuttle Orbiter for trimmed flight during entry, approach, and landing is quite limited. This puts a considerable constraint on the allowable mass distribution of shuttle payloads. In an effort to extend the orbiter center-of-gravity envelope, a study was undertaken at the Langley Research Center to examine the feasibility of developing simple, "bolt-on" modifications. Modifications which were studied included changes in fuselage nose shape and wing fillet planform and the addition of fixed canard surfaces. Systems design analyses were undertaken to determine the weight penalties. Aerodynamic heating tests and analyses provided information on the impact of the modifications on thermal protection system requirements. Wind-tunnel force and moment tests were conducted across the speed range to assess the effectiveness of the modifications in extending the center-of-gravity envelope and the influence of the modifications on flight characteristics. Aerodynamic characteristics of the modifications at Mach 10.3 and at transonic speeds are presented in references 1 and 2, respectively, the effect of the modifications on the orbiter heat-transfer characteristics at Mach 10.3 are given in reference 3, and the system design analyses are given in reference 4.

As a part of the aerodynamic studies, an investigation of the effects of several configuration modifications on the hypersonic static stability and longitudinal trim characteristics of a 0.004-scale model of the 139B orbiter was conducted in the Langley 22-Inch Helium Tunnel. The modifications consisted of a revised forebody shape, three forward wing-body fillets having increased planform area, and four canards of varying planform shape and area. The 139B model used in this investigation was an earlier version of the 140A/B model used in the greater part of the c.g. expansion study, however, the differences between the configurations were not large enough to alter the incremental effects of the individual modifications. Force and moment data were obtained over an angle-of-attack range of 18° to 54° at zero sideslip angle and most of the tests were conducted at a Mach number of 20.3 with a corresponding Reynolds number of 1.95×10^6 based on body length. In addition to the aerodynamic data, photographs of electron-beam-illuminated flow patterns are presented.

SYMBOLS

The longitudinal aerodynamic data are presented about the stability system of axes while the lateral-directional aerodynamics are presented about the body axes (fig. 1). All the aerodynamic data contained herein were nondimensionalized using the values of the baseline model wing reference area, span and mean aerodynamic chord. The moment reference point is located at 65 percent of the fuselage reference length (i.e., 8.52085 cm (3.35466 in.) aft of the model nose). Values are given in both SI and US Customary Units.

A	aspect ratio
b	wing span, 9.517 cm (3.747 in.)
$\bar{c}$	mean aerodynamic chord, 4.823 cm (1.899 in.)
C_A	axial force coefficient, $\frac{\text{Axial force}}{q_\infty S_{ref}}$

C_D	drag coefficient, $\frac{\text{Drag}}{q_\infty S_{ref}}$
C_L	lift coefficient, $\frac{\text{Lift}}{q_\infty S_{ref}}$
C_m	pitching moment coefficient, $\frac{\text{Pitching moment}}{q\, S_{ref}\, \bar{c}}$
C_N	normal force coefficient, $\frac{\text{Normal force}}{q_\infty S_{ref}}$
c.g.	center of gravity
L/D	lift-drag ratio
ℓ_B	fuselage reference length, 13.109 cm (5.161 in.)
M	Mach number
q_∞	free-stream dynamic pressure, Newtons per meter^2 (lb/ft^2)
R_ℓ	free-stream Reynolds number based on ℓ
S_{ref}	wing reference area, 0.0039987 m^2 (0.04304 ft^2)
X_{cp}/ℓ	center-of-pressure location defined by $X_{cg}/\ell - \frac{C_m}{C_N}\,\frac{c}{\ell}$
XMRP	moment reference point on X axis
ZMRP	moment reference point on Z axis
	angle-of-attack, deg
δ_{BF}	body flap deflection angle (positive for trailing-edge deflected downward), deg
δ_e	elevon deflection angle (positive for trailing-edge deflected downward), deg
δ_{SB}	split rudder flare angle (positive for trailing-edges deflected outboard), deg

Model Configuration Components:

B1	baseline fuselage forebody

B4	enlarged planform and cambered fuselage forebody modification
C2	canard used with baseline fillet removed
C3	intermediate fillet-canard
C4	large fillet-canard
C5	small fillet-canard (designated H-19 in reference 5)
E	baseline elevon
F	baseline body flap
M	OMS pod
S0	baseline planform fillet
S1	intermediate wing-body fillet
S2	forward extended wing-body fillet
S3	large wing-body fillet
W	baseline wing (outboard panel) having a leading-edge sweep of 45°
V	baseline vertical tail

APPARATUS AND TESTS

Test Facility

The LaRC 22-Inch Helium Tunnel is a blowdown-type tunnel with a normal operational time of 30 seconds for aerodynamic force and moment tests. Studies are conducted in the 22-inch diameter test section at Mach numbers from 17.6 to 22.2, at stagnation pressures from 1.4 to 20.7 MPa (200 to 3000 psi), and at stagnation temperatures from 289 to 533°K (520 to 960°R). These test conditions allow Reynolds number variations from 3.9×10^6 to 37.7×10^6 per meter (1.2×10^6 to 11.5×10^6 per foot). Operational characteristics of the contoured nozzle flow characteristics are available in reference 5.

Models

The baseline model was a 0.004-scale representation of the Rockwell International 139B configuration (Model 34-0) tested previously and reported in reference 6. Sketches of the model and modifications are presented in figures 2 and 3, and photographs of the model are presented in figure 4. The configuration stations shown in figure 3 are full-size vehicle station dimensions (in inches) and the areas of the modifications are also full scale.

The modifications designed to extend the forward c.g. trim capability of the model are designated as follows:

Symbol	Figure	
S1	3(b)	Intermediate wing-body fillet, leading-edge sweep 75.5°
S2	3(c)	Forward extended wing-body fillet
S3	3(d)	Large wing-body fillet, leading-edge sweep 71.6°
B4	3(a)	Modified forebody, camber, length, planform
C2	3(e)	Canard used with baseline fillet removed
C3	3(f)	Intermediate fillet-canard
C4	3(g)	Large fillet-canard
C5	3(g)	Small fillet-canard (designated H-19 in reference 6)

As stated previously, most of the tests supporting the c.g. study utilized models representing the 140A/B orbiter configurations. The major differences between the 139B and 140A/B configurations were that the 140A/B wing was thicker along the elevon hingeline and utilized a body flap having a larger wedge angle to accommodate the increased upsweep of the vehicle trailing edge resulting from the thicker wing. In either case, the body-flap deflections from the nominal zero setting were designed to present the same lower surface angle to free stream for both positive and negative deflections. At the nominal positive body-flap setting, the windward surface angle was 10° with respect to the X-axis, and at the negative deflection the windward surface was -18° relative to the X-axis. Subsequent to the tests, the body-flap windward surface angles were measured. The results of the measurements are shown below:

Nominal Body Flap Setting	Nominal	Measured
0°	-3.75°	-3.5° to -4.0°
13.75°	10°	9.3° to 10.35°
-14.25°	-18°	-17.65° to -17.4°

The range of measured angles represents the variation between the left and right ends of the body flap. Since all modifications were tested separately the individual incremental effect on model stability and trim was obtained with a high degree of confidence that the effect of the errors in body-flap angles on the increment would be neglig le.

Tests

The model was sting supported, with aerodynamic forces and moments measured by an internally mounted six-component strain gage balance Angles of attack were varied from 18° to 54° at zero sideslip angle and were measured by an optical method using a prism mounted on the model to reflect light from a point adjacent to the test section window onto electric eyes set at calibrated intervals.

In order to obtain maximum trim capability the model was tested with the elevons set at -40° in combination with a body-flap setting of -14.25° to represent forward c.g. locations; to represent trim about aft c.g. locations, the elevons were set at 15°, and the body flap set at 13.75°. Some combinations of the modified forebody and fillets and canards were also tested. The rudder flare (speed brake) was set at 55° included angle for all configurations tested. All configurations tested are listed in the data set/run collation summary in the appendix. The investigation was conducted with helium as a test medium at a total pressure setting of 6.895 MPa (1000 psia) with a corresponding Mach number of 20.3 and a Reynolds number of 1.95×10^6 based on a model length (ℓ_B) of 13.109 cm. The effects of Reynolds number variation from 1.09 to 3.83×10^6 were investigated for a selected configuration. The test conditions are listed in table I. Photographs of the electron-beam-illuminated flow field were recorded for each configuration investigated.

Measurements

The aerodynamic forces and moments measured by the internal strain gage balance were reduced to coefficient form using the following reference dimensions:

S = wing planform area = 39.987 cm^2

ℓ_{REF} = wing mean aerodynamic chord - 4.823 cm

b = wing span = 9.517 cm

The reference center-of-gravity location for moment data is:

XMRP = 8.522 cm aft of nose (65 percent body length)

YMRP = 0.0

ZMRP = 0.0, fuselage reference line

Model base pressures were not measured and all data are presented as uncorrected for base pressure; however, C_{A_b} is tabulated for selected conditions in reference 7 for the baseline configuration. Uncertainties in the force and moment data are listed in table II.

RESULTS AND DISCUSSION

Aerodynamic Data

Aerodynamic data obtained in this investigation are tabulated in the appendix. The basic longitudinal aerodynamic characteristics, C_L, C_D, L/D, C_N, and C_m, of the model with the various modifications for the maximum forward c.g. trim case (δ_e = -40°, δ_{BF} = 14.5°) are presented in figures 5 through 9. The effect of variation in Mach and Reynolds numbers on the model characteristics with the maximum width forebody B4 combined with the C4 canard is presented in figure 10. The maximum positive and negative trim characteristics of the model with various combinations of the forebody B4 and the canards are presented in figures 11(a) through 11(f). These data show a break in the stability ($\partial C_m/\partial C_N$) of the model in the form of a pitch-up that occurred between angles of attack of 45° and 50°. The pitch-up appears to be more severe for the positive control deflections (trailing-edge down). A comparison of the data of figures 6 and 7 of reference 7 (for a range of body-flap and elevon deflections) showed that the character of the pitch-up was relatively unaffected by body-flap deflections, but was very sensitive to positive elevon deflections. Although the cause of the pitch-up is unknown, it was reasoned that the disturbance was associated with an area of separation on the windward surfaces of the model wings.

Effect of Modifications on Longitudinal Trim Capability

The objective of the study was to extend the trimmed forward center-of-gravity capability of the orbiter. A good indication of the effectiveness of the modifications in providing additional forward trimmed center-of-gravity capability is their effect on the model center-of-pressure location, X_{cp}/ℓ. The effects of the various planform modifications on the model center-of-pressure location for the maximum forward c.g. trim case are presented in figures 12 through 16. As shown in figure 12, the most effective fillet modification was S2, in which most of the added planform area was placed at the forward end. This modification moved the center-of-pressure location forward by about 3 percent of the model body length, ℓ. Although the S3 fillet was considerably larger than S2 (compare figures 3(c) and 3(d)), the more aft distribution of its planform area rendered it less effective. Removal of the baseline fillet, S0, shifted the value of X_{cp}/ℓ aft by about 1.3 percent body length (fig. 13). With the baseline fillet replaced by the C2 canard, the center of pressure was moved forward by about 2.5 percent ℓ, indicating that the C2 canard was more effective than the baseline fillet in providing forward c.g. trim capability at Mach 20.3. Figure 14 shows that the most effective in-fillet canard was C4 (the largest planform area) and the forward increment in X_{cp}/ℓ produced by this modification was 0.03. At the test Mach number of 20.3 the C4 canard effectiveness is equivalent to that of the most effective fillet, S2, but the data of reference 2 indicate that the canard would cause the vehicle to exceed the subsonic longitudinal instability limit. With the subsonic stability constraint taken into consideration, the canard size would probably be limited to that of the C3 canard. On this basis, the most effective hypersonic modification from the standpoint of forward center-of-pressure movement was the S2 fillet. Figures 15 and 16 show that the effect of the forebody B4 on the value of X_{cp}/ℓ was to produce a forward shift of 1 percent of the body length. The combined effect of Mach and Reynolds number was a more forward location of the C_p with increasing Mach and Reynolds number at the lower angles of attack (18^o - 35^o). As angle of attack was increased, this effect tended to diminish, and at angles of attack above 45^o, it became negligible. The effect of several of the modifications on the center-of-pressure location of the maximum trim configurations (representing forward and aft center-of-gravity locations) is shown in figure 18. These data indicate that the aft center-of-pressure locations ($\delta_e = 15^o$, $\delta_{BF} = 13.75^o$) are biased forward by the modifications by the same amount as the forward C_p locations.

Flow Visualization

Figures 19 through 32 present the results of the electron beam flow visualization studies. In the absence of more detailed flow-field measurements, only qualitative observations on the character of the observed flow fields can be made. The most notable observation on the effect of the modifications on the character of the flow field is that the intersection of the bow shock wave with the wing shock tends to move outboard with the modifications in place. Figures 19 through 22 show the effect of the fillets. Removal of the baseline fillet causes the bow shock-wing shock intersection to move further inboard (compare figure 23 with figure 19). The interaction between the bow shock and the shocks from the canards, figures 24 through 26, tended to move the bow shock-wing shock interaction further outboard. The intersection of the bow shock with the canard shock occurred in the region of the canard tips. The wide forebody B4 tended to move the bow shock outboard in the region of the canard tips, but did not materially affect the location of the bow shock-wing shock interaction (figures 27 through 32).

SUMMARY OF RESULTS

Tests were conducted at Mach 20.3 in the Langley 22-Inch Helium Tunnel to determine the effects of fuselage forebody and wing-fillet modifications and canards on the longitudinal aerodynamic characteristics of a Space Shuttle Orbiter configuration. The results are summarized as follows:

1. The canard C2 was more effective than the baseline wing fillet in producing a forward shift in model center of pressure.

2. The S2 fillet modification produced the largest forward shift in center of pressure (3.0 percent body length) of any of the wing fillet modifications tested due to the fact that the area distribution of this fillet was more forward than that of the other fillet configurations.

3. The largest in-fillet canard, C4, produced a forward center-of-pressure shift equivalent to that of the S2 fillet, however, it would not meet the subsonic stability criteria.

4. The forebody modification B4 produced a forward shift in center of pressure of 1.0 percent.

REFERENCES

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3. Dunavant, James C.: Space Shuttle Orbiter Trimmed Center-of-Gravity Extension Study, Volume III - Impact of Retrofits for Center-of-Gravity Extension on Orbiter Thermal Protection System. NASA TM X-72661, 1976.

4. MacConochie, Ian O.; LeMessurier, Robert W.; and Walsh, Robert F.: Space Shuttle Orbiter Trimmed Center-of-Gravity Extension Study, Volume VI - System Design Studies. NASA TM X-72661, 1976.

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6. Allen, E. C.; and Tuttle, T.: Static Stability and Control Effectiveness of Models 12-0 and 34-0 of the Vehicle 3 Configuration. NASA CR-128780, August 1973.

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TABLE I - TEST CONDITIONS

MACH NUMBER	$R_{e\ell} \times 10^{-6}$	DYNAMIC PRESSURE (kPa)	STAGNATION TEMPERATURE (DEGREES K)
20.3	1.95	10.964	307
19.0	1.09	6.661	300
21.6	3.83	18.226	271

TABLE II - MAXIMUM DATA UNCERTAINTIES

MACH NO.	19.0	20.3	21.6
P_t (MPa)	3.45	6.90	13.79
C_N	± .0301	± .0183	± .0109
C_A	± .0042	± .0026	± .0015
C_m	± .0130	± .0079	± .0047
C_ℓ	± .0028	± .0017	± .0010
C_n	± .0045	± .0027	± .0016
C_Y	± .0099	± .0060	± .0036

Langley balance HH20

APPENDIX

TABULATED DATA

The data presented herein are identified in table I (Data Set/Run Number Collation Summary) by configuration and run number. These data are also stored on tape in the Space Shuttle Data System (DATAMAN) and are identified by Shuttle test number LA-40 and data set identification letters RH. Access to the data may be obtained by writing to the following address:

Chrysler Corporation, Space Division
Dept. 2910, P.O. Box 29200
New Orleans, LA 70189

The symbols listed below define the parameters tabulated in the following pages.

CN	normal force coefficient
CA	axial force coefficient
CLM	Pitching moment coefficient
CBL	rolling moment coefficient
CYN	yawing moment coefficient
CY	side force coefficient
CL	lift coefficient
CD	drag coefficient
L/D	lift-drag ratio

TEST : LaRC 22"– 7426 (Ia–40)

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE : 9/10/75

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	δe	δBF	δSB	NO. OF RUNS	MACH 19.0	MACH 20.3	MACH 21.6
RH3001	Baseline –139B	A	0	–40	–14.25	55			1	
02	Baseline –139B			15	13.75				18	
03	–139B + C2 –5C			–40	–14.25				15	
04	–139B + C3			–40	–14.25				23	
05	–139B + C3			15	13.75				20	
06	–139B + C4			–40	–14.25				5	
07	–139B + C4			15	13.75				19	
08	–139B + C5			–40	–14.25				24	
09	–139B – S0			–40					16	
10	–139B + S1			–40					14	
11	–139B + S2			–40					9	
12	–139B + S3			–40					10	
13	B4			–40					2	
14	B4			15	13.75				8	
15	B4 C3			–40	–14.25				22	
16	B4 C3			–40	–14.25			25		
17	B4 C3			–40	–14.25					26
18	B4 C3			15	13.75				21	

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES: A) 18° ⟶ 54°, Δα = 3°

Baseline – 139B = $B_1\ F_1\ M_1\ S_0\ W_1\ E_1\ V_1$

B4 = $B_4\ F_1\ M_1\ S_0\ W_1\ E_1\ V_1$

TEST: 22" 7426

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE: 9/10/75

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES: δ_e	δ_{BF}	δ_{SB}						NO. OF RUNS	MACH NUMBERS: 20.3 (TEST RUN NUMBERS)		
RH3019	B4 C4	A	0	-40	-14.25	55							6		
20	B4 C4	A	0	15	13.75	55							7		
21	B4 S1	A	0	-40	-14.25	55							12		
22	B4 S1 (Re-run)	A	0	-40	-14.25	55							13		
23	B4 S3	A	0	-40	14.25	55							11		

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICENTS

IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

LARC 22-7426(LA-40) (B1F1M1)(W1E1S0)(V1)   (RH3001)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	-40.000
AILRON =	.000	BDFLAP =	-14.250
SPDBRK =	55.000	RE,L =	1.940

RUN NO. 1/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.31553	.06138	.00357	.00011	-.00119	.00248	.28112	.15588	1.80347
20.300	20.000	.00000	.38624	.06145	.00514	.00011	-.00117	.00302	.34193	.18985	1.80110
20.300	23.000	.00000	.48244	.06263	.00617	.00017	-.00124	.00328	.41961	.24615	1.70468
20.300	26.000	.00000	.59382	.06420	.01039	.00021	-.00127	.00404	.50558	.31801	1.58979
20.300	28.000	.00000	.66644	.06389	.01208	.00053	-.00136	.00432	.55844	.36929	1.51222
20.300	30.000	.00000	.73107	.06495	.01445	.00041	-.00143	.00517	.60066	.42178	1.42409
20.300	33.000	.00000	.86852	.06643	.02084	.00082	-.00168	.00657	.69222	.52874	1.30919
20.300	36.000	.00000	.98715	.06505	.02274	.00059	-.00173	.00699	.76039	.63286	1.20151
20.300	39.000	.00000	1.10373	.06348	.02229	.00055	-.00173	.00772	.81781	.74394	1.09930
20.300	42.000	.00000	1.21670	.06229	.02417	.00049	-.00212	.00975	.86250	.86042	1.00242
20.300	45.000	.00000	1.34066	.06159	.03006	.00086	-.00233	.01108	.90444	.99155	.91215
20.300	48.000	.00000	1.46986	.05844	.02395	.00050	-.00232	.01237	.94010	1.13143	.83090
20.300	51.000	.00000	1.56138	.05958	.04323	.00038	-.00256	.01409	.93630	1.25091	.74849
20.300	54.000	.00000	1.62436	.05808	.06545	.00124	-.00263	.01513	.90778	1.34827	.67329

TABULATED SOURCE DATA, LARC 22-7426 (LA40)

LARC 22-7426(LA-40) (B1F1M1)(W1E1S0)(V1) (RH3002)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	15.000		
AILRON =	.000	BDFLAP =	13.750		
SPDBRK =	55.000	RE,L =	1.920		

RUN NO. 18/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.42409	.07589	-.08228	-.00190	-.00148	.00049	.37988	.20323	1.86923
20.300	20.000	.00000	.51479	.07985	-.09546	-.00202	-.00159	.00137	.45643	.25110	1.81770
20.300	23.000	.00000	.62901	.08546	-.11152	-.00229	-.00178	.00160	.54561	.32443	1.68174
20.300	26.000	.00000	.77173	.09185	-.13049	-.00261	-.00189	.00201	.65336	.42036	1.55244
20.300	28.000	.00000	.85650	.09519	-.14160	-.00282	-.00216	.00304	.71155	.48615	1.46365
20.300	30.000	.00000	.93648	.09847	-.15251	-.00284	-.00225	.00334	.76178	.55352	1.37625
20.300	33.000	.00000	1.11423	.10560	-.17507	-.00362	-.00258	.00454	.87696	.69541	1.26106
20.300	36.000	.00000	1.25506	.11002	-.19261	-.00419	-.00275	.00586	.95069	.82671	1.14998
20.300	39.000	.00000	1.39860	.11496	-.21271	-.00481	-.00291	.00758	1.01457	.96950	1.04648
20.300	42.000	.00000	1.53967	.12000	-.23758	-.00669	-.00303	.00985	1.06390	1.11942	.95040
20.300	45.000	.00000	1.77429	.12953	-.30967	-.00348	-.00430	.01330	1.16302	1.34620	.86393
20.300	48.000	.00000	1.88646	.12805	-.29740	-.00217	-.00491	.01592	1.16713	1.48759	.78458
20.300	51.000	.00000	1.95914	.12434	-.25913	-.00220	-.00510	.01769	1.13630	1.60078	.70984
20.300	54.000	.00000	2.00384	.12272	-.21677	-.00278	-.00492	.01809	1.07854	1.69328	.63696

LARC 22-7426(LA-40) (B1F1M1C2)(W1E1)(V1) (RH3003)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	-40.000
AILRON =	.000	BDFLAP =	-14.250
SPDBRK =	55.000	RE,L =	1.960

RUN NO. 15/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.32094	.07473	.01925	.00129	-.00207	.00030	.28214	.17024	1.65725
20.300	20.000	.00000	.39674	.07642	.02065	.00061	-.00207	.00021	.34668	.20751	1.67066
20.300	23.000	.00000	.48648	.07864	.02747	.00091	-.00219	.00015	.41708	.26247	1.58906
20.300	26.000	.00000	.60293	.08072	.03589	.00058	-.00242	.00042	.50653	.33686	1.50369
20.300	28.000	.00000	.67630	.08057	.03826	.00106	-.00254	.00038	.55931	.38864	1.43914
20.300	30.000	.00000	.74655	.08181	.04466	.00069	-.00276	.00159	.60563	.44412	1.36365
20.300	33.000	.00000	.88653	.08116	.05496	.00100	-.00303	.00253	.69931	.55090	1.26938
20.300	36.000	.00000	1.00244	.08000	.06527	.00138	-.00301	.00265	.76396	.65394	1.16824
20.300	39.000	.00000	1.11835	.07820	.07194	.00052	-.00314	.00309	.81991	.76457	1.07238
20.300	42.000	.00000	1.22475	.07641	.08007	.00116	-.00351	.00485	.85904	.87630	.98029
20.300	45.000	.00000	1.35961	.07110	.08554	.00081	-.00353	.00518	.91112	1.01167	.90061
20.300	51.000	.00000	1.57613	.06634	.11252	.00104	-.00375	.00770	.34034	1.26663	.74239
20.300	54.000	.00000	1.64168	.06487	.13659	.00151	-.00404	.00915	.91248	1.36628	.66786

LARC 22-7428(LA-40) (B1F1M1C3;W1E1S0)(V1)　　(RH3004)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	-40.000
AILRON =	.000	BDFLAP =	-14.250
SPDBRK =	55.000	RE,L =	1.960

RUN NO. 23/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.34050	.06507	.02793	-.00034	-.00175	.00290	.30373	.16711	1.81754
20.300	20.000	.00000	.41514	.06630	.03349	-.00042	-.00163	.00236	.36742	.20429	1.79853
20.300	23.000	.00000	.51347	.06800	.04090	-.00030	-.00179	.00339	.44608	.26322	1.69472
20.300	26.000	.00000	.63411	.06951	.05172	-.00059	-.00177	.00396	.53946	.34046	1.58453
20.300	28.000	.00000	.70723	.07098	.05887	-.00048	-.00184	.00447	.59113	.39469	1.49769
20.300	30.000	.00000	.78113	.07078	.06372	-.00062	-.00215	.00486	.64109	.45186	1.41879
20.300	33.000	.00000	.92318	.07070	.07637	-.00080	-.00233	.00579	.73574	.56209	1.30894
20.300	36.000	.00000	1.04844	.07051	.08821	-.00082	-.00234	.00765	.80676	.67330	1.19822
20.300	39.000	.00000	1.17389	.06905	.09903	-.00124	-.00248	.00878	.86883	.79242	1.09643
20.300	42.000	.00000	1.27530	.06723	.10784	-.00149	-.00257	.01005	.90274	.90330	.99938
20.300	45.000	.00000	1.40593	.06447	.11802	-.00174	-.00281	.01163	.94856	1.03973	.91231
20.300	48.000	.00000	1.53807	.06211	.11790	-.00084	-.00310	.01436	.98301	1.18457	.82985
20.300	51.000	.00000	1.65418	.06177	.13025	-.00115	-.00327	.01562	.99301	1.32441	.74977
20.300	54.000	.00000	1.72147	.06078	.15211	-.00117	-.00336	.01733	.96268	1.42842	.67395

LARC 22-7426(LA-40) (B1F1M1C3)(W1E1S0)(V1) (RH3005)

PARAMETRIC DATA

BETA = .000 ELEVTR = 15.000
AILRON = .000 BDFLAP = 13.750
SPDBRK = 55.000 RE,L = 1.960

RUN NO. 20/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.44409	.07913	-.05566	-.00131	-.00124	.00165	.39790	.21249	1.87258
20.300	20.000	.00000	.54124	.08430	-.06614	-.00179	-.00138	.00201	.47976	.26433	1.81499
20.300	23.000	.00000	.65788	.09026	-.07810	-.00284	-.00140	.00247	.57031	.34014	1.67668
20.300	26.000	.00000	.80934	.09701	-.09089	-.00314	-.00122	.00320	.68490	.44198	1.54963
20.300	28.000	.00000	.89692	.10084	-.09656	-.00311	-.00143	.00413	.74460	.51012	1.45966
20.300	30.000	.00000	.98778	.10406	-.10379	-.00325	-.00163	.00536	.80341	.58400	1.37570
20.300	33.000	.00000	1.16103	.11092	-.11448	-.00380	-.00195	.00756	.91331	.72537	1.25910
20.300	36.000	.00000	1.31099	.11524	-.12679	-.00434	-.00200	.00875	.99287	.86381	1.14941
20.300	39.000	.00000	1.45769	.12011	-.13689	-.00509	-.00139	.01064	1.05725	1.01070	1.04606
20.300	42.000	.00000	1.58874	.12331	-.14848	-.00573	-.00204	.01269	1.09815	1.15472	.95102
20.300	45.000	.00000	1.82095	.13229	-.21680	-.00528	-.00284	.01641	1.19407	1.38115	.86455
20.300	48.000	.00000	1.95522	.13160	-.21122	-.00330	-.00361	.02037	1.21050	1.54107	.78549
20.300	51.000	.00000	2.04649	.12893	-.17545	-.00300	-.00373	.02273	1.18770	1.67156	.71053
20.300	54.000	.00000	2.10291	.12649	-.13668	-.00318	-.00362	.02266	1.13373	1.77564	.63849

TABULATED SOURCE DATA, LARC 22-7426 (LA40)

LARC 22-7426(LA-40) (B1F1M1C4)(W1E1S0)(V1) (RH3006)

PARAMETRIC DATA

BETA = .000 ELEVTR = -40.000
AILRON = .000 BDFLAP = -14.250
SPDBRK = 55.000 RE,L = 1.970

RUN NO. 5/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.34615	.06766	.03481	-.00082	-.00207	.00357	.30830	.17131	1.79961
20.300	20.000	.00000	.42668	.06981	.04312	-.00090	-.00179	.00322	.37707	.21154	1.78253
20.300	23.000	.00000	.52402	.07139	.05275	-.00114	-.00195	.00373	.45447	.27047	1.68031
20.300	26.000	.00000	.64597	.07294	.06580	-.00141	-.00174	.00322	.54862	.34873	1.57317
20.300	28.000	.00000	.72768	.07397	.07421	-.00159	-.00196	.00453	.60777	.40693	1.49354
20.300	30.000	.00000	.79621	.07450	.08041	-.00162	-.00202	.00457	.65229	.46262	1.40999
20.300	33.000	.00000	.94760	.07401	.09713	-.00176	-.00237	.00674	.75442	.57817	1.30484
20.300	36.000	.00000	1.06975	.07382	.11261	-.00218	-.00232	.00703	.82205	.68850	1.19397
20.300	39.000	.00000	1.19021	.07282	.12705	-.00250	-.00242	.00924	.87914	.80561	1.09127
20.300	42.000	.00000	1.30263	.07115	.13990	-.00320	-.00239	.00929	.92044	.92450	.99560
20.300	45.000	.00000	1.42885	.06755	.15148	-.00377	-.00249	.01075	.96258	1.05812	.90971
20.300	48.000	.00000	1.57123	.06430	.15645	-.00354	-.00279	.01323	1.00357	1.21068	.82893
20.300	51.000	.00000	1.68165	.06403	.16772	-.00304	-.00320	.01533	1.00854	1.34719	.74862
20.300	54.000	.00000	1.75619	.06341	.19078	-.00307	-.00322	.01648	.98096	1.45806	.67279

LARC 22-7428(LA-40) (B1F1M1C4)(W1E1S0)(V1) (RKC007)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	15.000
AILRON =	.000	BDFLAP =	13.750
SPDBRK =	55.000	RE,L =	1.860

RUN NO. 19/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.44258	.08173	-.05617	-.00096	-.00156	.00040	.39566	.21450	1.84453
20.300	20.000	.00000	.53781	.08762	-.06437	-.00137	-.00158	.00169	.47541	.26628	1.78537
20.300	23.000	.00000	.65561	.09316	-.07271	-.00136	-.00146	.00242	.56709	.34192	1.65854
20.300	26.000	.00000	.80973	.09928	-.08605	-.00216	-.00146	.00275	.68426	.44420	1.54044
20.300	28.000	.00000	.90191	.10272	-.09240	-.00226	-.00150	.00348	.74811	.51412	1.45513
20.300	30.000	.00000	.98490	.10622	-.09553	-.00223	-.00165	.00530	.79984	.58444	1.36855
20.300	33.000	.00000	1.16583	.11245	-.10784	-.00253	-.00169	.00705	.91650	.72927	1.25675
20.300	36.000	.00000	1.31884	.11734	-.11707	-.00308	-.00153	.00906	.99799	.87012	1.14695
20.300	39.000	.00000	1.46302	.12074	-.12617	-.00436	-.00156	.01043	1.06100	1.01454	1.04579
20.300	42.000	.00000	1.59154	.12366	-.13514	-.00546	-.00130	.01179	1.10090	1.15685	.95087
20.300	45.000	.00000	1.83010	.13205	-.19901	-.00407	-.00164	.01772	1.20070	1.38745	.86540
20.300	48.000	.00000	1.96480	.13074	-.19813	-.00125	-.00256	.02025	1.21755	1.54761	.78673
20.300	51.000	.00000	2.06396	.12835	-.16339	.00009	-.00263	.02346	1.19915	1.68479	.71176
20.300	54.000	.00000	2.11864	.12651	-.12159	-.00070	-.00260	.02417	1.14295	1.78837	.63910

TABULATED SOURCE DATA, LARC 22-7426 (LA40)

LARC 22-7426(LA-40) (B1F1M1C5)(W1E1S0)(V1) (RH3008)

PARAMETRIC DATA

BETA = .000 ELEVTR = -40.000
AILRON = .000 BDFLAP = -14.250
SPDBRK = 55.000 RE,L = 1.950

RUN NO. 24/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.33580	.06227	.02139	-.00007	-.00172	.00238	.30012	.18299	1.84138
20.300	20.000	.00000	.41350	.06509	.02803	-.00004	-.00164	.00301	.36630	.20259	1.80813
20.300	23.000	.00000	.50877	.06643	.03195	-.00061	-.00190	.00300	.44237	.25994	1.70182
20.300	26.000	.00000	.62964	.06889	.04097	-.00062	-.00193	.00401	.53572	.33794	1.58525
20.300	28.000	.00000	.70183	.07016	.04496	-.00065	-.00187	.00398	.58674	.39144	1.49893
20.300	30.000	.00000	.77230	.06895	.04806	-.00097	-.00191	.00422	.63435	.44586	1.42275
20.300	33.000	.00000	.91708	.06941	.05667	-.00100	-.00212	.00612	.73133	.55769	1.31136
20.300	36.000	.00000	1.04029	.06936	.06616	-.00041	-.00233	.00796	.80084	.66758	1.19961
20.300	39.000	.00000	1.15657	.06837	.07525	-.00104	-.00252	.00919	.85580	.78098	1.09580
20.300	42.000	.00000	1.26352	.06707	.08305	-.00170	-.00263	.01070	.89410	.89530	.99866
20.300	45.000	.00000	1.39858	.06479	.09115	-.00180	-.00268	.01258	.94313	1.03476	.91145
20.300	48.000	.00000	1.52018	.06206	.09219	-.00120	-.00255	.01455	.97108	1.17124	.82910
20.300	51.000	.00000	1.63897	.06247	.10441	-.00123	-.00286	.01638	.98290	1.31303	.74857
20.300	54.000	.00000	1.70706	.06078	.12450	-.00094	-.00308	.01808	.95421	1.41677	.67351

TABULATED SOURCE DATA, LARC 22-7426 (LA40)

LARC 22-7426(LA-40) (B1F1M1)(W1E1)(V1) (RH3009)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	-40.000
AILRON =	.000	BDFLAP =	-14.250
SPDBRK =	55.000	RE.L =	1.930

RUN NO. 16/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.29132	.07100	-.00386	.00043	-.00139	-.00264	.25512	.15755	1.61935
20.300	20.000	.00000	.36186	.07179	-.00758	.00056	-.00182	-.00249	.31548	.19122	1.64981
20.300	23.000	.00000	.44667	.07418	-.00519	.00089	-.00184	-.00201	.38218	.24281	1.57400
20.300	26.000	.00000	.55786	.07325	-.00767	.00015	-.00205	-.00218	.46929	.31039	1.51196
20.300	28.000	.00000	.62014	.07379	-.00743	.00022	-.00210	-.00255	.51291	.35629	1.43960
20.300	30.000	.00000	.68664	.07344	-.00815	.00027	-.00223	-.00266	.55793	.40692	1.37111
20.300	33.000	.00000	.81465	.07353	-.00770	.00005	-.00267	-.00191	.64318	.50536	1.27271
20.300	36.000	.00000	.93055	.07349	-.00705	.00043	-.00305	-.00141	.70971	.60648	1.17022
20.300	39.000	.00000	1.03981	.07019	-.01100	.00062	-.00336	-.00061	.76392	.70892	1.07758
20.300	42.000	.00000	1.14172	.06758	-.01561	.00074	-.00358	.00033	.80325	.81418	.98657
20.300	45.000	.00000	1.26827	.06537	-.01924	.00072	-.00388	.00122	.85058	.94303	.90197
20.300	48.000	.00000	1.37296	.06430	-.01264	.00081	-.00429	.00271	.87090	1.06333	.81903
20.300	51.000	.00000	1.45251	.06185	.00143	.00060	-.00448	.00322	.86602	1.16774	.74163
20.300	54.000	.00000	1.50529	.05946	.02074	.00104	-.00464	.00425	.83668	1.25276	.66787

TABULATED SOURCE DATA, LARC 22-7426 (LA40)

LARC 22-7426(LA-40) (B1F1M1)(W1E1S1)(V1) (RH3010)

PARAMETRIC DATA

BETA = .000 ELEVTR = -40.000
AILRON = .000 BDFLAP = -14.250
SPDBRK = 55.000 RE,L = 1.910

RUN NO. 14/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.32276	.05715	.02472	.00038	-.00150	-.00017	.28930	.15409	1.87742
20.300	20.000	.00000	.39817	.05783	.02559	.00025	-.00151	-.00005	.35437	.19052	1.85999
20.300	23.000	.00000	.49268	.05968	.03527	.00043	-.00169	.00001	.43020	.24744	1.73859
20.300	26.000	.00000	.61202	.06097	.04361	.00067	-.00183	-.00028	.52335	.32309	1.61985
20.300	28.000	.00000	.68268	.06152	.04787	.00091	-.00187	-.00032	.57389	.37481	1.53113
20.300	30.000	.00000	.75084	.06240	.05354	.00103	-.00188	.00042	.61905	.42946	1.44146
20.300	33.000	.00000	.89044	.06227	.06291	.00124	-.00226	.00069	.71287	.53719	1.32704
20.300	36.000	.00000	1.01170	.06250	.07187	.00127	-.00245	.00155	.78175	.64523	1.21158
20.300	39.000	.00000	1.12761	.06183	.08138	.00143	-.00245	.00110	.83740	.75766	1.10523
20.300	42.000	.00000	1.23324	.06058	.08777	.00115	-.00285	.00290	.87594	.87021	1.00658
20.300	45.000	.00000	1.36523	.05937	.09616	.00146	-.00303	.00375	.92339	1.00735	.91665
20.300	48.000	.00000	1.49322	.05781	.10407	.00139	-.00337	.00488	.95620	1.14836	.83266
20.300	51.000	.00000	1.60203	.05761	.11778	.00119	-.00375	.00527	.96342	1.28126	.75193
20.300	54.000	.00000	1.66740	.05649	.14072	.00135	-.00379	.00637	.93437	1.38216	.67602

LARC 22-7426(LA-40) (B1F1M1)(W1E1S2)(V1)   (RH3011)

PARAMETRIC DATA

BETA = .000   ELEVTR = -40.000
AILRON = .000   BDFLAP = -14.250
SPDBRK = 55.000   RE,L = 1.990

RUN NO. 9/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.32390	.06252	.03663	.00011	-.00152	-.00021	.28872	.15955	1.80957
20.300	20.000	.00000	.40291	.06470	.04330	.00011	-.00142	-.00065	.35648	.19860	1.79495
20.300	23.000	.00000	.49616	.06612	.05296	.00016	-.00126	-.00063	.43089	.25473	1.69154
20.300	26.000	.00000	.61411	.06740	.06579	.00006	-.00146	.00005	.52241	.32978	1.58411
20.300	28.000	.00000	.68667	.06770	.07203	.00011	-.00166	-.00017	.57451	.38215	1.50336
20.300	30.000	.00000	.75734	.06846	.08041	.00030	-.00179	.00069	.62165	.43796	1.41943
20.300	33.000	.00000	.89907	.06904	.09434	.00058	-.00197	.00157	.71643	.54757	1.30838
20.300	36.000	.00000	1.01817	.06866	.10727	.00037	-.00220	.00213	.78336	.65401	1.19778
20.300	39.000	.00000	1.13598	.06845	.11959	.00049	-.00223	.00319	.83974	.76809	1.09328
20.300	42.000	.00000	1.24583	.06677	.12775	.00045	-.00259	.00437	.88115	.88324	.99764
20.300	45.000	.00000	1.38513	.06469	.14008	.00039	-.00277	.00614	.93369	1.02518	.91076
20.300	48.000	.00000	1.51501	.06231	.14360	.00062	-.00261	.00628	.96743	1.16757	.82859
20.300	51.000	.00000	1.62293	.06246	.15924	.00095	-.00279	.00730	.97280	1.30056	.74799
20.300	54.000	.00000	1.69690	.06200	.18439	.00111	-.00293	.00903	.94725	1.40926	.67216

LARC 22-7426(LA-40) (B1F1M1)(W1E1S3)(V1) (RH3012)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	-40.000
AILRON =	.000	BDFLAP =	-14.250
SPDBRK =	55.000	RE,L =	1.990

RUN NO. 10/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.35339	.05414	.03499	.00051	-.00118	-.00092	.31936	.16069	1.98743
20.300	20.000	.00000	.43015	.05553	.04004	.00073	-.00134	-.00036	.38522	.19930	1.93288
20.300	23.000	.00000	.53103	.05767	.04770	.00091	-.00131	-.00073	.46628	.26057	1.78947
20.30C	26.000	.00000	.65414	.05949	.05926	.00127	-.00159	-.00001	.56185	.34022	1.65142
20.300	28.000	.00000	.73090	.06032	.06364	.00123	-.00153	-.00055	.61703	.39640	1.55658
20.300	30.000	.00000	.80195	.06113	.07134	.00148	-.00158	.00021	.66395	.45391	1.46273
20.300	33.000	.00000	.95071	.06241	.08481	.00133	-.00181	.00077	.76334	.57014	1.33888
20.300	36.000	.00000	1.07555	.06290	.09640	.00142	-.00211	.00203	.83317	.68308	1.21972
20.300	39.000	.00000	1.19697	.06310	.10891	.00159	-.00239	.00329	.89051	.80232	1.10992
20.300	42.000	.00000	1.30890	.06304	.11956	.00182	-.00258	.00428	.93052	.92268	1.00850
20.300	45.000	.00000	1.44475	.06287	.13432	.00159	-.00285	.00536	.97714	1.06605	.91660
20.300	48.000	.00000	1.57074	.06230	.15053	.00180	-.00329	.00769	1.00473	1.20897	.83106
20.300	51.000	.00000	1.68243	.06279	.16818	.00183	-.00345	.00837	1.00999	1.34701	.74980
20.300	54.000	.00000	1.75891	.06234	.18964	.00194	-.00365	.01040	.98343	1.45963	.67375

LARC 22-7426(LA-40) (B4F1M1)(M1E1S0)(V1) (RH3013)

PARAMETRIC DATA

BETA = .000 ELEVTR = -40.000
AILRON = .000 BDFLAP = -14.250
SPDBRK = 55.000 RE,L = 1.980

RUN NO. 2/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.31299	.06820	.02684	-.00006	-.00271	.00160	.27752	.15873	1.74837
20.300	20.000	.00000	.39073	.06732	.02693	-.00001	-.00276	.00129	.34414	.19690	1.74780
20.300	23.000	.00000	.48461	.07029	.03012	-.00029	-.00270	.00080	.41862	.25406	1.64773
20.300	26.000	.00000	.60169	.07250	.03568	-.00014	-.00286	.00201	.50901	.32893	1.54749
20.300	28.000	.00000	.67448	.07414	.03906	-.00011	-.00295	.00219	.56072	.38212	1.46742
20.300	30.000	.00000	.74082	.07428	.04295	-.00010	-.00319	.00361	.60443	.43474	1.39033
20.300	33.000	.00000	.88166	.07587	.05000	-.00020	-.00359	.00517	.69810	.54382	1.28371
20.300	36.000	.00000	.99891	.07615	.05800	-.00033	-.00363	.00549	.76333	.64876	1.17668
20.300	39.000	.00000	1.12060	.07581	.06309	-.00022	-.00390	.00766	.82316	.76413	1.07725
20.300	42.000	.00000	1.23162	.07485	.06725	-.00048	-.00397	.00808	.86519	.87974	.98346
20.300	45.000	.00000	1.36074	.07322	.06972	-.00062	-.00391	.00934	.91042	1.01396	.89789
20.300	48.000	.00000	1.49959	.07221	.07303	-.00020	-.00429	.01117	.94975	1.16273	.81683
20.300	51.000	.00000	1.58752	.07316	.09051	.00004	-.00444	.01264	.94220	1.27978	.73622
20.300	54.000	.00000	1.65329	.07265	.11614	-.00007	-.00455	.01439	.91300	1.38025	.66148

LARC 22-7426(LA-40) (B4F1H1)(W1E1S0)(V1) (RH3014)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	15.000
AILRON =	.000	BDFLAP =	13.750
SPDBRK =	55.000	RE,L =	1.930

RUN NO. 8/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.41833	.08057	-.05882	-.00120	-.00219	-.00062	.37296	.20590	1.81135
20.300	20.000	.00000	.51298	.08826	-.07639	-.00176	-.00225	-.00017	.45254	.25650	1.76428
20.300	23.000	.00000	.62911	.09245	-.09350	-.00221	-.00227	-.00026	.54298	.33091	1.64086
20.300	26.000	.00000	.77377	.09990	-.10902	-.00266	-.00240	.00079	.65166	.42899	1.51907
20.300	28.000	.00000	.86498	.10408	-.11987	-.00214	-.00247	.00160	.71487	.49798	1.43552
20.300	30.000	.00000	.94416	.10717	-.12878	-.00274	-.00233	.00209	.76408	.56489	1.35262
20.300	33.000	.00000	1.11740	.11482	-.14569	-.00252	-.00301	.00373	.87459	.70488	1.24078
20.300	36.000	.00000	1.25940	.12113	-.15925	-.00324	-.00310	.00548	.94768	.83825	1.13054
20.300	39.000	.00000	1.40584	.12554	-.17731	-.00341	-.00313	.00677	1.01354	.98229	1.03182
20.300	42.000	.00000	1.54369	.13111	-.19622	-.00531	-.00294	.00791	1.05945	1.13036	.93727
20.300	45.000	.00000	1.77352	.14145	-.26682	-.00306	-.00423	.01330	1.15405	1.35409	.85227
20.300	48.000	.00000	1.91484	.14096	-.25770	-.00162	-.00468	.01507	1.17652	1.51733	.77539
20.300	51.000	.00000	1.97666	.13891	-.21578	-.00176	-.00464	.01640	1.13600	1.62358	.69969
20.300	54.000	.00000	2.01793	.13656	-.17317	-.00217	-.00457	.01758	1.07563	1.71281	.62799

LARC 22-7426(LA-40) (B4F1M1C3)(W1E1S0)(V1) (RH3015)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	-40.000
AILRON =	.000	BDFLAP =	-14.250
SPDBRK =	55.000	RE.L =	1.950

RUN NO. 22/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.33302	.06849	.04666	-.00009	-.00303	.00028	.29556	.16805	1.75876
20.300	20.000	.00000	.41379	.07087	.05060	-.00015	-.00305	.00030	.36460	.20812	1.75186
20.300	23.000	.00000	.51267	.07401	.05904	-.00044	-.00298	.00045	.44300	.26844	1.65028
20.300	26.000	.00000	.63849	.07627	.06966	-.00051	-.00305	.00135	.54043	.34845	1.55096
20.300	28.000	.00000	.71503	.07832	.07789	-.00070	-.00338	.00193	.59456	.40484	1.46865
20.300	30.000	.00000	.78644	.07889	.08482	-.00029	-.00359	.00271	.64164	.46154	1.39020
20.300	33.000	.00000	.93592	.08035	.10157	-.00041	-.00386	.00398	.74117	.57712	1.28425
20 300	36.000	.00000	1.06153	.08041	.11569	-.00074	-.00397	.00557	.81154	.68900	1.17784
20.300	39.000	.00000	1.18581	.07958	.12880	-.00122	-.00398	.00609	.87147	.80810	1.07841
20.300	42.000	.00000	1.29716	.07783	.13787	-.00125	-.00411	.00760	.91190	.92581	.98497
20.300	45.000	.00000	1.43120	.07620	.15248	-.00158	-.00436	.00922	.95813	1.06589	.89890
20.300	48.000	.00000	1.56134	.07394	.15694	-.00161	-.00460	.01159	.98979	1.20978	.81816
20.300	51.000	.00000	1.68780	.07396	.17289	-.00066	-.00491	.01399	1.00469	1.35821	.73972
20.300	54.000	.00000	1.75655	.07383	.20066	-.00118	-.00488	.01510	.97275	1.46447	.66423

LARC 22-7426(LA-40) (B4F1M1C3)(W1E1S0)(V1) (RH3016)

PARAMETRIC DATA

BETA = .000 ELEVTR = -40.000
AILRON = .000 BDFLAP = -14.250
SPDBRK = 55.000 RE.L = 1.090

RUN NO. 25/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
19.000	18.000	.00000	.34349	.07310	.04619	.00051	-.00294	-.00103	.30980	.17752	1.74512
19.000	20.000	.00000	.41471	.07288	.04528	.00007	-.00297	-.00098	.36478	.21033	1.73434
19.000	23.000	.00000	.50840	.07677	.05685	.00012	-.00304	-.00031	.43799	.26931	1.62634
19.000	26.000	.00000	.63472	.08010	.06436	-.00054	-.00319	-.00011	.53537	.35024	1.52859
19.000	28.000	.00000	.70611	.08138	.07001	-.00046	-.00336	-.00015	.58525	.40335	1.45097
19.000	30.000	.00000	.77901	.08149	.07685	-.00133	-.00359	.00089	.63390	.46008	1.37780
19.000	33.000	.00000	.92395	.08406	.09502	.00012	-.00389	.00158	.72910	.57371	1.27085
19.000	36.000	.00000	1.04808	.08196	.10344	-.00093	-.00378	.00118	.79974	.68235	1.17204
19.000	39.000	.00000	1.17031	.08356	.11909	-.00171	-.00411	.00312	.85691	.80144	1.06922
19.000	42.000	.00000	1.27397	.08155	.12904	-.00196	-.00392	.00314	.89217	.91305	.97713
19.000	45.000	.00000	1.41115	.07956	.14355	-.00165	-.00407	.00369	.94158	1.05409	.89326
19.000	48.000	.00000	1.53539	.07663	.15040	-.00085	-.00413	.00459	.97043	1.19229	.81392
19.000	51.000	.00000	1.64650	.07607	.16536	-.00074	-.00424	.00641	.97706	1.32744	73605
19.000	54.000	.00000	1.72294	.07785	.19729	-.00072	-.00438	.00761	.94974	1.43965	.65970

LARC 22-7426(LA-40) (B4F1M1C3)(W1E1S0)(V1) (RH3017)

PARAMETRIC DATA

BETA = .000 ELEVTR = -40.000
AILRON = .000 BDFLAP = -14.250
SPDBRK = 55.000 RE.L = 3.830

RUN NO. 26/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
21.600	18.000	.00000	.33595	.06777	.05294	-.00026	-.00330	-.00163	.29857	.16827	1.77437
21.600	20.000	.00000	.41773	.07029	.06081	-.00072	-.00375	-.00107	.36849	.20893	1.76375
21.600	23.000	.00000	.52035	.07309	.07212	-.00107	-.00356	-.00088	.45042	.27060	1.66453
21.600	26.000	.00000	.65163	.07488	.08557	-.00121	-.00374	-.00025	.55286	.35296	1.56634
21.600	28.000	.00000	.73172	.07612	.09529	-.00113	-.00388	.00093	.61033	.41073	1.48596
21.600	30.000	.00000	.80665	.07679	.10480	-.00097	-.00394	.00203	.66019	.46983	1.40517
21.600	33.000	.00000	.95678	.07710	.12042	-.00103	-.00430	.00424	.76043	.58576	1.29820
21.600	36.000	.00000	1.08721	.07788	.13355	-.00121	-.00454	.00643	.83380	.70205	1.18766
21.600	39.000	.00000	1.21275	.07814	.14469	-.00142	-.00468	.00839	.89331	.82393	1.08420
21.600	42.000	.00000	1.31019	.07647	.15017	-.00251	-.00484	.00998	.92249	.93352	.98819
21.600	45.000	.00000	1.46665	.07438	.16133	-.00172	-.00524	.01379	.98449	1.08968	.90347

LARC 22-7426(LA-40) (B4F1M1C3)(W1E1S0)(V1) (RH3018)

PARAMETRIC DATA

BETA	=	.000	ELEVTR	=	15.000
AILRON	=	.000	BDFLAP	=	13.750
SPDBRK	=	55.000	RE.L	=	1.960

RUN NO. 21/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.44062	.08337	-.03821	-.00193	-.00281	-.00105	.39329	.21544	1.82550
20.300	20.000	.00000	.53760	.08906	-.04889	-.00204	-.00283	-.00068	.47472	.26756	1.77426
20.300	23.000	.00000	.65941	.09584	-.06092	-.00268	-.00271	-.00046	.56955	.34587	1.64669
20.300	26.000	.00000	.81260	.10387	-.07189	-.00266	-.00277	.00074	.68483	.44958	1.52326
20.300	28.000	.00000	.90707	.10777	-.08079	-.00315	-.00303	.00097	.75030	.52100	1.44011
20.300	30.000	.00000	.98930	.11158	-.08338	-.00295	-.00325	.00206	.80097	.59128	1.35463
20.300	33.000	.00000	1.17658	.11901	-.09354	-.00347	-.00367	.00422	.91691	.73736	1.24352
20.300	36.000	.00000	1.32011	.12486	-.09967	-.00410	-.00385	.00563	.99460	.87695	1.13416
20.300	39.000	.00000	1.46659	.12920	-.10702	-.00499	-.00391	.00731	1.05844	1.02336	1.03429
20.300	42.000	.00000	1.59682	.13314	-.11658	-.00671	-.00367	.00844	1.09758	1.16742	.94017
20.300	45.000	.00000	1.83049	.14273	-.17592	-.00597	-.00444	.01194	1.19343	1.39528	.85533
20.300	48.000	.00000	1.97438	.14308	-.17464	-.00304	-.00547	.01484	1.21479	1.56298	.77722
20.300	51.000	.00000	2.07427	.14109	-.13828	-.00241	-.00558	.01739	1.19573	1.70080	.70304
20.300	54.000	.00000	2.12159	.13975	-.08734	-.00288	-.00548	.01818	1.13398	1.79855	.63050

LARC 22-7426(LA-40) (B4F1M1C4)(W1E1S0)(V1) (RH3019)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	-40.000
AILRON =	.000	BDFLAP =	-14.250
SPDBRK =	55.000	RE.L =	2.010

RUN NO. 6/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.630	.00000	.33613	.07144	.05262	-.00072	-.00332	.00157	.29760	.17182	1.73209
20.300	20.000	.00000	.42007	.07424	.05859	-.00093	-.00328	.00168	.36935	.21343	1.73051
20.300	23.000	.00000	.52233	.07719	.06754	-.00109	-.00329	.00175	.45065	.27514	1.63787
20.300	26.000	.00000	.64443	.07919	.08117	-.00133	-.00361	.00291	.54450	.35367	1.53954
20.300	28.000	.00000	.72135	.08068	.08893	-.00148	-.00348	.00163	.59804	.40989	1.46146
20.300	30.000	.00000	.79715	.08171	.09785	-.00162	-.00372	.00308	.64950	.46934	1.38385
20.300	33.000	.00000	.94932	.08290	.11483	-.00173	-.00406	.00410	.75102	.58656	1.28037
20.300	36.000	.00000	1.07480	.08333	.13256	-.00212	-.00396	.00407	.82055	.69917	1.17361
20.300	39.000	.00000	1.19881	.08227	.14745	-.00235	-.00424	.00538	.87987	.81837	1.07515
20.300	42.000	.00000	1.30956	.08080	.16236	-.00277	-.00433	.00609	.91913	.93631	.98165
20.300	45.000	.00000	1.44040	.07777	.17668	-.00326	-.00474	.00784	.96353	1.07350	.89755
20.300	48.000	.00000	1.59660	.07616	.19125	-.00356	-.00486	.00876	1.01174	1.23747	.81759
20.300	51.000	.00000	1.70123	.07533	.20220	-.00292	-.00520	.01122	1.01208	1.36951	.73901
20.300	54.000	.00000	1.77653	.07544	.22916	-.00272	-.00533	.01217	.98318	1.48159	.66360

LARC 22-7428(LA-40) (B4F1M1C4)(N1E1S0)(V1)　　(RH3020)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	15.000
AILRON =	.000	BDFLAP =	13.750
SPDBRK =	55.000	RE,L =	1.980

RUN NO. 7/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.43559	.08583	-.03233	-.00204	-.00288	.00181	.38775	.21623	1.79323
20.300	20.000	.00000	.53951	.09333	-.04155	-.00214	-.00270	.00278	.47505	.27222	1.74507
20.300	23.000	.00000	.66701	.09934	-.05306	-.00253	-.00258	.00291	.57517	.35207	1.63369
20.300	26.000	.00000	.81922	.10674	-.06205	-.00276	-.00253	.00345	.68952	.45506	1.51525
20.300	28.000	.00000	.91094	.11101	-.06809	-.00308	-.00280	.00410	.75220	.52567	1.43093
20.300	30.000	.00000	1.00361	.11486	-.07114	-.00260	-.00303	.00491	.81173	.60127	1.35001
20.300	33.000	.00000	1.18090	.12160	-.07778	-.00396	-.00336	.00581	.92415	.74515	1.24023
20.300	36.000	.00000	1.33464	.12782	-.08428	-.00474	-.00367	.00804	1.00462	.88789	1.13147
20.300	39.000	.00000	1.48382	.13164	-.08814	-.00477	-.00358	.00908	1.07030	1.03610	1.03301
20.300	42.000	.00000	1.62139	.13560	-.09486	-.00620	-.00374	.01033	1.11419	1.18569	.93970
20.300	45.000	.00000	1.84909	.14473	-.14996	-.00653	-.00432	.01353	1.20517	1.40985	.85482
20.300	48.000	.00000	2.01644	.14407	-.15000	-.00407	-.00513	.01641	1.24220	1.59491	.77885
20.300	51.000	.00000	2.09637	.14144	-.11365	-.00475	-.00528	.01765	1.20937	1.71828	.70386
20.300	54.000	.00000	2.15096	.13917	-.06613	-.00391	-.00542	.01874	1.15171	1.82196	.63213

LARC 22-7426(LA-40) (B4F1M1)(W1E1S1)(V1) (RH3021)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	-40.000		
AILRON =	.000	BDFLAP =	-14.250		
SPDBRK =	55.000	RE.L =	1.980		

RUN NO. 12/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.32604	.06101	.04425	-.00014	-.00281	-.00352	.29123	.15877	1.83426
20.300	20.000	.00000	.40432	.06326	.04891	-.00003	-.00282	-.00373	.35830	.19773	1.81211
20.300	23.000	.00000	.49970	.06574	.05610	.00005	-.00301	-.00291	.43429	.25576	1.69800
20.300	26.000	.00000	.62183	.06760	.06828	.00024	-.00284	-.00333	.52926	.33335	1.58769
20.300	28.000	.00000	.69612	.06937	.07379	.00040	-.00293	-.00335	.58207	.38806	1.49995
20.300	30.000	.00000	.76565	.07058	.08070	.00037	-.00340	-.00222	.62779	.44395	1.41409
20.300	33.000	.00000	.91022	.07176	.09484	.00042	-.00358	-.00194	.72430	.55592	1.30287
20.300	36.000	.00000	1.03659	.07260	.10590	.00057	-.00388	-.00091	.79594	.66802	1.19149
20.300	39.000	.00000	1.15512	.07264	.11903	.00030	-.00388	-.00099	.85198	.78339	1.08755
20.300	42.000	.00000	1.26516	.07223	.12794	.00028	-.00417	.00042	.89187	.90023	.99071
20.300	45.000	.00000	1.39817	.07114	.13902	-.00035	-.00414	.00101	.93835	1.03896	.90316
20.300	48.000	.00000	1.53008	.07027	.15049	-.00011	-.00459	.00281	.97160	1.18409	.82054
20.300	51.000	.00000	1.63442	.07017	.16353	.00038	-.00464	.00393	.97404	1.31434	.74108
20.300	54.000	.00000	1.71085	.07034	.18755	.00036	-.00506	.00488	.94870	1.42546	.66554

LARC 22-7426(LA-40) (B4F1M1)(W1E1S1)(V1)　　(RH3022)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	-40.000
AILRON =	.000	BDFLAP =	-14.250
SPDBRK =	55.000	RE.L =	1.980

RUN NO. 13/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.33053	.06127	.04439	.00005	-.00279	-.00196	.29542	.16041	1.84170
20.300	20.000	.00000	.40652	.06360	.04948	.00021	-.00276	-.00185	.36025	.19881	1.81208
20.300	23.000	.00000	.50561	.06626	.05624	.00026	-.00278	-.00213	.43953	.25855	1.69996
20.300	26.000	.00000	.62567	.06855	.06834	.00042	-.00285	-.00188	.53230	.33589	1.58475
20.300	28.000	.00000	.69957	.06992	.07455	.00043	-.00305	-.00104	.58485	.39016	1.49899
20.300	30.000	.00000	.77728	.07118	.08129	.00078	-.00312	-.00091	.63756	.45028	1.41590
20.300	33.000	.00000	.91434	.07210	.09570	.00064	-.00345	-.00040	.72756	.55845	1.30282
20.300	36.000	.00000	1.04610	.07391	.10783	.00098	-.00356	.00072	.80287	.67467	1.19001
20.300	39.000	.00000	1.16180	.07348	.11847	.00061	-.00361	.00117	.85664	.78825	1.08677
20.300	42.000	.00000	1.26834	.07320	.12857	.00011	-.00372	.00212	.89358	.90308	.98948
20.300	45.000	.00000	1.40620	.07258	.14320	.00004	-.00388	.00317	.94301	1.04565	.90184
20.300	48.000	.00000	1.54202	.07146	.15291	.00004	-.00410	.00521	.97871	1.19376	.81986
20.300	51.000	.00000	1.64152	.07108	.16534	.00060	-.00441	.00652	.97780	1.32044	.74051
20.300	54.000	.00000	1.72370	.07136	.19001	.00075	-.00459	.00771	.95543	1.43645	.66513

LARC 22-7426(LA-40) (B4F1M))(W1E1S3)(V1) (RK3023)

PARAMETRIC DATA

BETA =	.000	ELEVTR =	-40.000
AILRON =	.000	BDFLAP =	-14.250
SPDBRK =	55.000	RE,L =	1.970

RUN NO. 11/ 0

MACH	ALPHA	BETA	CN	CA	CLM	CBL	CYN	CY	CL	CD	L/D
20.300	18.000	.00000	.35182	.05735	.05342	.00036	-.00262	-.00298	.31688	.16326	1.94092
20.300	20.000	.00000	.43427	.06050	.06023	.00065	-.00270	-.00297	.38739	.20538	1.88621
20.300	23.000	.00000	.53285	.06306	.06935	.00062	-.00280	-.00268	.46585	.26625	1.74972
20.300	26.000	.00000	.66011	.06604	.08320	.00076	-.00286	-.00241	.56435	.34873	1.61833
20.300	28.000	.00000	.73723	.06745	.09145	.00084	-.00292	-.00208	.61927	.40567	1.52654
20.300	30.000	.00000	.81056	.06969	.09836	.00082	-.00303	-.00171	.66762	.46477	1.43646
20.300	33.000	.00000	.96120	.07089	.11544	.00083	-.00329	-.00084	.76752	.58296	1.31658
20.300	36.000	.00000	1.09246	.07279	.13091	.00070	-.00349	.00025	.84103	.70102	1.19972
20.300	39.000	.00000	1.21766	.07336	.14503	.00061	-.00367	.00134	.90014	.82331	1.09332
20.300	42.000	.00000	1.32956	.07374	.15768	.00097	-.00375	.00222	.93901	.94472	.99396
20.300	45.000	.00000	1.46804	.07453	.17752	.00028	-.00405	.00363	.98536	1.09076	.90336
20.300	48.000	.00000	1.60582	.07499	.19453	.00061	-.00432	.00622	1.01877	1.24354	.81925
20.300	51.000	00000	1.70644	.07582	.21593	.00046	-.00442	.00685	1.01498	1.37387	.73877
20.300	54.000	.00000	1.79039	.07564	.23571	.00089	-.00475	.00937	.99117	1.49291	.66391

Notes:

1. Positive directions of force coefficients, moment coefficients, and angles are indicated by arrows
2. For clarity, origins of wind and stability axes have been displaced from the center of gravity

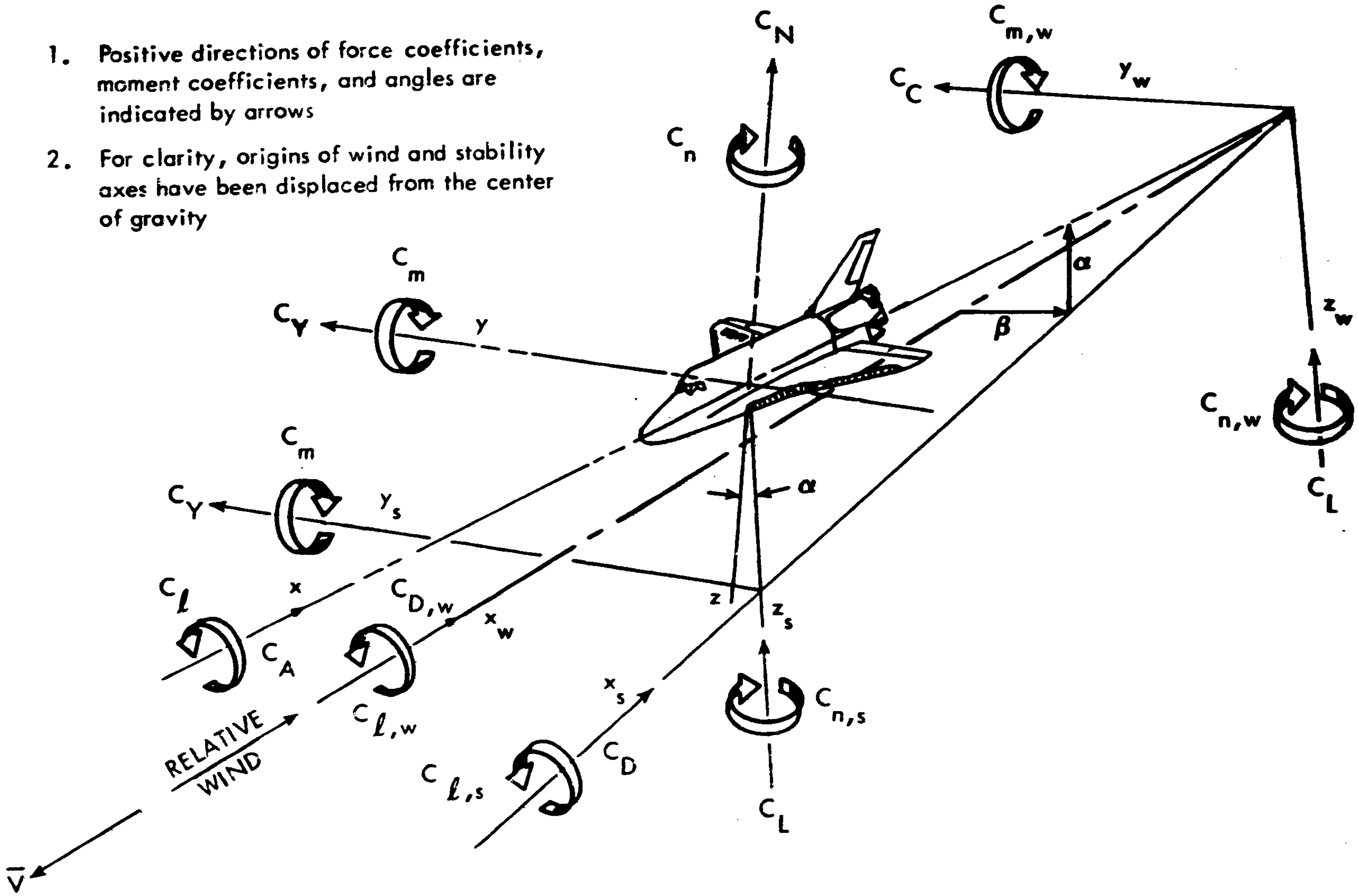


Figure 1.- System of axes used in the investigation

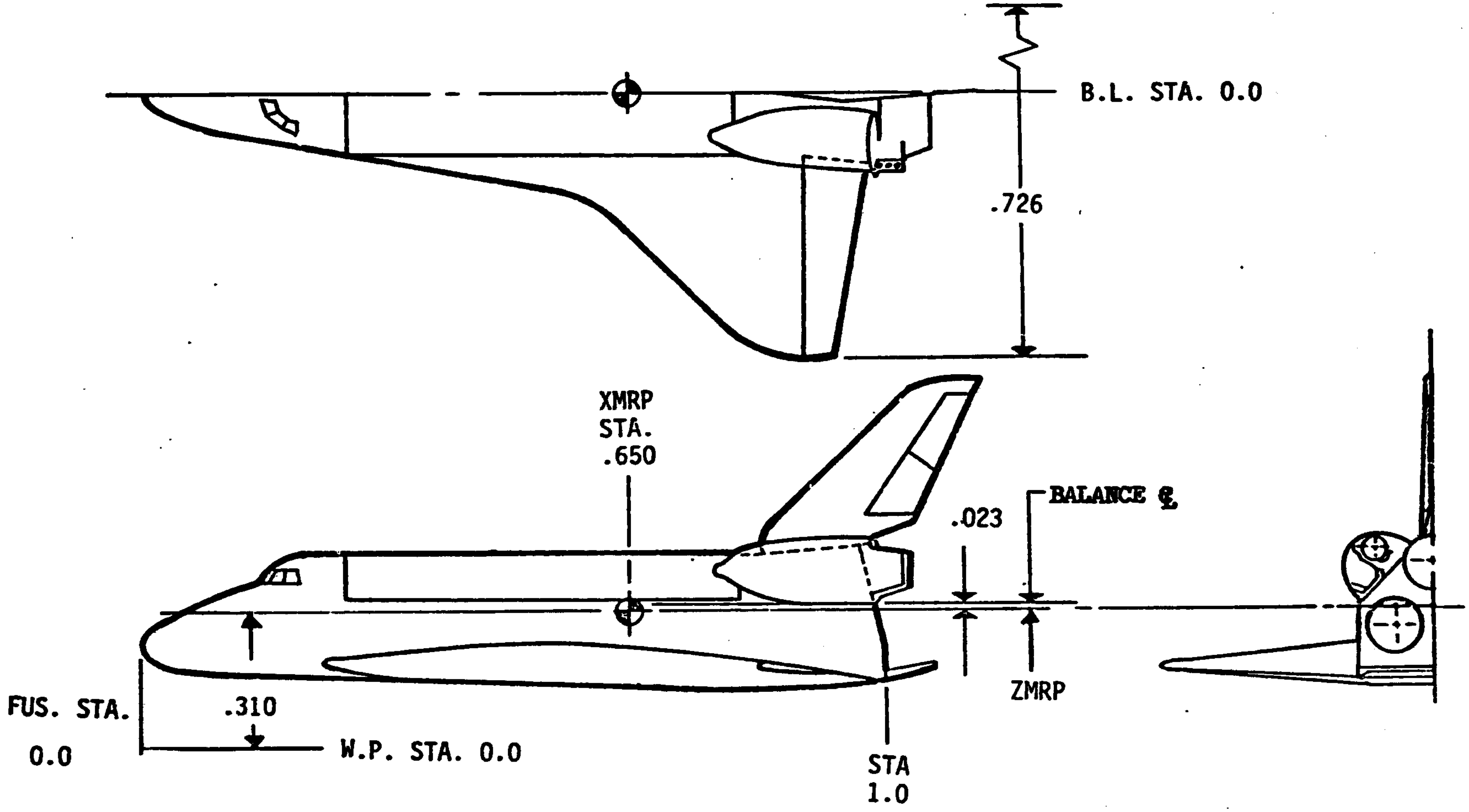
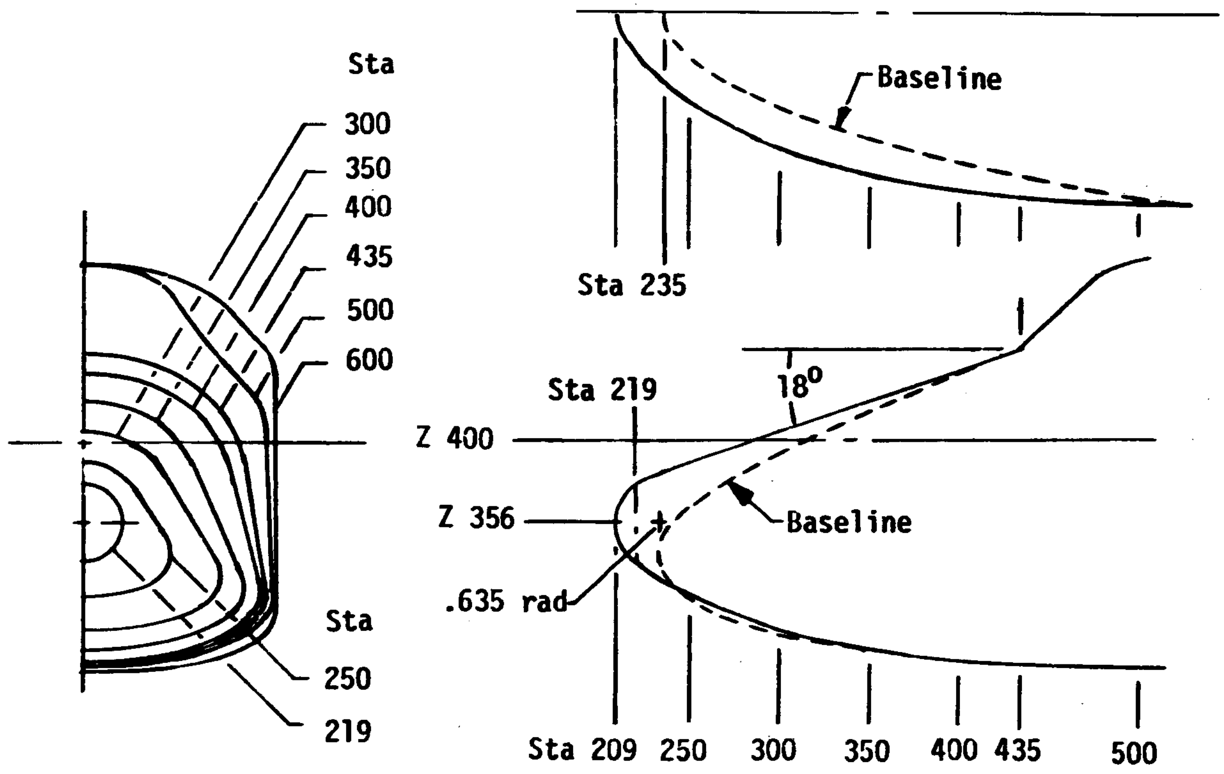
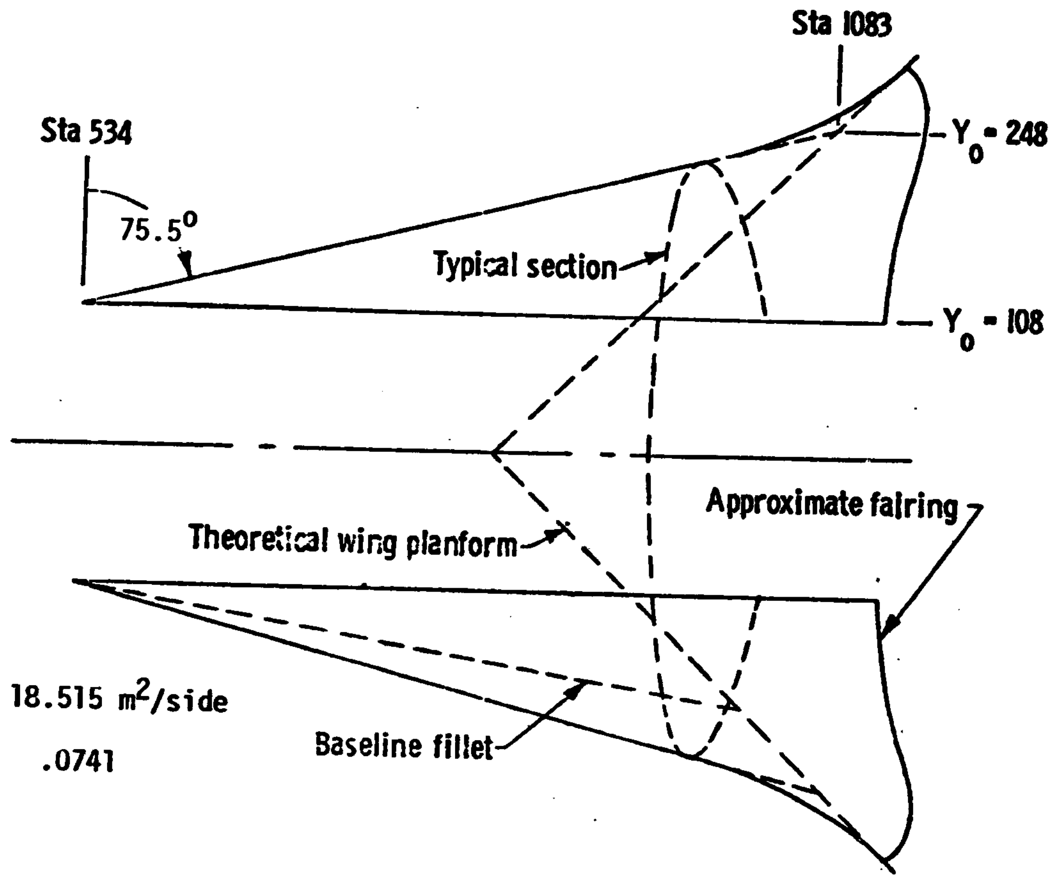


Figure 2.- General arrangement of orbiter model. All dimensions are normalized with respect to body length (13.109 cm (5.161 in.)).



(a) Maximum width forebody, B4

Figure 3.- Sketches of modifications tested. Body stations shown are full-scale vehicle stations.

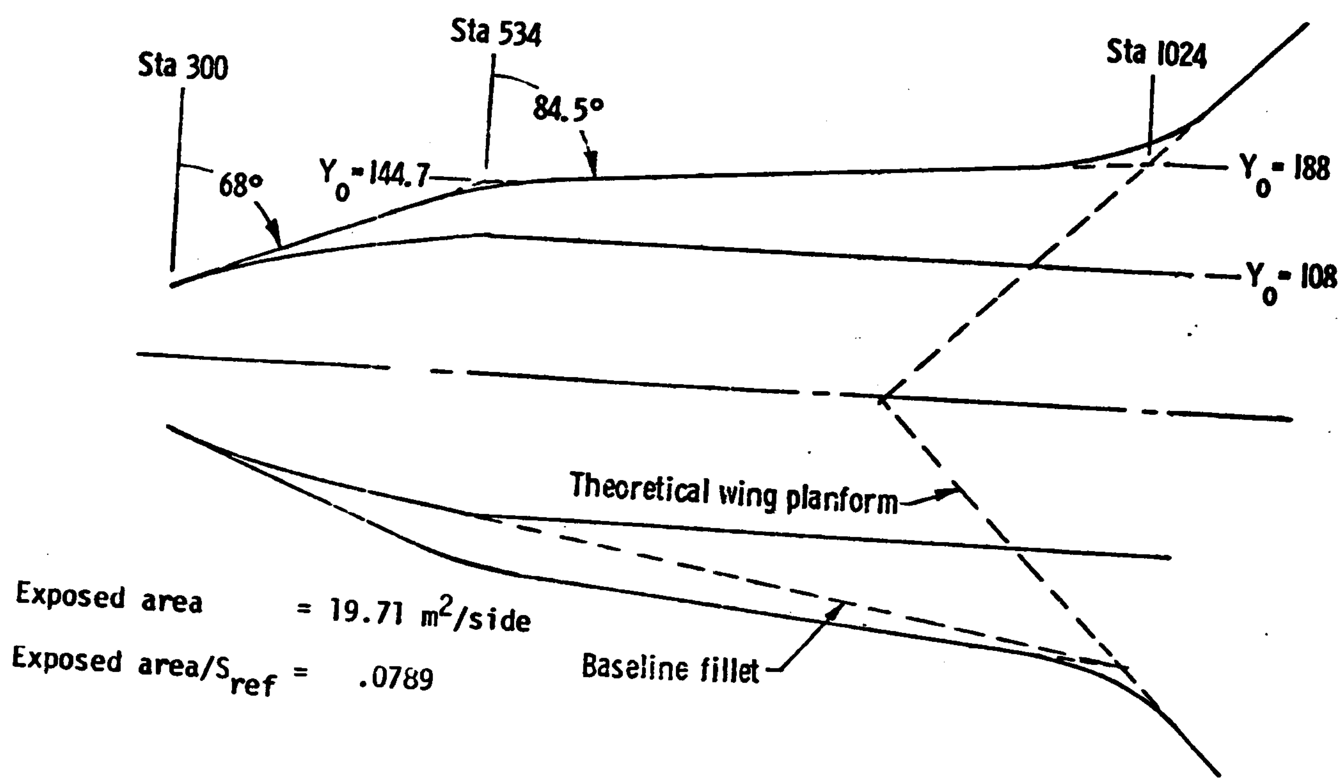


Exposed area = 18.515 m^2/side

Exposed area/S_{ref} = .0741

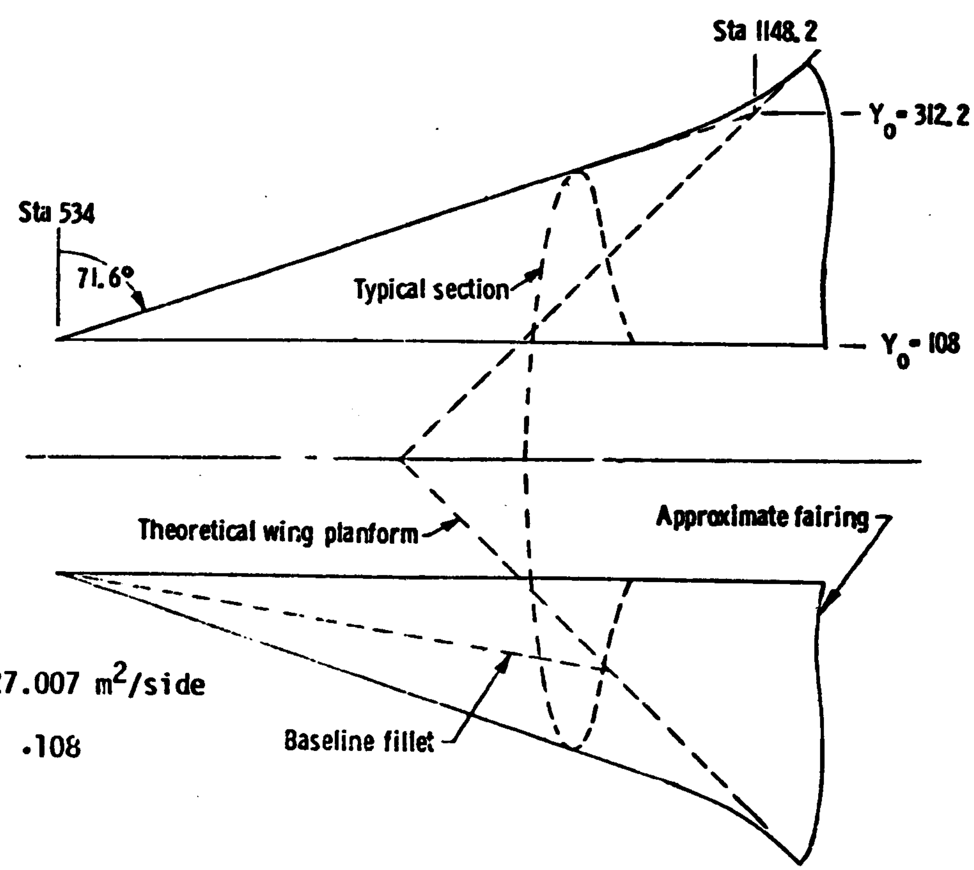
(b) Removable fillet, S1

Figure 3.- Continued.



(c) Removable fillet, S2

Figure 3.- Continued.

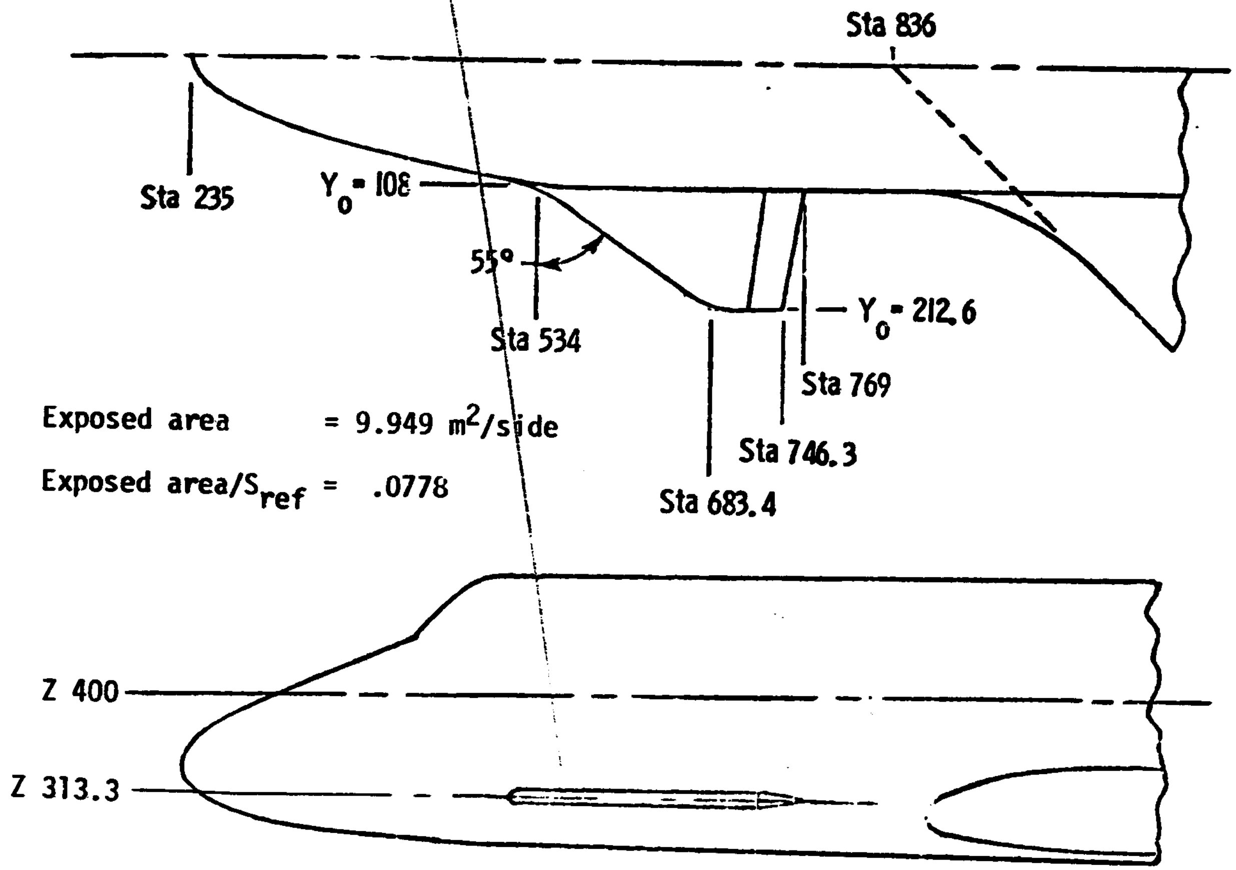


Exposed area = 27.007 m^2/side

Exposed area/S_{ref} = .108

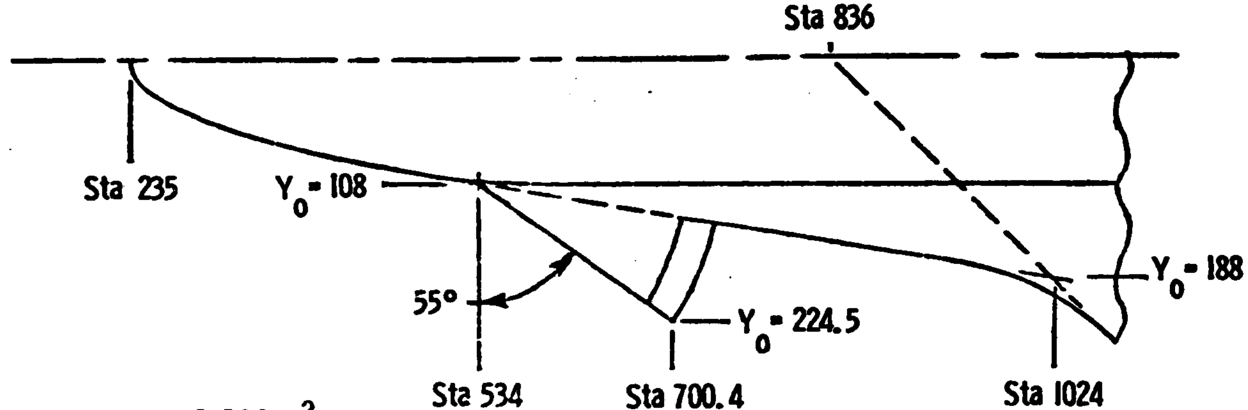
(d) Removable fillet, S3

Figure 3.- Continued.



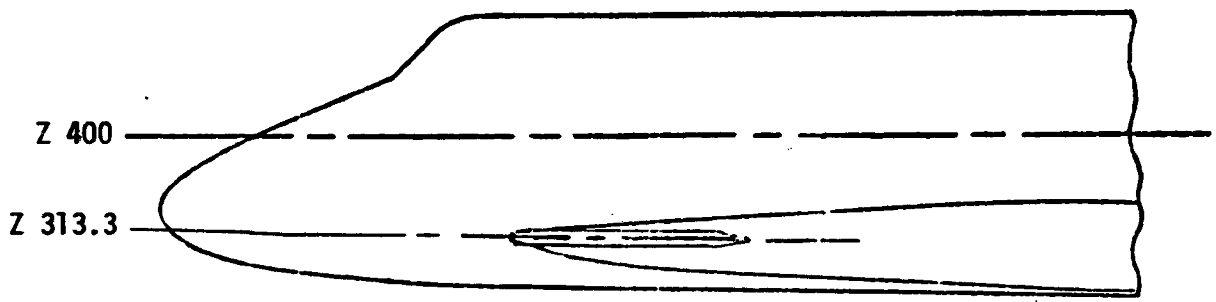
(e) Canard trimmer C2, fillet removed

Figure 3.- Continued.



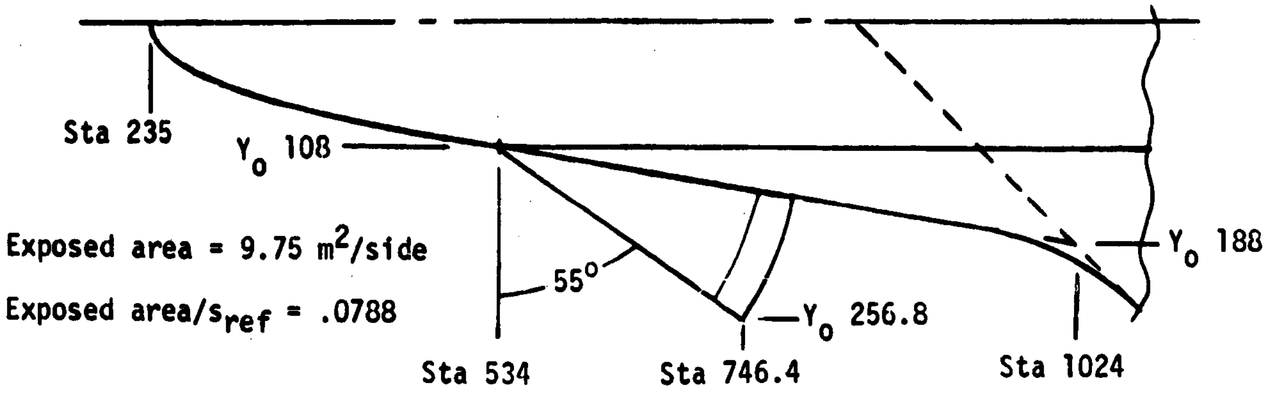
Exposed area = 6.184 m^2/side

Exposed area/S_{ref} = .0483

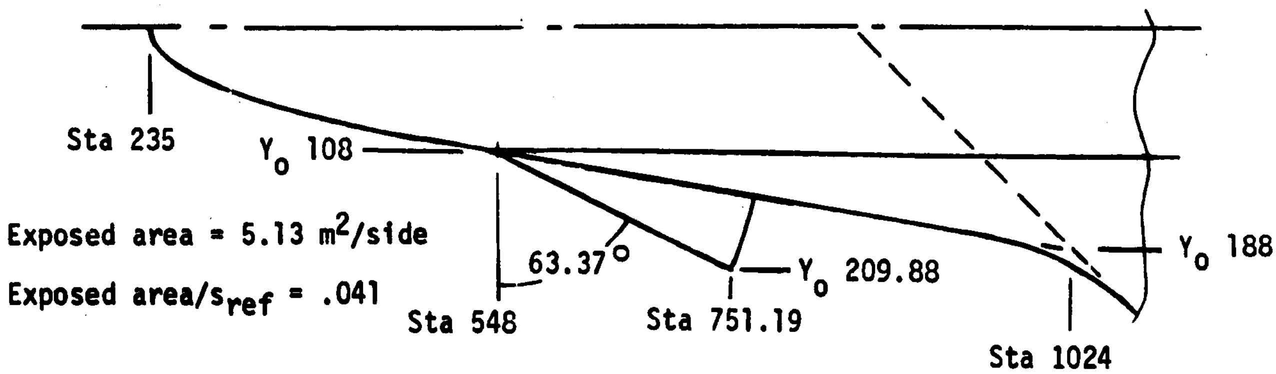


(f) Canard trimmer C3, baseline fillet

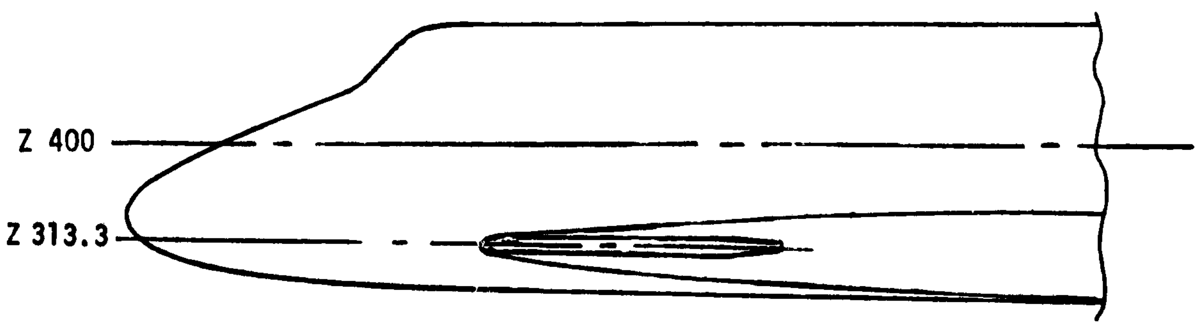
Figure 3.- Continued.



CANARD C4

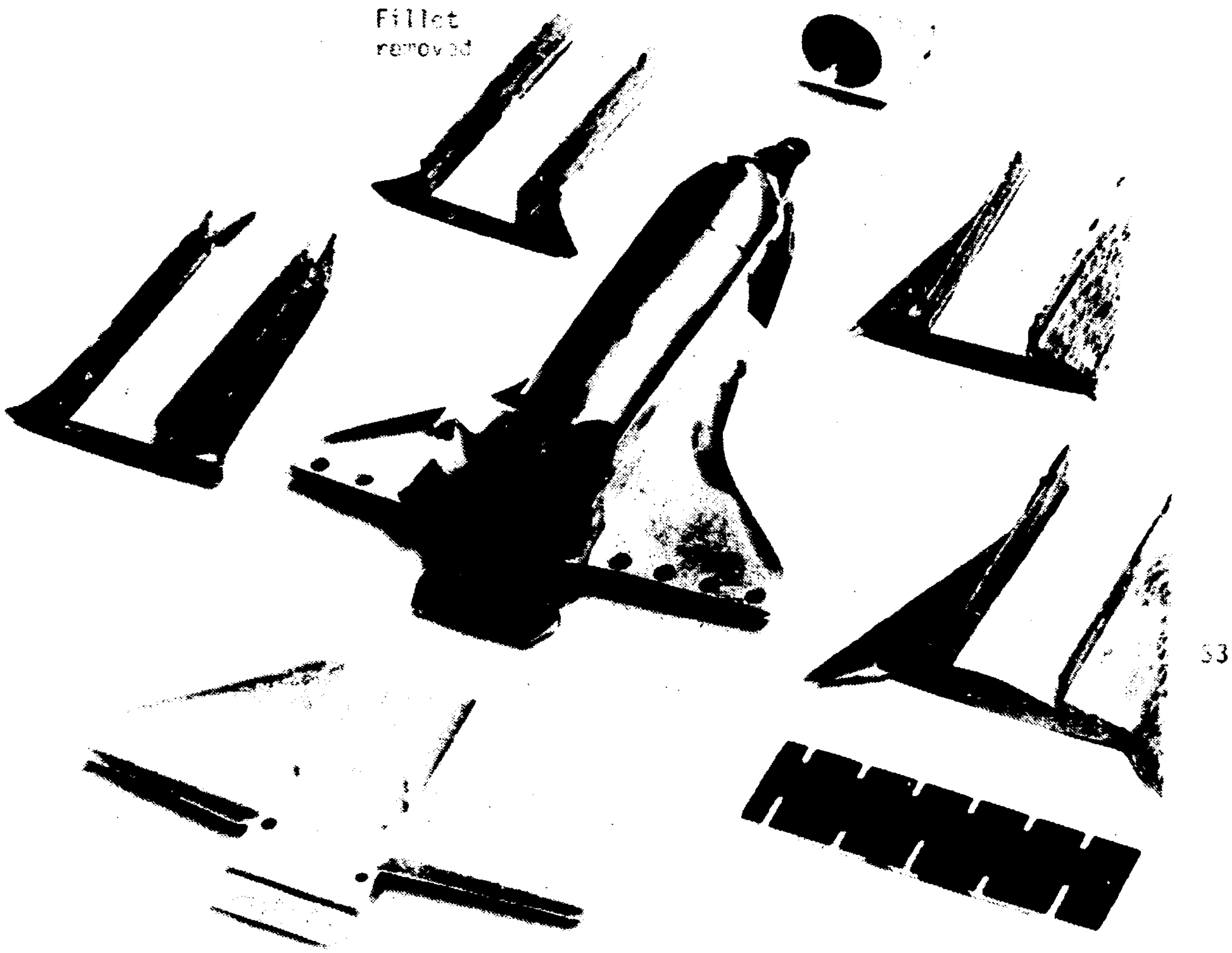


CANARD C5



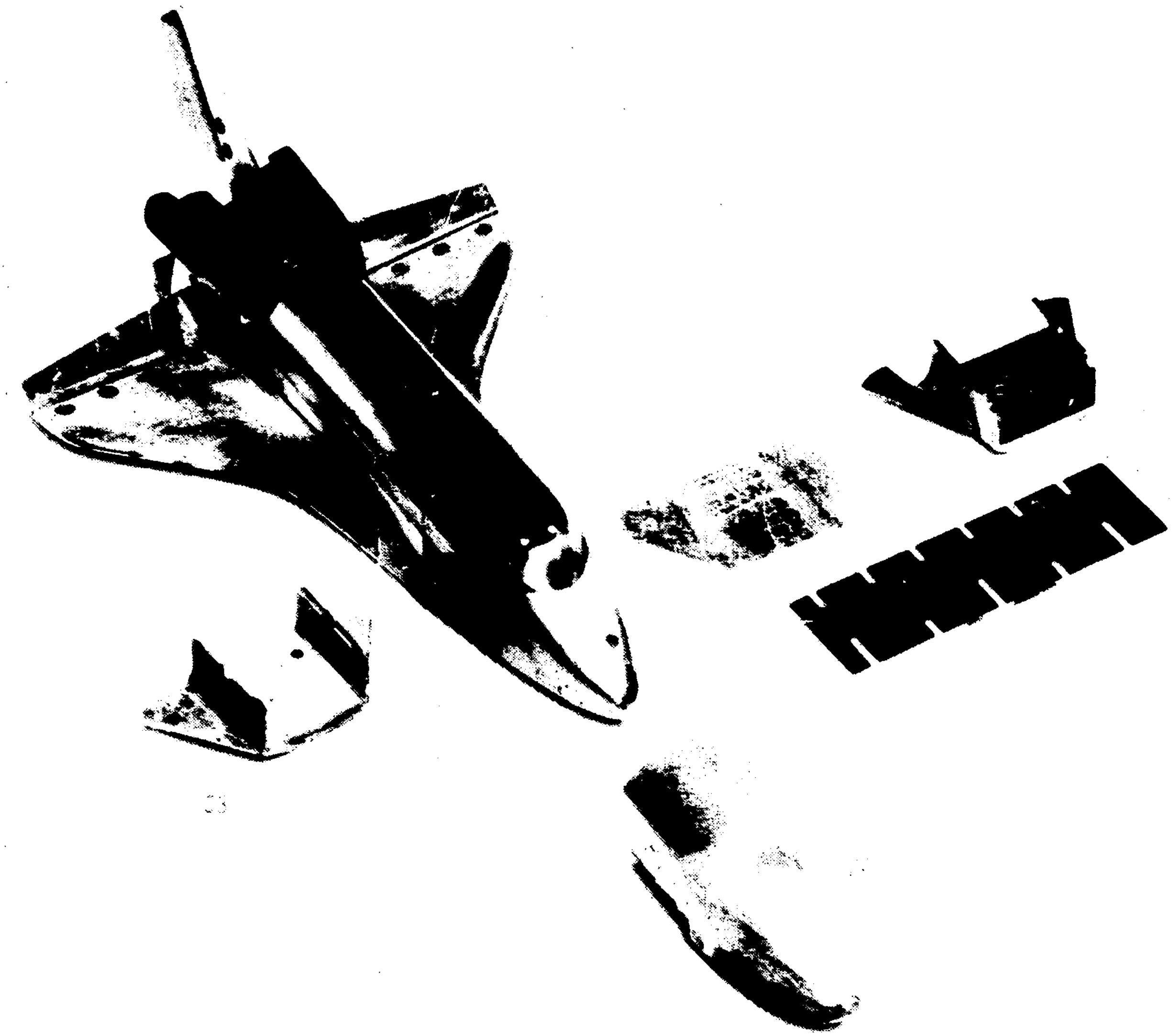
(g) Canard trimmers, C4 and C5, baseline fillet

Figure 3.-Concluded



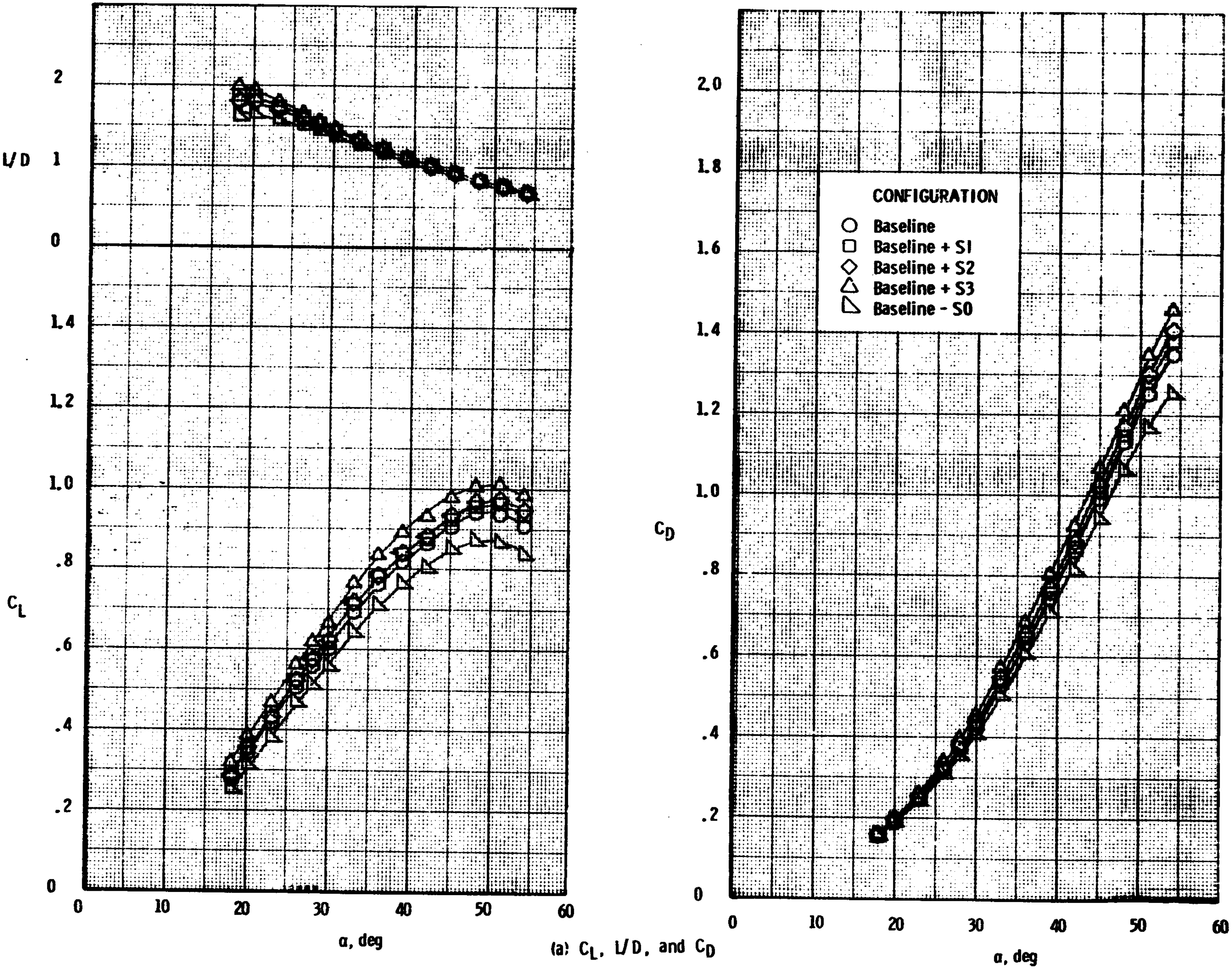
(a) Fillet and forebody modifications

Figure 4.- Photographs of model and components.



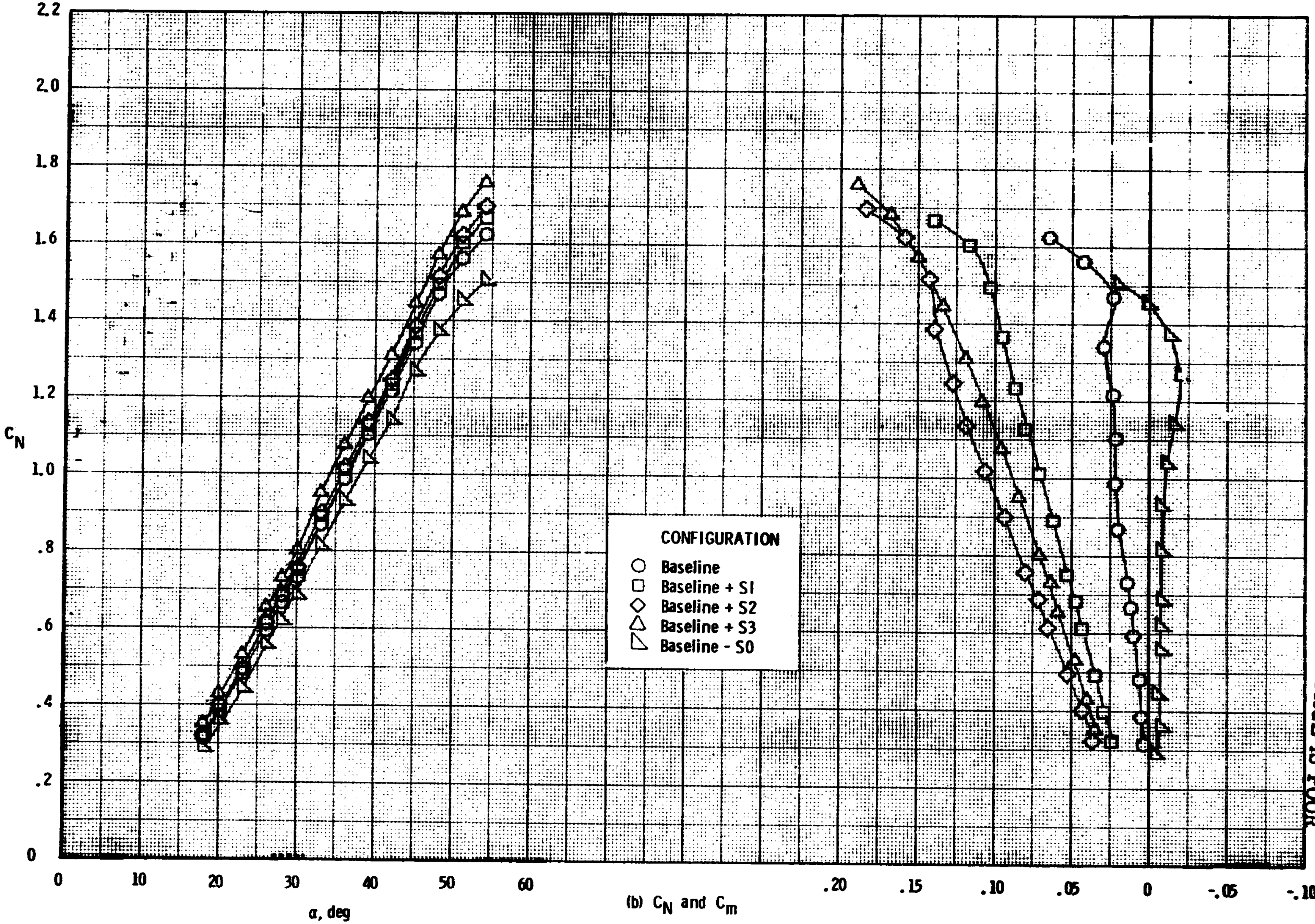
(b) Canards and forebody modifications.

Figure 4.- Concluded.



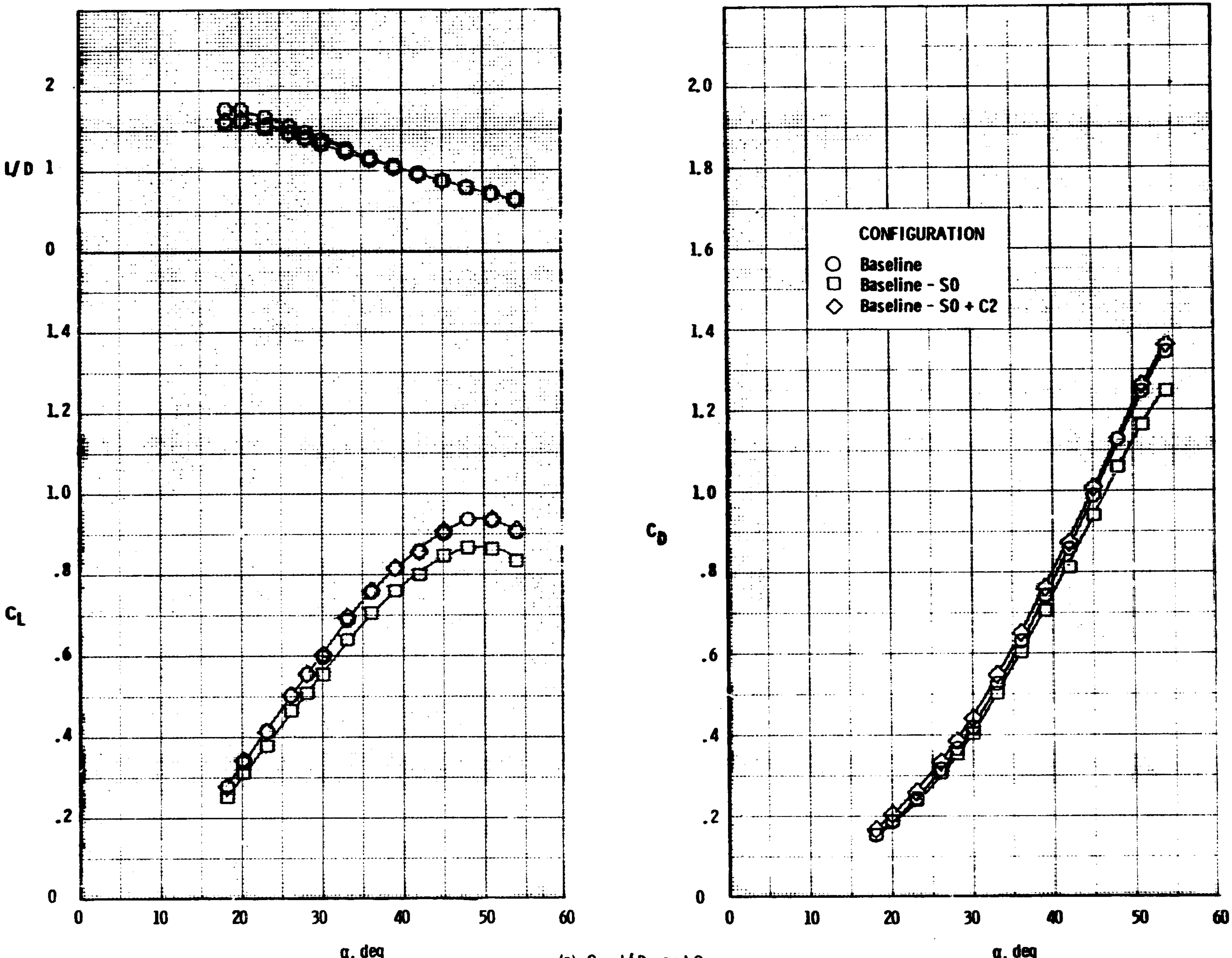
(a) C_L, L/D, and C_D

Figure 5.- Effect of fillet planform modifications on the longitudinal characteristics of the 139B orbiter. $\delta_e = -40$, $\delta_{BF} = -14.25$, M = 20.3.



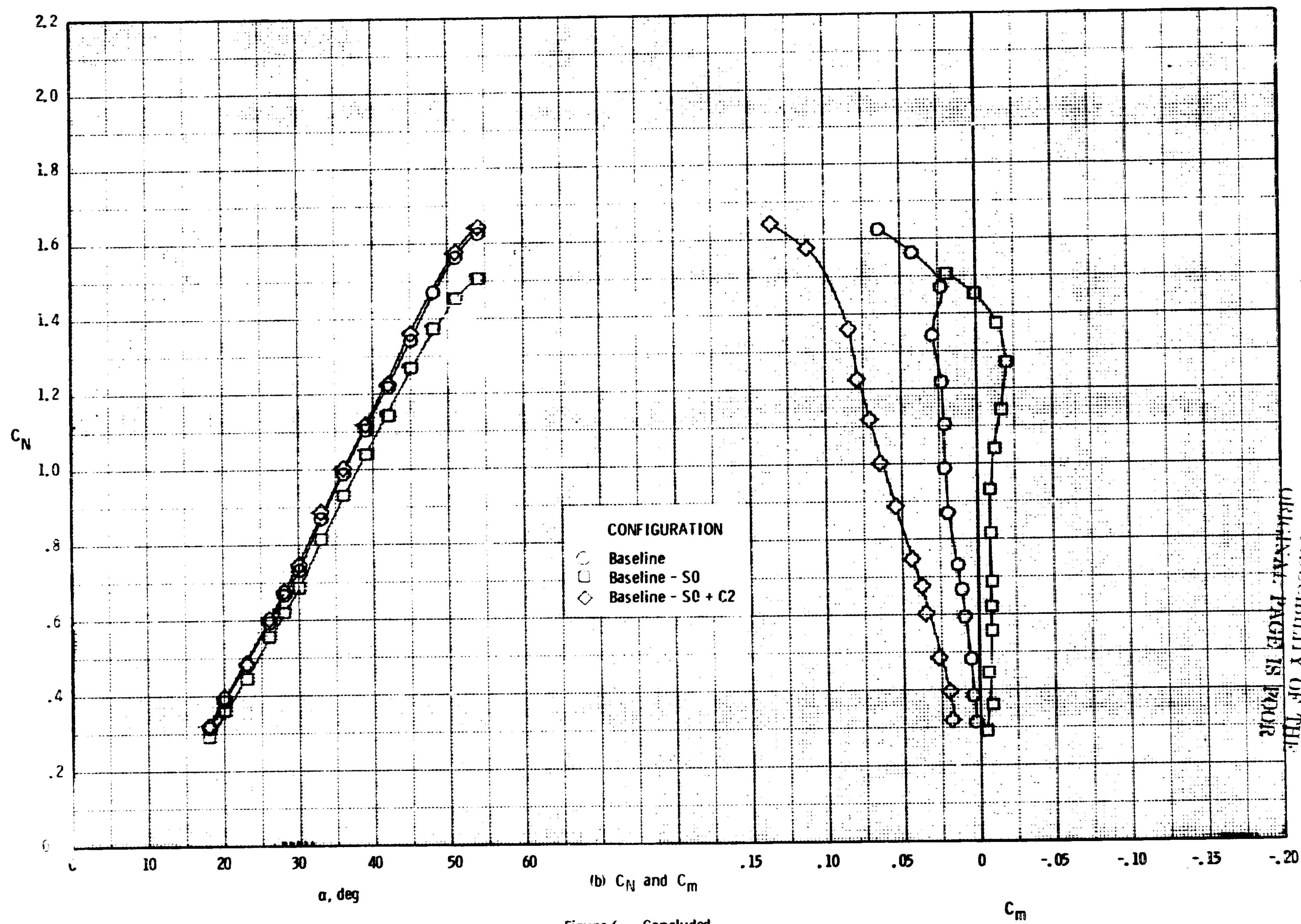
(b) C_N and C_m

Figure 5.- Concluded.



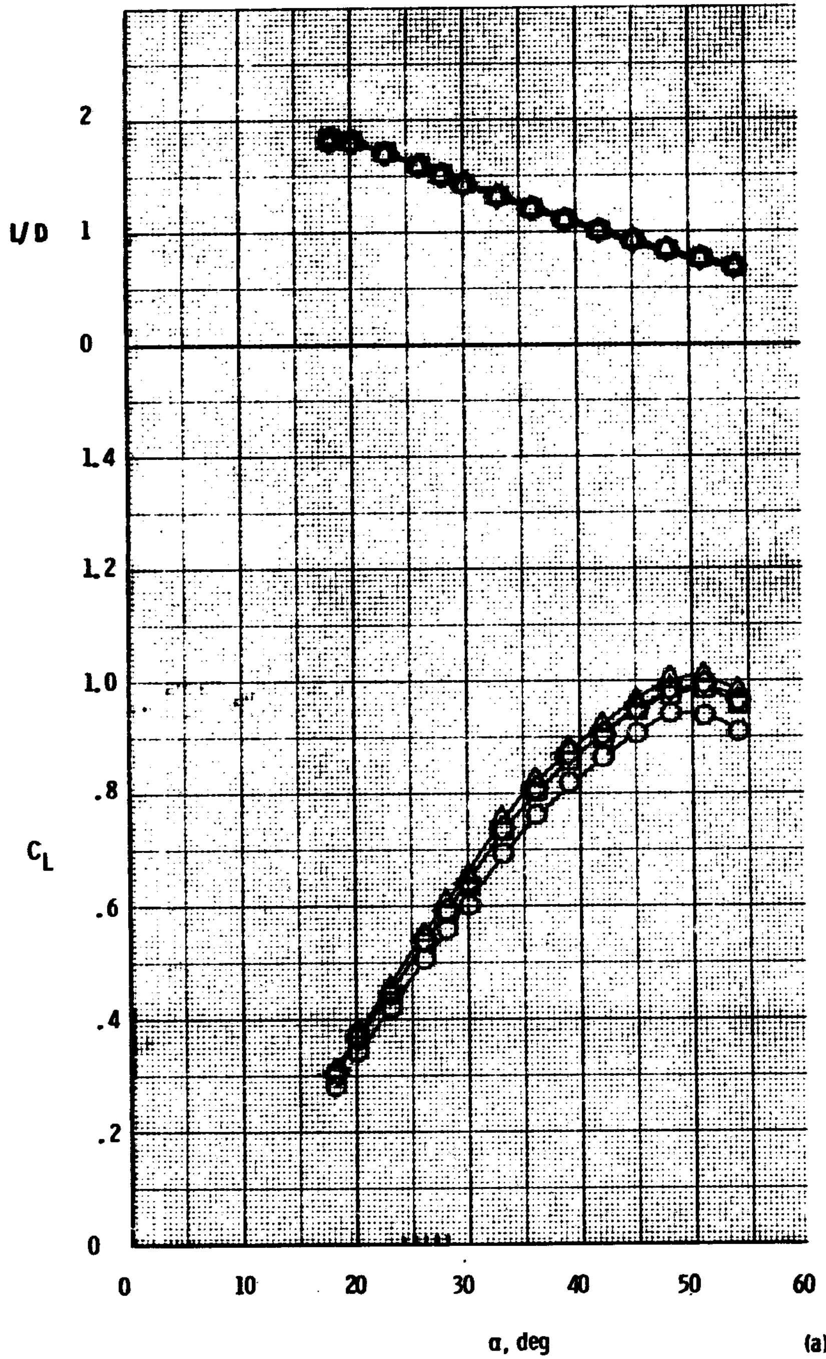
(a) C_L, L/D, and C_D

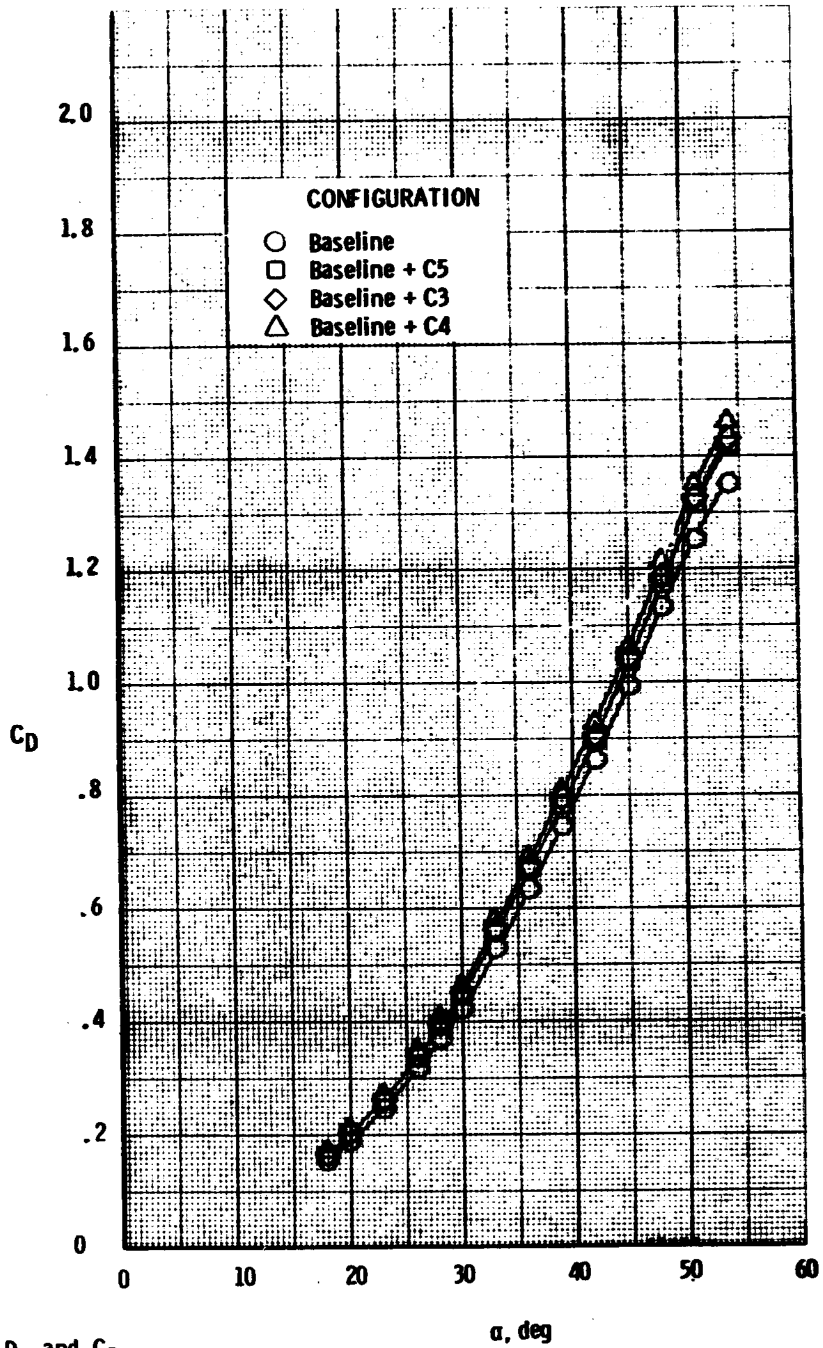
Figure 6.- Effect of replacing baseline fillet with a canard on the longitudinal characteristics of the 139B orbiter. $\delta_e = -40$, $\delta_{BF} = 14.25$, M = 20.3.



(b) C_N and C_m

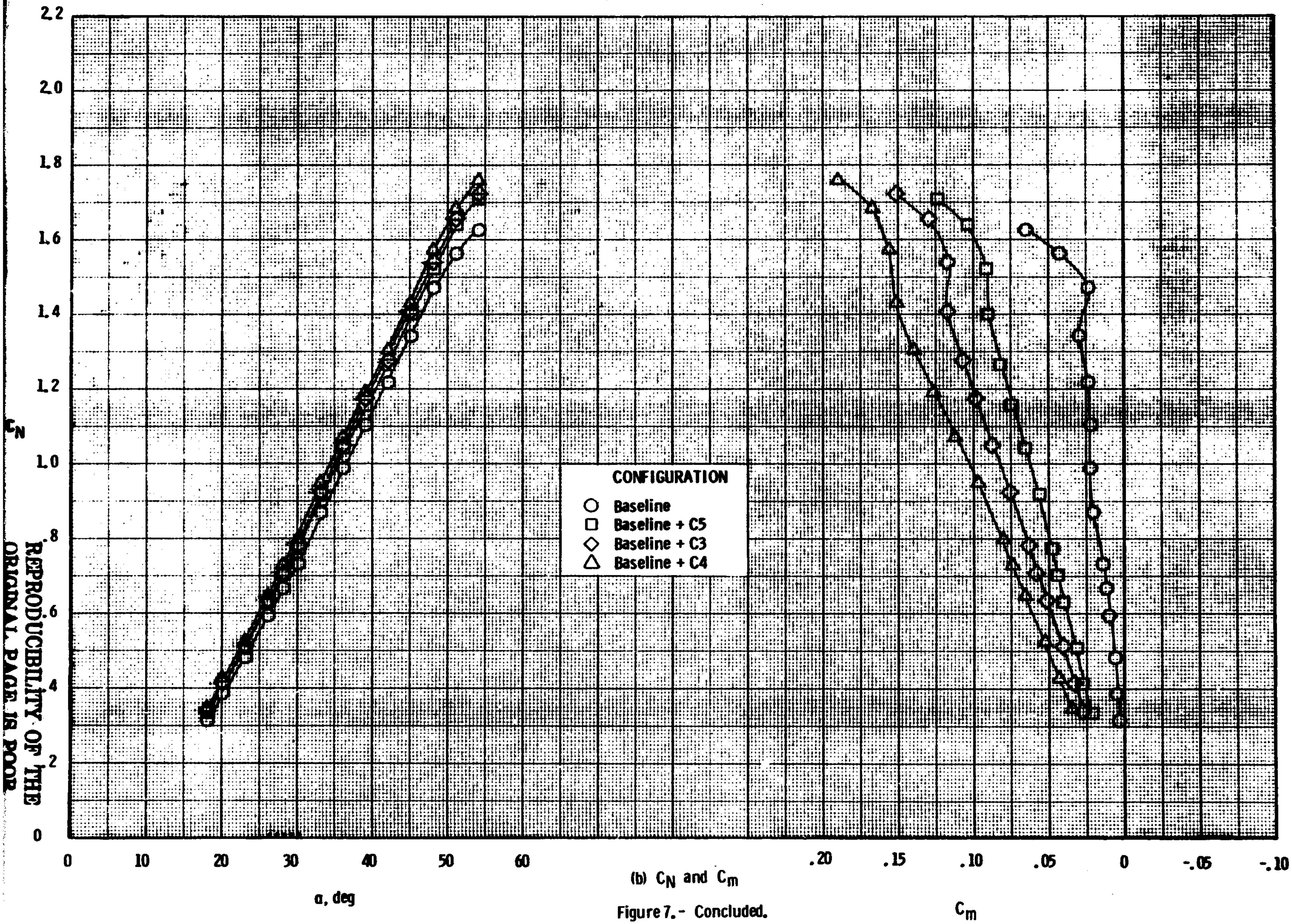
Figure 6.- Concluded.





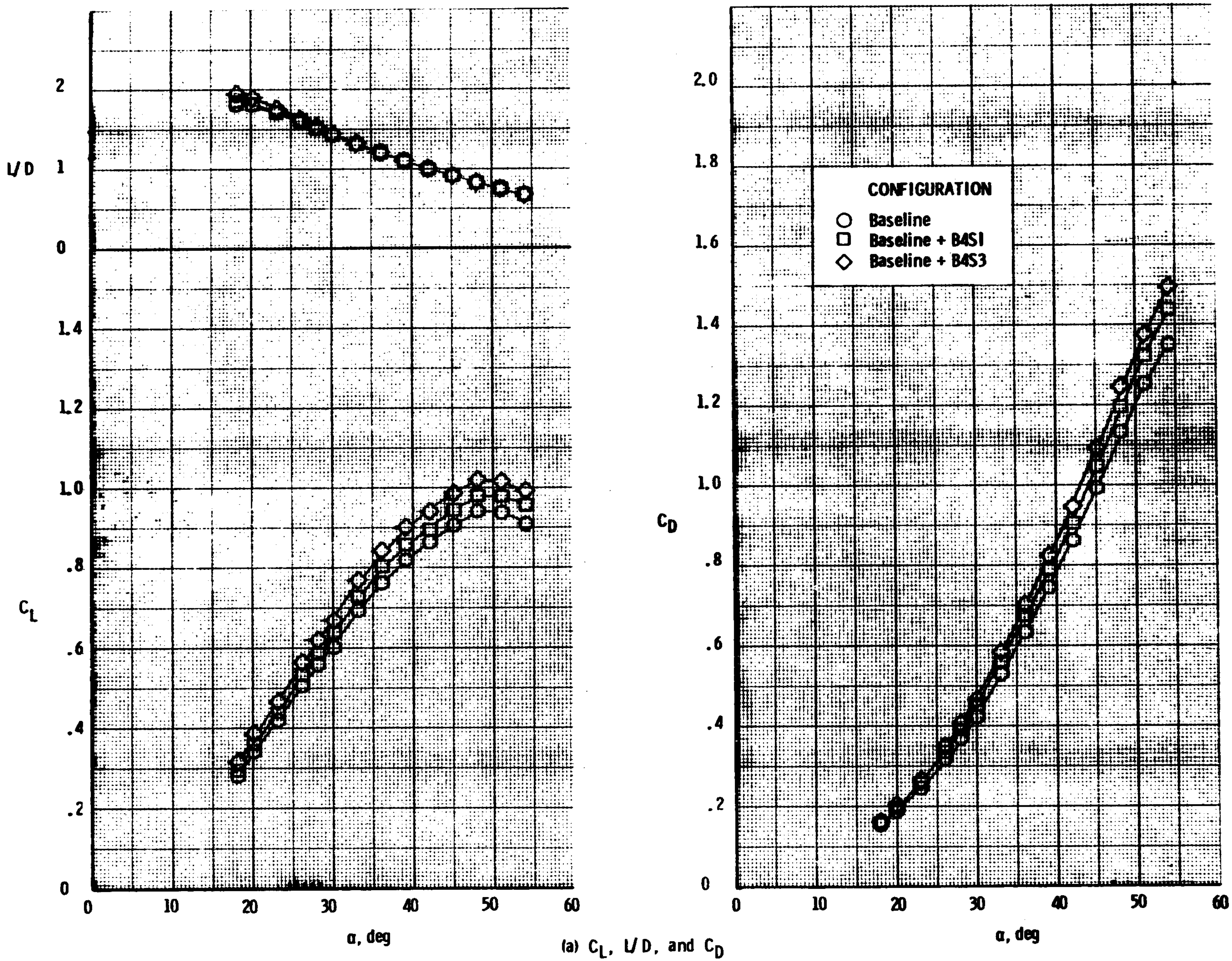
(a) C_L, L/D, and C_D

Figure 7.- Effect of in-fillet canards on the longitudinal characteristics of the 139B orbiter. $\delta_e = -40$, $\delta_{BF} = -14.25$, $M = 20.3$.



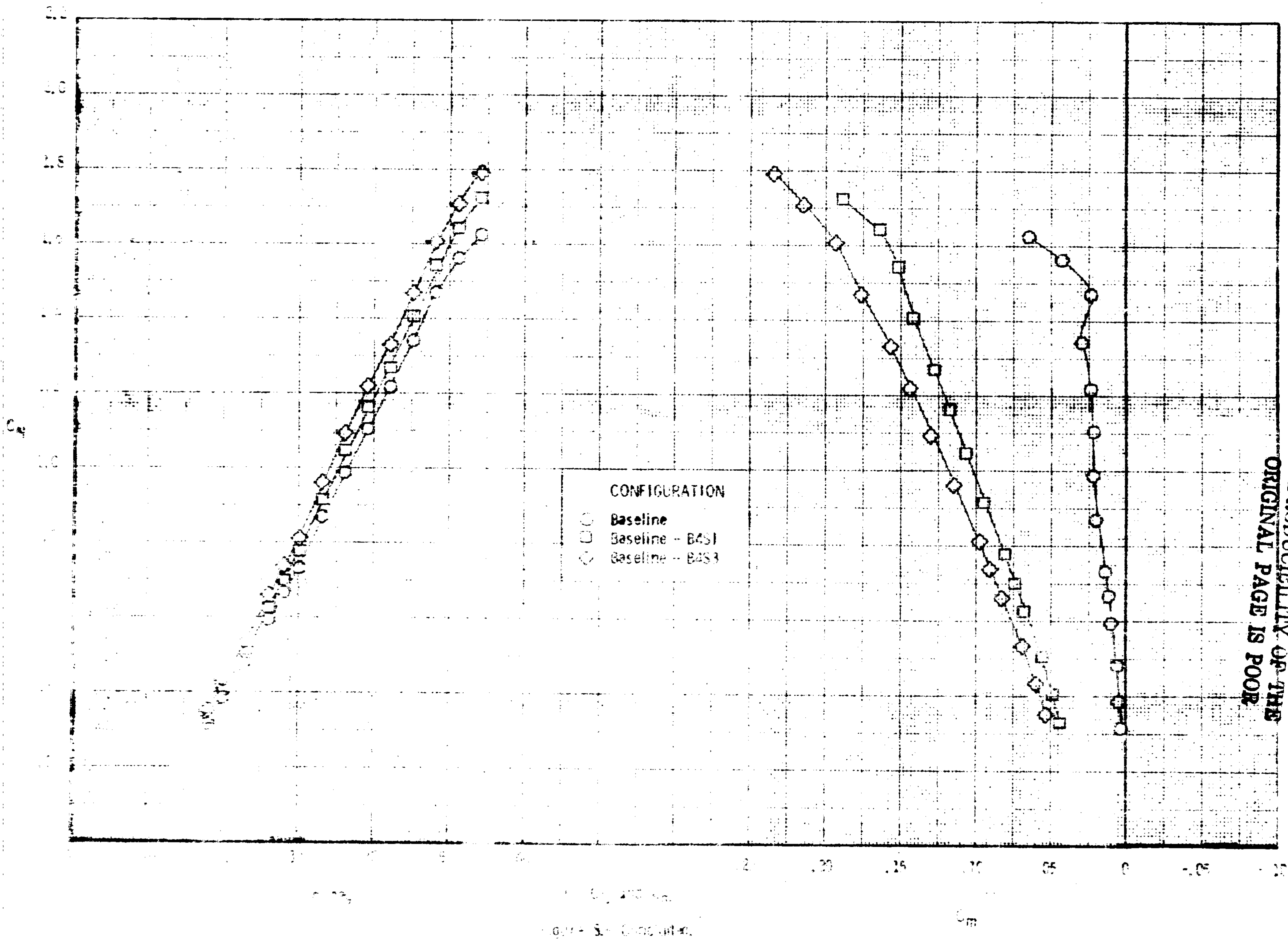
(b) C_N and C_m

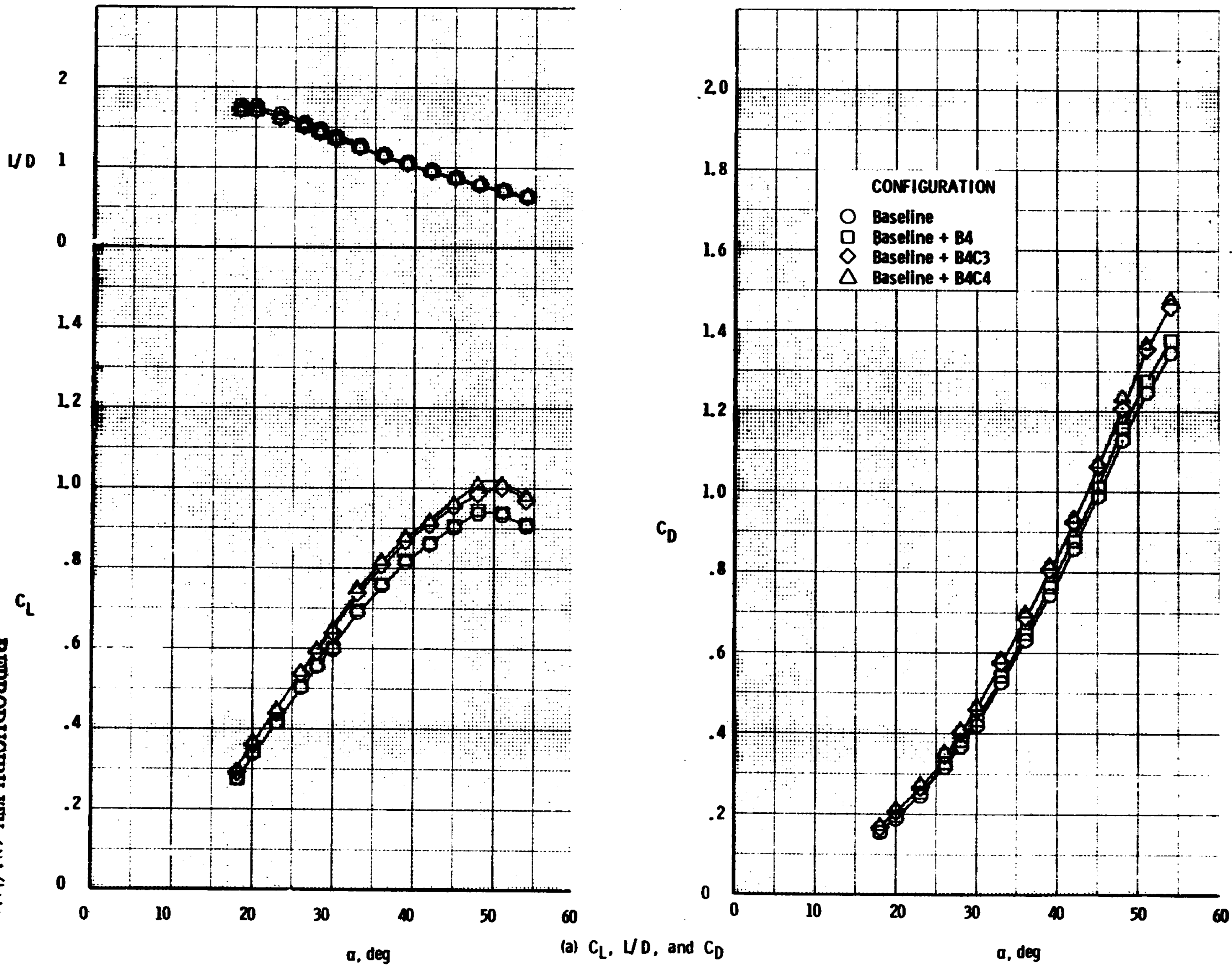
Figure 7.- Concluded.



(a) C_L, L/D, and C_D

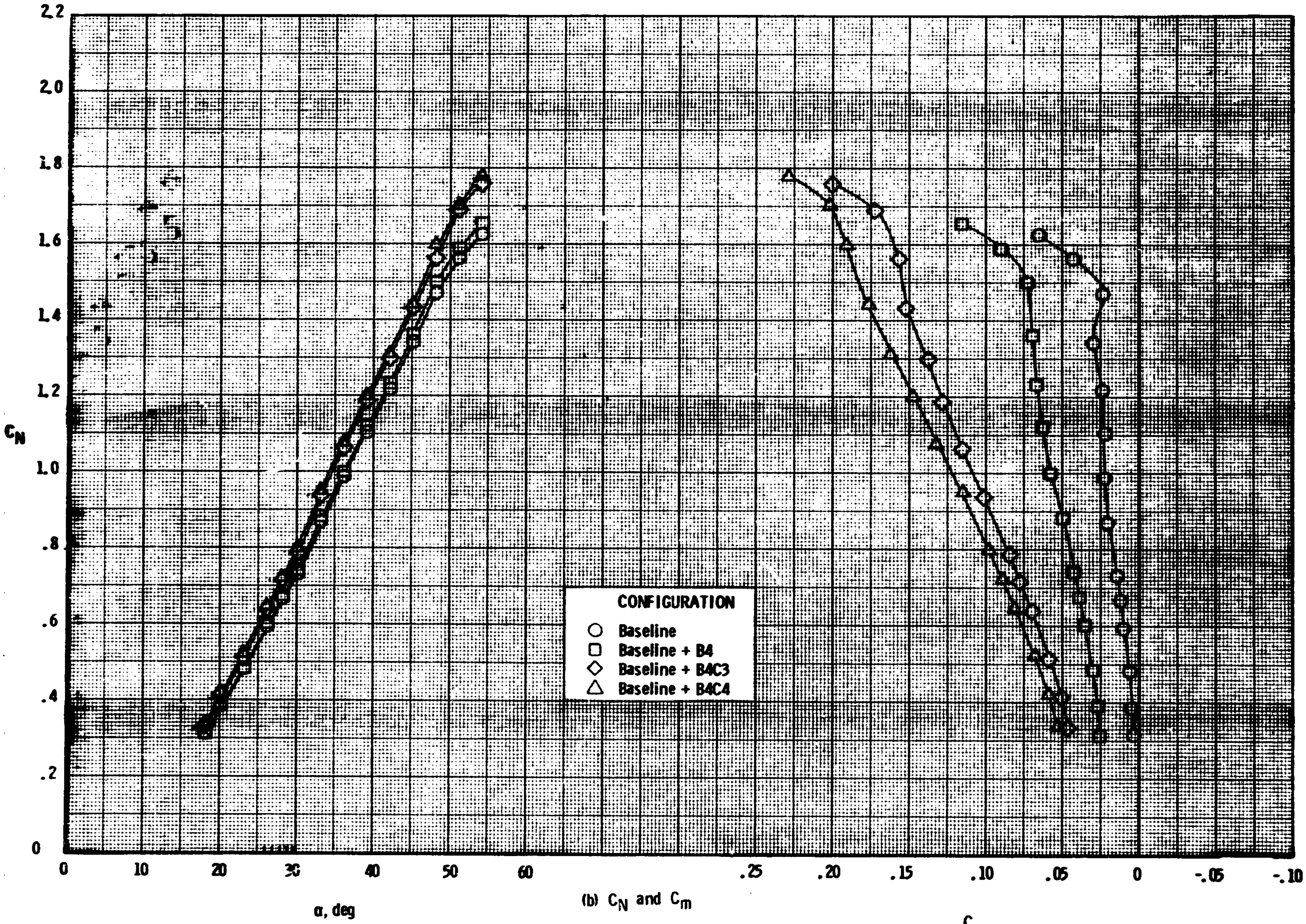
Figure 8.- Effect of forebody and forebody-fillet combinations on the longitudinal characteristics of the 139B orbiter. $\delta_e = -40$, $\delta_{BF} = -14.25$, M = 20.3.


CONFIGURATION
Baseline
Baseline -- B4S1
Baseline -- B4S3
C_m



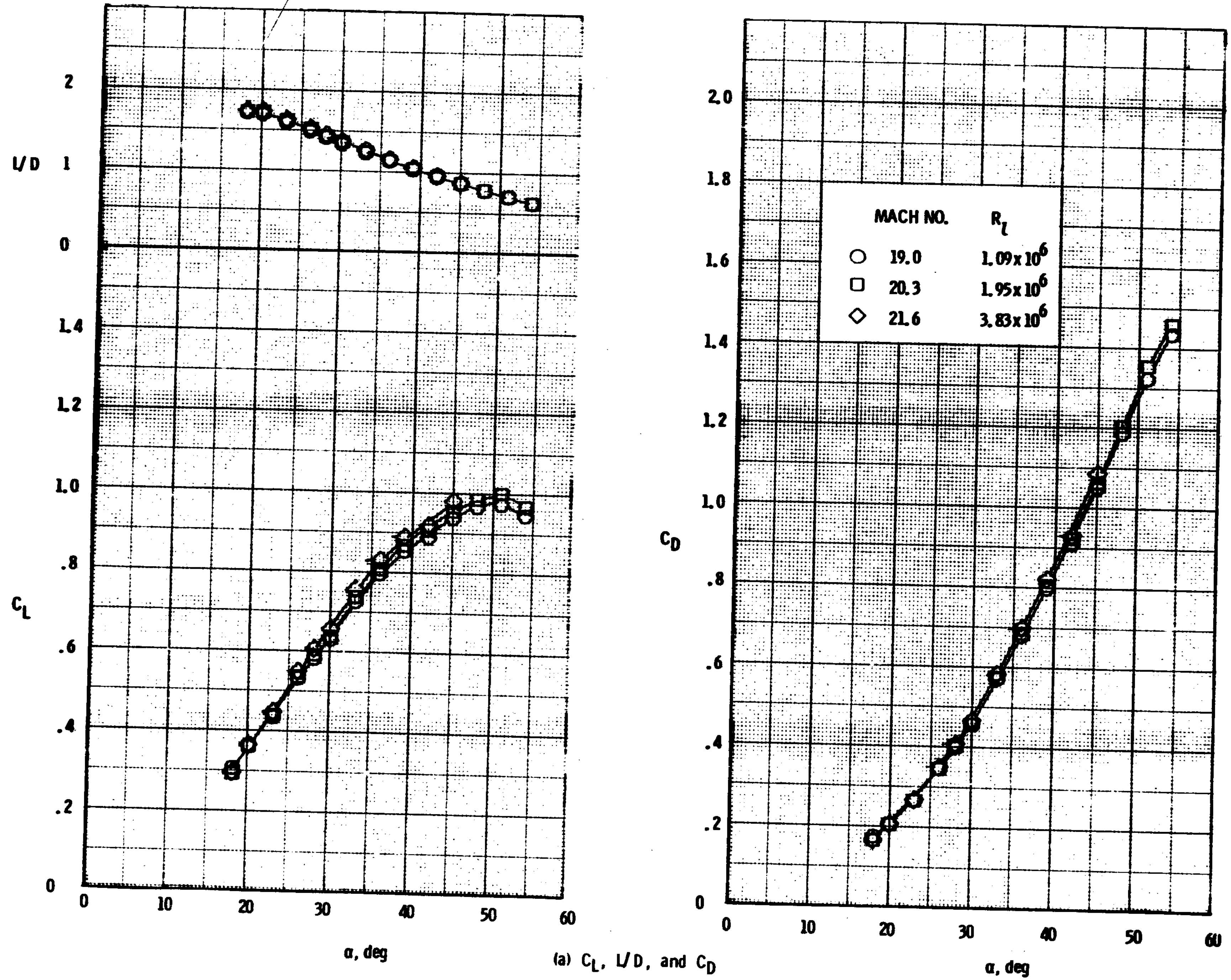
(a) C_L, L/D, and C_D

Figure 9.- Effect of forebody-canard combinations on the longitudinal characteristics of the 139B orbiter. $\delta_e = -40$, $\delta_{BF} = -14.25$, $M = 20.3$.



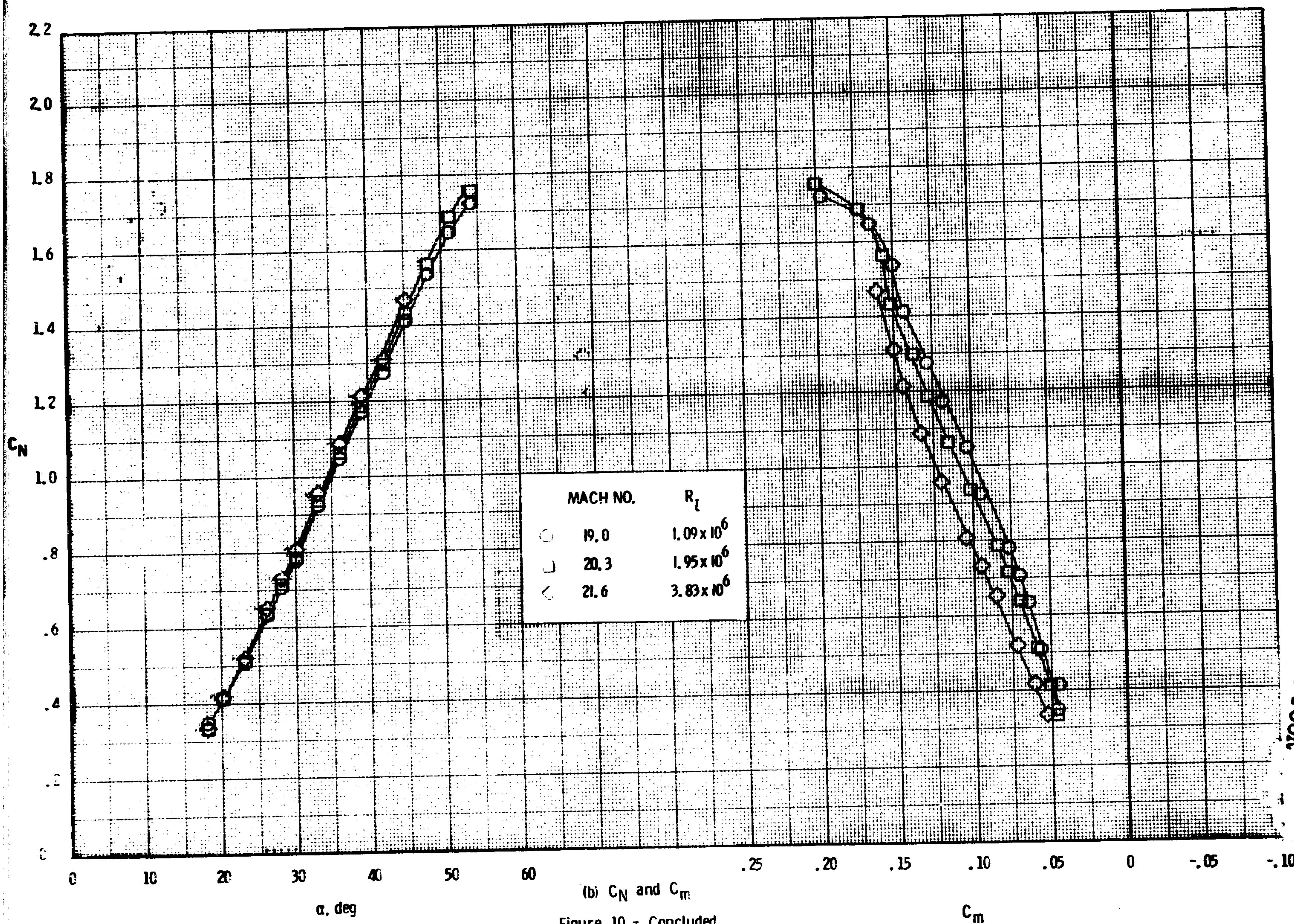
(b) C_N and C_m

Figure 9.- Concluded.



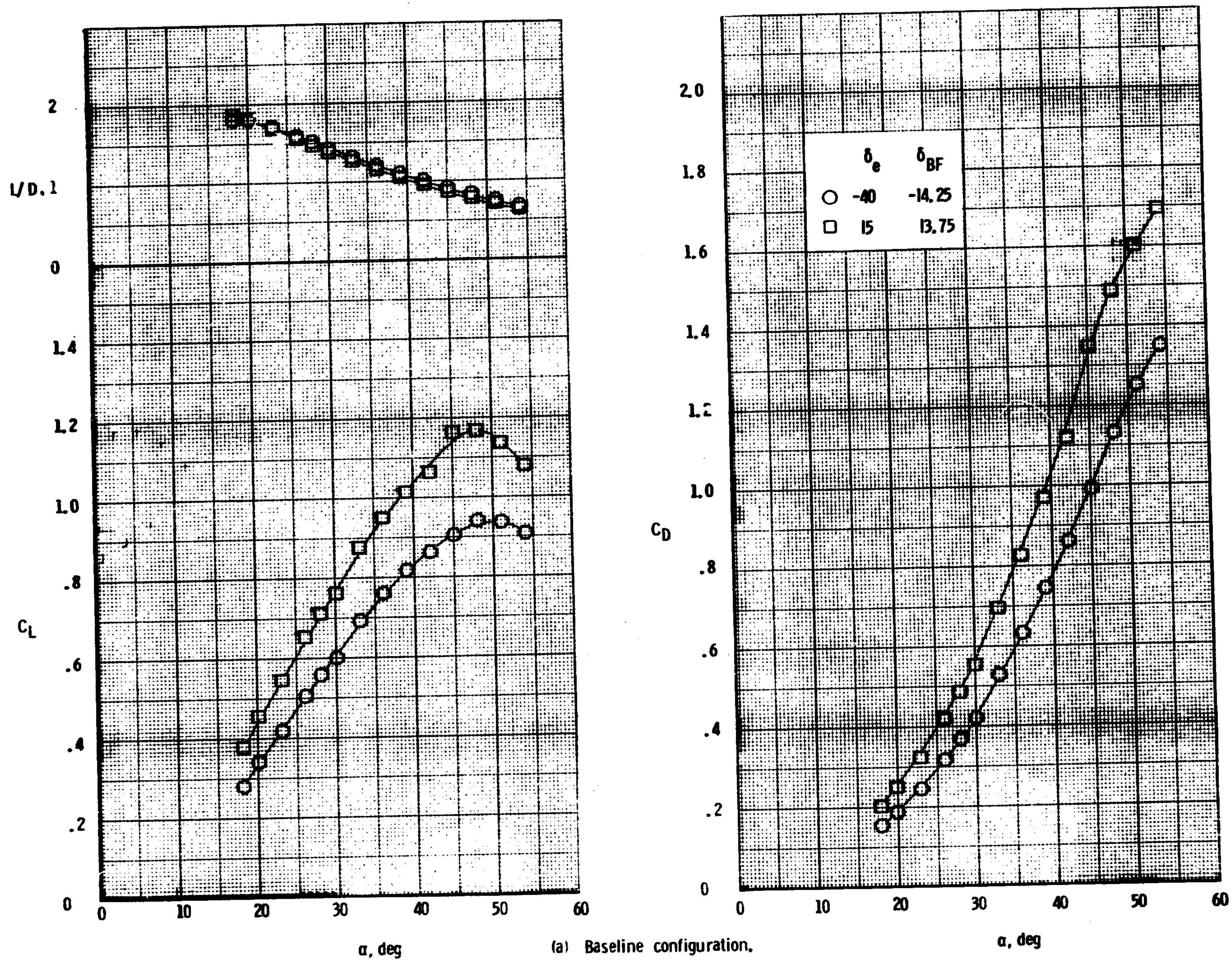
(a) C_L, L/D, and C_D

Figure 10.- Effect of Mach and Reynolds number on the longitudinal characteristics of the 139B orbiter, with forebody-canard combination B4C3. $\delta_e = -40°$, $\delta_{BF} = -14.25$.



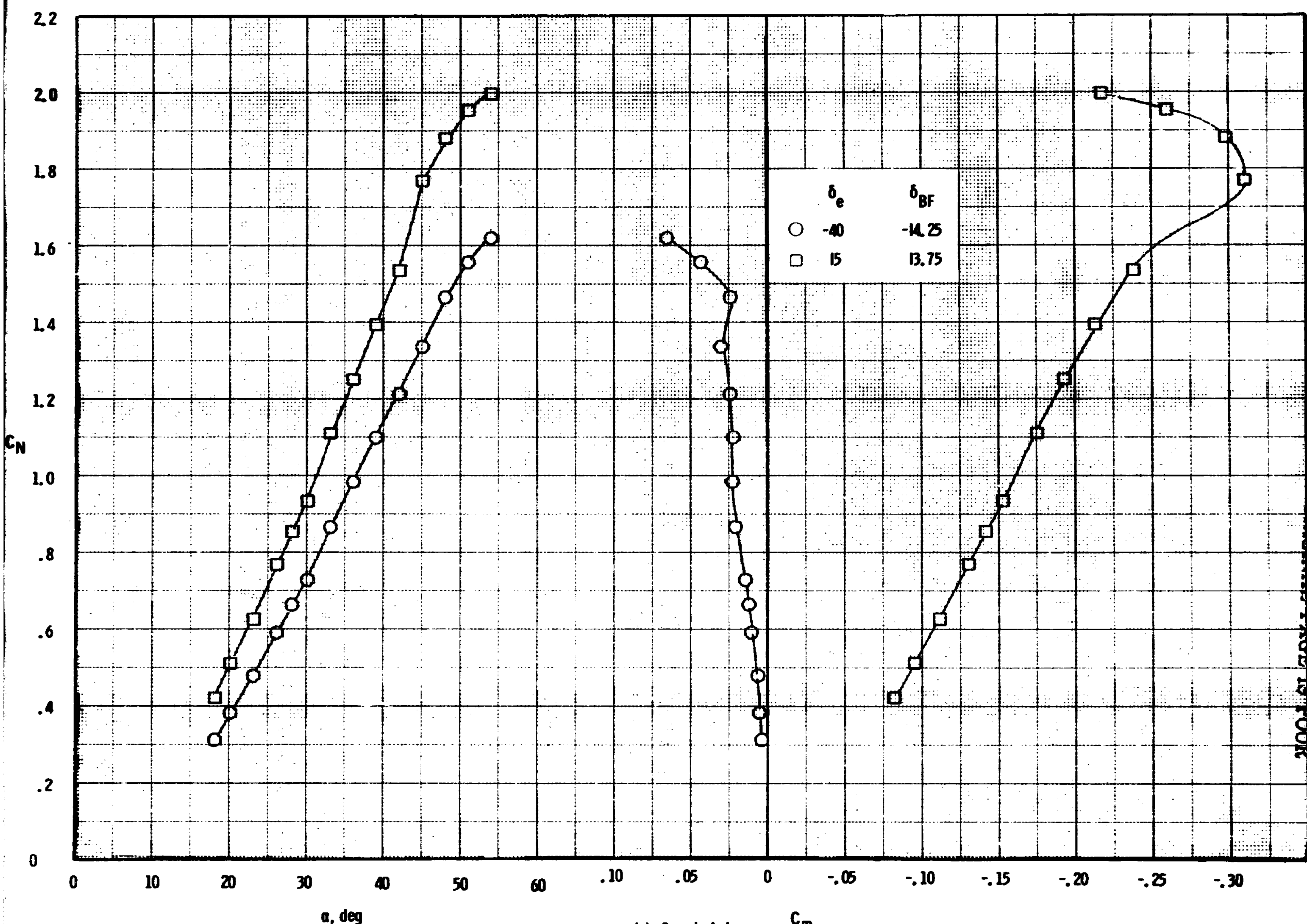
(b) C_N and C_m

Figure 10. - Concluded.



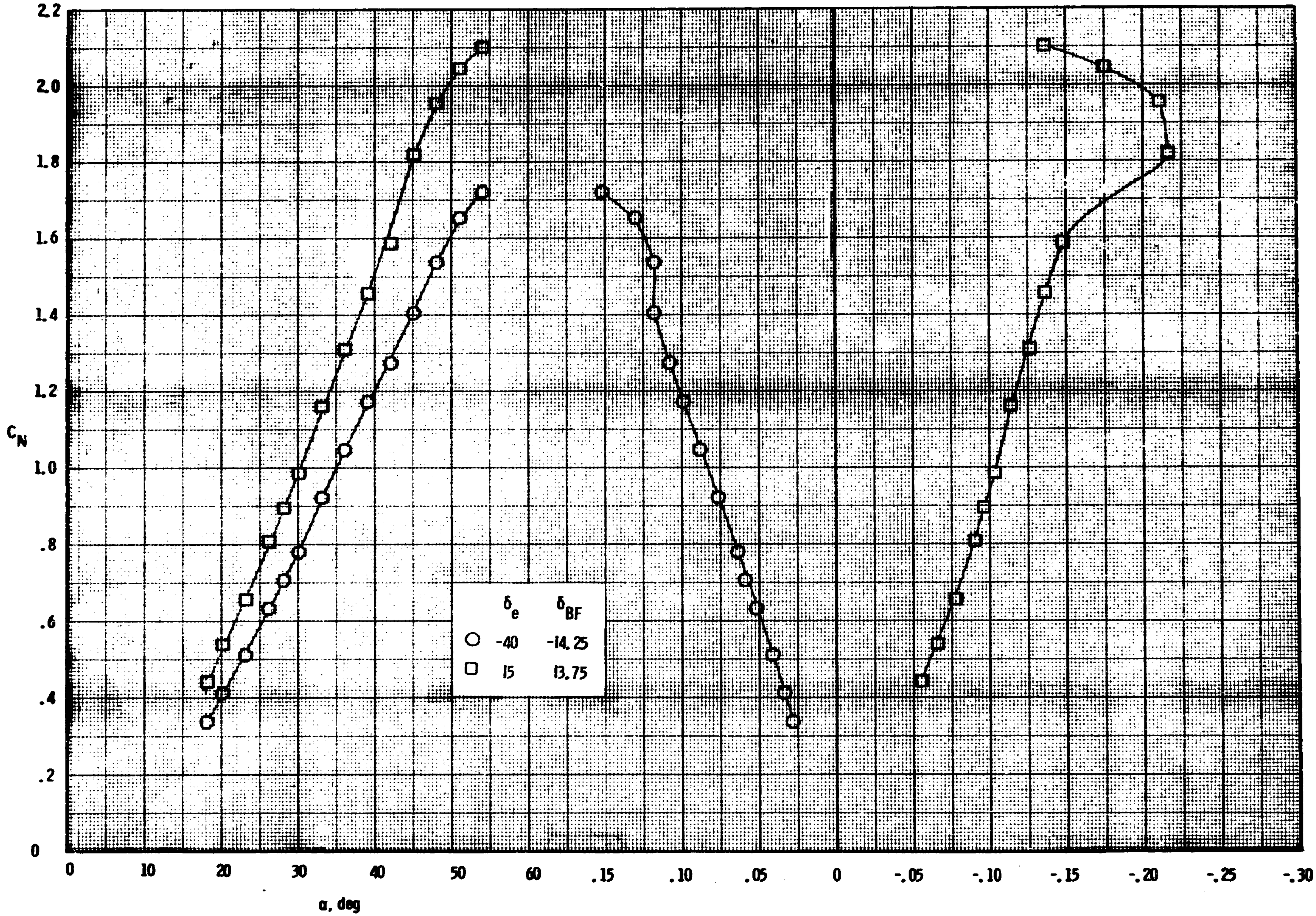
(a) Baseline configuration.

Figure 11.- Effect of maximum elevon and body-flap deflections on the longitudinal characteristics of the 139B orbiter with various forebody and canard combinations. M = 20.3.



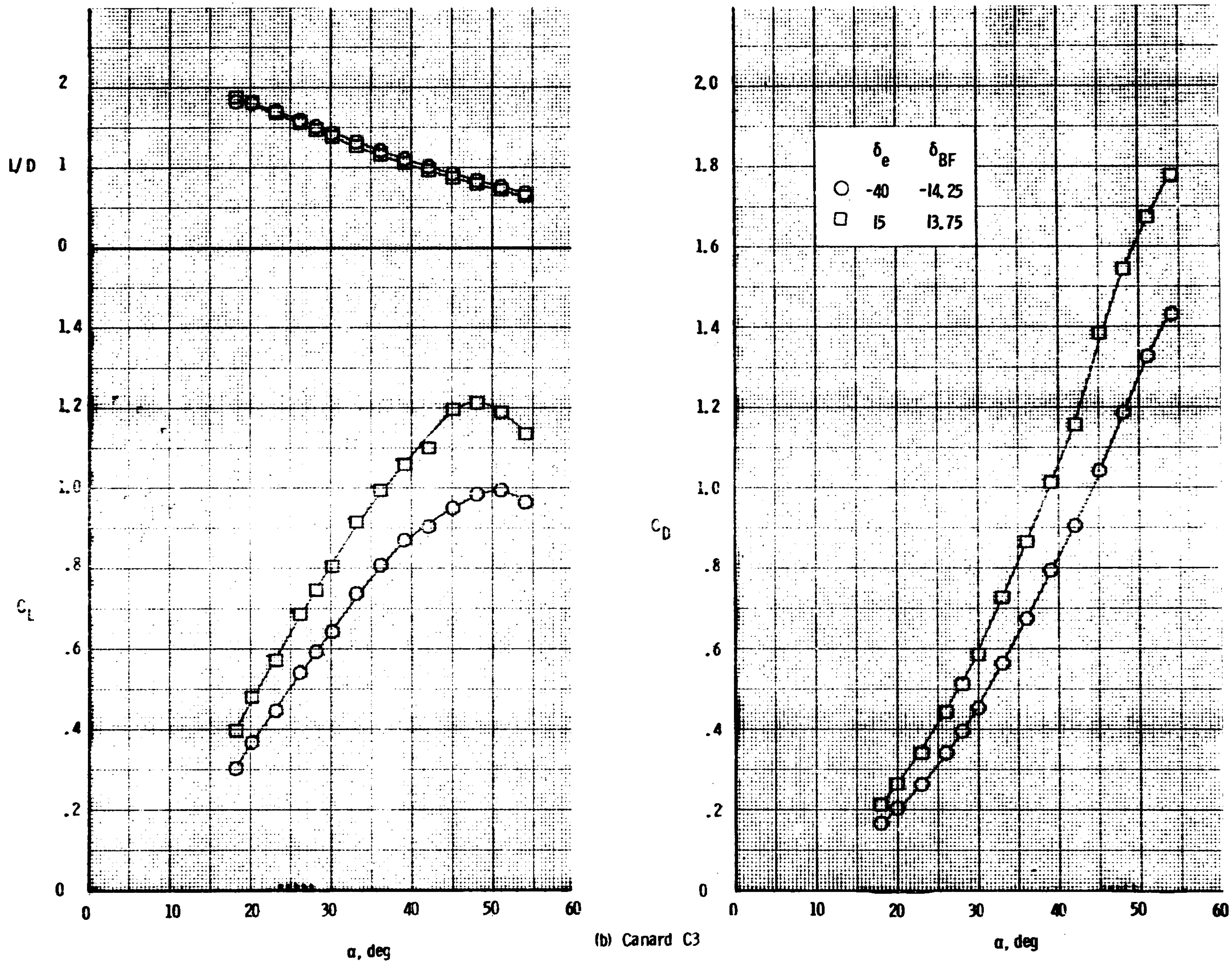
(a) Concluded.

Figure 11.- Continued.



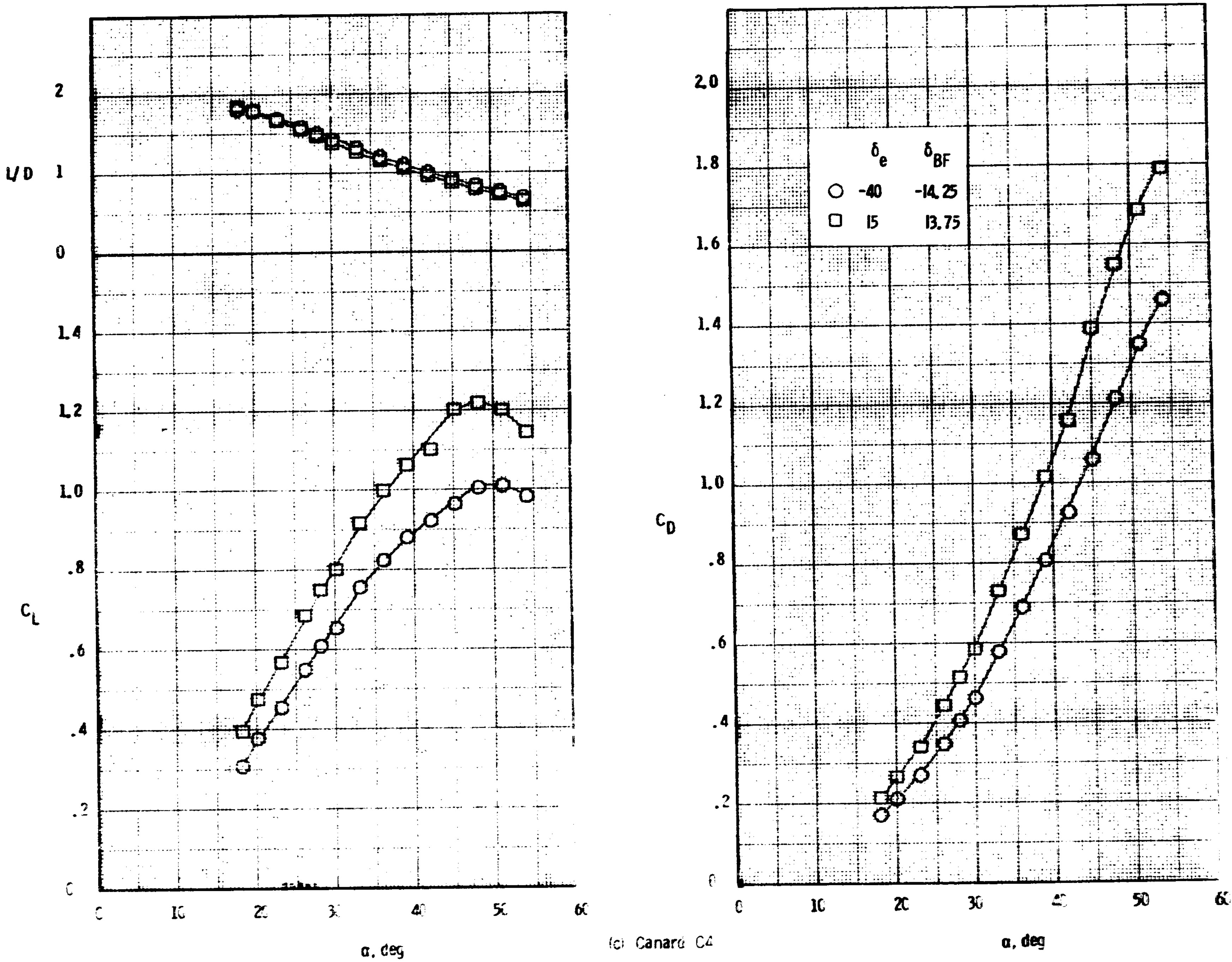
(b) Concluded.

Figure 11.- Continued.



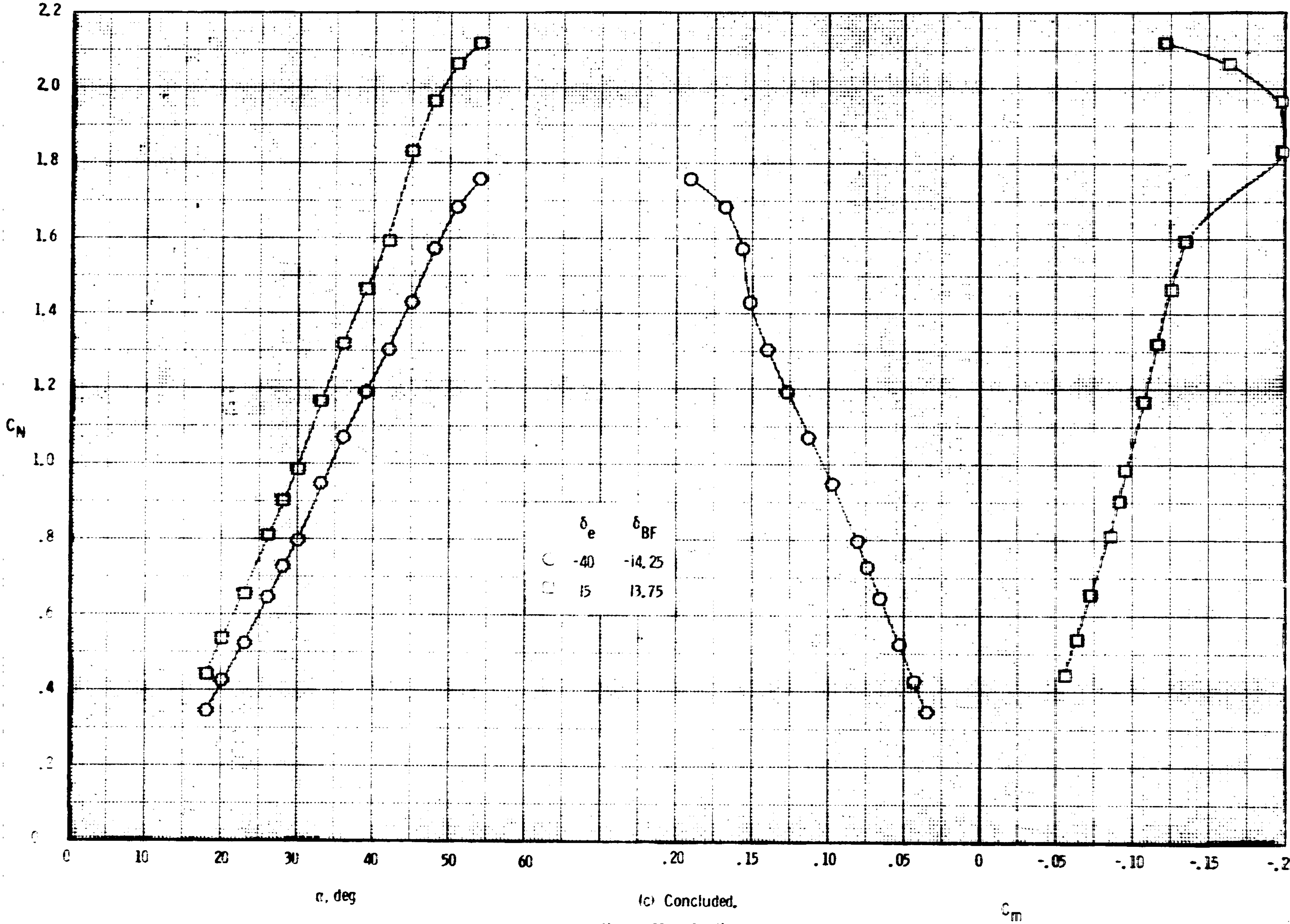
(b) Canard C3

Figure 11.- Continued.



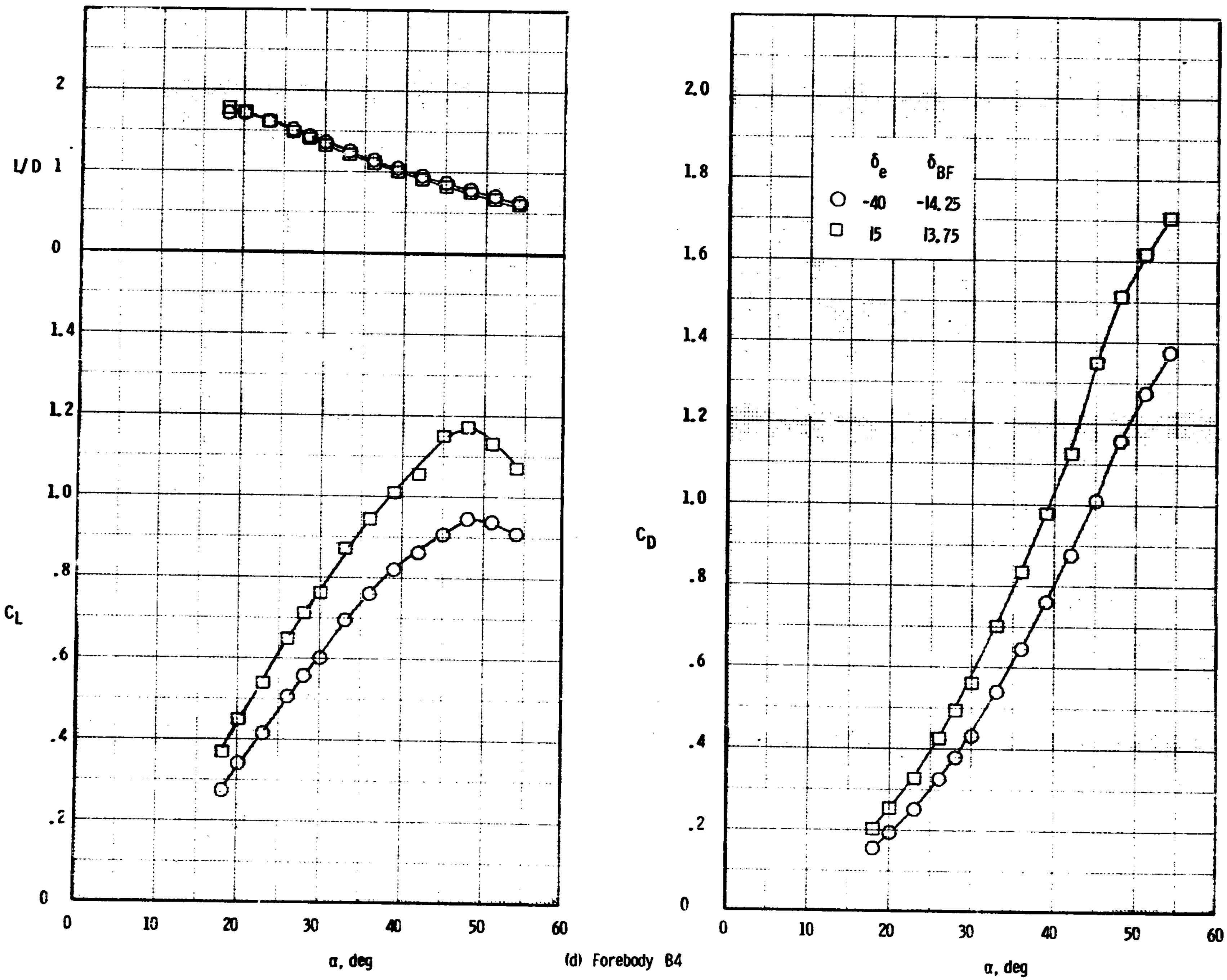
(c) Canard C4

Figure 11.- Continued.



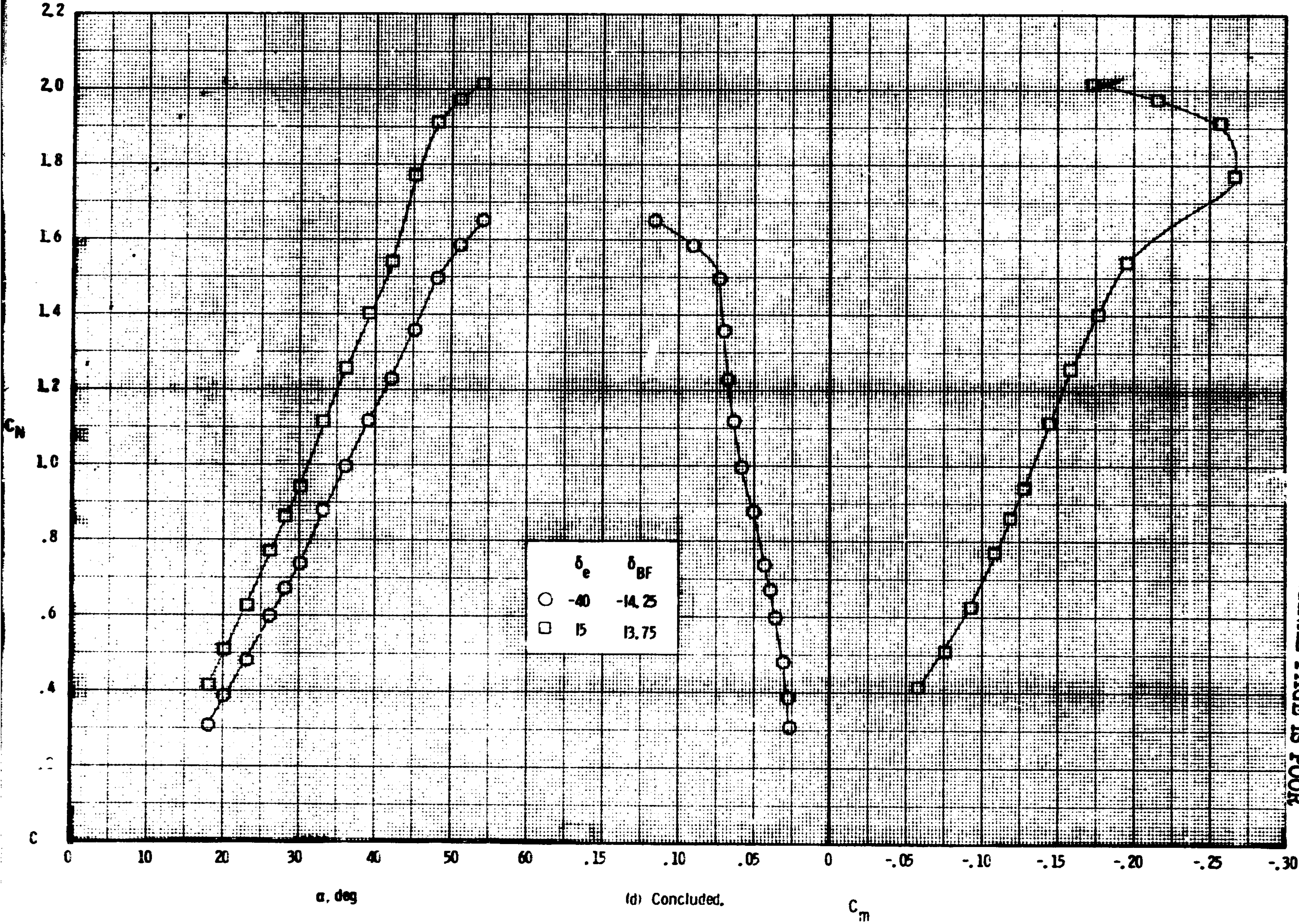
(c) Concluded.

Figure 11.- Continued.



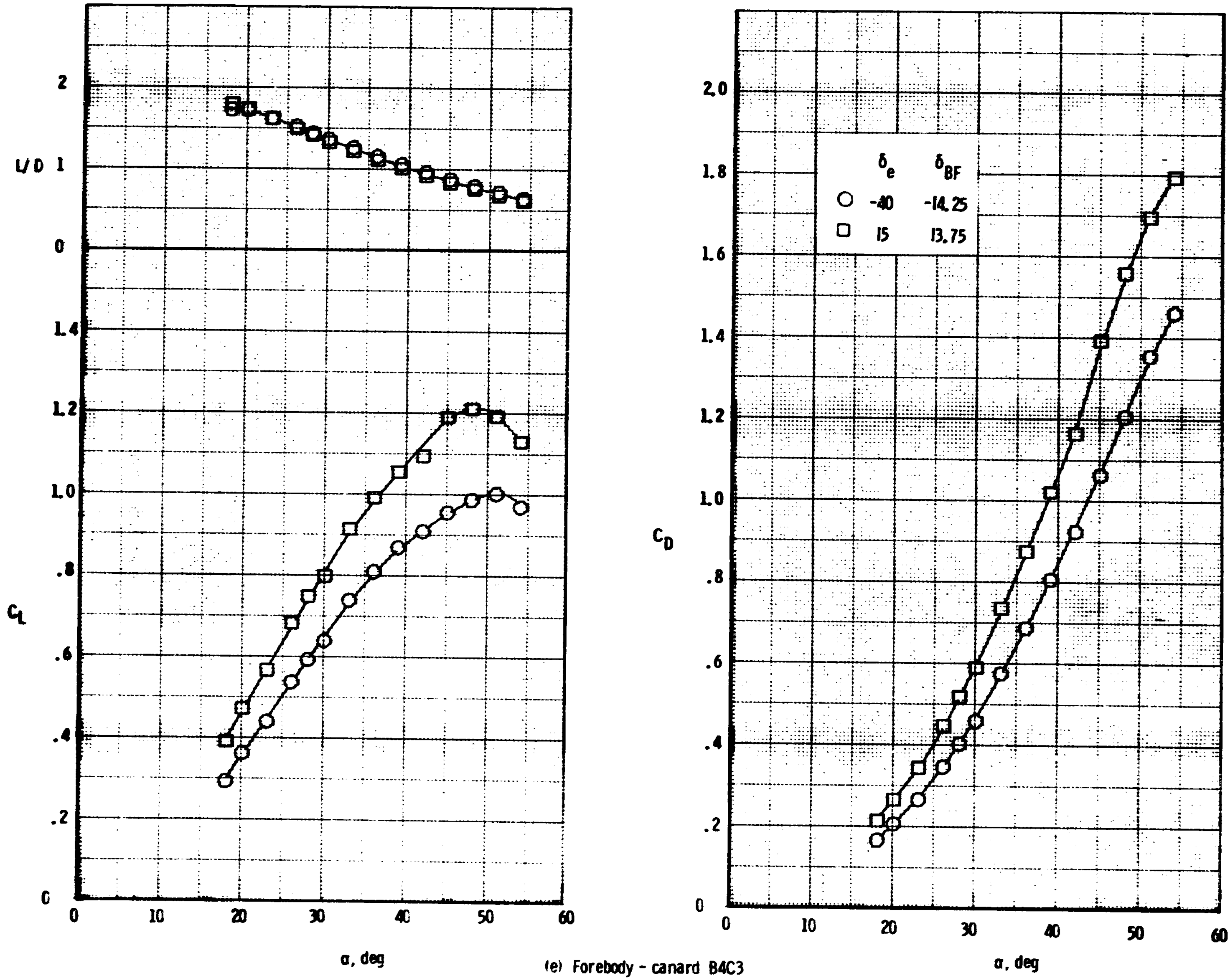
(d) Forebody B4

Figure 11.- Continued.



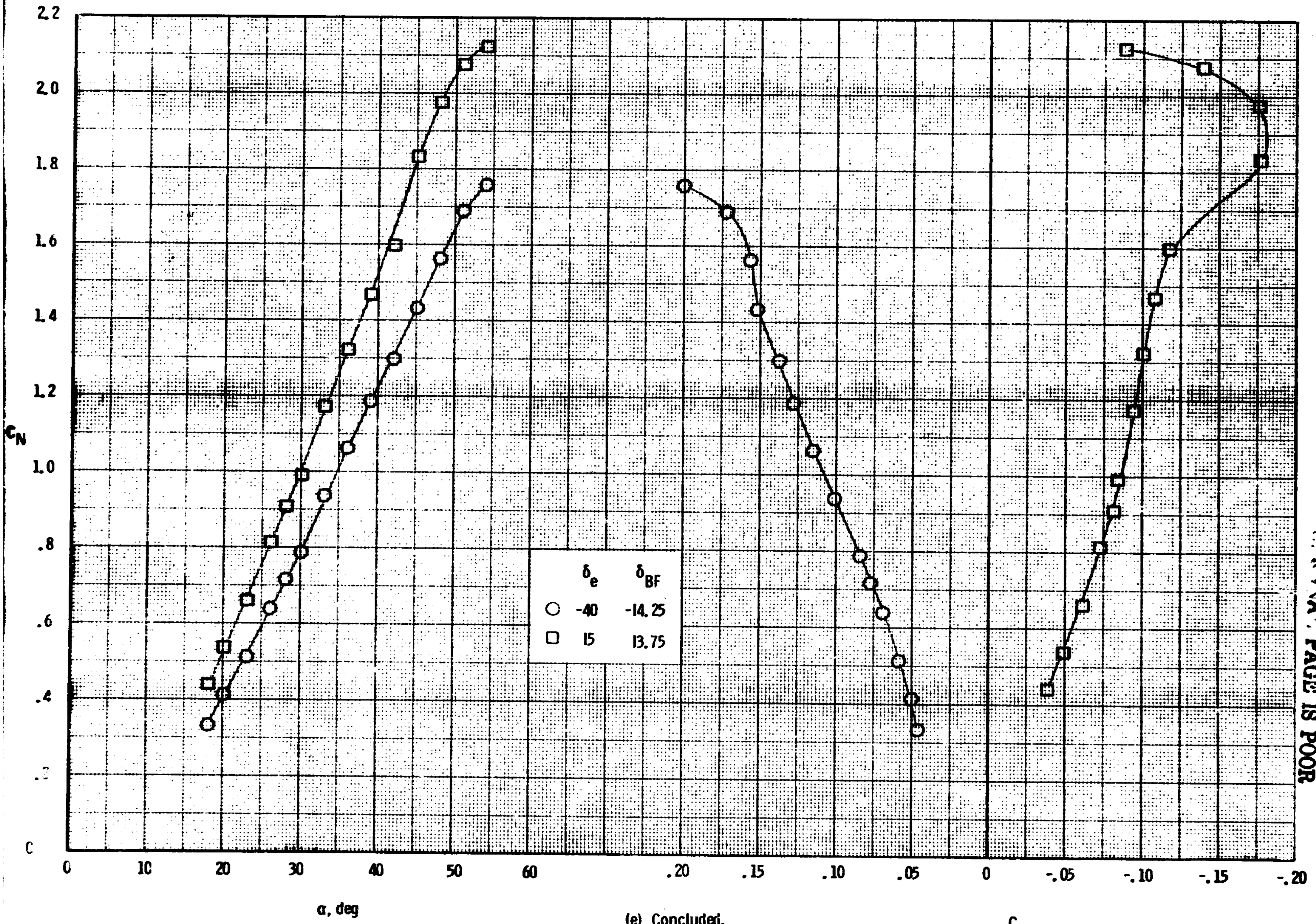
(d) Concluded.

Figure 11.- Continued.



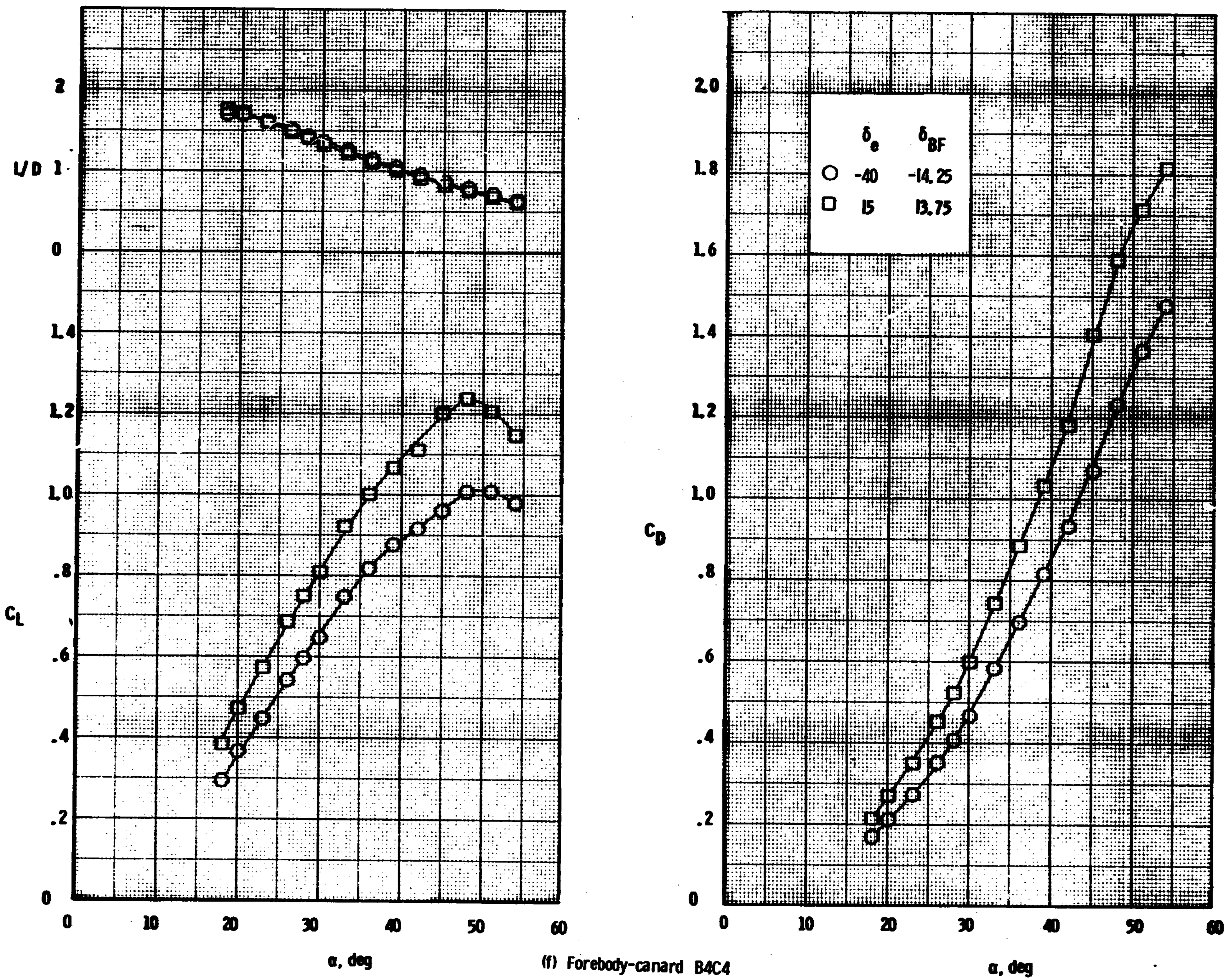
(e) Forebody - canard B4C3

Figure 11.- Continued.



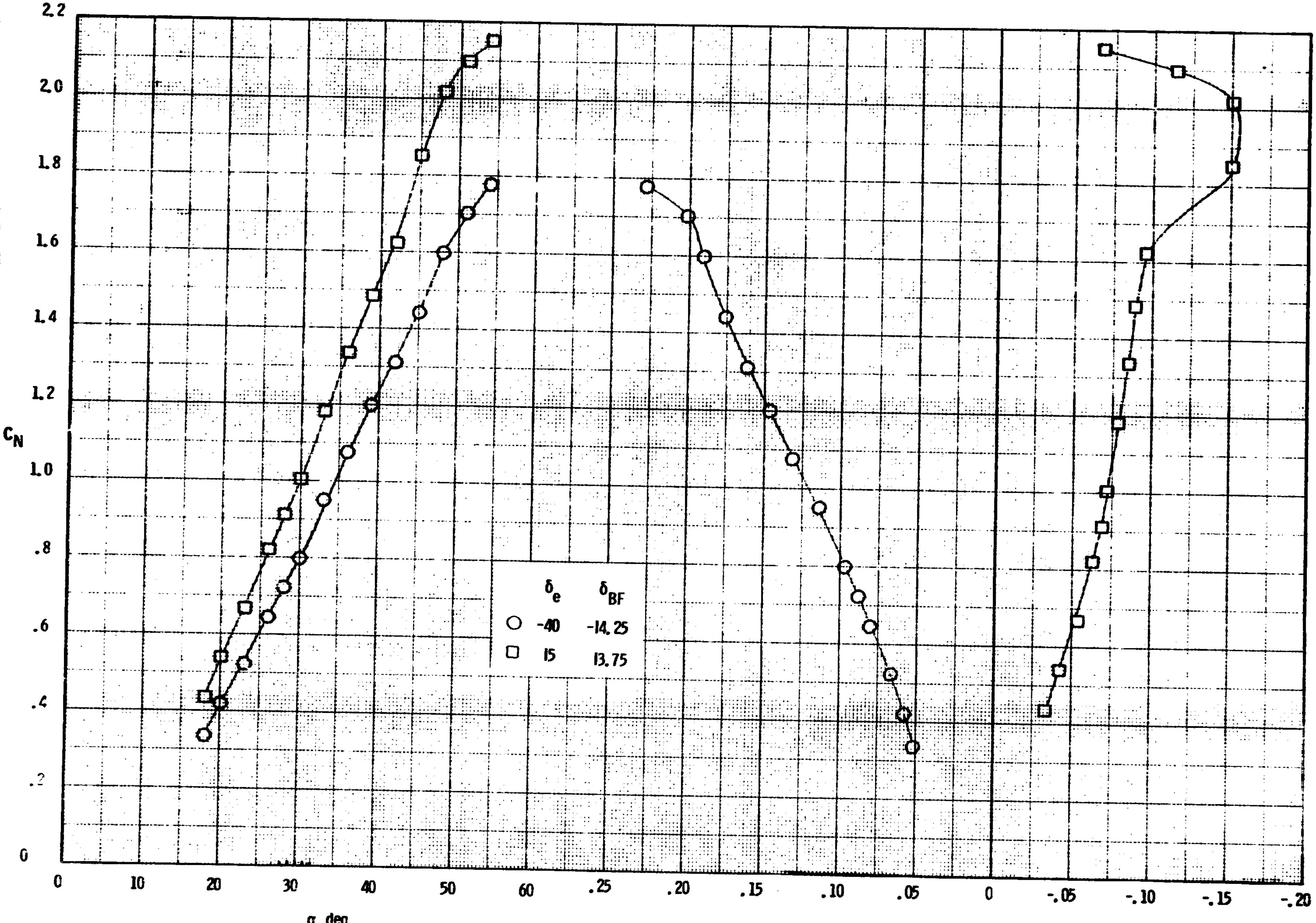
(e) Concluded.

Figure 11.- Continued.



(f) Forebody-canard B4C4

Figure 11.- Continued.



(f) Concluded.

Figure 11.- Concluded.

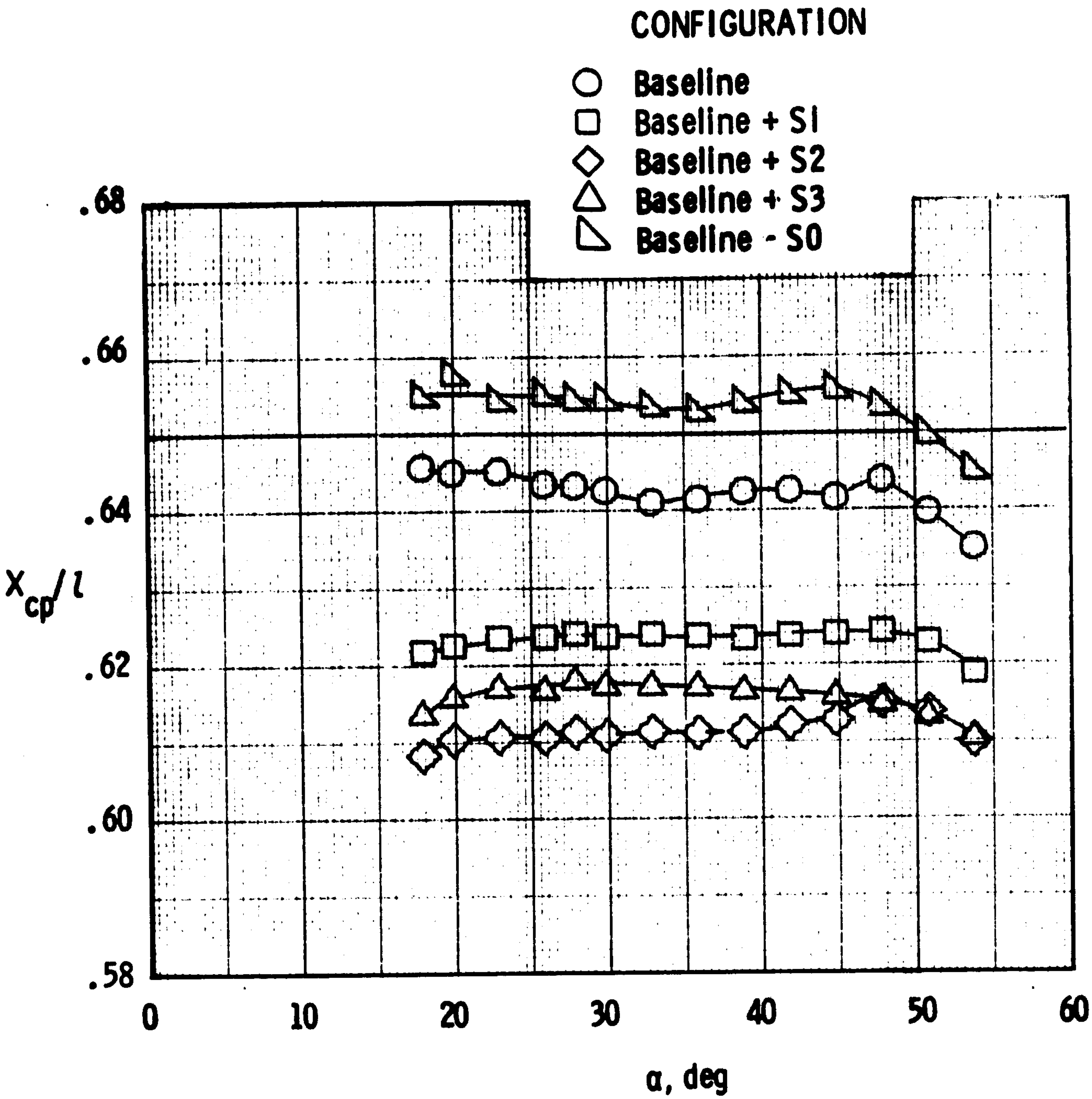


Figure 12.- Effect of fillet planform modifications on the orbiter longitudinal center-of-pressure location at Mach 20.3. $\delta_e = -40^0$, $\delta_{BF} = -14.25^0$.

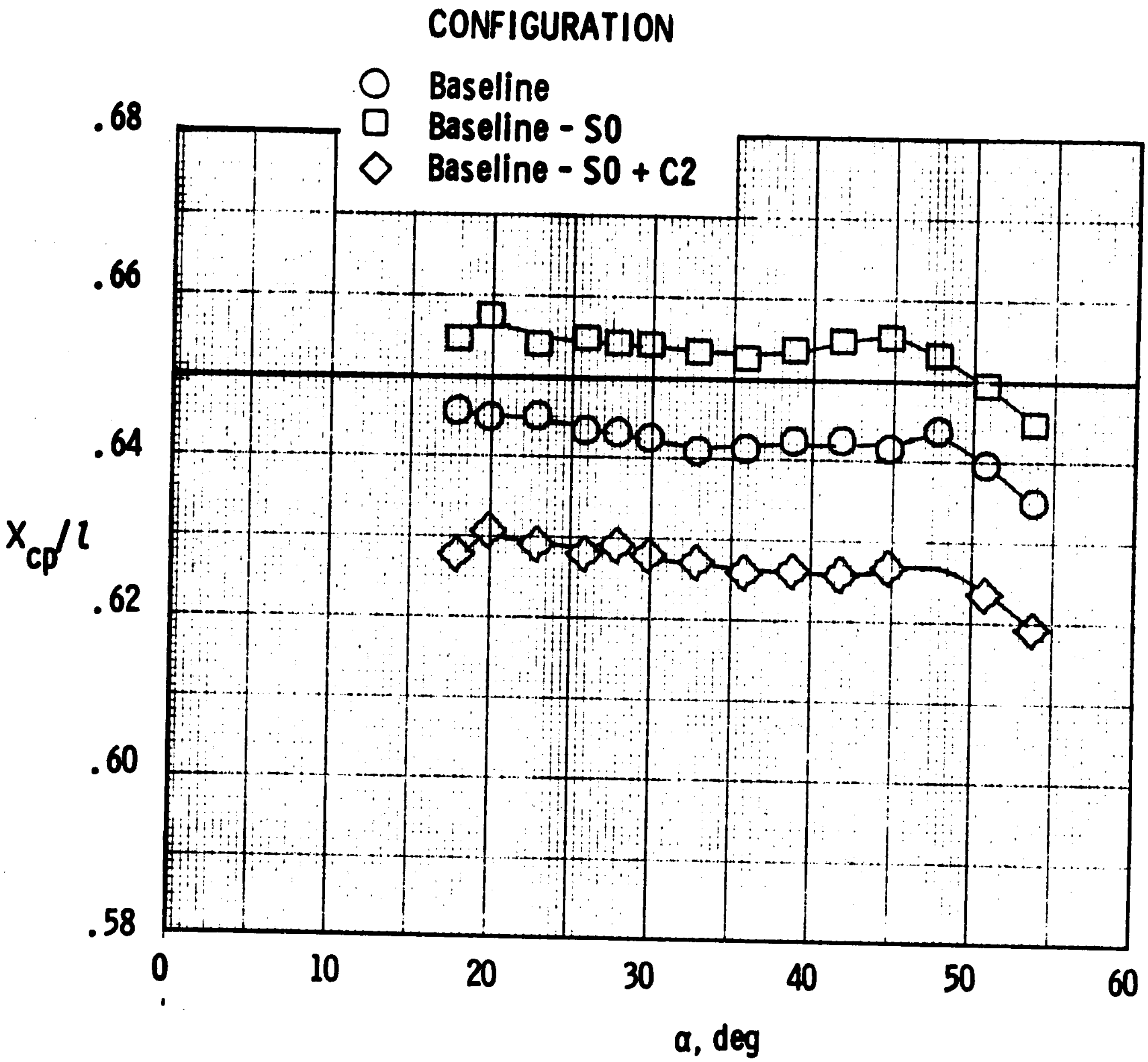


Figure 13.- Effect of replacing the baseline fillet with a canard on the orbiter longitudinal center of pressure location at Mach 20.3. $Se = -40^{o}$, $S_{Bf} = -14.25^{o}$.

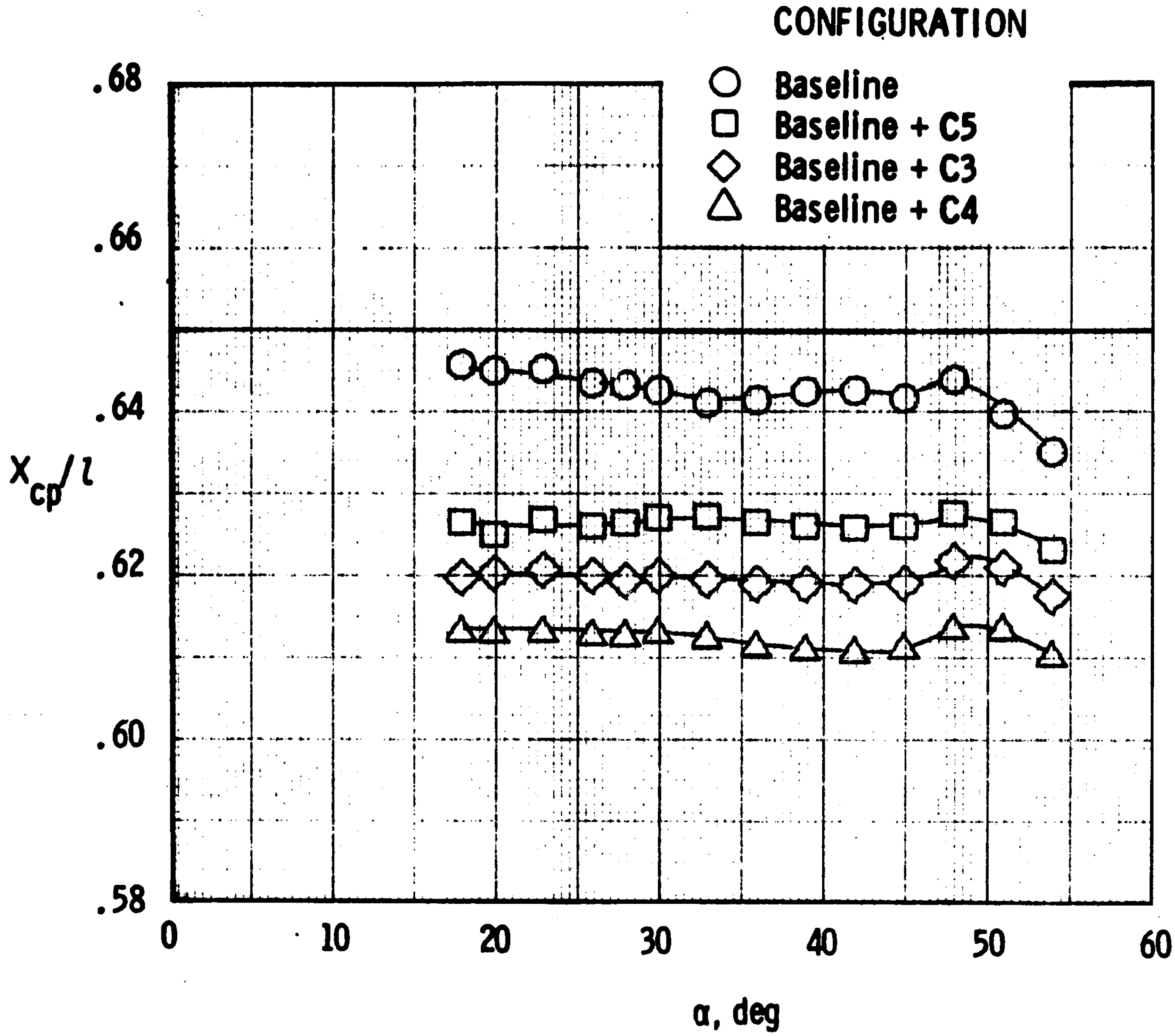


Figure 14.- Effect of in-fillet canards on the orbiter longitudinal center of pressure location at Mach 20.3. $Se = -40^{0}$, $S_{Bf} = -14.25^{0}$.

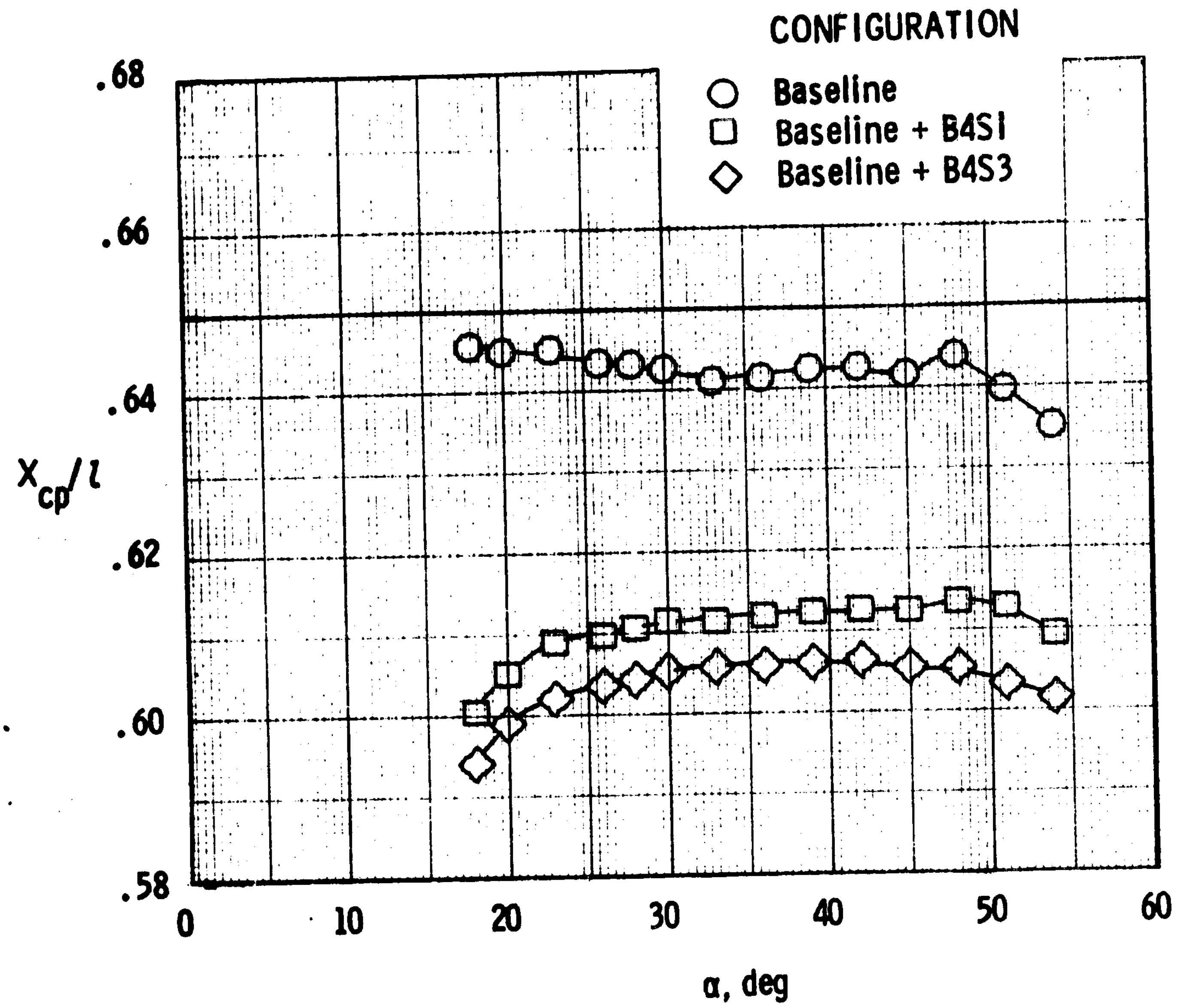


Figure 15.- Effect of forebody-fillet combinations on the orbiter longitudinal center of pressure location at Mach 20.3. $\delta_e = -40^{\circ}$, $\delta_{Bf} = -14.25^{\circ}$.

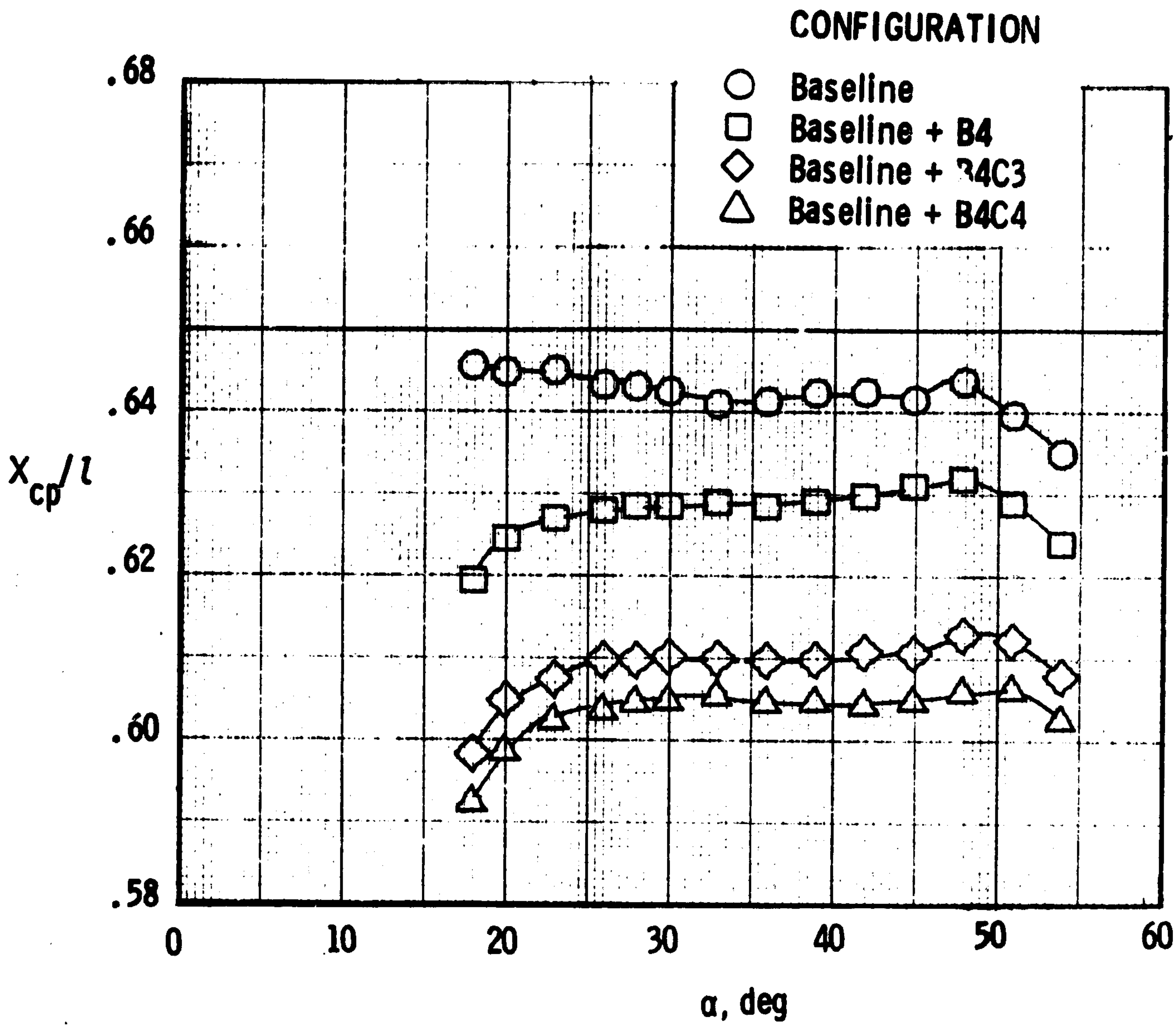


Figure 16.- Effect of forebody-canard combinations on the orbiter longitudinal center of pressure location at Mach 20.3. $Se = -40^{o}$, $S_{Bf} = -14.25^{o}$.

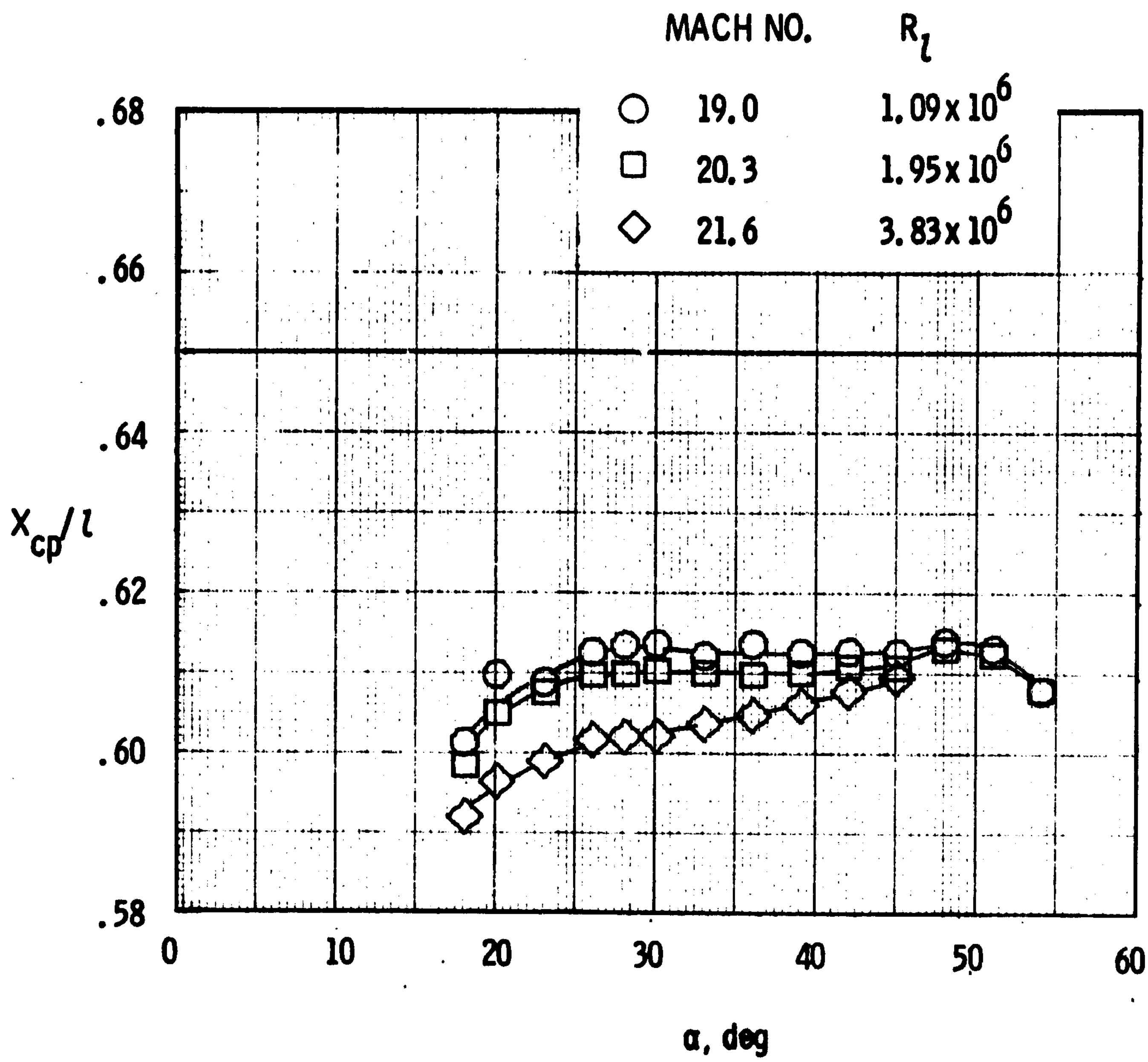
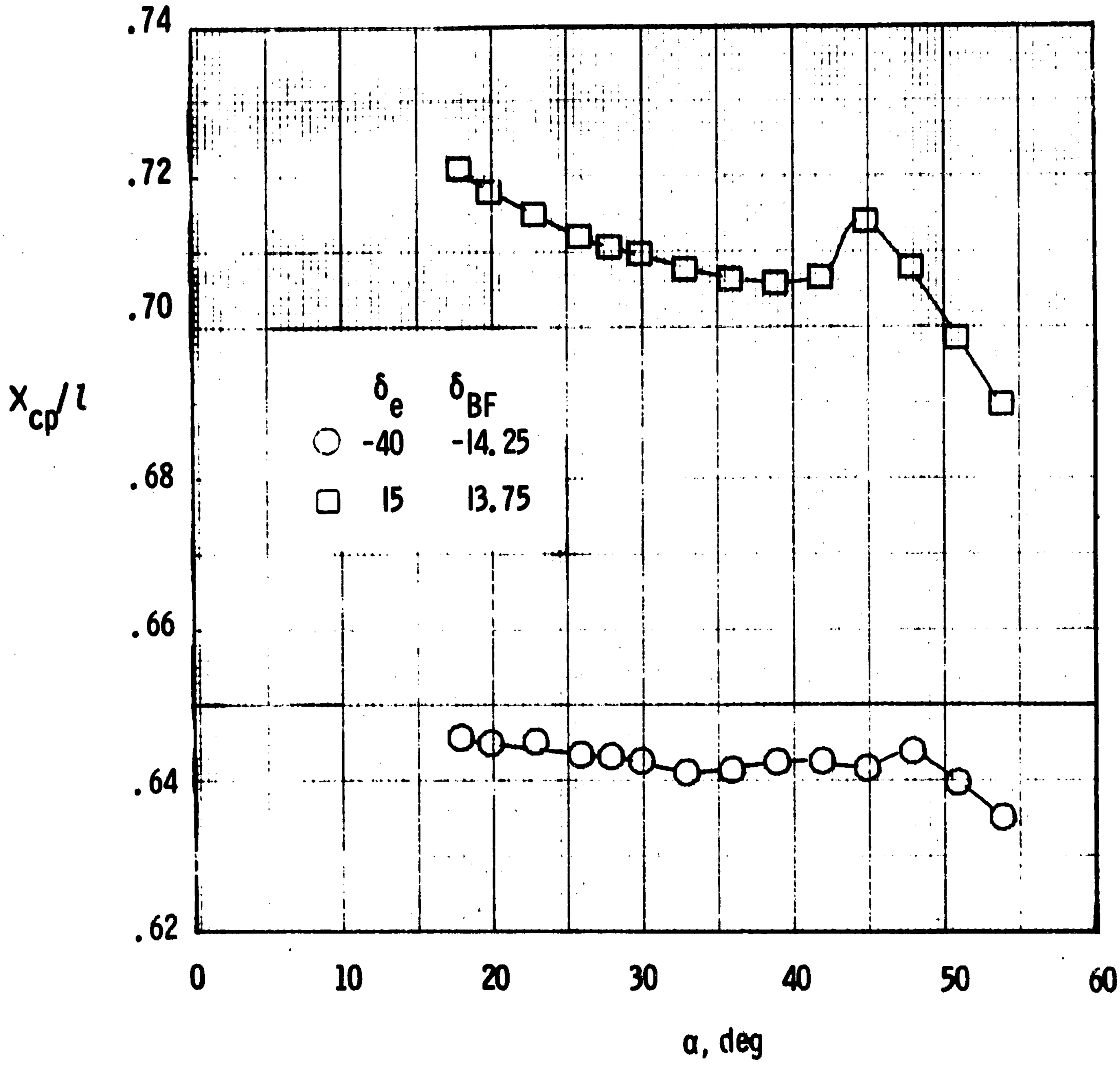
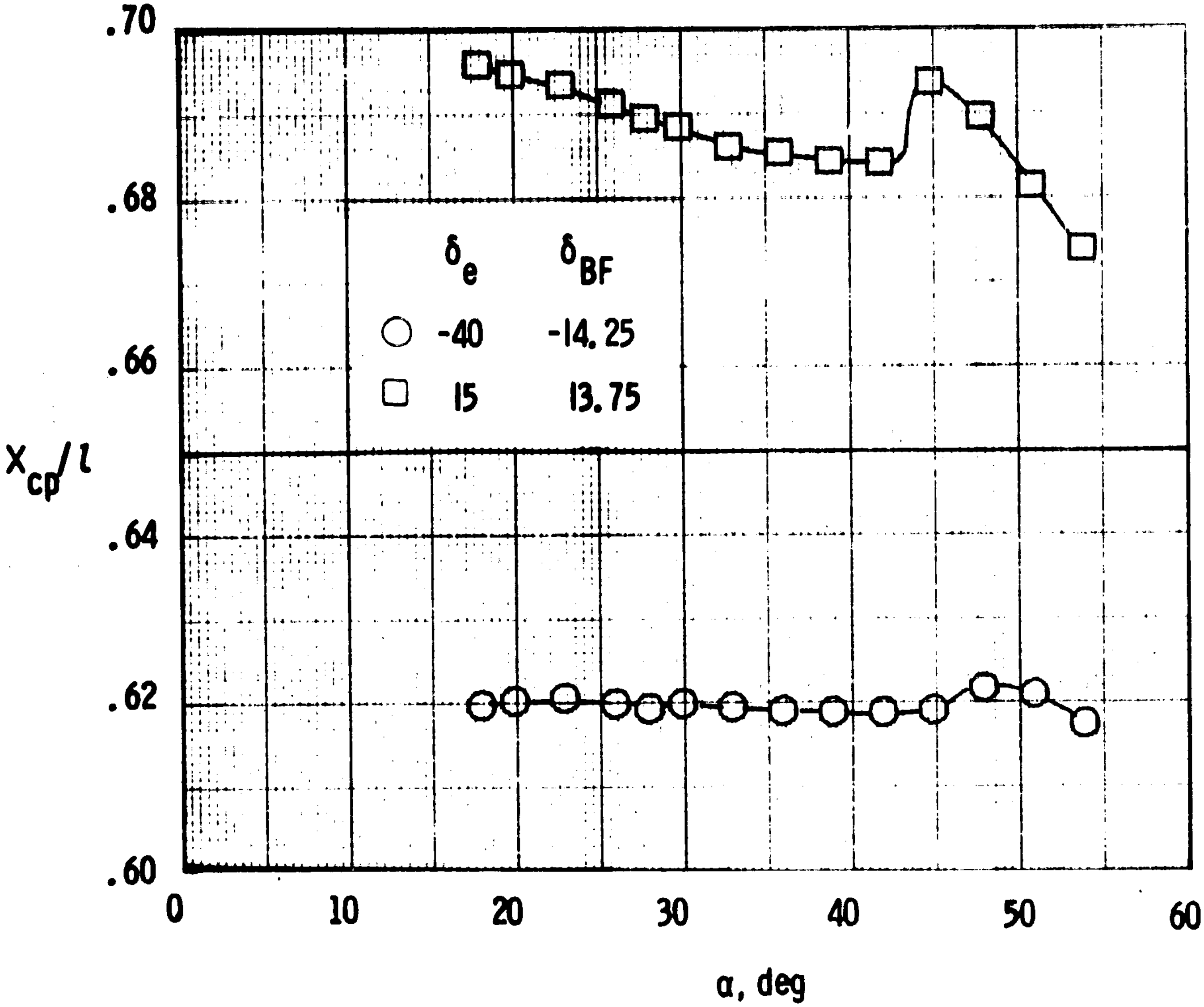


Figure 17.- Effect of Mach and Reynolds number on the orbiter longitudinal center of pressure location. Configuration B4C3, $S_e = -40^o$, $S_{Bf} = -14.25^o$.



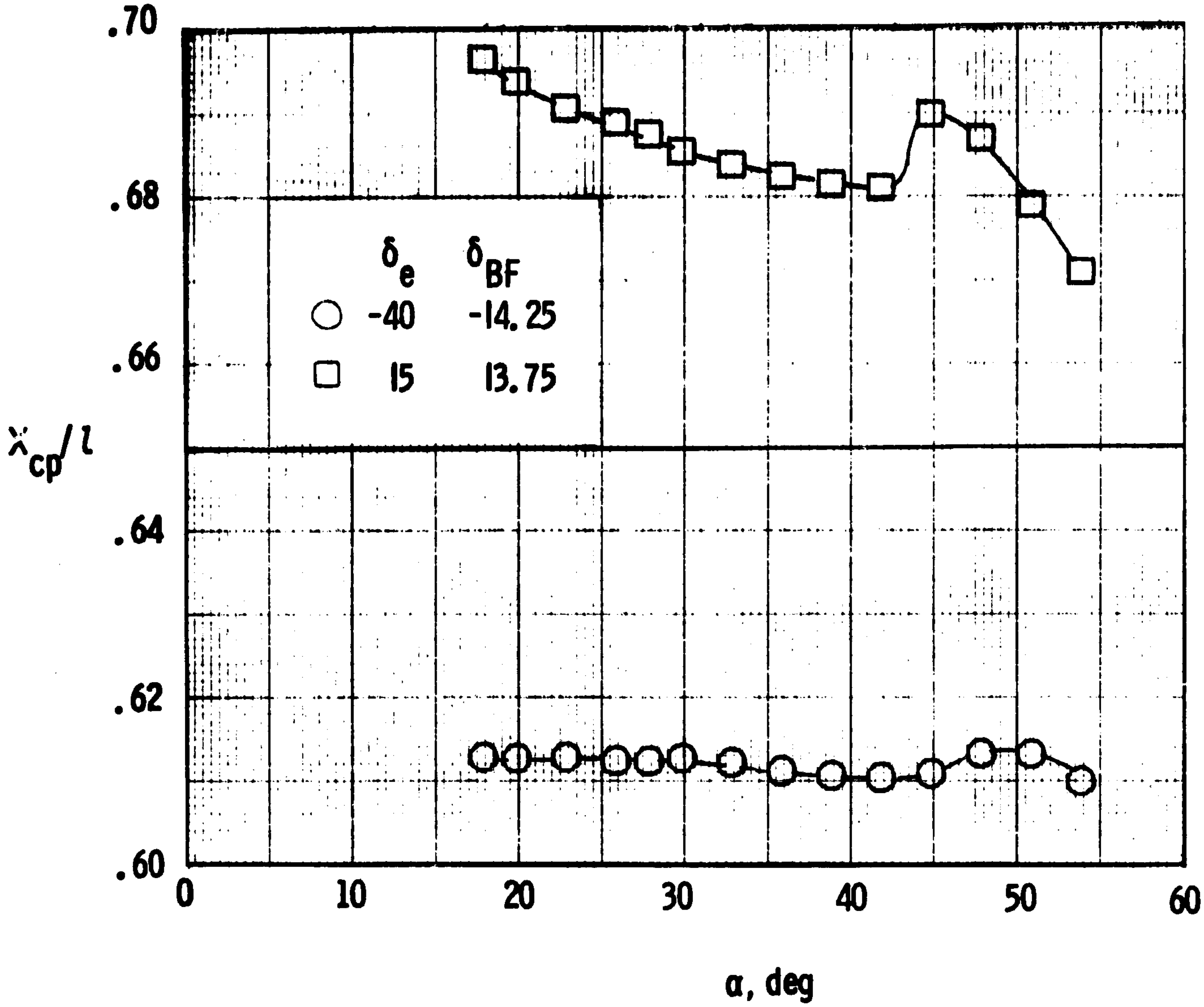
(a) Baseline configuration

Figure 18.- Effect of maximum elevon and body-flap deflections on the orbiter longitudinal center-of-pressure location for various forebody and canard combinations. M = 20.3.



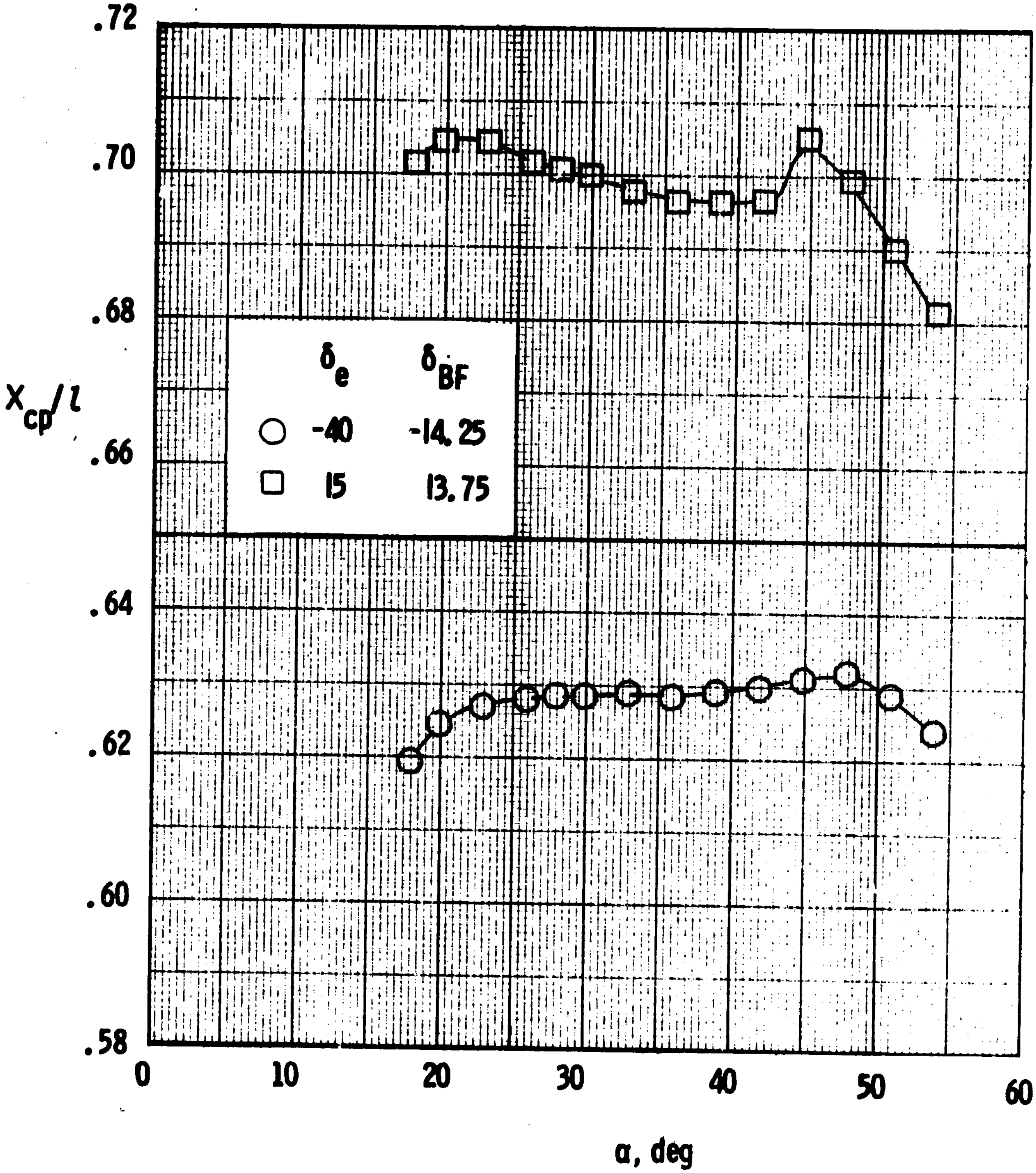
(b) Canard C3

Figure 18.- Continued



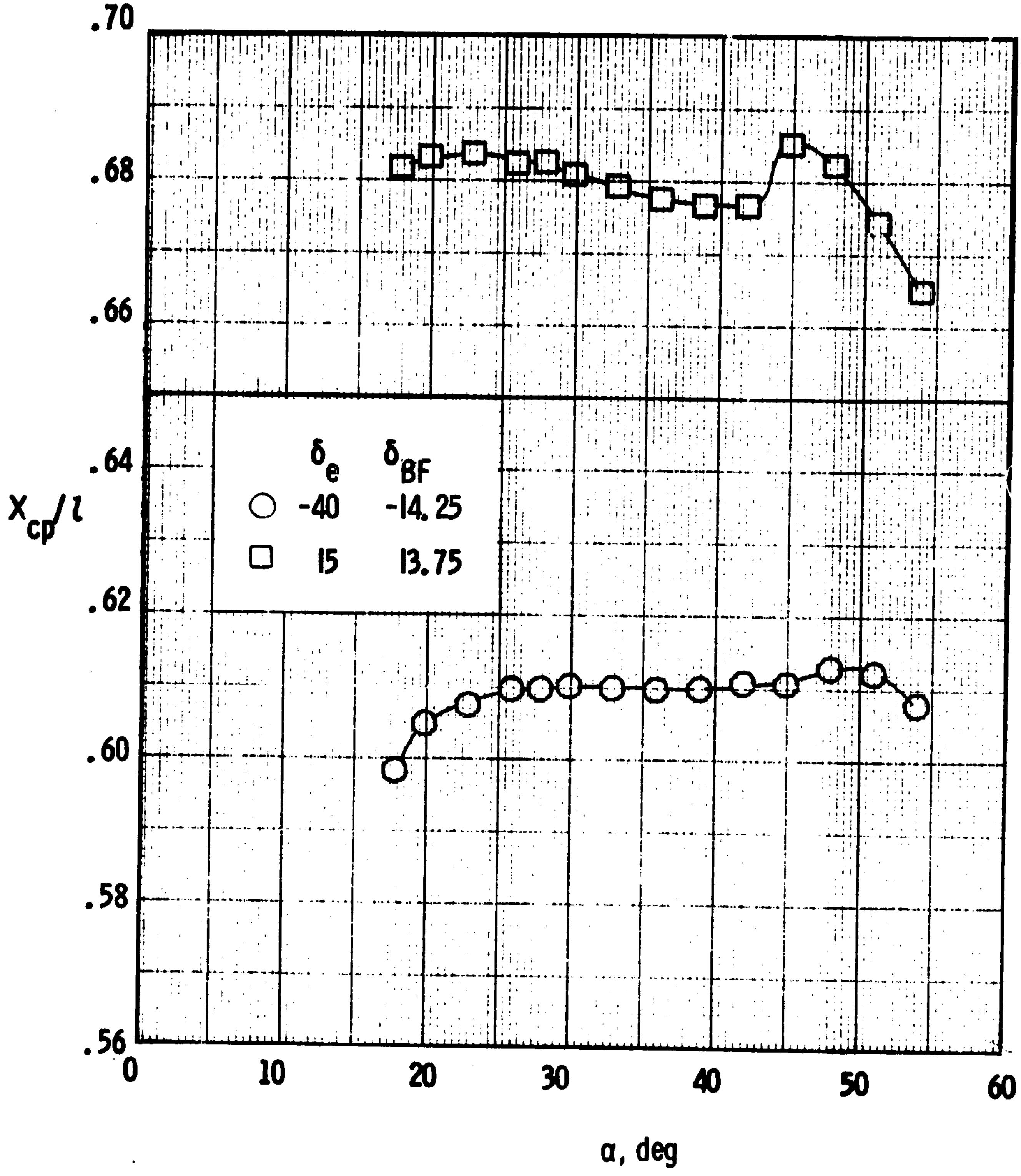
(c) Canard C4

Figure 18.- Continued



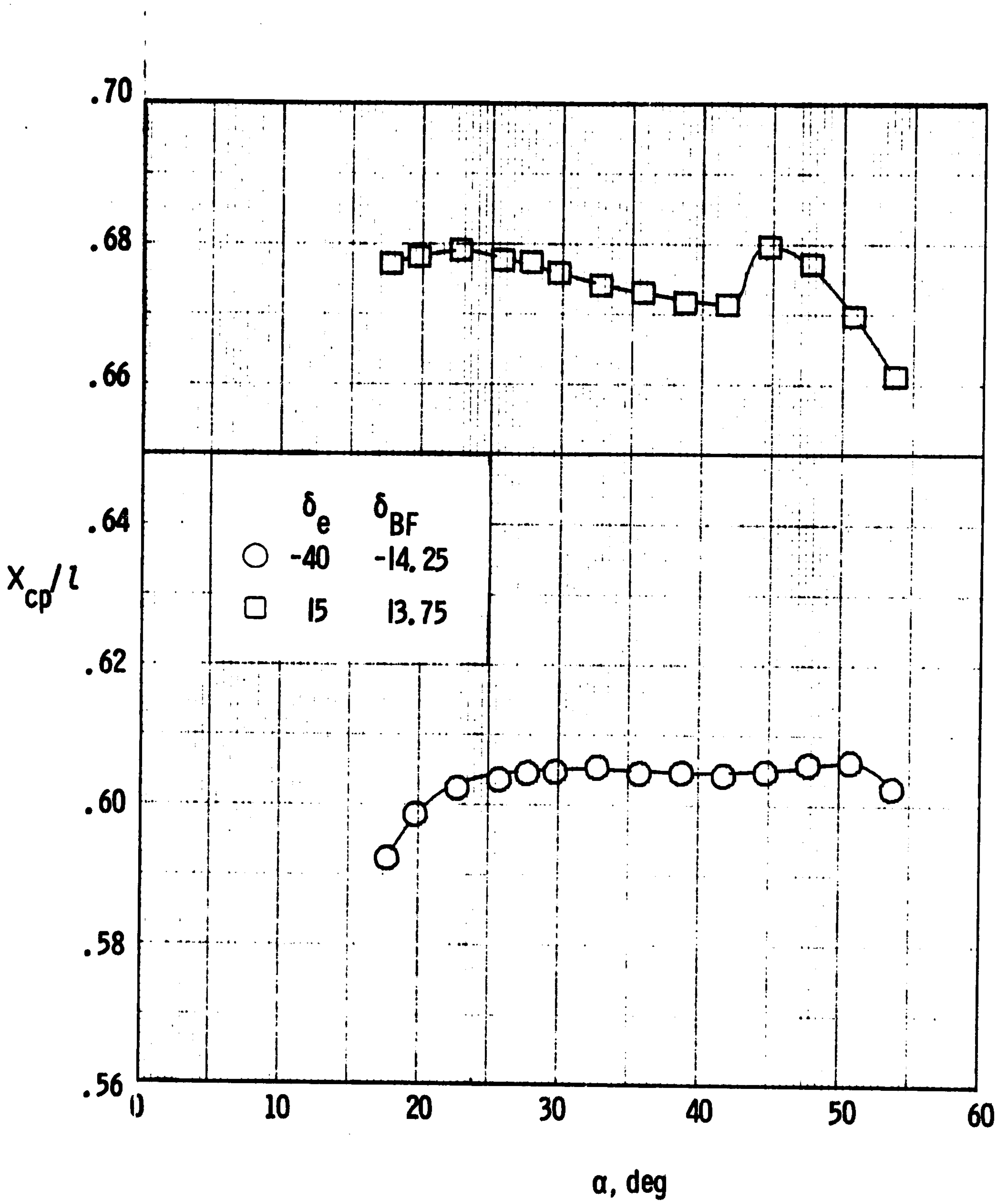
(d) Forebody B4

Figure 18.- Continued



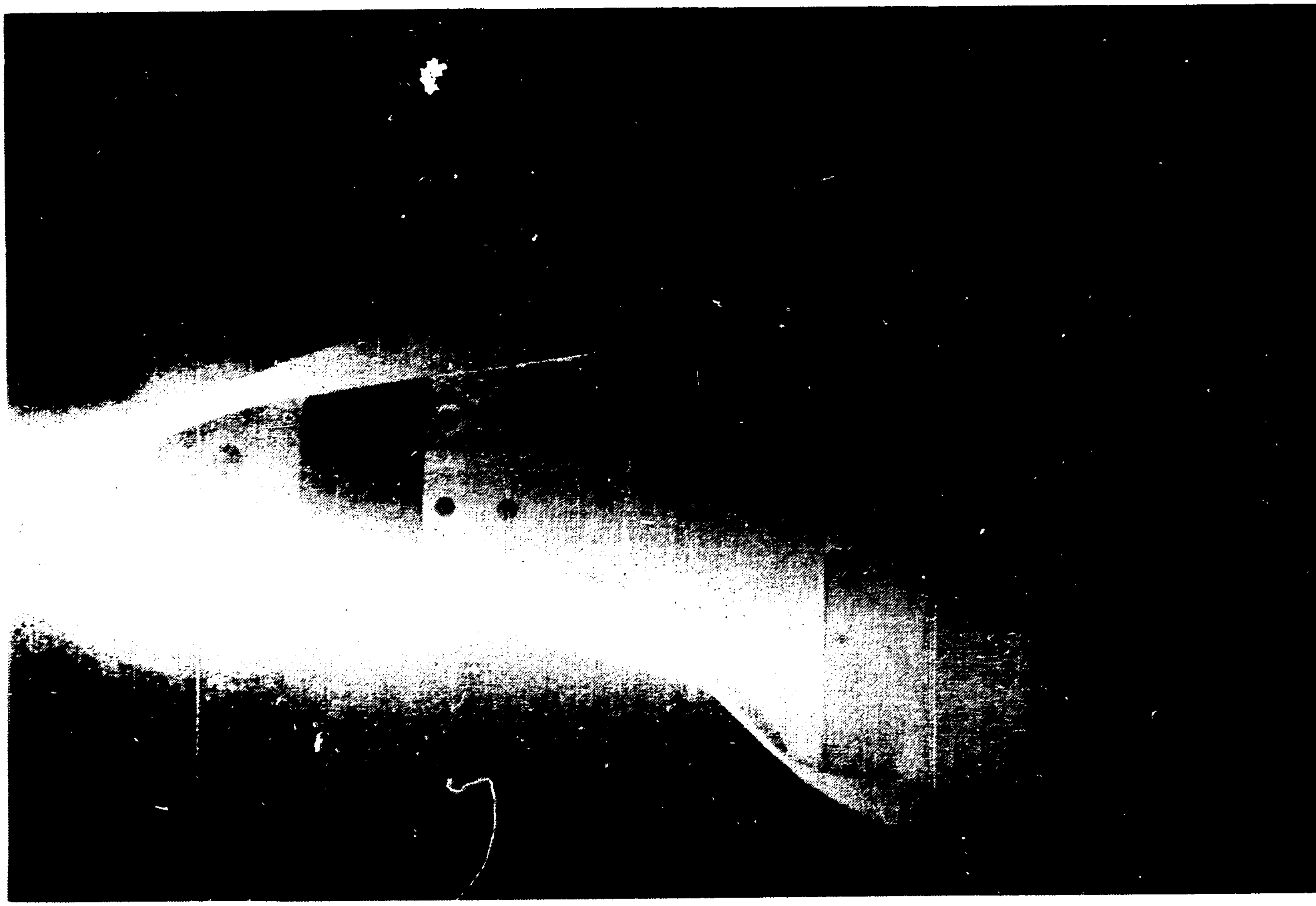
(e) Forebody-canard B4C3

Figure 18.- Continued



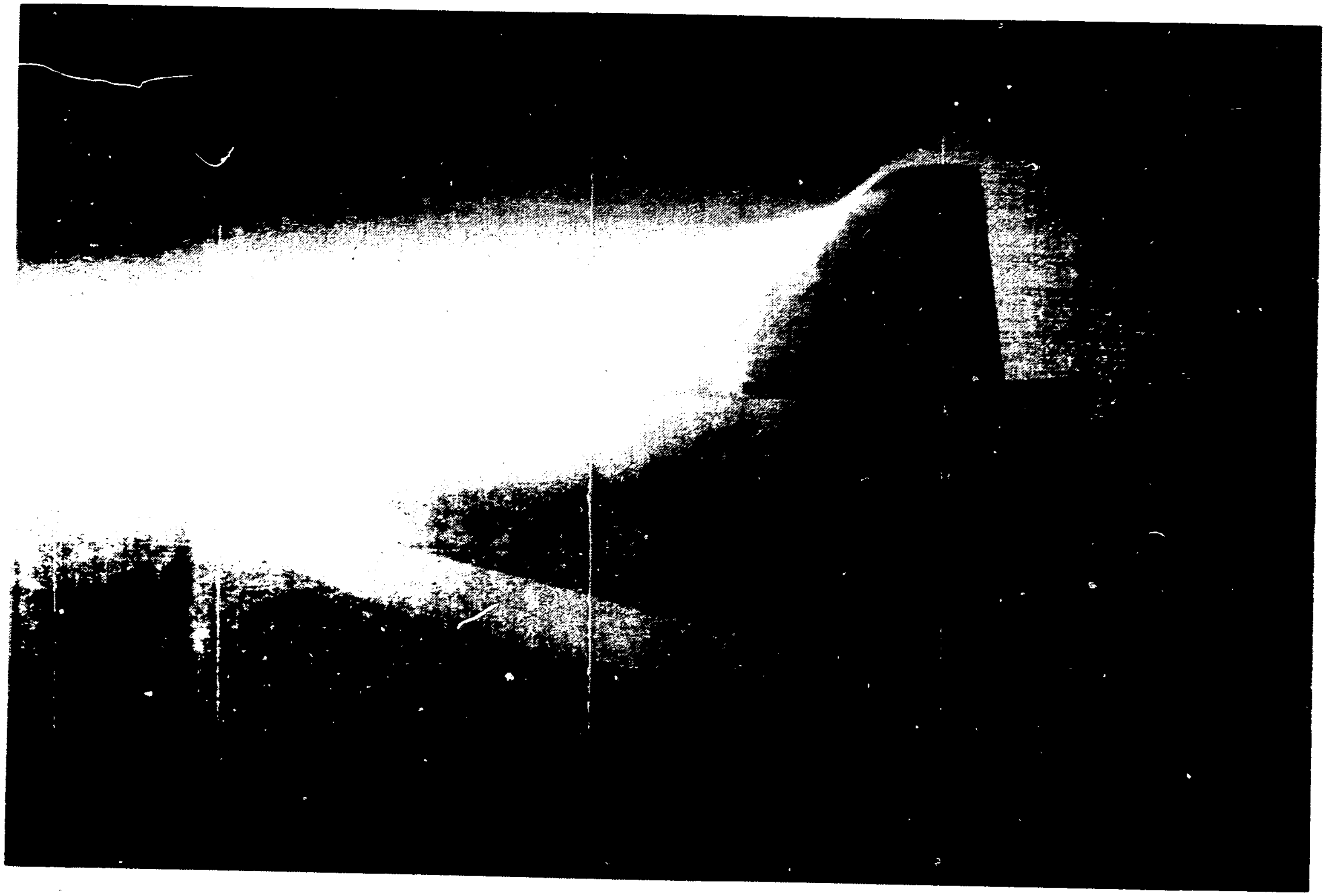
(f) Forebody-canard B4C4

Figure 18.- Concluded



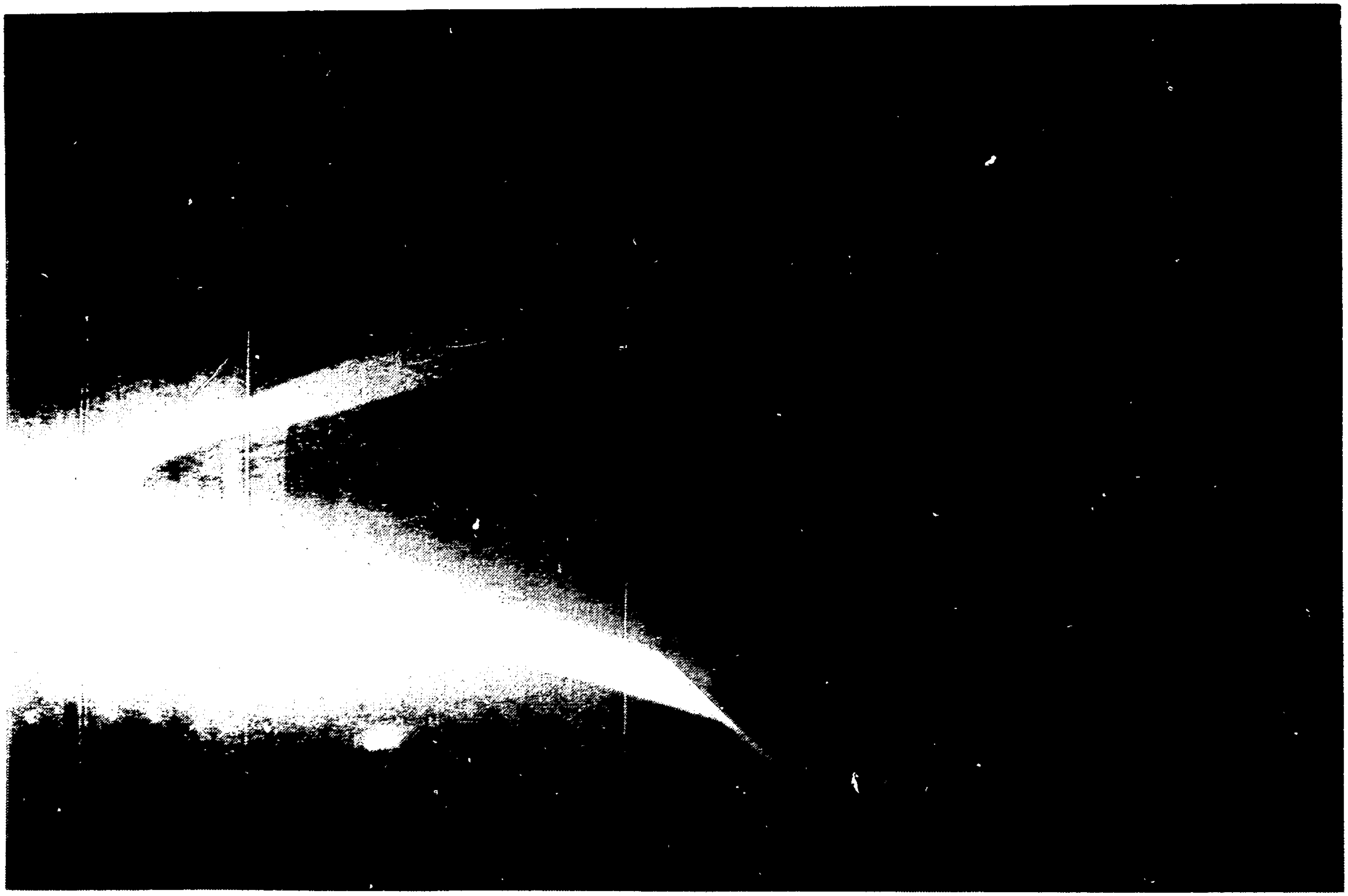
(b) Bottom view

Figure 19.- Concluded



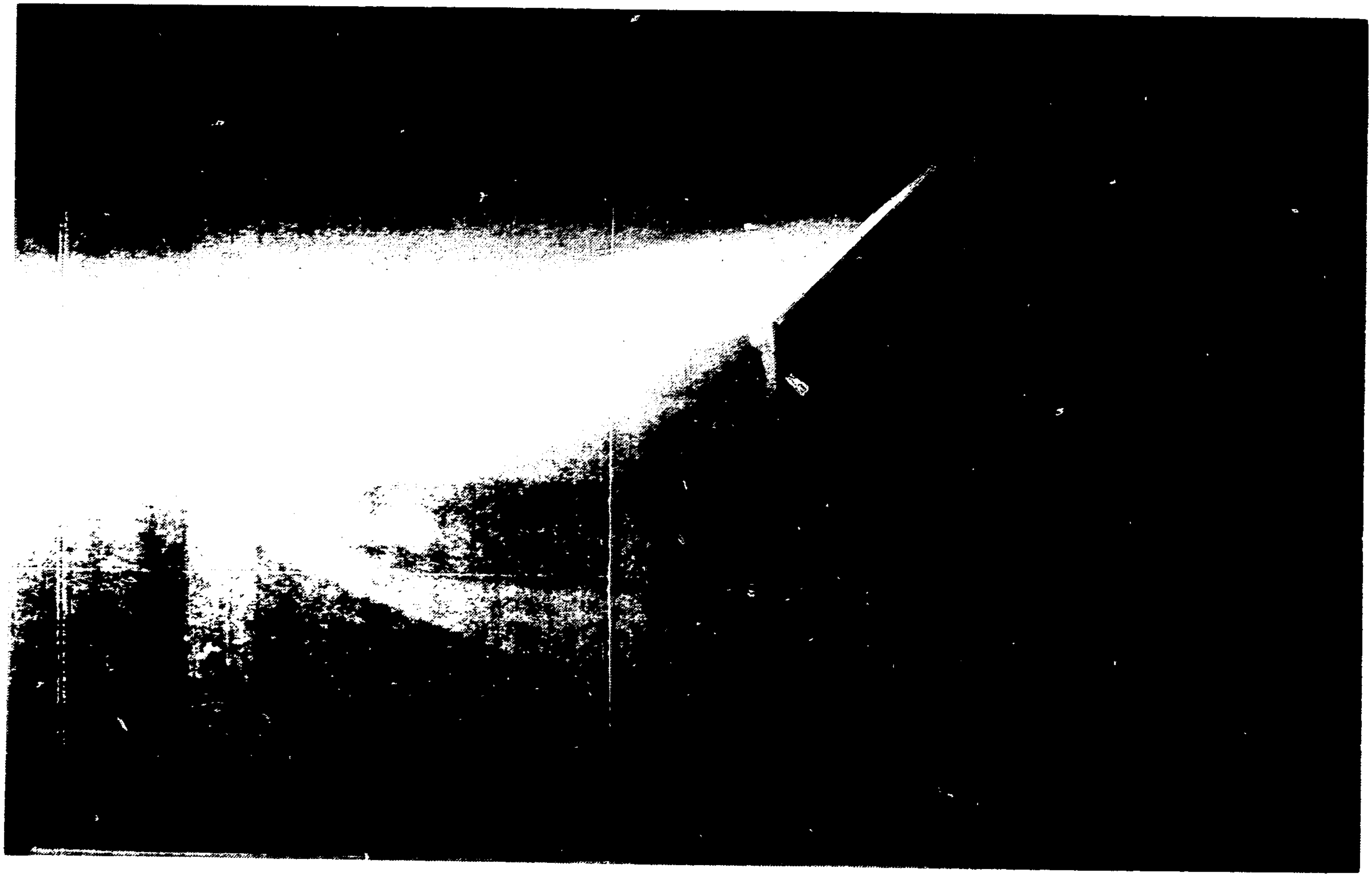
(a) Top View

Figure 20.- Electron beam flow visualization on the 139B orbiter with the [illegible] fillet $\delta_e = -40^0$, $\delta_{BF} = -14.25^0$, $\alpha = 30^0$, $M = 20.3$, $R_{e_\ell} = 1.91 \times 10^6$.



(b) Bottom view

Figure 20.- Concluded



(a) Top view

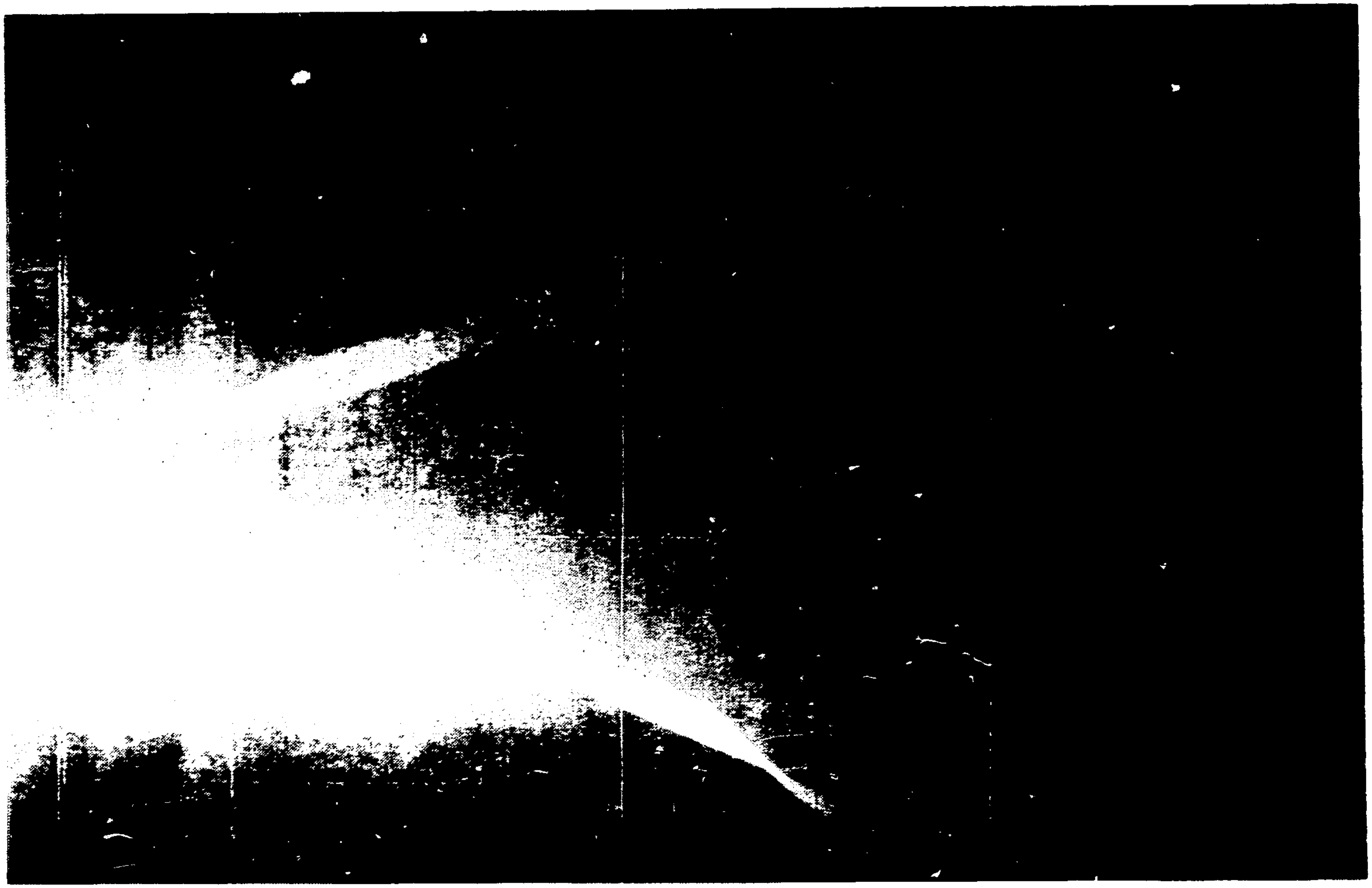
Figure 21.- Electron beam flow visualization on the 139B orbiter with the S2 fillet. $\delta_e=-40^0$, $\delta_{BF}=-14.25^0$, $\alpha=30^0$, M=20.3, R_{e_ℓ} =1.99 X 10^6.

(b) Bottom view

Figure 21.- Concluded

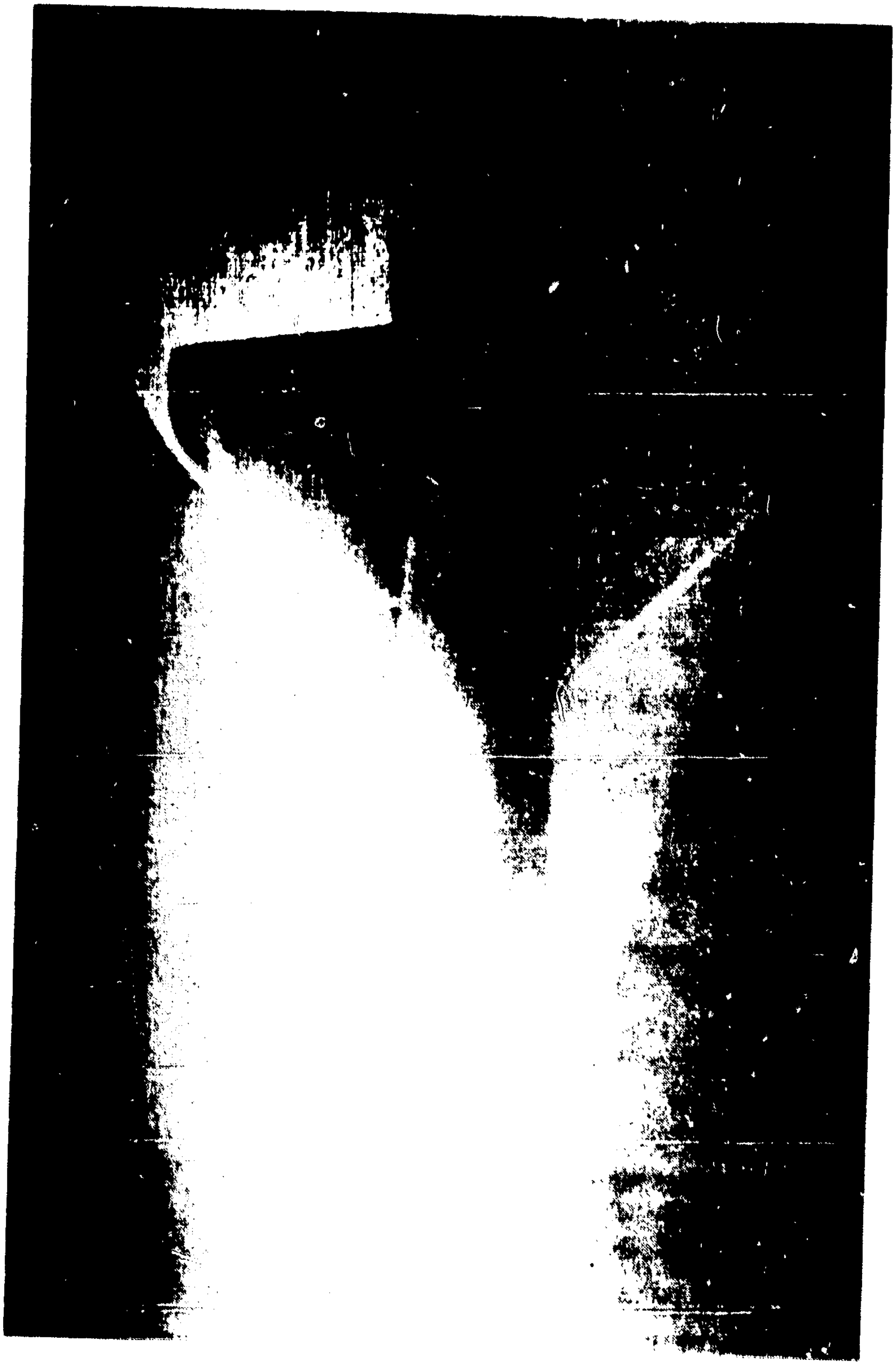
(a) Top view

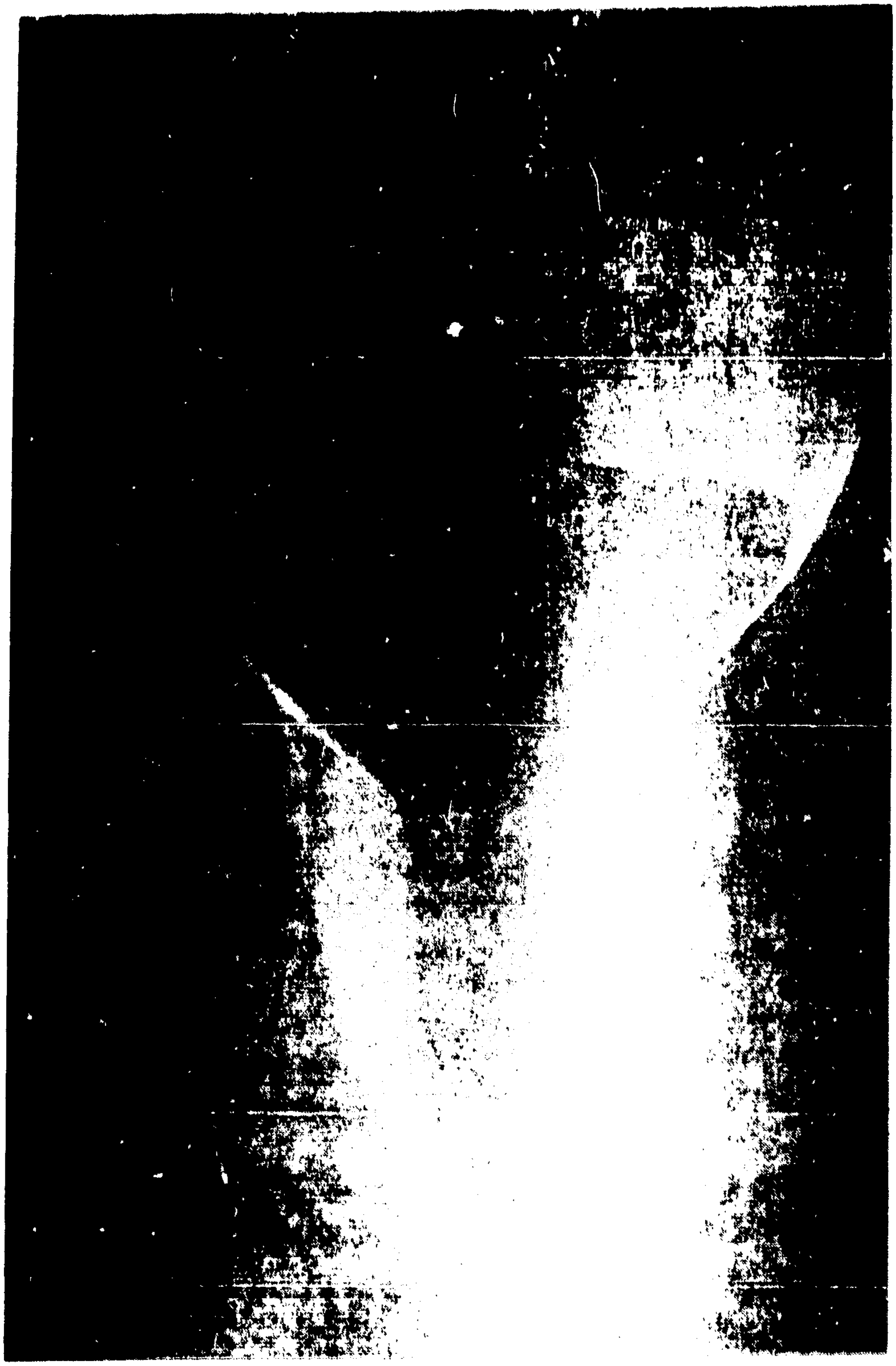
Figure 22.- Electron beam flow visualization on the 1398 orbiter with [illegible].
$\delta_e=-40^0$, $\delta_{BF}=-14.25^0$, $\alpha=30^0$, $M=20.3$, $R_{e_\infty}=1.39 \times 10^6$.



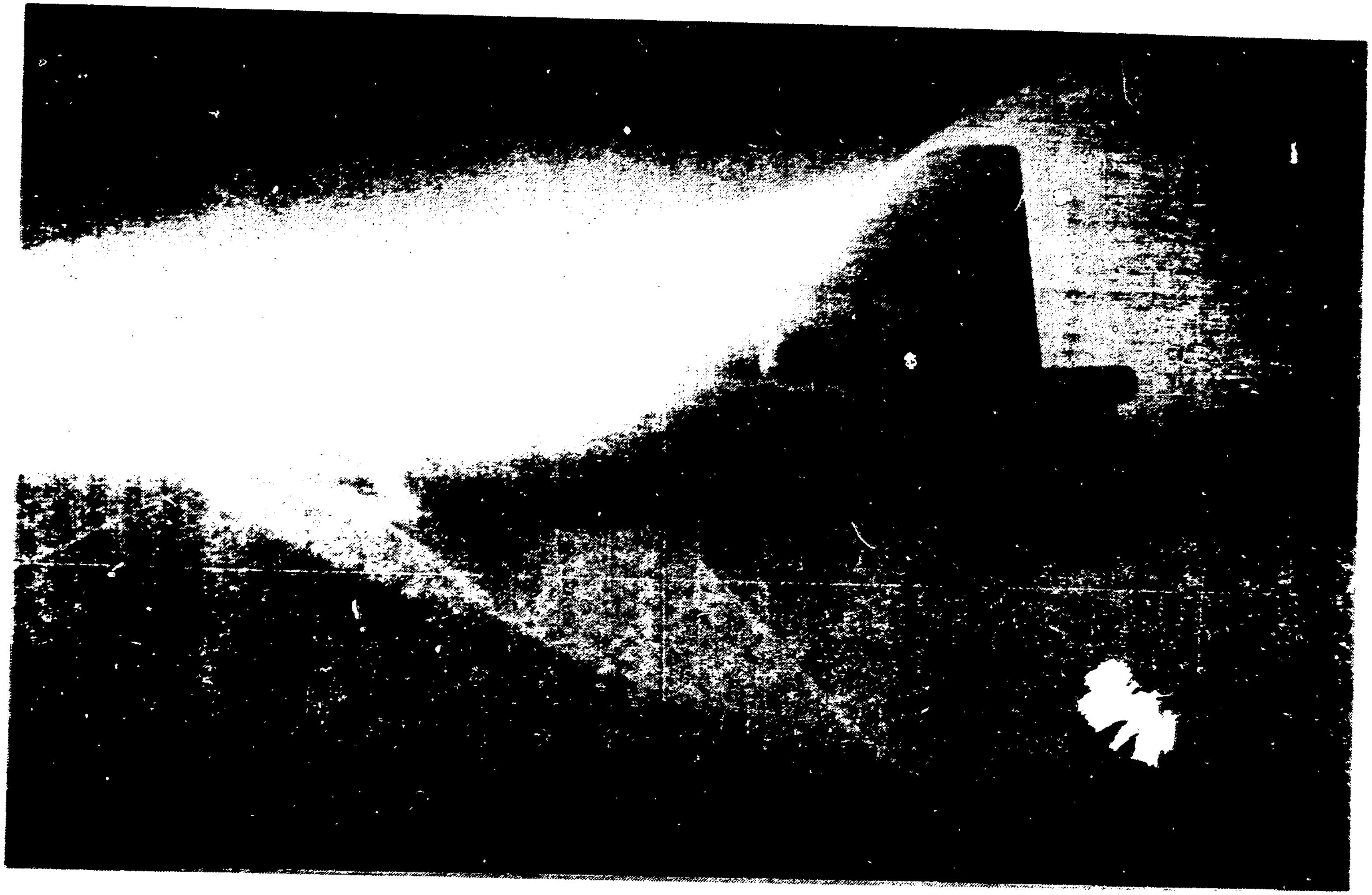
(b) Bottom view

Figure 22.- Concluded



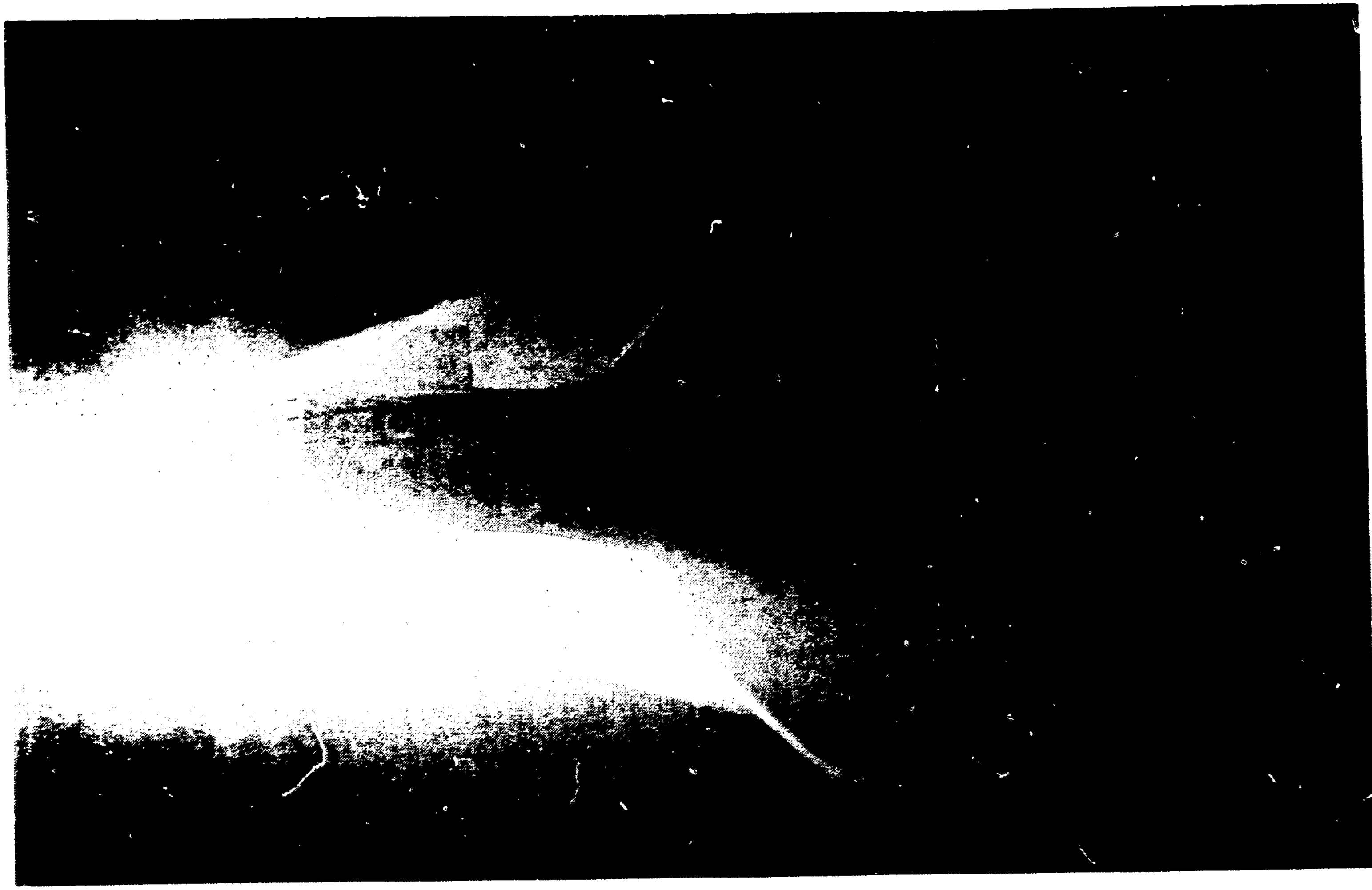


C-2



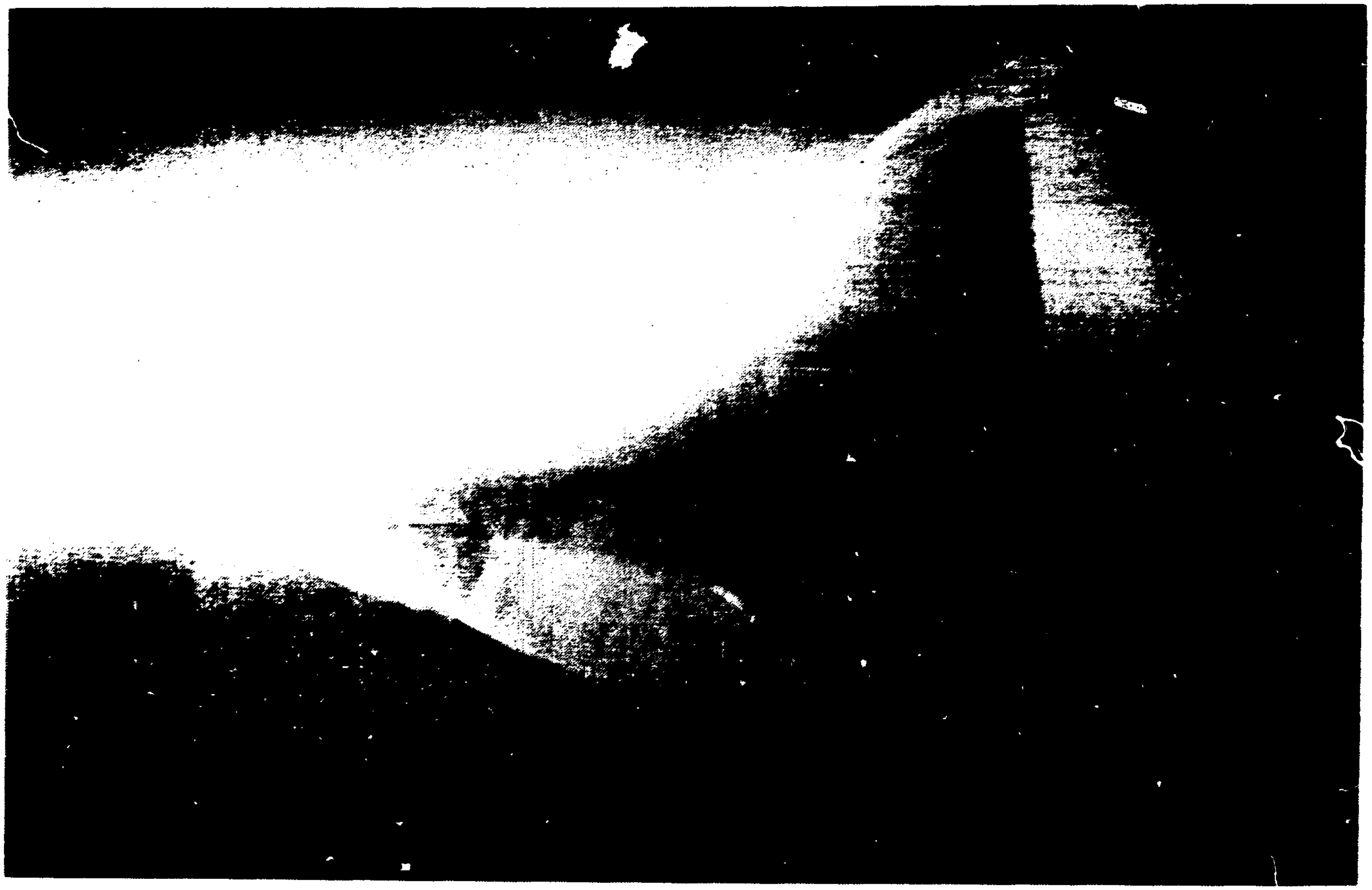
(a) Top view

Figure 24.- Electron beam flow visualization on the 139B orbiter with the canard, and with the fillet S_c removed. α_e = 40°, δ_{BF} = -14.0°, M = ...



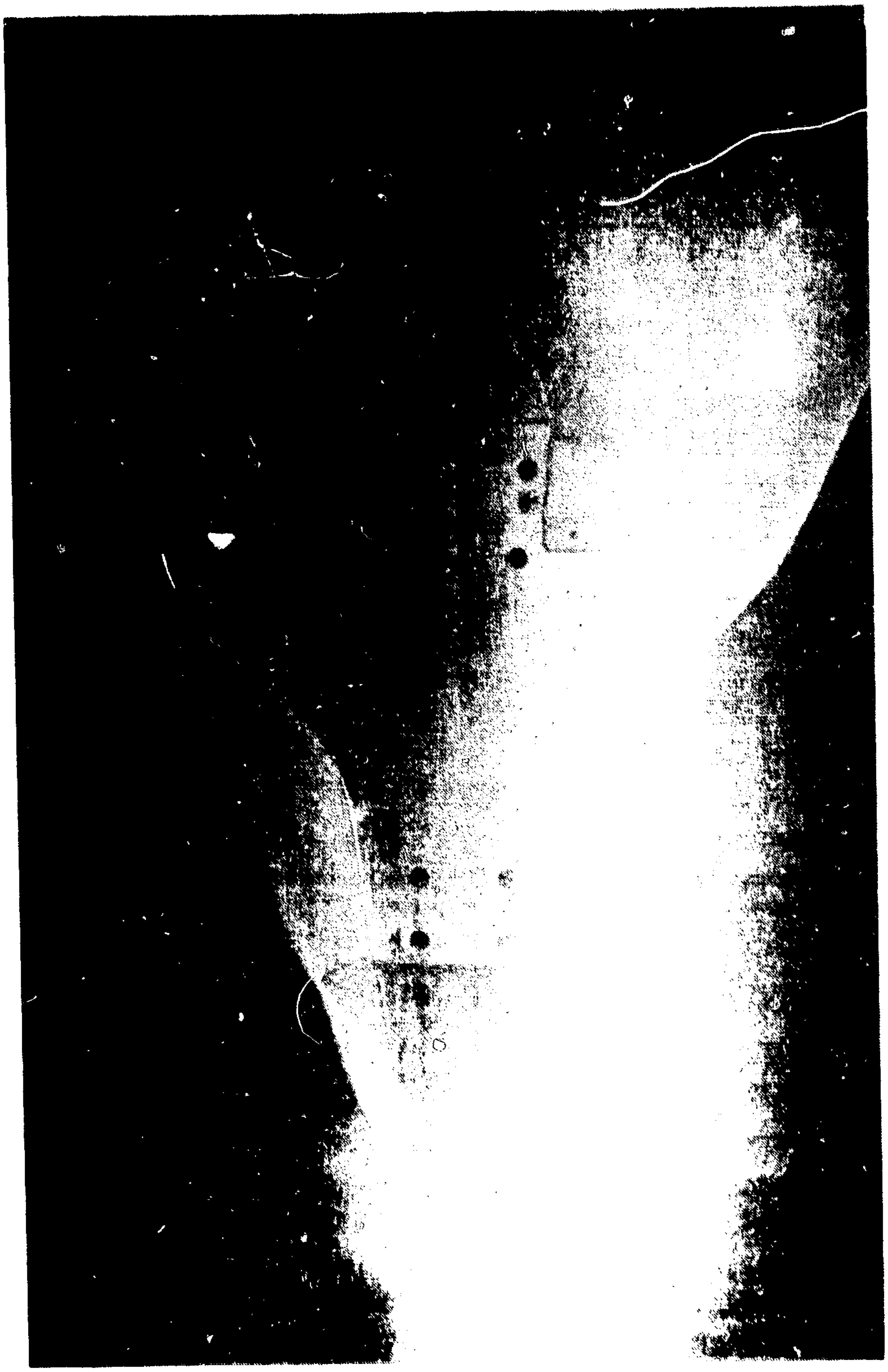
(b) Bottom view

Figure 24.- Concluded



(a) Top view

Figure 25.- Electron beam flow visualization on the 139B orbiter with the C3 canard.
$\delta_e = 15^0$, $\delta_{BF} = 13.75^0$, $\alpha = 30^0$, M = 20.3, $R_e = 1.96 \times 10^6$.



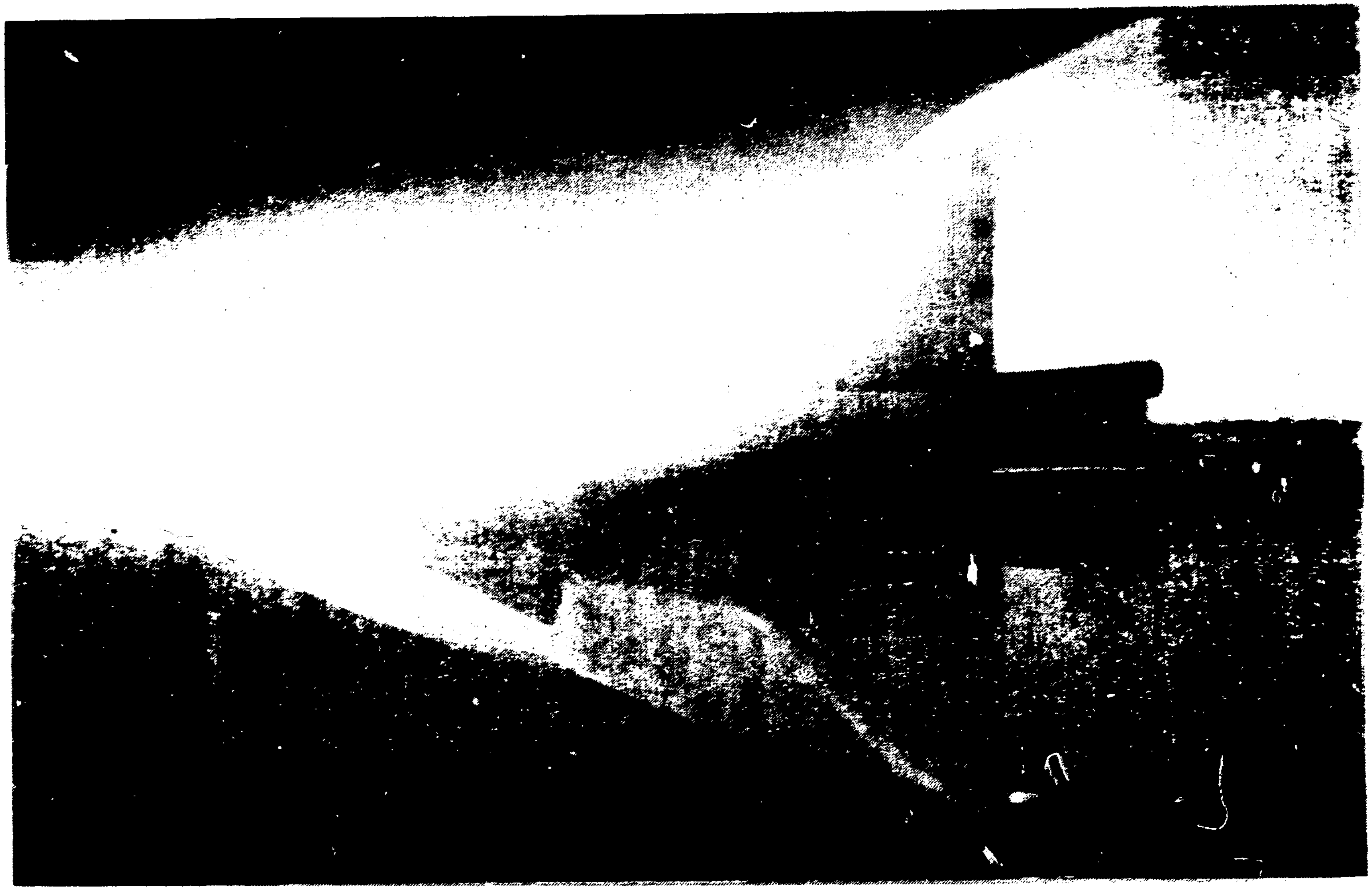
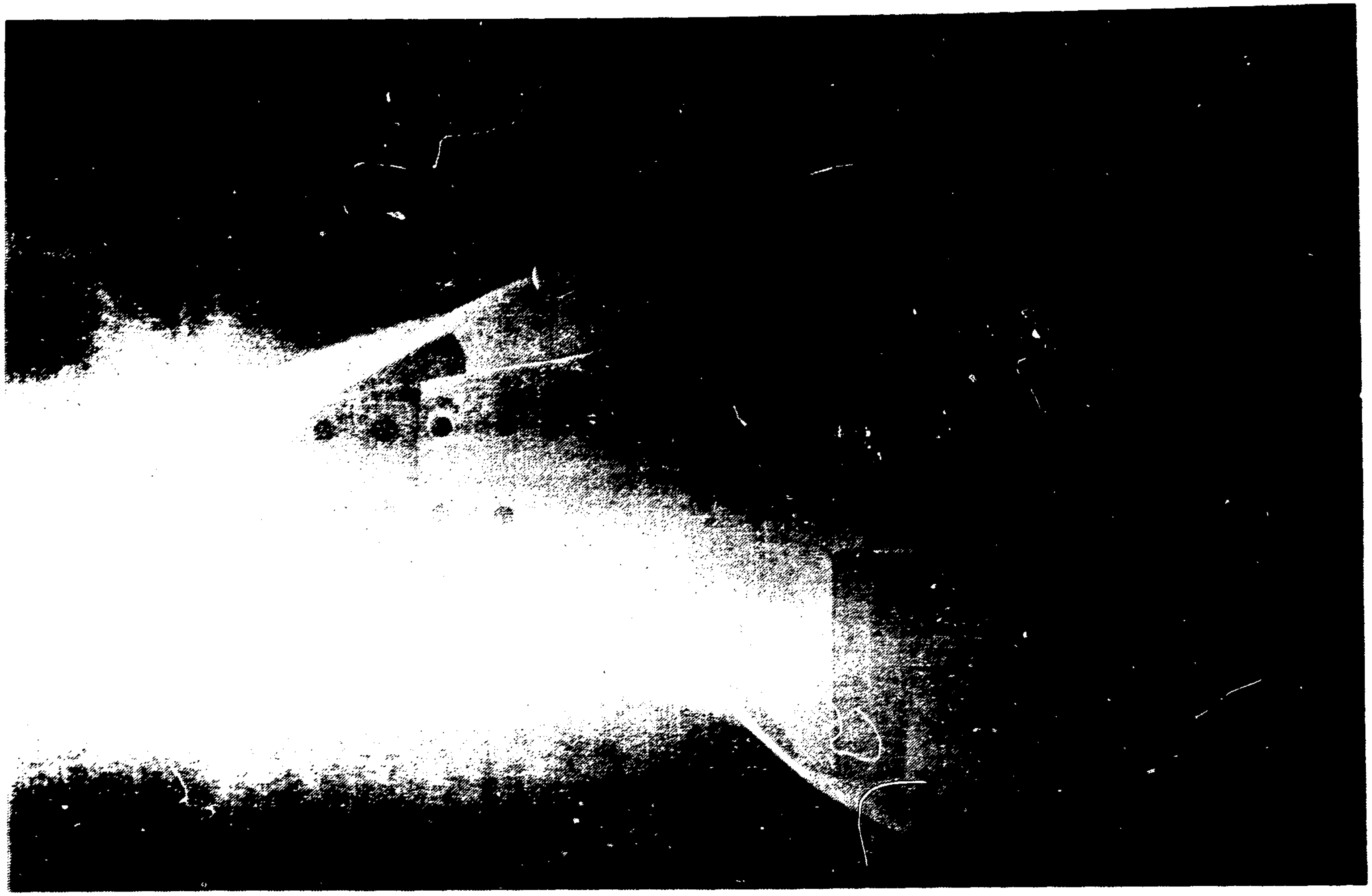
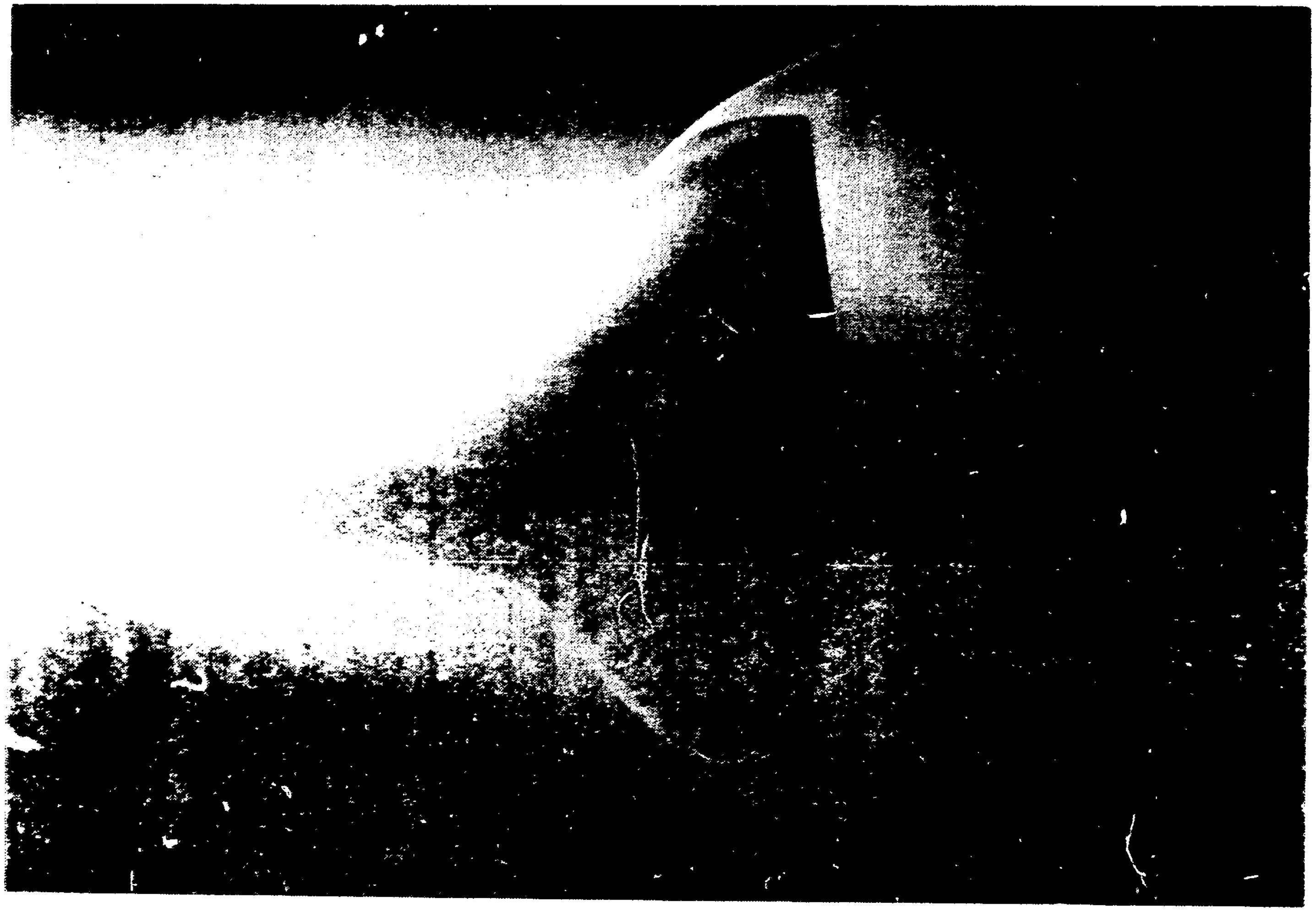


Figure 25.- [illegible]



(b) Bottom view

Figure 26 - Concluded



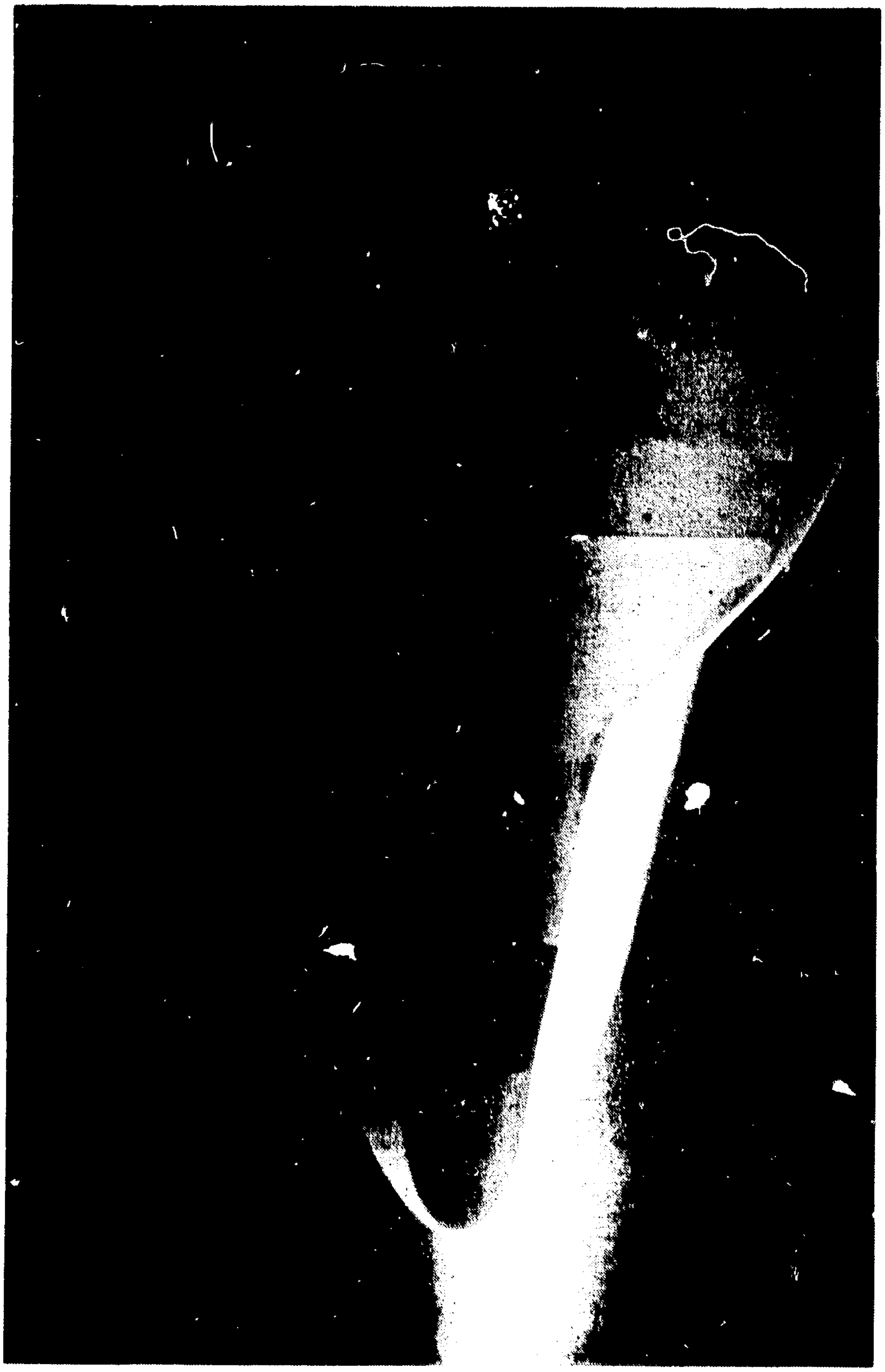
[illegible] Top View

[illegible] flow visualization on the 139B orbiter with the maximum width [illegible]

[illegible]

(b) Bottom view

Figure 26.- Concluded



(b) Bottom view

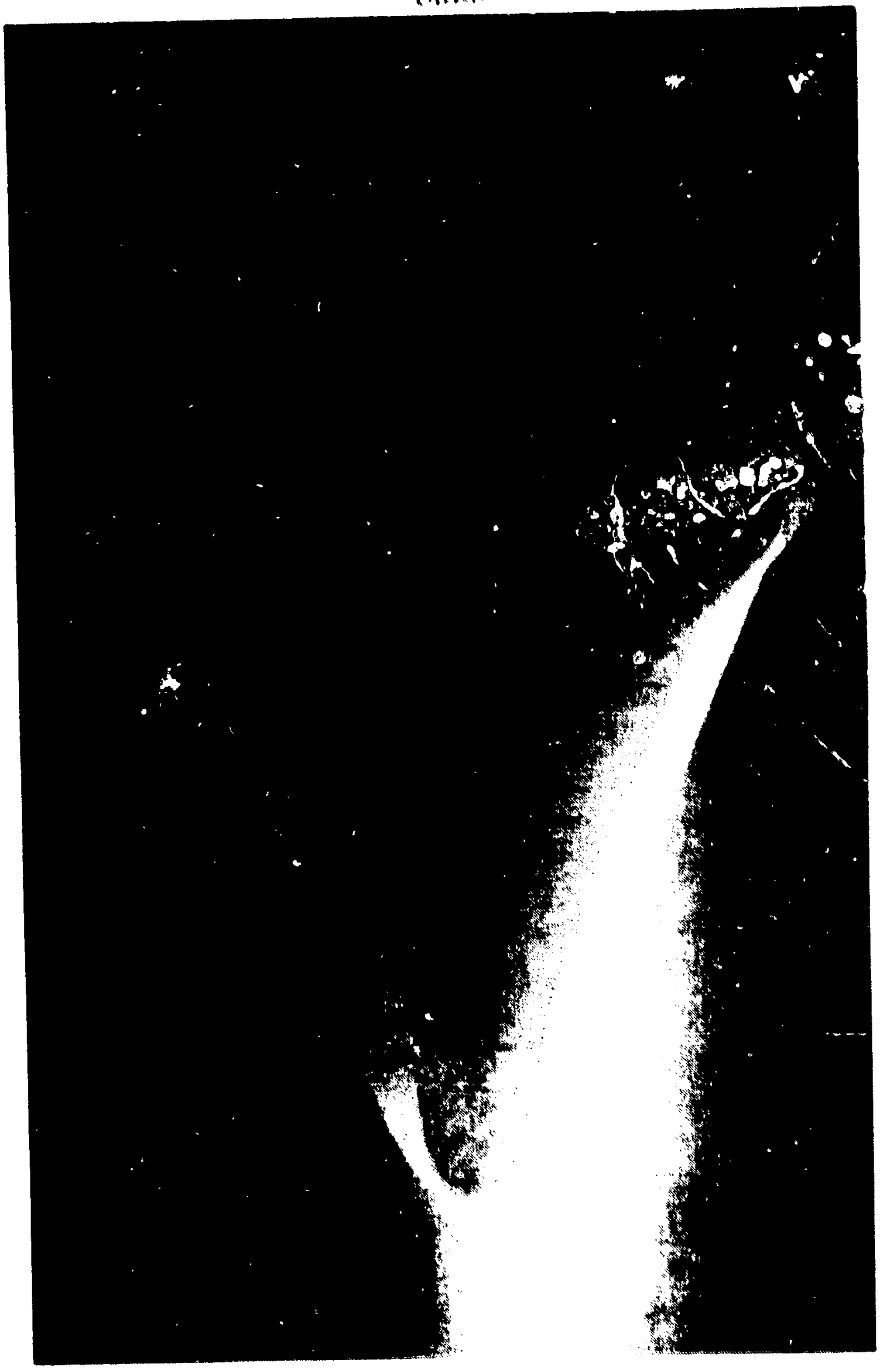
Figure 27. - Concluded.

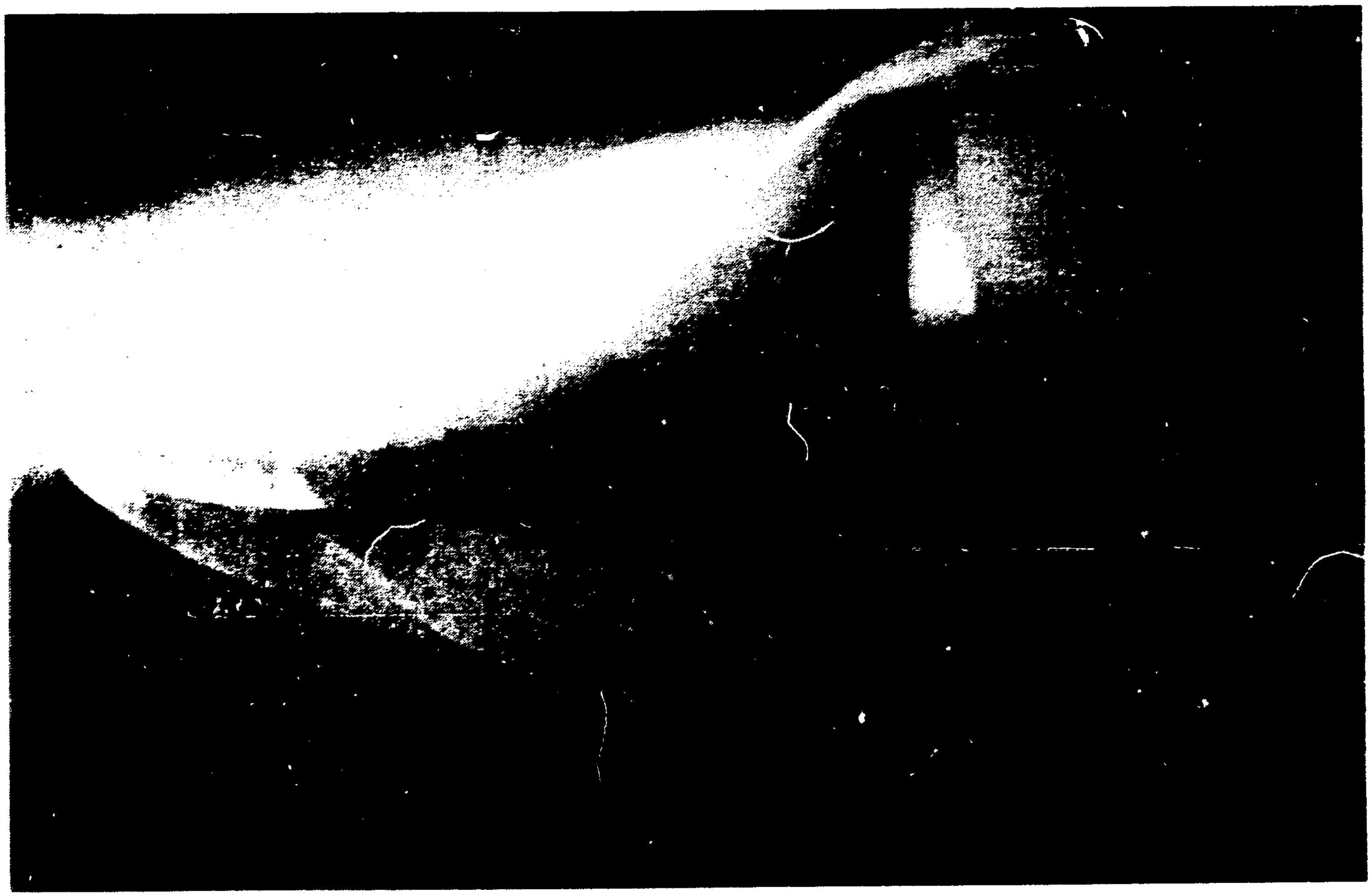
(a) Top view.

Figure 28.- Electron beam flow visualization on the [illegible] fillet. $\delta_e = -40°$, $\delta_{BF} = -14.25°$, [illegible]

(a) Top view

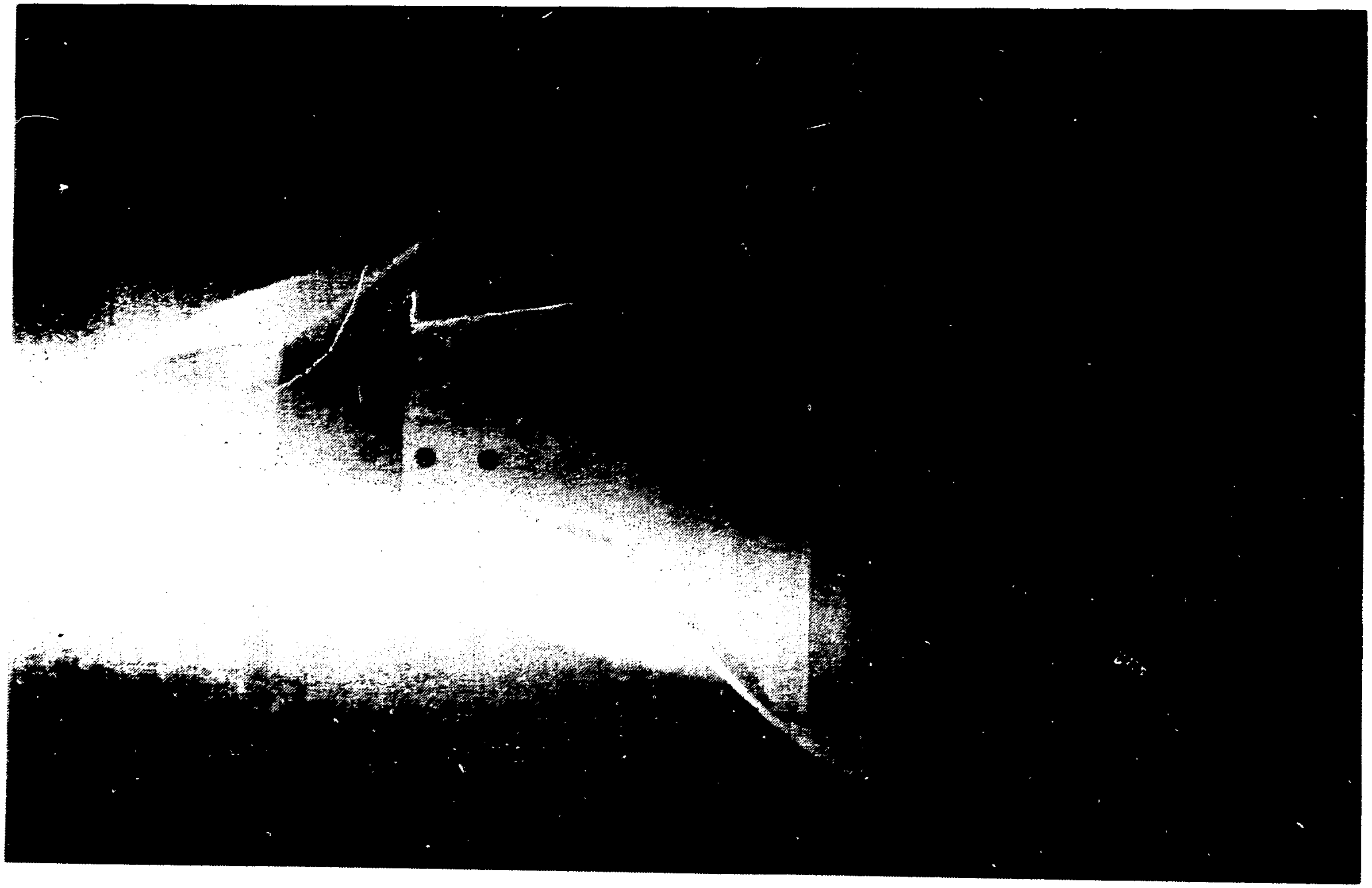
Figure 29.- Electron beam flow visualization on the 139B orbiter with the maximum width forebody B4 and S3 fillet. $\delta_e=-40^0$, $\delta_{BF}=-14.25^0$, $\alpha=30^0$, $M=20.3$, $R_{e_\ell}=1.97 \times 10^5$.





(a) Top view. $\delta_e = -40^\circ$, $\delta_{BF} = -14.25^\circ$.

Figure 30.- Electron beam flow visualization on the 139B orbiter with the maximum width forebody [illegible] and the C_3 canard. $\alpha = 30^\circ$, $M = 20.3$, R_∞ [illegible] 1.25×10^6.

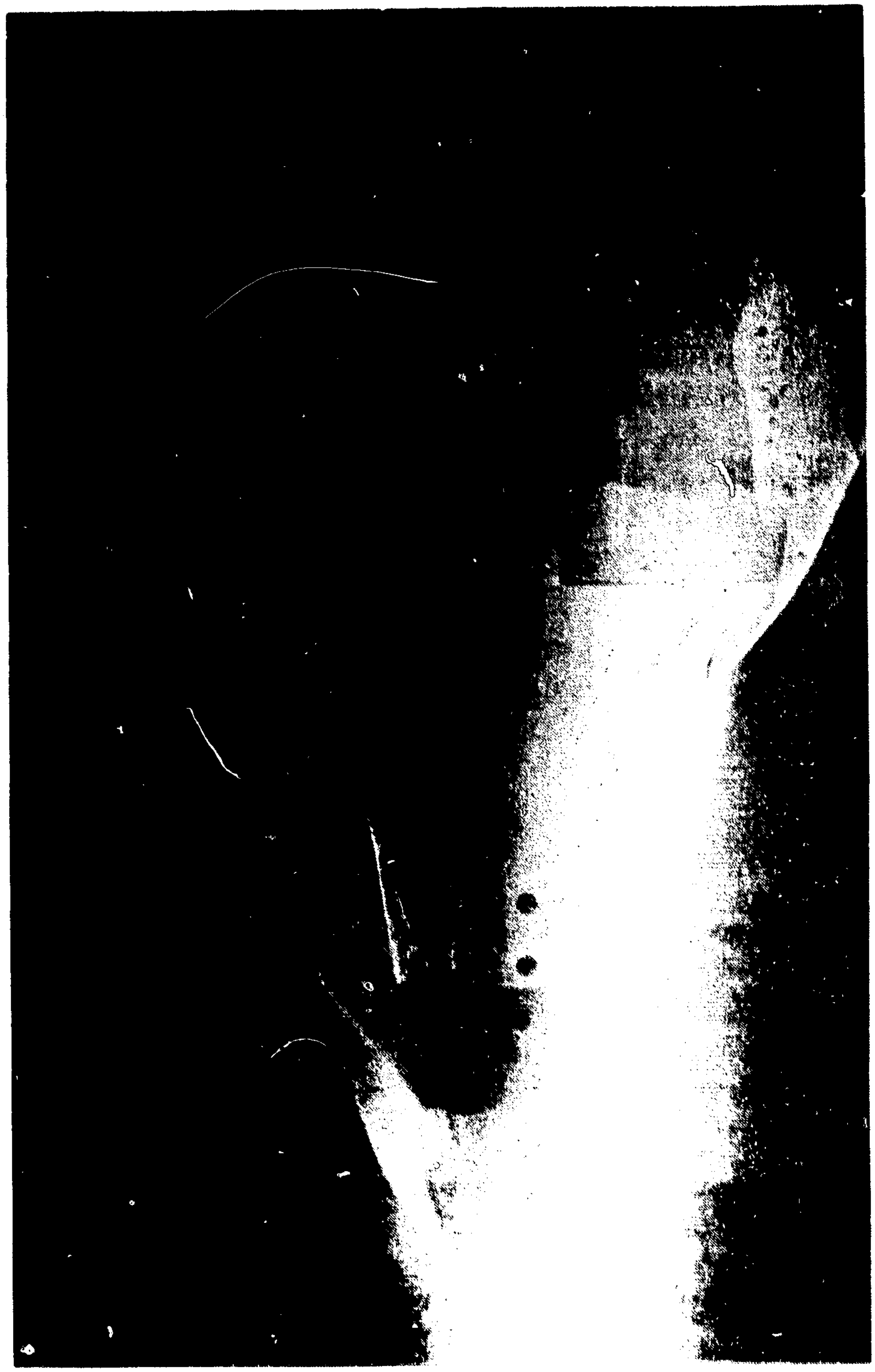


(b) Bottom view. $\delta_e = -40^\circ$, $\delta_{BF} = -14.25^\circ$

Figure 30.- Continued.

(c) Top view. $\delta_e = 15^\circ$, $\delta_{BF} = 13.75^\circ$

Figure 30.- Continued.



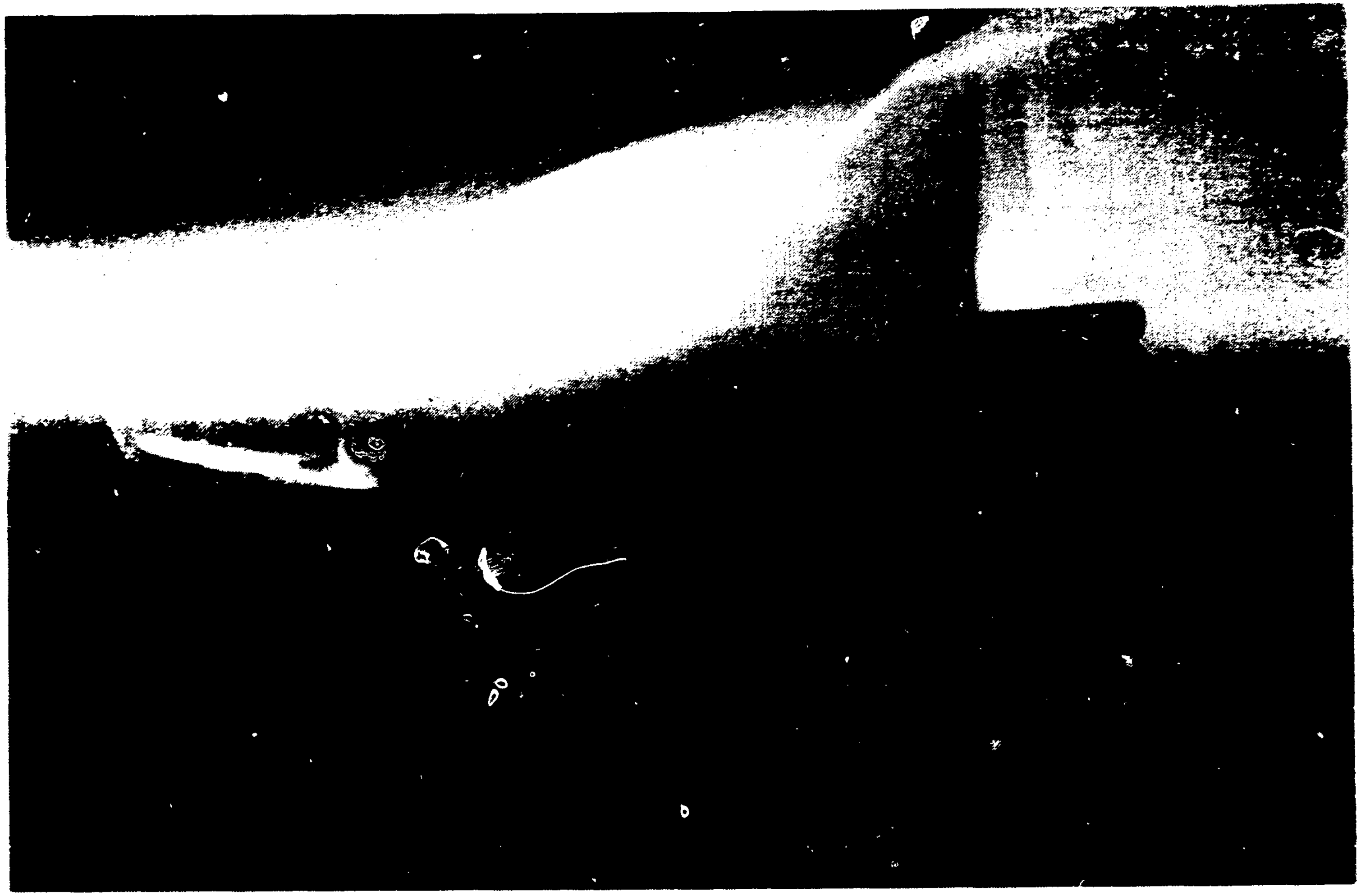
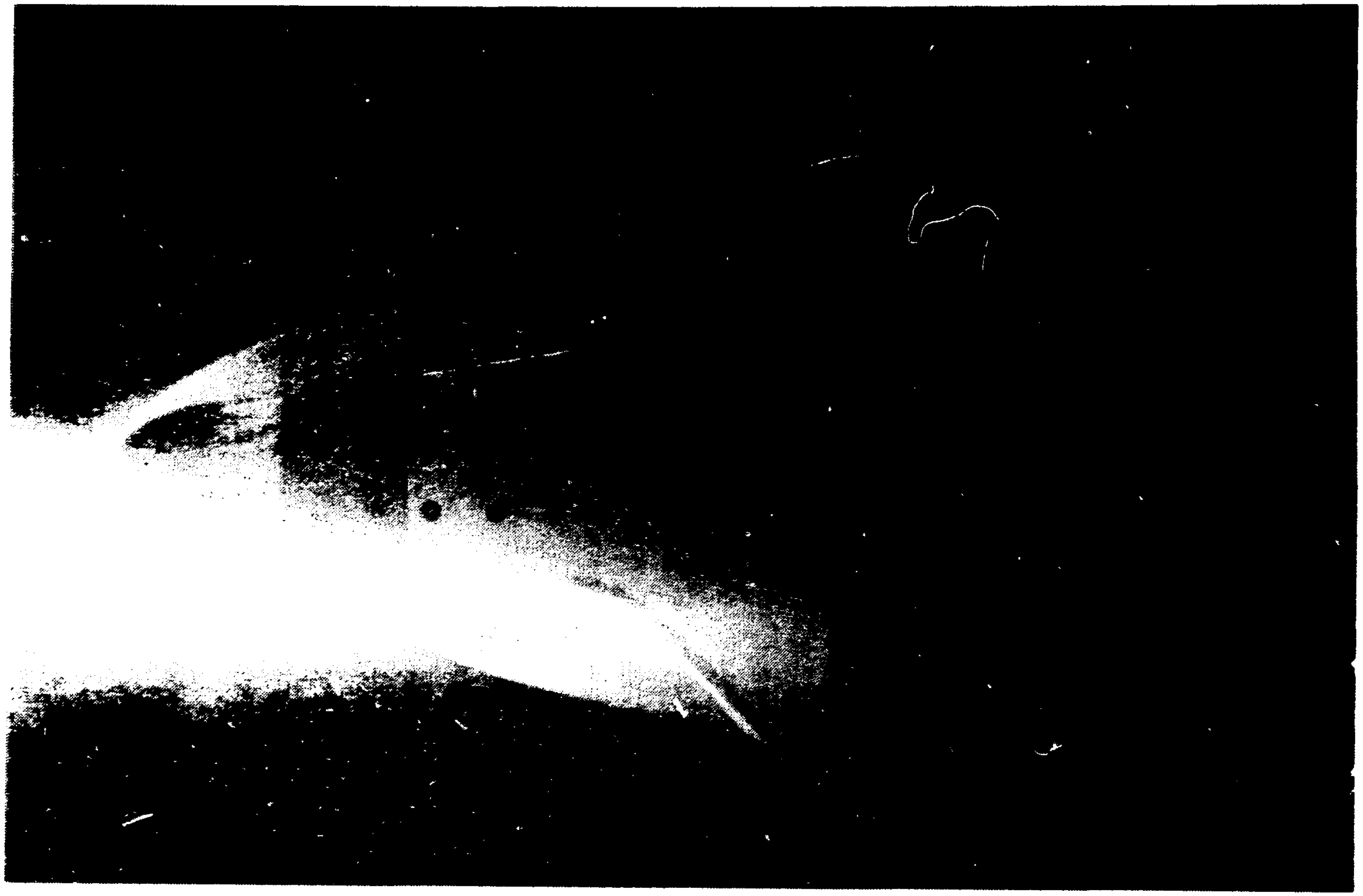
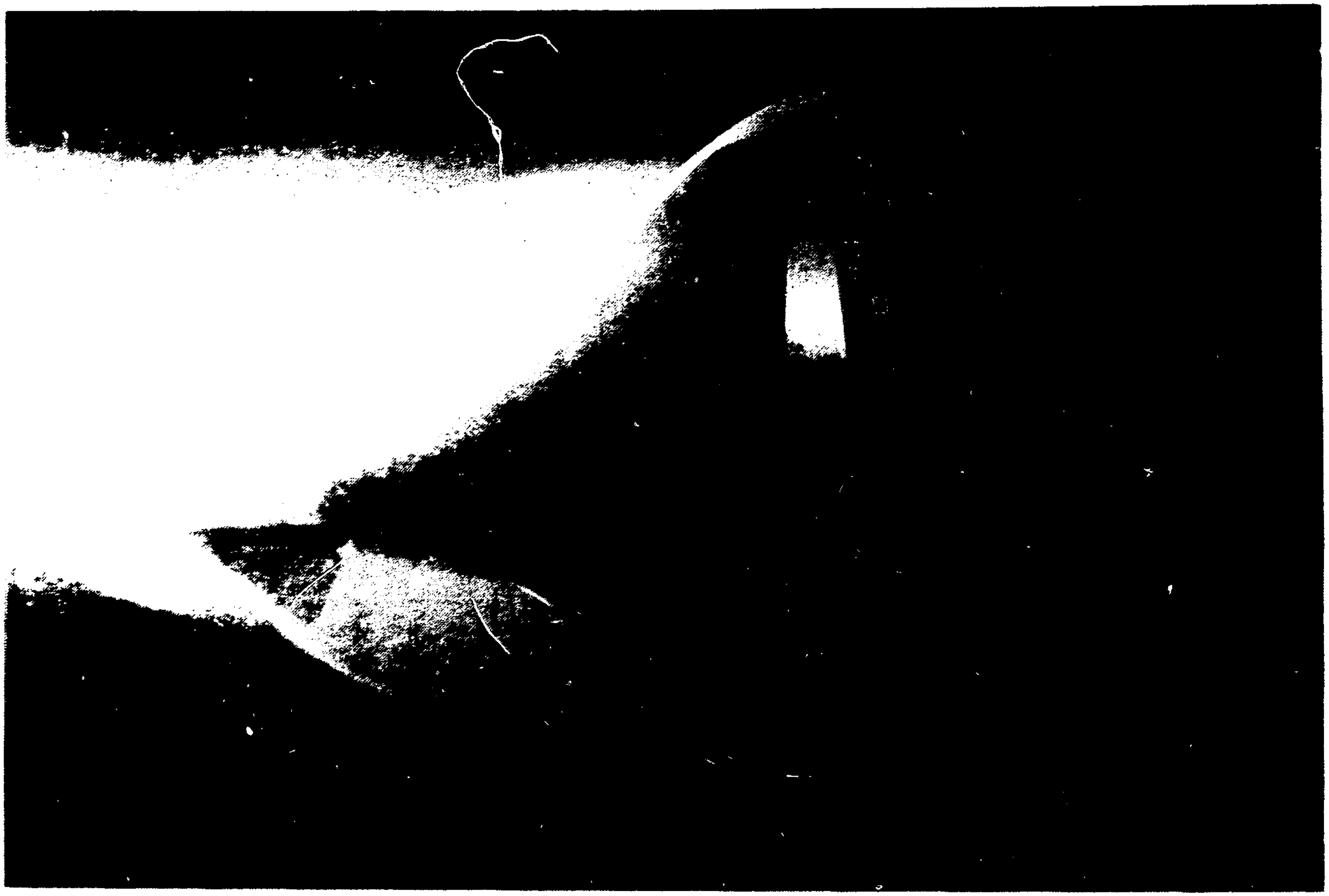


Figure 31.- Electron beam flow visualization on the [illegible] orbiter with the forward [illegible] canard. [illegible]

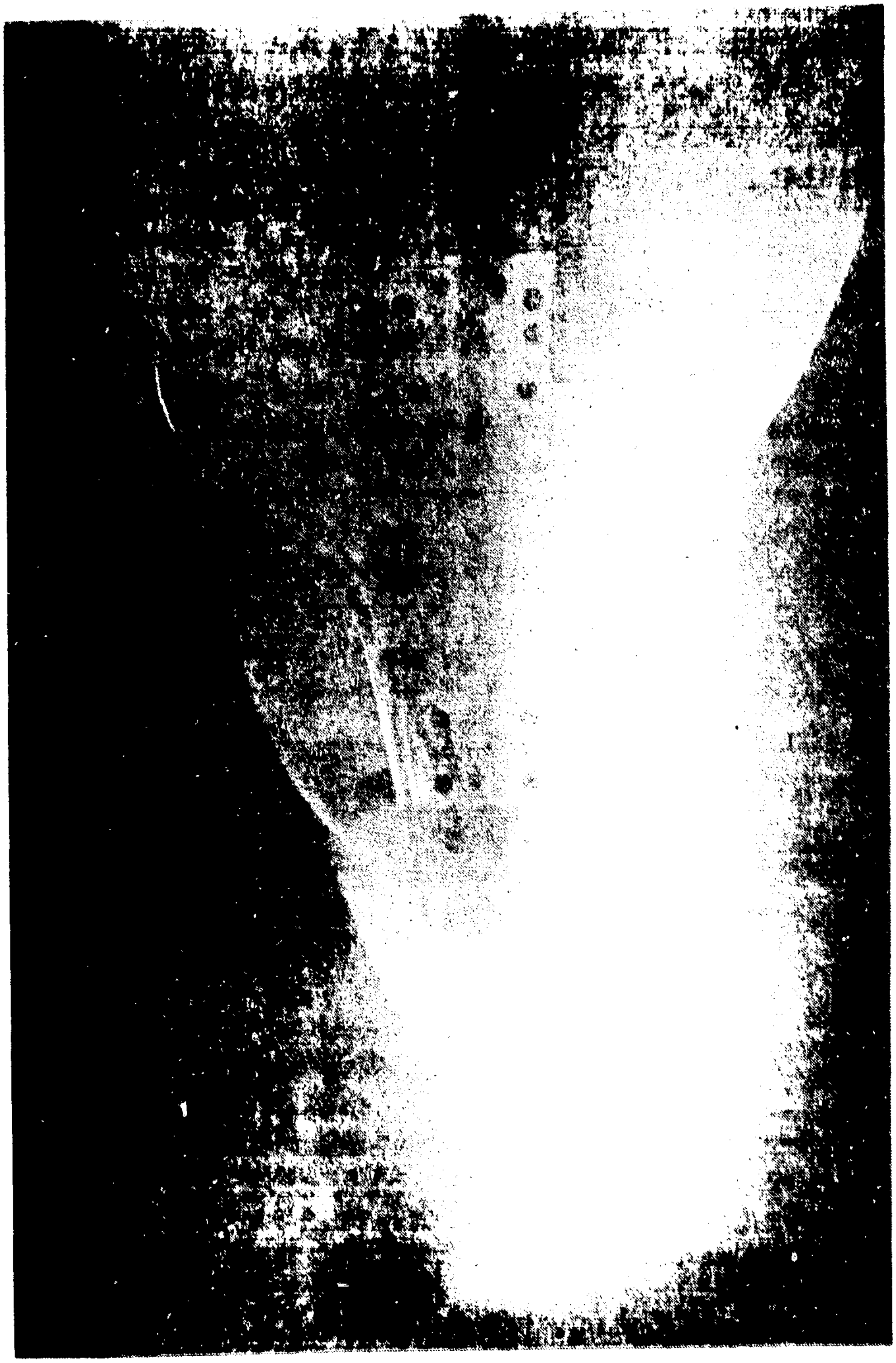


(b) Bottom view

Figure 31.- Concluded.

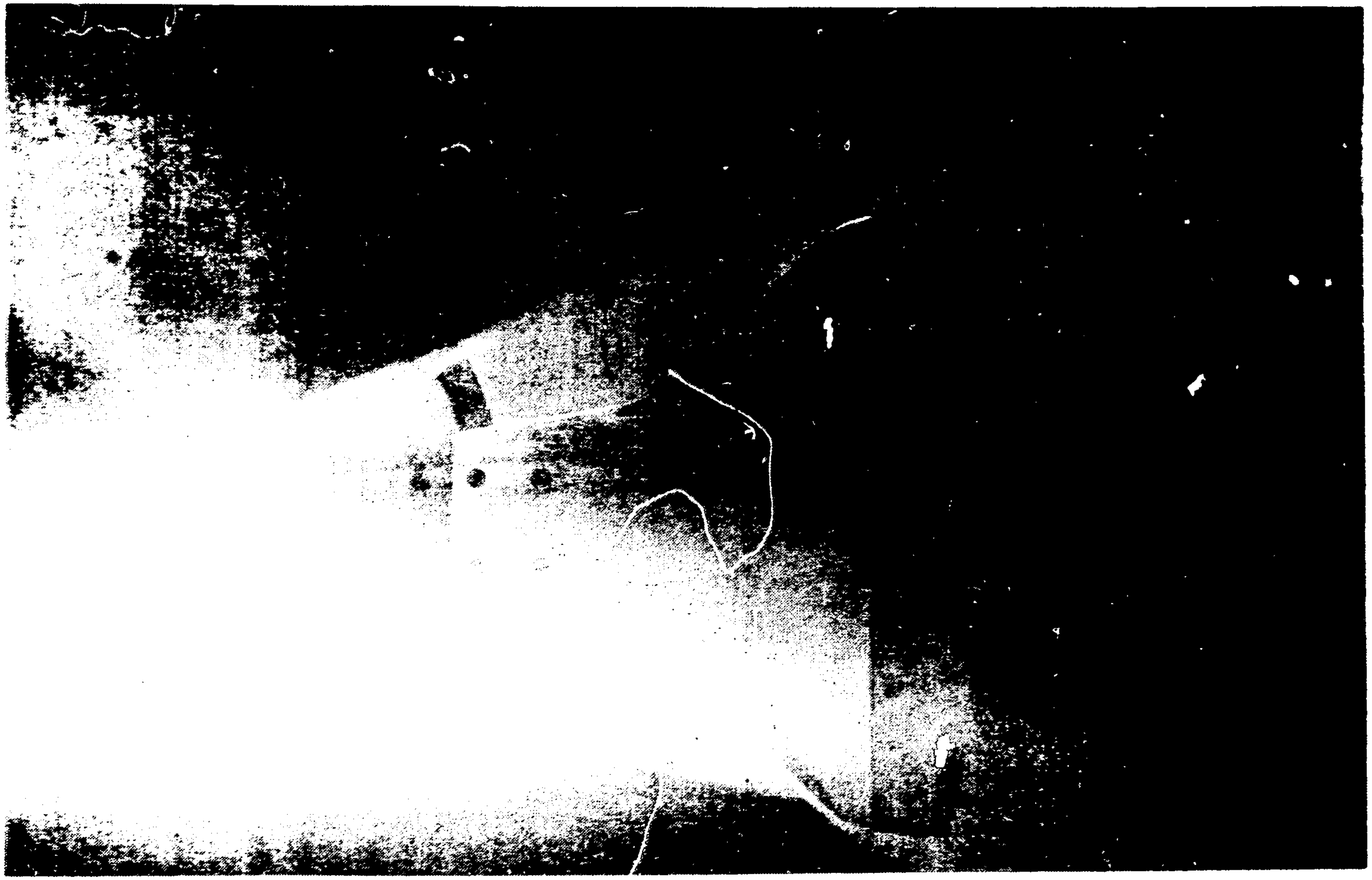


Electron beam flow visualization on the 139B orbiter with the maximum width forebody F4 and the [illegible] ... $M = 10.3$, $R_{e_\infty} = $ [illegible]$\times10^{6}$. ... $\delta_{BF} = -14.25°$.



(c) Top view. $\delta_e = 15^\circ$, $\delta_{BF} = 13.75^\circ$

Figure 32.- Continued.



(d) Bottom view. $\delta_a = 15^\circ$, $\delta_{BF} = 13.75^\circ$

Figure 32.- Concluded.

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15. Supplementary Notes

16. Abstract

Force tests were conducted at Mach 20.3 to determine the effect of several forebody, wing-fillet, and canard modifications on the hypersonic trim capability of a 139B Space Shuttle Orbiter model. Force and moment data were obtained at angles of attack of 18^{0} to 54^{0} at zero sideslip angle and at a Reynolds number of 1.9×10^{6} based on body length. The results indicated that wing-fillet and canard modifications would increase the allowable forward trimmed center-of-gravity capability by as much as 3.0 percent of the body length.

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