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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(NASA-CR-134415) RESULTS OF REACTION CONTROL SYSTEM ON-ORBIT JET SIMULATION USING AN 0.0175-SCALE CONFIGURATION 3 SPACE SHUTTLE ORBITER MODEL (21-0) IN (Chrysler Corp.) 56 p HC $4.25 CSCL 21H

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SPACE SHUTTLE

AEROTHERMODYNAMIC DATA REPORT

JOHNSON SPACE CENTER

HOUSTON, TEXAS

DATA MANagement services.

SPACE DIVISION CHRYSLER CORPORATION

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PUBLICATION CHANGE

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TITLE: RESULTS OF REACTION CONTROL SYSTEM ON-ORBIT JET SIMULATION USING AN 0.0175-SCALE CONFIGURATION 3 SPACE SHUTTLE ORBITER MODEL (21-0) IN THE LaRC 60-FOOT VACUUM SPHERE (OA99)

NUMBER: DMS-DR-2172 DATE: OCTOBER 1974 BRANCH: FLIGHT TECHNOLOGY

Table V, p. 27 lists the following data:

Run #	Configuration	Impingement Forces (Lbs) Side
5	-139 Orbiter (MOD) LT. Pitch-up	
6	-139 Orbiter (MOD) LT. Pitch-up	-.1768

Corrected data are as follows:

Run #	Configuration	
5	-139 Orbiter (MOD) LT. Pitch-down	
6	-139 Orbiter (MOD) LT. Pitch-down	.1768

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PAGE 1 OF 1

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RESULTS OF REACTION CONTROL SYSTEM ON-ORBIT JET SIMULATION USING AN 0.0175-SCALE CONFIGURATION 3 SPACE SHUTTLE ORBITER MODEL (21-0) IN THE LaRC 60-FOOT VACUUM SPHERE (OA99)

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for

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Johnson Space Center
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Houston, Texas

WIND TUNNEL TEST SPECIFICS:

Test Number:	60-foot Vacuum Sphere R3289
NASA Series Number:	OA99
Model Number:	21-0
Test Dates:	March 26-April 12, 1974
Occupancy Hours:	52

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Chrysler Corporation Space Division assumes no responsibility for the data presented other than display characteristics.

RESULTS OF REACTION CONTROL SYSTEM

ON-ORBIT JET SIMULATION USING AN 0.0175-SYSTEM

CONFIGURATION 3 SPACE SHUTTLE ORBITER MODEL (21-0)

IN THE LaRC 60-FOOT VACUUM SPHERE (OA99)

By J. Marroquin, Rockwell International Space Division

ABSTRACT

An experimental investigation was conducted in the Langley Research Center 60-foot Vacuum Sphere (test OA99) from March 26 through April 12, 1974, to obtain detailed effects of the RCS jet flow direct impingement on the Orbiter during on-orbit flight of the Space Shuttle Vehicle.

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INTRODUCTION

An experimental investigation was conducted March 26 through April 12, 1974, to determine RCS direct impingement effects on the Space Shuttle Vehicle during on-orbit flight. Langley Research Center 60-foot Vacuum Sphere was the test site; Orbiter Model 21-0 was used. Nominal test conditions are in Table I.

RCS flow was simulated by blowing a jet of cold air from non-metric nozzles attached to the model sting support system near the fuselage base (figure 2d). Thrust was obtained by setting the nozzle plenum pressure (as specified by the nozzle calibration). Nozzle thrust was measured by a 10 lb. capacity load cell. Nozzles were calibrated at near vacuum conditions and corrected to total vacuum conditions. A plot of both measured and theoretical thrusts as a function of model plenum pressure is in figure 2i.

Three RCS on-orbit flight conditions were simulated. Six-component force data were measured on the complete model using the LaRC 0.50-inch diameter balance (number HH09). It was supported by a LaRC sting.

Six force data runs, including three re-runs, were recorded at various sphere pressure levels and displayed on oscillograph recorders. Model pressure data, applicable to several altitudes, were obtained for two RCS modes using a dummy sting.

Two pressure hook-ups were used. One hook-up, used during tests of pitch down jets (N_{70}), measured pressures on the wing, bodyflap, SSME, and fuselage (see Table IVa). The other hook-up, used during tests of pitch-up jets (N_{69}), measured pressures on the vertical tail (see Table IVb).

NOMENCLATURE
general

Symbol	Plot Symbol	Definition
δ_{BF}	BDFLAP	bodyflap deflection angle, degrees
δ_e	ELEVTR	elevator deflection angle, degrees
δ_{RF}	RUDFLR	rudder flare angle, degrees
α	ALPHA	angle of attack, degrees
β	BETA	angle of sideslip, degrees
P_a		atmospheric pressure, psia
		Reference and C. G. Definitions
b_{ref}	BREF	wing span or reference span, ft
L_{ref}	LREF	reference length or wing mean aerodynamic chord, ft
S_{ref}	SREF	wing area or reference area, ft^2
MRC	MRC	moment reference center
C.G.		center of gravity
		Body-Axis System
N	NF	normal force, lbs
A	AF	axial force, lbs
Y	SF	side force, lbs
m	PM	pitching moment, in-lbs
n	YM	yawing moment, in-lbs
ℓ	RM	rolling moment, in-lbs

NOMENCLATURE (Concluded)

Additional Nomenclature

Symbol	Plot Symbol	Definition
P_C		model RCS plenum chamber pressure, psia
P_{V1}		sphere pressure prior to run, microns
P_{V2}		sphere pressure after run, microns
T_C		model plenum chamber temperature, °F
T_V		sphere chamber temperature, °F
		Simulation Nozzle Design
A^*		nozzle throat area, in^2
A_{ref}		reference area, in^2
e		exit
$\dot{m}$		mass flow rate of the nozzle, lbm/sec
TH		vacuum thrust of the nozzle, lbf
γ		specific heat
ϵ		expansion ratio
θ_p		nozzle lip angle
λ		plume shape parameter
ϕ		Newtonian impact angle
		Abbreviations
RCS		reaction control system
SSME		space shuttle main engines
OMS		orbiter maneuvering system
MPS		main propulsion system
L/H		left hand side
R/H		right hand side

CONFIGURATION INVESTIGATED

The test article (provided by Rockwell) was an 0.0175-scale model (21-0) of the VL70-000139 definition of the SSV Orbiter Configuration 3. The model was constructed of light weight, glazed cast foam with fixed control surfaces. A three-view drawing of the model showing the principal dimensions and photographs of the model installed in the chamber are shown in figures 2a and 3a, respectively.

The model was installed vertically in the LaRC 60-foot Vacuum Chamber. The RCS plenum-nozzle assembly was non-metrically attached to the sting. Nozzle N_{68} (yaw control) and N_{70} (pitch down control) was located on the left side of the RCS plenum. Nozzle N_{69} (pitch up control) was located on the plenum right side. Each nozzle contained two orifices, through which cold air flowed, as shown in figure 2e. Orifices were plugged on non-firing nozzles.

The following nomenclature was used to designate the model components:

$0 = B_{17}\ C_7\ E_{22}\ F_5\ M_6\ N_{39}\ R_5\ V_5\ W_{103}$

Component	Definition
B_{17}	Vehicle configuration 3 fuselage lightweight Orbiter per Rockwell lines VL70-000139
C_7	Basic vehicle configuration 3 canopy per Rockwell lines VL70-000139
E_{22}	Basic vehicle configuration 3 elevon per W_{103} Rockwell lines VL70-000139
F_5	Basic vehicle body flap 3 configuration per Rockwell lines VL70-000139
M_6	Modified OMS-RCS pod for the Rockwell SSV configuration 3 (VL70-000139)

N_{39}	Configuration 3A MPS nozzles
R_5	Basic vehicle 3 configuration rudder per Rockwell lines VL70-000095
V_5	Basic vehicle configuration 3 light weight Orbiter. Centerline vertical tail doublewedge airfoil with rounded leading edge. VL70-000139 and VL70-000095
W_{103}	Vehicle configuration 3 wing per lines VL70-000139 (same planform as W_{89} except dihedral at TE)

<u>RCS Nozzles</u>

N_{68}	L/H yaw nozzle, not canted
N_{69}	R/H pitch up, not canted
N_{70}	L/H pitch down, canted 12° AFT and 20° outboard

RCS NOZZLE DESIGN

The simulation technique employed for the nozzle design was based on the analytical method of Hill and Draper, in which a single unique parameter, λ, was derived that closely approximates the internal iso-properties of a vacuum plume. The correlation between test and full-scale flight forces, moments, and pressures is summarized below.

	full scale	model
A. RCS Jet Characteristics		
Chamber Pressure, P_c	150 psia	1000 psia
Chamber Temperature, T_c	5450°R	530 °R
Specific Heat, γ	1.232	1.4
Nozzle Throat Area A*	3.619 in.^{2}	0.0011045 in.^{2}
Expansion Ratio, ϵ	20	6.2
Nozzle Lip Angle, Θ_p	9°	10°
Exit Area, A_e	72.382 in.^{2}	0.00685 in.^{2}
Exit Mach No., M_e	3.93	3.4
Mass Flow Rate, $\dot{m}$	3.287 lbm/sec	0.0242 lbm/sec
Vacuum Thrust, TH	950 lbf.	1.78 lbf.
B. Simulation Parameter		
Plume Parameter, λ	4.74	4.74 (matched)
Throat Area Ratio (A^*/A_{ref})	3.619	3.619 (matched)
Total pressure Ratio (P_c/P_A)	5.47×10^9	5.45×10^7 (close)

RCS NOZZLE CALIBRATION

The RCS nozzles were calibrated in the intermittent blowdown-vacuum test section 7' x 5' x 16' Test Chamber Rocket Nozzle Test Facility at the Los Angeles Division from 13 through 15 March 1974. The calibration determined nozzle thrust as a function of plenum chamber pressure (P_c).

Test chamber and nozzle plenum chamber pressures were recorded by a dial gage. Nozzle thrust was measured by a Revere No. 244267, 10-lb capacity load cell. All three nozzles were calibrated under near vacuum conditions to simulate the same on-orbit flight conditions tested in the LRC vacuum sphere; see Table I. Calibration results are shown in figure 21.

TEST FACILITY DESCRIPTION

The 60-foot Vacuum Sphere at Langley Research Center, Hampton, Virginia is shown in figure 3. This cell is capable of simulating pressure altitudes over 91.5 Km (300,000 ft.). Evacuation is continuously maintained by six oil diffusion pumps.

Test OA99 data were recorded within 570 milliseconds after RCS jets commenced firing to maintain adequate pressure altitude. A high speed electronically operated, hydraulically controlled valve (located outside and under the test chamber) was used to control RCS jet flow. The valve was operated with hydraulic pressures between 450 psia and 1000 psia.

Vacuum chamber initial pressure, final pressure, and nominal temperature are presented in Table I for each run.

DATA REDUCTION

Force and moments measured by the Orbiter internal strain-gauge balance were reduced about the MRC X_0 = 1076.68, Z_0 = 375.0, and Y_0 = 0.0 (Table V).

Pressure data were obtained on three oscillograph recorders and hand reduced (Table VI).

REFERENCES

1. Pretest Information for test of the 0.0175-Scale Space Shuttle Orbiter Model 21-0 Configuration 3 in the LRC 60-foot Vacuum Sphere to Determine RCS direct impingement data for the 139 Orbiter during on-orbit flight conditions. (OA99), Rockwell International Report SD74-SH-0143, dated March 18, 1974.

2. Drawings.
   Rockwell Drawing VL70-000094, Lines Control Aft Body, OMS RCS Pod, Configuration 139.

   Rockwell Drawing VL70-000095, Lines Control Vertical Tail, Configuration 139.

   Rockwell Drawing VL70-000139A, Lines Study Orbiter, Preliminary Vehicle 3.

   Rockwell Drawing VL70-008401 (for information only) OMS/RCS Aft Fuselage Pod-Equipment arrangement, Integrated Structure MCR 428.

   Rockwell Drawing SS-A01231, dated March 5, 1974, Modification 21-0 Plastic Master for Langley 60-foot Vacuum Sphere.

   Rockwell Drawing SS-A01232, dated March 4, 1974, Instrumentation and assembly 21-0 Plastic Master, Langley 60-foot Vacuum Sphere.

3. SAS/AERO/74-197-Simulation and Nozzles Design Requirement for RCS on-orbit Plume Direct Impingement Test (OA99), dated 3-22-74.

TABLE I. - Test Conditions

DATE	RUN NO.	NOZZLE CONF.	RCS PLENUM P_c PSIA	RCS PLENUM T_c °F	VACUUM SPHERE T_V °F	VACUUM SPHERE PV_1 MICRON HG	VACUUM SPHERE PV_2 MICRON HG	PROGRAM TEST TIME (MILLI-SECONDS)	REMARKS
4-3-74	1	N68	1000	100	90	4.3	10.0	570	FORCE & MOMENT DATA
4-3-74	2	N68	↕	99	90	6.5	21.0	↕	↕
4-4-74	3	N69	↕	88	93	2.3	22.0	↕	↕
4-4-74	4	N69	↕	88	93	22.0	30.0	↕	↕
4-5-74	5	N70	1000	97	82	0.61	15.0	570	FORCE & MOMENT DATA
4-5-74	6	N70	750	97	82	9.0	22.0	570	FORCE & MOMENT DATA
4-10-74	7	N70	1000	83	76	31.3	47.5	150	PRESS. DATA PITCH-DOWN(SPH LEAKAGE)
4-10-74	8	↕	400	83	76	41.9	49.4	150	PRESS. DATA PITCH-DOWN(SPH LEAKAGE)
4-11-74	9	↕	1000	80	78	5.3	20.0	570	REPEAT OF PITCH-DOWN
↕	10	↕	↕	80	78	19.2	34.9	↕	↕
↕	11	↕	↕	79	77	32.1	47.4	↕	↕
4-11-74	12	N70	↕	79	77	46.0	61.0	↕	REPEAT OF PITCH-DOWN
4-12-74	13	N69	↕	104	85	0.41	14.0	↕	PITCH-UP
↕	14	↕	↕	104	85	11.4	25.3	↕	↕
↕	15	↕	↕	104	85	23.3	38.2	↕	↕
↕	16	↕	↕	104	85	36.2	51.2	↕	↕
4-12-74	17	N69	1000	104	85	48.6	63.6	570	PITCH-UP

TABLE II.

RCS VACUUM DIRECT IMPINGEMENT TEST

TEST: 0A99 — DATA SET/RUN NUMBER COLLATION SUMMARY — DATE: 4-14-74

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	δ_e	δ_{BF}	δ_{RF}	Γ_a	P_c	T_c °F	RCS FIRING	NO. OF RUNS		DATE
1	$0 + N_{68}$	0	0	0	0	0	0	1000	100	YAW (LEFT)	1	FORCE	4-3-74
2	$0 + N_{68}$	↑	↑	↑	↑	↑	↑	1000	99	YAW (LEFT)	1	↑	4-3-74
3	$0 + N_{69}$							1000	88	PITCH UP (R/H)	1		4-4-74
4	$0 + N_{69}$							1000	88	PITCH UP (R/H)	1		4-4-74
5	$0 + N_{70}$							1000	97	PITCH DOWN (L/H)	1	↓	4-5-74
6	$0 + N_{70}$							750	97	PITCH DOWN (L/H)	1	FORCE	4-5-74
7	$0 + N_{70}$							1000	83	PITCH DOWN (L/H)		PRESS.	4-10-74
8	$0 + N_{70}$							450	83	PITCH DOWN (L/H)		↑	4-10-74
9	$0 + N_{70}$							1000	80	RERUN PITCH DN L/H			4-11-74
10	$0 + N_{70}$							↑	80	↑			↑
11	$0 + N_{70}$							↓	79	↓			↓
12	$0 + N_{70}$							1000	79	RERUN PITCH DN (L/H)			4-11-74
13	$0 + N_{69}$							1000	104	PITCH UP (R/H)			4-12-74
14	$0 + N_{69}$							↑	↑	↑			↑
15	↑												
16	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓		↓	↓
17	$0 + N_{69}$	0	0	0	0	0	0	1000	104	PITCH UP (R/H)		PRESS	4-12-74

TEST RUN NUMBER

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

$0 = P_{17}C_7E_{22}F_7M_6N_{39}R_5V_5W_{103}$

α OR β SCHEDULES

COEFFICIENTS

TABLE III. - MODEL DIMENSIONAL DATA

MODEL COMPONENT : BODY - B_{17}

GENERAL DESCRIPTION : Fuselage, 3 configuration, lightweight orbiter per Rockwell Lines VL70-000139

MODEL SCALE: 0.0175

DRAWING NUMBER : VL70-000139

DIMENSIONS :	FULL SCALE	MODEL SCALE
Length = In.	1290.3	22.58025
Max Width - In.	267.6	4.6830
Max Depth - In.	244.5	4.27875
Fineness Ratio	4.82175	4.82175
Area - Ft^2	386.67	0.118398
Max. Cross-Sectional		
Planform		
Wetted		
Base		

*REVISED 4/24/74

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT : CANOPY - C_7

GENERAL DESCRIPTION : Configuration 3 per Rockwell Lines VL70-000139

MODEL SCALE: 0.0175

DRAWING NUMBER : VL70-000139

DIMENSIONS :

	FULL SCALE	MODEL SCALE
*Length (X_o=433 to X_o= 578) IN.FS	145.00	2.538
Max Width	57.14	9.99950
Max Depth		
Fineness Ratio		
Area		
Max. Cross-Sectional		
Planform		
Wetted		
Base		

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT: ELEVON - E_{22}

GENERAL DESCRIPTION: 3 Configuration per W_{103} Rockwell Lines VL70-000139 data for (1) of (2) sides.

MODEL SCALE: 0.0175

DRAWING NUMBER: VL70-000139

DIMENSIONS:	FULL-SCALE	MODEL SCALE
Area - Ft^2	205.52	0.06293
Span (equivalent) - In.	353.34	6.18345
Inb'd equivalent chord	114.78	2.00865
Outb'd equivalent chord	55.00	0.962[illegible]
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	0.208	0.208
At Outb'd equiv. chord	0.400	0.400
Sweep Back Angles, degrees		
Leading Edge	0.00	0.00
Trailing Edge	- 10.24	- 10.24
Hingeline	0.00	0.00
Area Moment (Normal to hinge line) Ft^3	1548.07	0.00820

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT : BODY FLAP - F_5

GENERAL DESCRIPTION : Body flap for Fuselage B_{17}. 3 configuration per Rockwell Lines VL70-000139.

MODEL SCALE: 0.0175

DRAWING NUMBER : VL70-000139

DIMENSIONS :	FULL SCALE	MODEL SCALE
Length - In.	84.70	1.48225
Max Width - In.	267.6	4.6830
Max Depth		
Fineness Ratio		
Area - Ft^2		
Max. Cross-Sectional	142.5195	0.04364
Planform		
Wetted		
Base	38.0958	0.01167

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT : OMS POD - M_6

GENERAL DESCRIPTION : Configuration 3

Aft end of OMS POD cut off for RCS installation. See Figures 2 and 3 and Convair Model Drawing No. WT-73-108150.

MODEL SCALE: 0.0175

DRAWING NUMBER : VL70-000139

DIMENSIONS :

	FULL SCALE	MODEL SCALE
Length (OMS Fwd. Sta X_o=1233.0)	327.000	5.7225
Max Width (@ X_o = 1450.0)	109.000	1.9075
Max Depth		
Fineness Ratio		
Area		
Max. Cross-Sectional		
Planform		
Wetted		
Base		

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT: MPS NOZZLES - N_{39}

GENERAL DESCRIPTION: Configuration 3A MPS Nozzles

MODEL SCALE = 0.0175

DRAWING NO. See figures.

DIMENSIONS		FULL SCALE	MODEL SCALE
Mach No.			
Length ~ in.			
Gimbal Point to Exit Plane			
Throat to Exit Plane			
Diameter ~ in.			
Exit		94.000	1.645
Throat			
Inlet			
Area ~ ft^2.			
Exit		48.193	0.01475669
Throat			
Gimbal Point (station) ~ in.			
Upper Nozzle			
X	NOT USED		
Y			
Z			
Lower Nozzles			
X		1462.0	25.585
Y		± 53.000	± 0.9275
Z		342.7	5.99725
Null Position ~ deg.			
Upper Nozzle			
Pitch			
Yaw			
Lower Nozzles			
Pitch			
Yaw			

*REVISED 4/24/74

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT: RUDDER - R_5

GENERAL DESCRIPTION: 2A, 3 and 3A Configuration per Rockwell Lines VL70-000095

MODEL SCALE: 0.0175

DRAWING NUMBER: VL70-000095

DIMENSIONS:	FULL-SCALE	MODEL SCALE
*Area - Ft^2	100.15	0.031
Span (equivalent) - In.	201.0	3.5175
Inb'd equivalent chord	91.585	1.60274
Outb'd equivalent chord	50.833	0.88958
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	0.400	0.400
At Outb'd equiv. chord	0.400	0.400
Sweep Back Angles, degrees		
Leading Edge	34.83	34.83
Trailing Edge	26.25	26.25
Hingeline	34.83	34.83
* Area Moment (Product of Area & $\bar{c}$) - Ft^3	526.13	0.00279
*Product of Area and Mean Chord Inc.	73.2	1.281

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT: VERTICAL - V_5

GENERAL DESCRIPTION: Centerline Vertical Tail, doublewedge airfoil with rounded leading edge.

MODEL SCALE: 0.0175

DRAWING NUMBER: VL70-000139, VL70-000095

DIMENSIONS:

	FULL-SCALE	MODEL SCALE
TOTAL DATA		
Area (Theo) - Ft^2		
Planform	425.92	0.13042
Span (Theo) - In	315.72	5.52510
Aspect Ratio	1.675	1.675
Rate of Taper	0.507	0.507
Taper Ratio	0.404	0.404
Sweep Back Angles, degrees		
Leading Edge	45.000	45.000
Trailing Edge	26.249	26.249
0.25 Element Line	41.130	41.130
Chords:		
Root (Theo) WP	268.50	4.69875
Tip (Theo) WP	108.47	1.89823
MAC	199.81	3.49667
Fus. Sta. of .25 MAC	1463.50	25.61125
W. P. of .25 MAC	635.522	11.1216
B. L. of .25 MAC	0.00	0.00
Airfoil Section		
Leading Wedge Angle - Deg	10.000	10.000
Trailing Wedge Angle Deg	14.290	14.290
Leading Edge Radius	2.00	0.0350
Void Area	13.17	0.23048
Blanketed Area	12.67	0.22173

TABLE III. - MODEL DIMENSIONAL DATA - Concluded.

MODEL COMPONENT: WING-W 103

GENERAL DESCRIPTION: Configuration 3 Orbiter per Lines VL70-000139.

MODEL SCALE: 0.0175

TEST NO.

DWG. NO. VL70-000139

DIMENSIONS:	FULL-SCALE	MODEL SCALE
TOTAL DATA		
Area (Theo.) - Ft^2		
Planform	2690.00	0.0823813
Span (Theo In.	936.68	16.3919
Aspect Ratio	2.265	2.265
Rate of Taper	1.177	1.177
Taper Ratio	0.200	0.200
Dihedral Angle, degrees	3.500	3.500
Incidence Angle, degrees	3.000	3.000
Aerodynamic Twist, degrees	+ 3.000	+ 3.000
Sweep Back Angles, degrees		
Leadi Edge	45.000	45.000
Trail Edge	- 10.24	- 10.24
0.25 Element Line	35.209	35.209
Chords:		
Root (Theo) B.P.0.0.	689.24	12.0617
Tip, (Theo) B.P.	137.85	2.41237
MAC	474.81	8.309175
Fus. Sta. of .25 MAC	1136.89	19.895575
W.P. of .25 MAC	299.20	5.236
B.L. of .25 MAC	182.13	3.187275
EXPOSED DATA		
Area (Theo) - Ft^2	1752.29	0.536551
Span, (Theo) - In. BP108	720.68	12.6119
Aspect Ratio	2.058	2.058
Taper Ratio	0.2451	0.2451
Chords		
Root BP108	562.40	9.842
Tip 1.00 $\frac{b}{2}$	137.85	2.412375
MAC	393.03	6.87803
Fus. Sta. of .25 MAC	1185.31	20.74293
W.P. of .25 MAC	300.20	5.2535
B.L. of .25 MAC	251.76	4.4058
Airfoil Section (Rockwell Mod NASA) XXXX-64		
Root $\frac{b}{2}$ =	0.10	0.10
Tip $\frac{b}{2}$ =	0.12	0.12
Data for (1) of (2) Sides		
Leading Edge Cuff Planform Area - Ft^2	120.33	0.036845
Leading Edge Intersects Fus M. L. @ Sta	560.0	9.8000
Leading Edge Intersects Wing @ Sta	1035.0	18.1125

TABLE IV. - Instrumentation and Transducer Information
a. (N_{70}) Pitch-Down

PRESS. TAP LOCATION	TAP NO.	RECORDER		TRANSDUCER				REMARKS
		RECORDER	CHANNEL	INV. NO.	S/N	EXCIT.	RANGE	
L/H WING	1	3	3	88634	5574	10 V.	1.0	
	2	3	5	89021	5570		1.0	
	3	3	7	138027	2203		0.5	
	4	3	9	NA	5499		1.0	
	5	3	11	100882	6225			
	6	3	13	130688	1866			
	7	3	15	130686	2346		1.0	
	8	3	17	138031	2207		0.5	
	9	3	19	130678	1856		1.0	
	10	3	21	130677	1855			
	11	3	23	130689	1867			
	12	2	4	87550	5489			
	13	2	6	100984	6226			
	14	2	7	87469	5496			
	15	2	8	89020	5497			
	16	2	9	85396	5249			
	17	2	10	87827	5522			
	18	2	11	85398	5251			
L/H WING	19	2	12	88238	5577	10 V		
BODY FLAP	20	1	9	125941	12922	5 V.	1.0	
				125939	12920		1.0	RUNS 7 & 8 RECORDER PROBLEMS
	21	1	10	130692	1890	10 V	3.0	RUNS 9, 10, 11 & 12
	22	1	3	88239	5579	10 V	1.0	
	23	1	5	87472	5503			
	24	1	6	87552	5491			
BODY FLAP	25	1	7	96863	6073		1.0	
L/H FUSELAGE	26	3	25	138026	2202		0.5	
	27	3	27	138029	2205			
	28	3	29	138032	2208			
	29	3	31	138034	2210			
	30	3	33	138033	2209			
	31	3	35	138035	2211		0.5	
L/H FUSELAGE	32	3	37	138028	2204		0.5	
SSME	33	2	14	101501	6110		1.0	
SSME	34	2	15	100877	6228		1.0	
SSME	35	2	16	86210	5253	10 V	1.0	
PLENUM CHAMBER	P_c	3	26	----	----	----	---	

TABLE IV. - Instrumentation and Transducer Information - Concluded.

b. (N69) Pitch-Up

PRESS. TAP LOCATIONS	TAP NO.	RECORDER		TRANSDUCER				REMARKS
		RECORDER	CHANNEL	INV. NO.	S/N	EXCIT	RANGE	
VERTICAL	36	3	7	138027	2203	10 V	0.5	
↕	37	3	17	138031	2207	↕	0.5	
	38	3	25	138026	2202		0.5	
	39	3	11	100882	6225		1.0	
	40	3	13	130688	1866		1.0	
	41	3	15	130686	2346		1.0	
	42	3	27	138029	2205		0.5	
	43	3	29	138032	2208		0.5	
	44	3	19	130678	1856		1.0	
	45	3	21	130677	1855		1.0	
	46	3	23	130689	1867		1.0	
	47	3	31	138034	2210		0.5	
	48	3	33	138033	2209		0.5	
	49	3	35	138035	2211		0.5	
VERTICAL	50	3	37	138028	2204	10 V	0.5	
PLENUM CHAMBER	P_c	3	26	---	--	----	---	

TABLE V. - RCS DIRECT IMPINGEMENT FORCE DATA

Run #	Configuration	Plenum Pressure	Impingement Forces(Lbs) Normal	Axial	Side	Impingement Moments (in-lbs) Pitch	Roll	Yaw
1	-139 Orbiter(MOD) Left Yaw Noz.	1000(psi)	-.0562	-.0083	-.0052	.3454	-.3497	.1033
2	-139 Orbiter(MOD) Left Yaw Noz.	1000(psi)	-.0459	-.0035	-.0077	.3226	-.3338	.1214
3	-139 Orbiter(MOD) RT. Pitch-up	1000(psi)	.0019	-.1116	-.2634	-.1716	-1.3367	2.1386
4	-139 Orbiter(MOD) RT. Pitch-up	1000(psi)	-.0032	-.1089	-.2599	-.1916	-1.3235	2.1011
5	-139 Orbiter(MOD) LT. Pitch-down	1000(psi)	-.9491	-.5081	.1803	7.8420	-1.9005	-1.1690
6	-139 Orbiter(MOD) LT. Pitch-down	800(psi)	-.7710	-.4209	.1768	6.4115	-1.5331	-.9325

TABLE VI. RCS DIRECT IMPINGEMENT PRESSURE DATA

RCS Jet Group: Right side, Up-firing

Run 13

P_c = 1000 Psia

Tap #	Imp. Press. ~ P_I MMHg
36	0.65
37	1.25
38	2.10
39	2.60
40	1.70
41	0.15
42	0.50
43	0.85
44	1.45
45	1.95
46	1.80
47	0.10
48	0.75
49	1.40
50	1.25

RCS Jet Group: Left side, Down-firing

Run 9

Tap #	P_I - MMHg	Tap #	P_I - MMHg	Tap #	P_I - MMHg
1	0	13	0	25	13.0
2	0	14	.1	26	.2
3	.1	15	.7	27	.5
4	.1	16	8.3	28	.1
5	.1	17	1.9	29	0
6	.1	18	.2	30	.2
7	.1	19	0	31	.1
8	.1	20	27.0	32	0
9	.4	21	110.0	33	.5
10	.5	22	3.0	34	.8
11	.6	23	38.0	35	.3
12	.2	24	8.0		

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

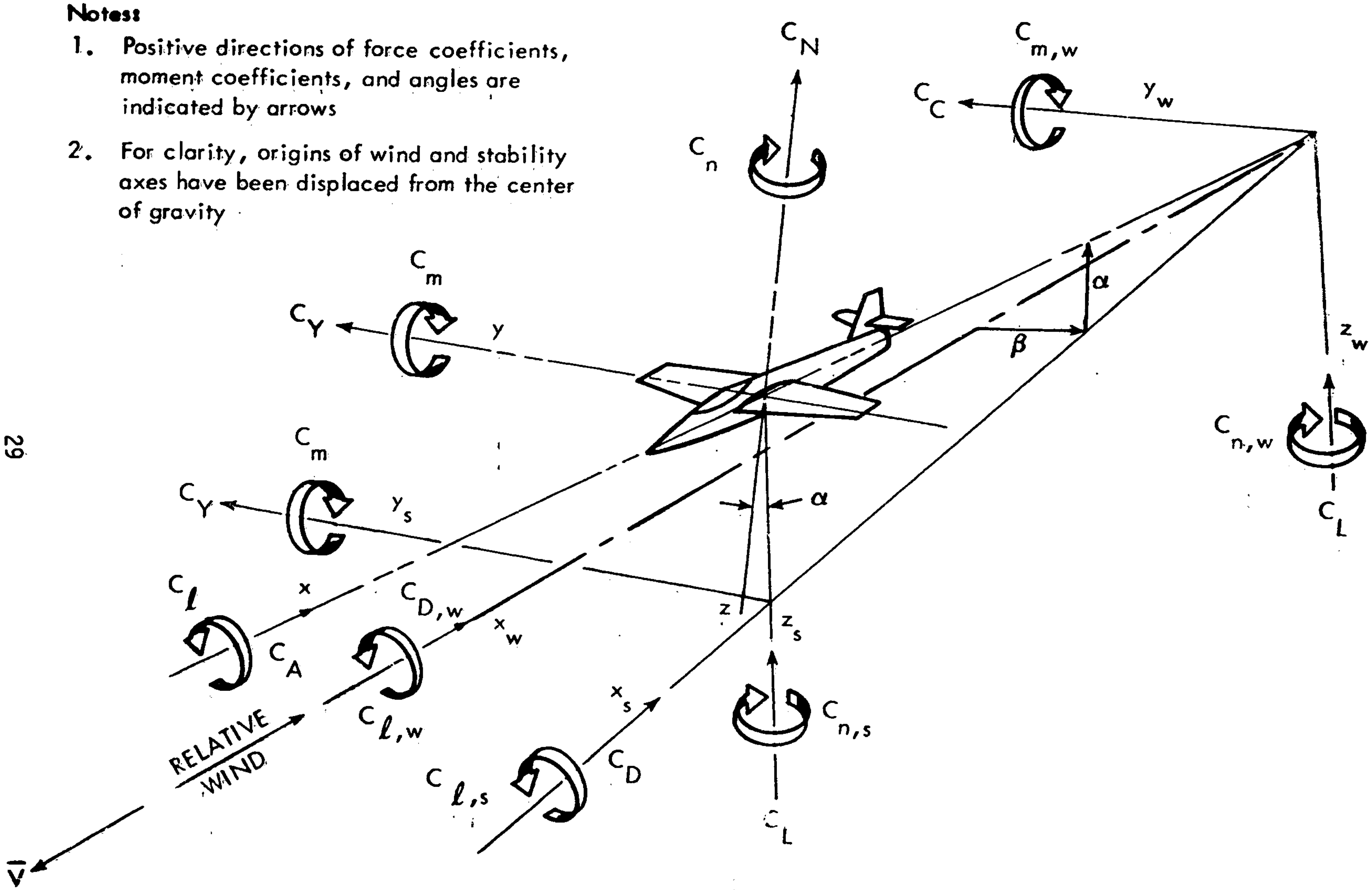
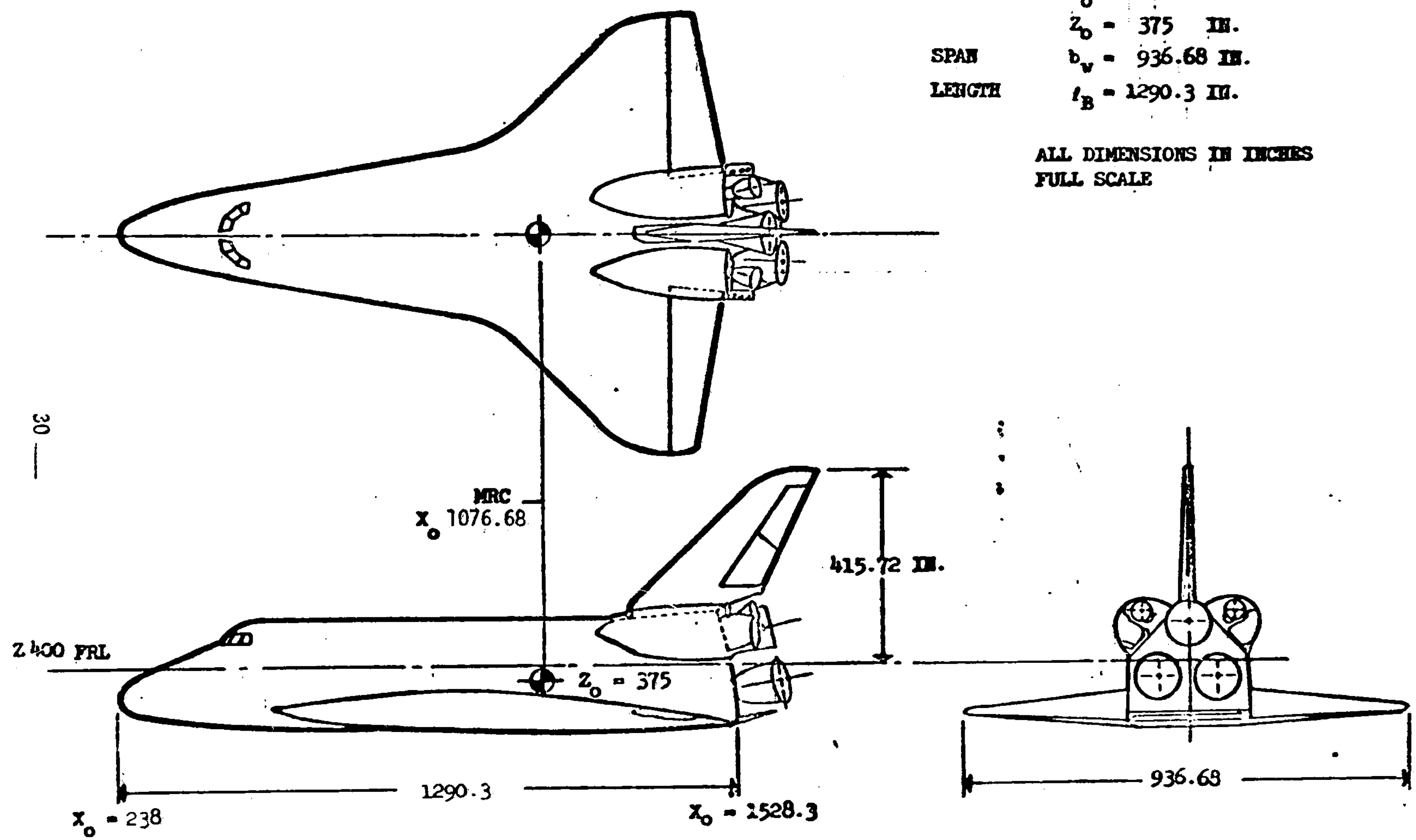


Figure 1. - Axis Systems

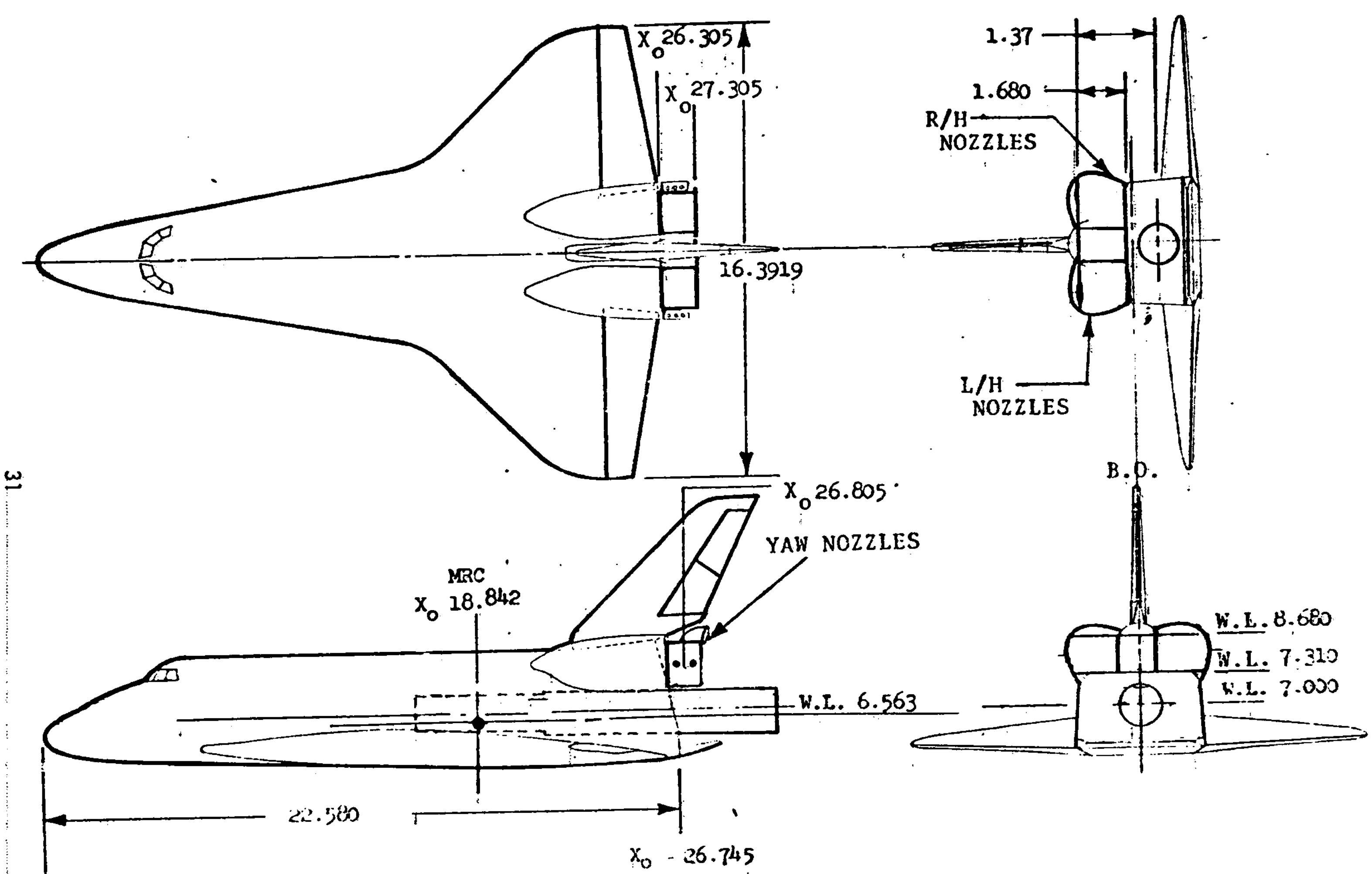
REFERENCE	DIMENSIONS (FS)
AREA	S_w = 2690 FT^2
MAC	C = 474.8 IN.
C.G.	X_o = 1076.48 IN.
	Z_o = 375 IN.
SPAN	b_w = 936.68 IN.
LENGTH	ℓ_B = 1290.3 IN.

ALL DIMENSIONS IN INCHES
FULL SCALE



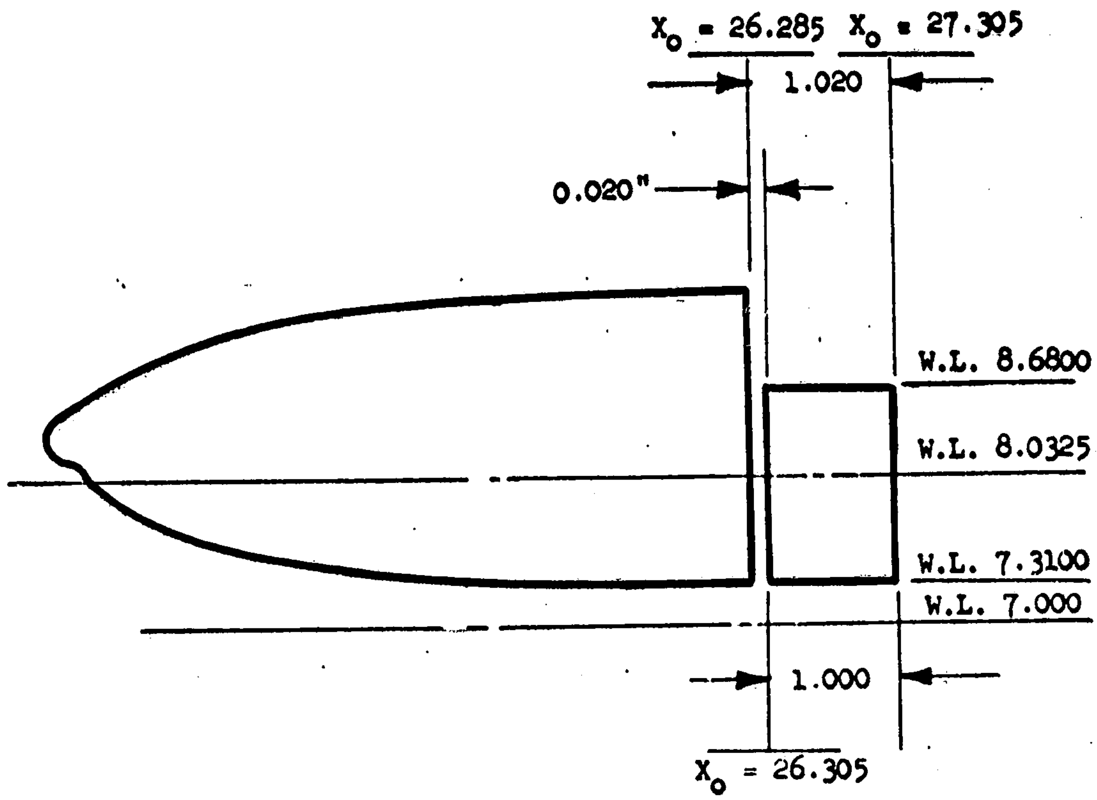
a. General Model Arrangement

Figure 2. - Model information.



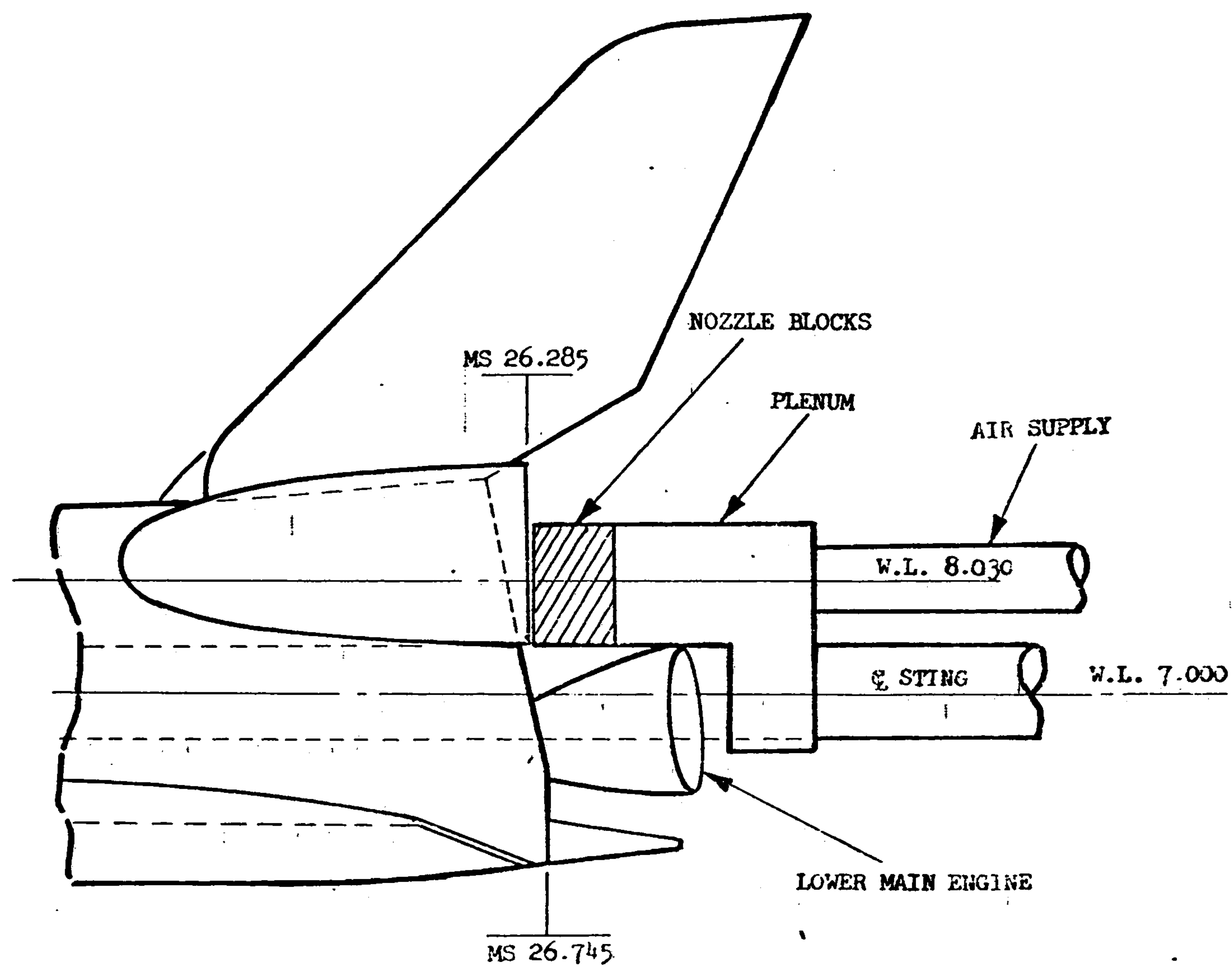
b. Modified OMS Pod and RCS Nozzle Location

Figure 2. - Continued.



c. M_6 OMS Pod

Figure 2. - Continued.

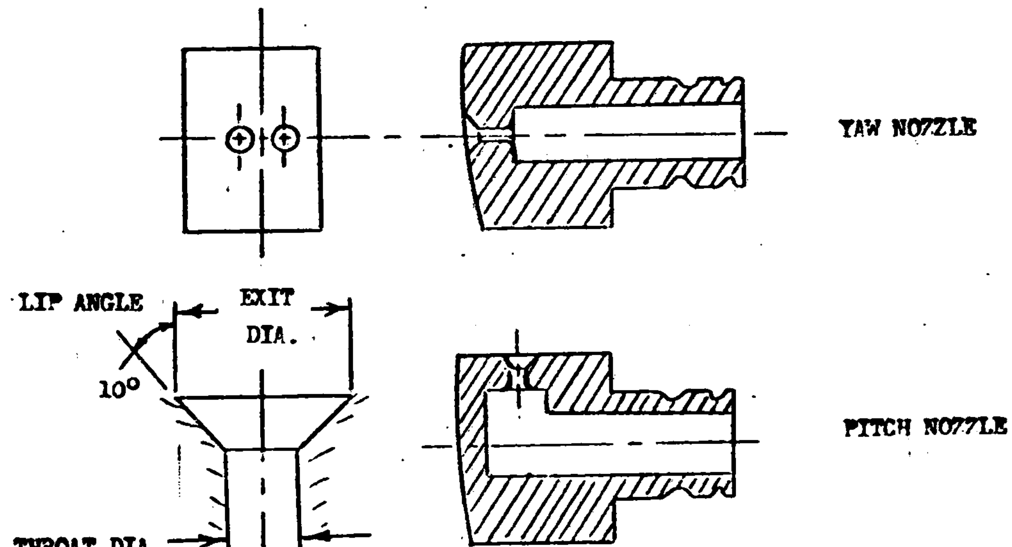


d. RCS Plenum Nozzle Block Installation

Figure 2. - Continued.

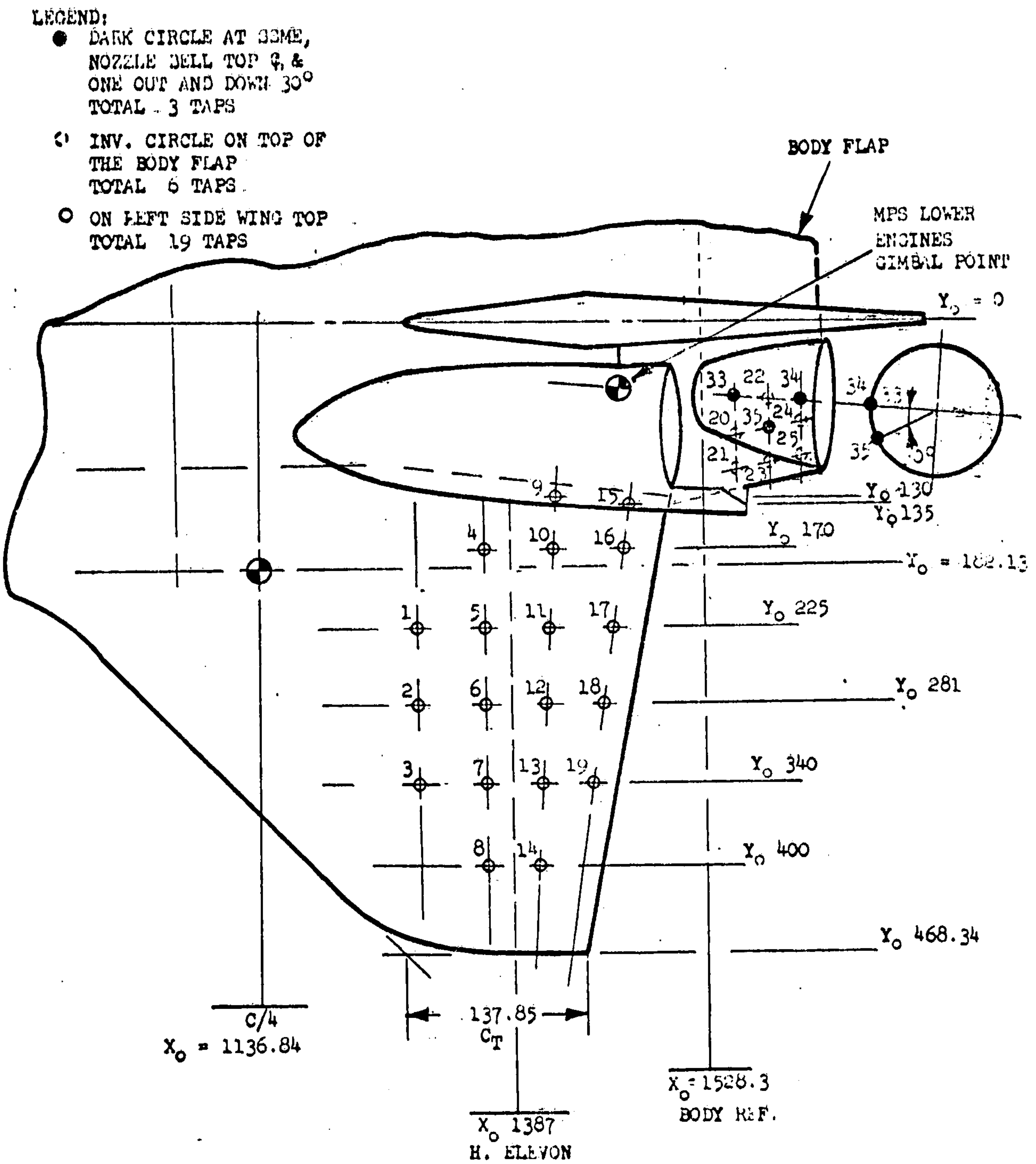
NOZZLE GEOMETRY

NOZZLE NO.	DASH NO.	NO. OF NOZZLE	THROAT DIA. (IN.)	THROAT AREA ($IN.^2$)	EXIT DIA. (IN.)	EXIT AREA ($IN.^2$)	AREA RATIO ($\frac{A_e}{A^*}$)	NOTES
N68	- 5	2	0.0375	.001104	0.0934	.006850	6.2	YAW JET. NOT CANTED LEFT HAND SIDE.
N69	-7	2	0.0375	.001104	0.0934	.006850	6.2	PITCH UP, RIGHT HAND SIDE. NOT CANTED
N70	-6	2	0.0375	.001104	0.0934	.006850	6.2	PITCH DOWN, LEFT HAND SIDE CANTED 12° AFT & 20° OUTBOARD
		LIP ANGLE $\theta_p = 10^\circ$						



e. Nozzle Configurations

Figure 2. - Continued.



f. L/H Wing, Body Flap and SSME Nozzle Pressure Tap Location/Identification

Figure 2. - Continued.

L/H WING SURFACE PRESSURE TAPS (19)

TAP NO.	X_o	Y_o	LOCATION
1	1320	225	(19) PRESSURE TAPS LOCATED ON THE UPPER L/H WING SURFACE
2	1320	281	
3	1320	340	
4	1370	170	
5	1370	225	
6	1370	281	
7	1370	340	
8	1370	400	
9	1424	130	
10	1420	170	
11	1418	225	
12	1414	281	
13	1412	340	
14	1408	400	
15	1478	135	
16	1472	170	
17	1466	225	
18	1456	281	
19	1448	340	(19) PRESSURE TAPS LOCATED ON THE UPPER L/H WING SURFACE

f. Pressure Tap Locations
Figure 2. - Continued.

BODY FLAP PRESSURE TAPS (6)

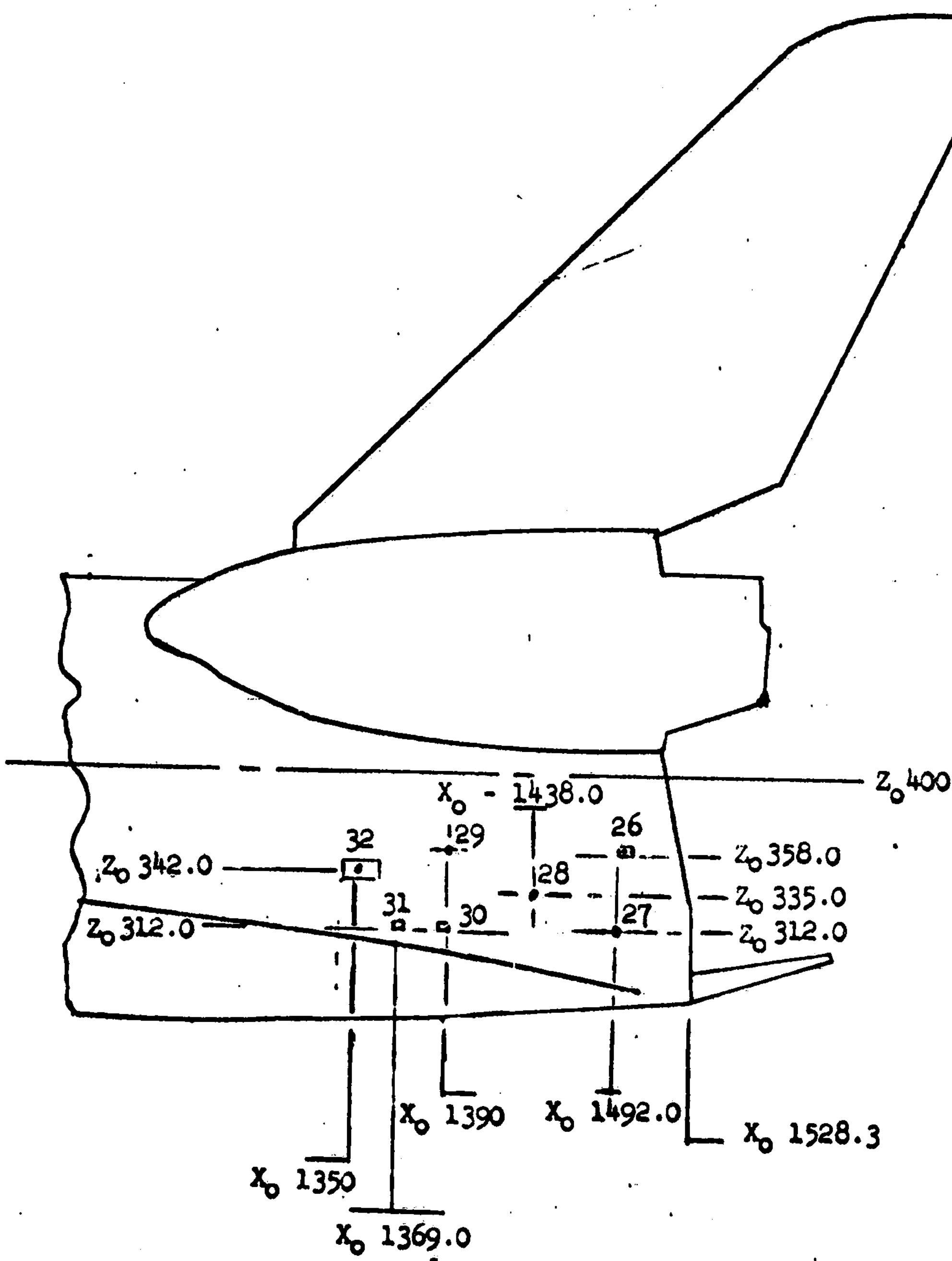
TAP NO.	X_o	Y_o	LOCATION
20	1556	85	(6) PRESSURE TAPS LOCATED ON THE UPPER L/H SIDE OF BODY FLAP
21	1556	112	↑
22	1582	58	
23	1582	106	
24	1604	75	↓
25	1604	100	(6) PRESSURE TAPS LOCATED ON THE UPPER L/H SIDE OF BODY FLAP

SSME NOZZLE BELL PRESSURE TAPS (3)

TAP NO.	X_o	Y_o	LOCATION
33	1556	℄ THRUST	FWD UPPER CENTERLINE OF THRUST OF SSME NOZZLE BALL.
34	1604	℄ THRUST	AFT UPPER CENTERLINE OF THRUST OF SSME NOZZLE BALL
35	1582	30° OFF CENTER	LEFT HAND SIDE OF SSME NOZZLE BELL LOOKING FWD, 30° CCW FROM CENTERLINE OF THRUST

Pressure Tap Locations

Figure 2f. - Concluded.



g. L/H Lower Aft Fuselage Pressure Taps

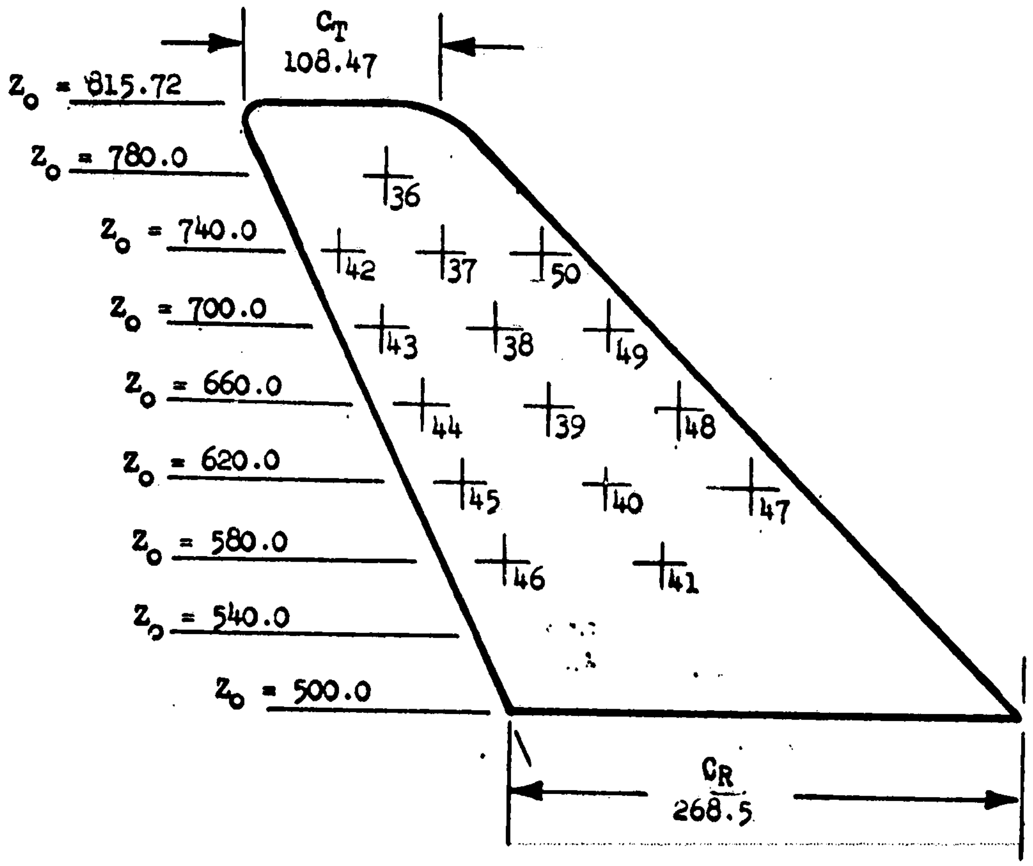
Figure 2. - Continued.

L/H LOWER AFT FUSELAGE PRESSURE TAPS (7)

TAP NO.	X_o	Z_o	LOCATION
26	1492.0	358.0	L/H LOWER AFT FUSELAGE (BOAT TAIL AREA)
27	1492.0	312.0	
28	1438.0	335.0	
29	1390.0	358.0	
30	1390.0	312.0	
31	1369.0	312.0	
32	1350.0	342.0	L/H LOWER AFT FUSELAGE (BOAT TAIL AREA)

Pressure Tap Locations

Figure 2g. - Concluded.



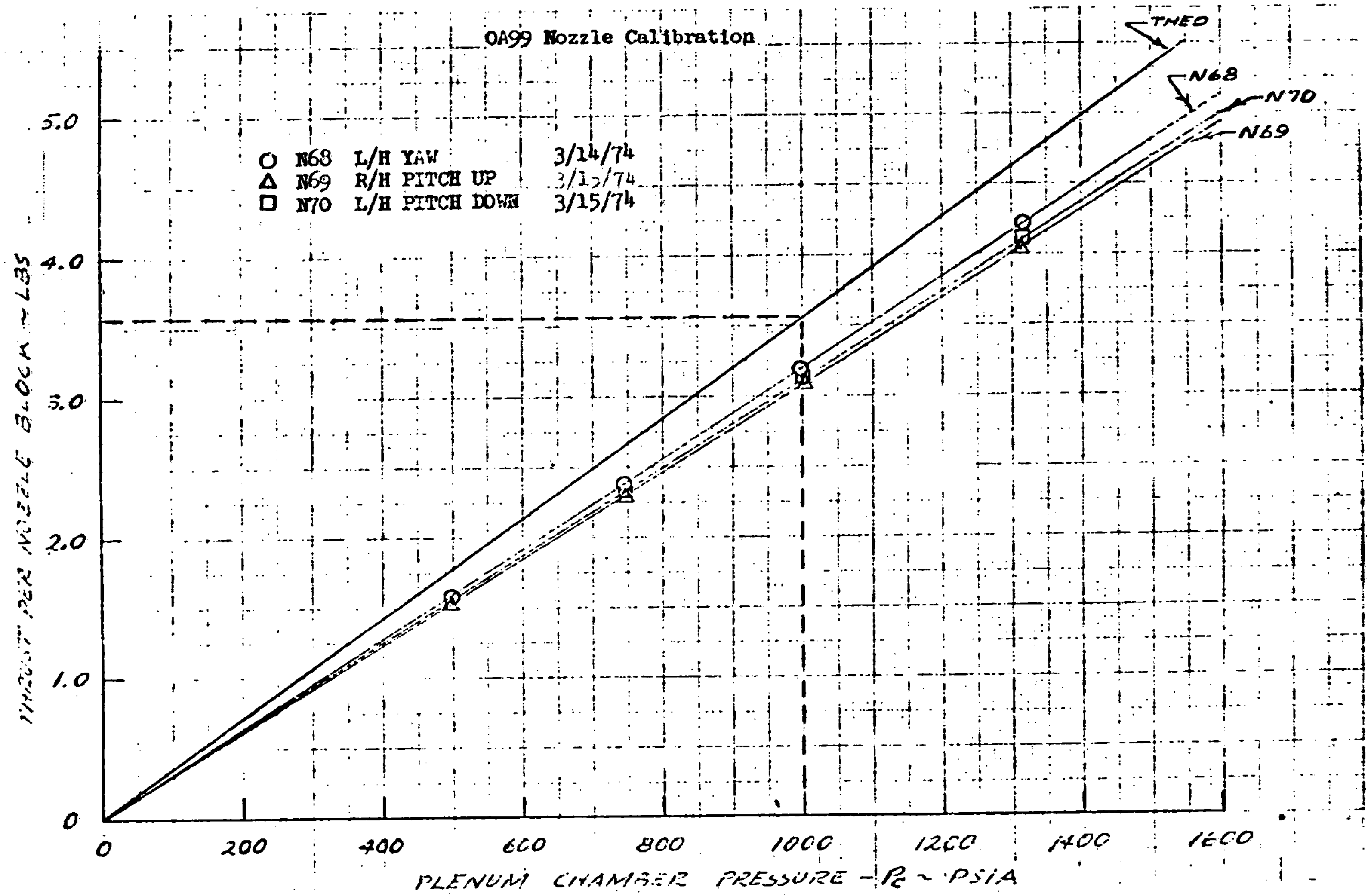
h. Pressure Taps on the Right Side of the Vertical Stabilizer and Rudder
Figure 2. - Continued.

VERTICAL TAIL (R/H) PRESSURE TAPS (15)

TAP NO.	X_o	Y_o	LOCATION
50	1533	740	R/H SIDE OF THE VERTICAL TAIL AND RUDDER
49	1495	700	↑
48	1460	660	
36	1616	780	
37	1587	740	
38	1557	700	
39	1528	660	
40	1500	620	
41	1471	580	
42	1641	740	
43	1619	700	
44	1596	660	
45	1576	620	
46	1553	580	↓
47	1423	620	R/H SIDE OF THE VERTICAL TAIL AND RUDDER

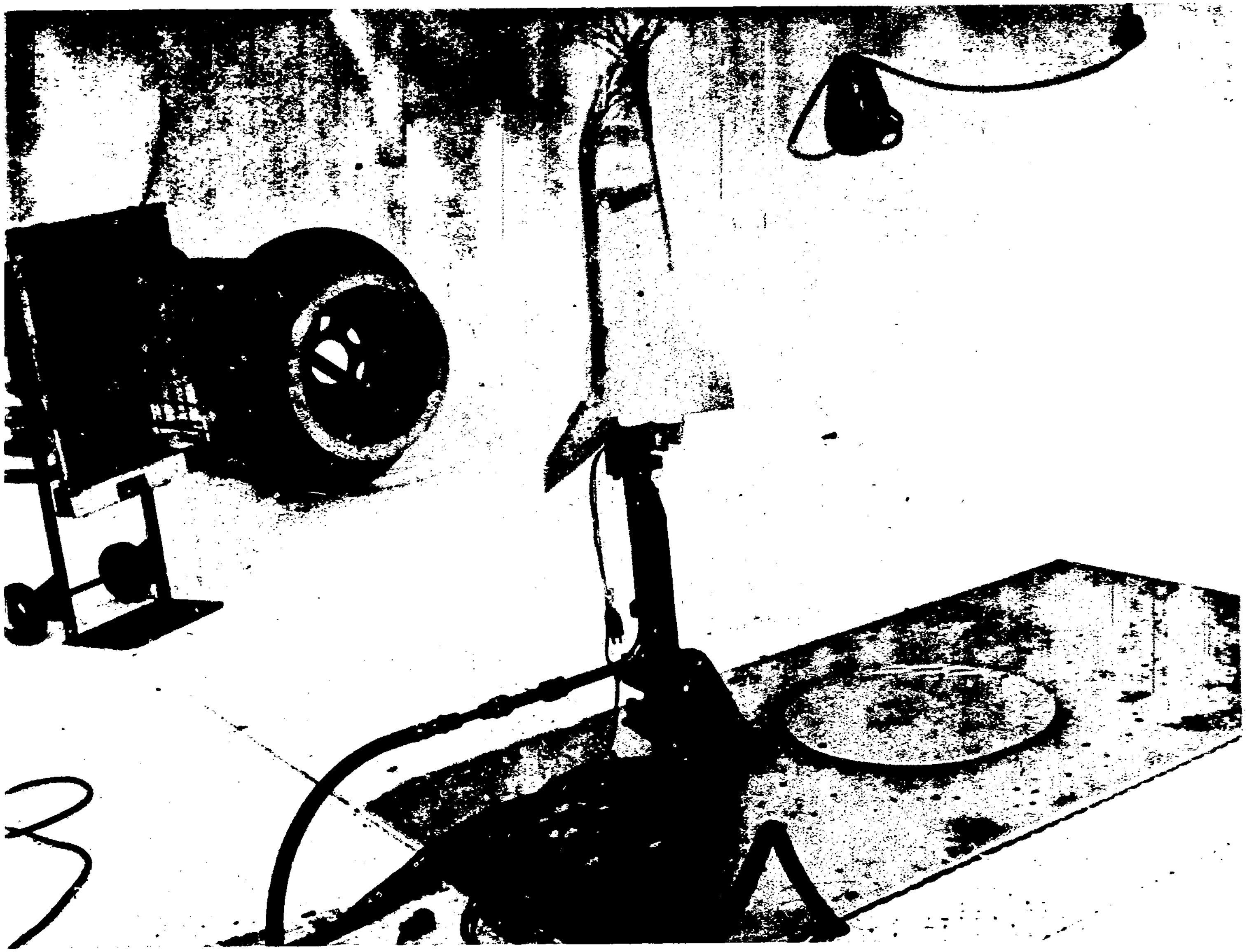
Pressure Tap Locations

Figure 2h. - Concluded.



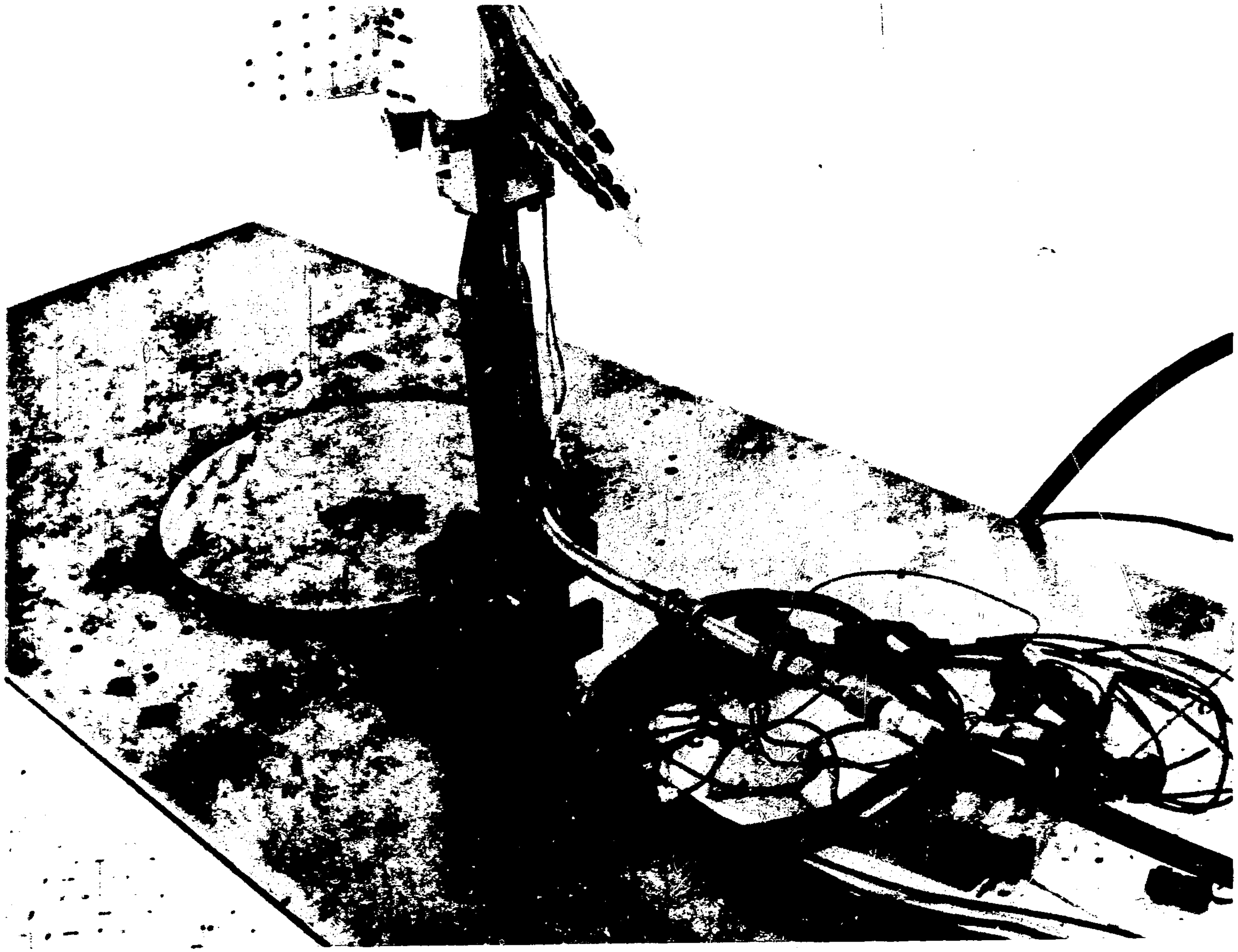
i. RCS Nozzle Calibration

Figure 2. - Concluded.



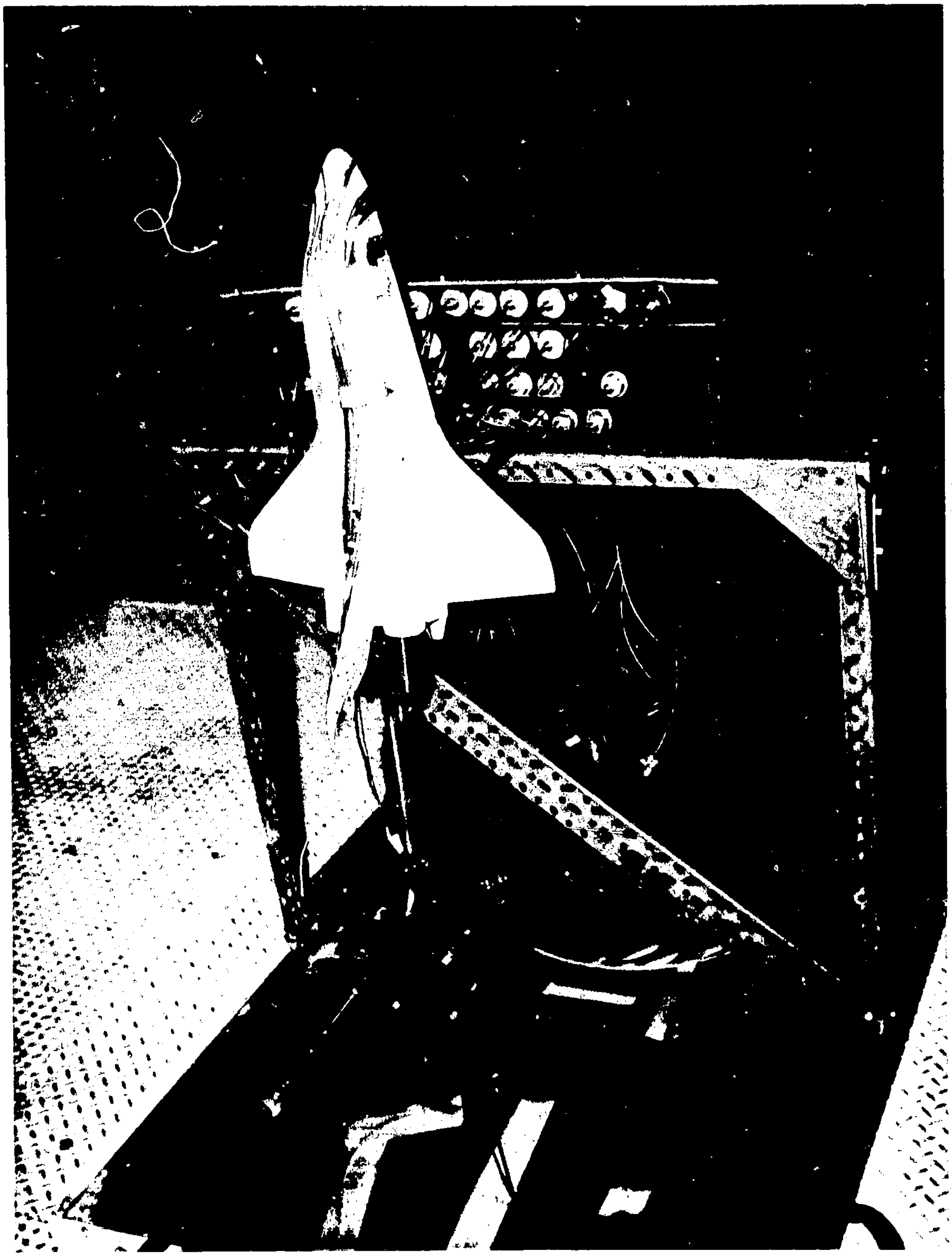
a. General Installation Photograph

Figure 3. - Model photographs.



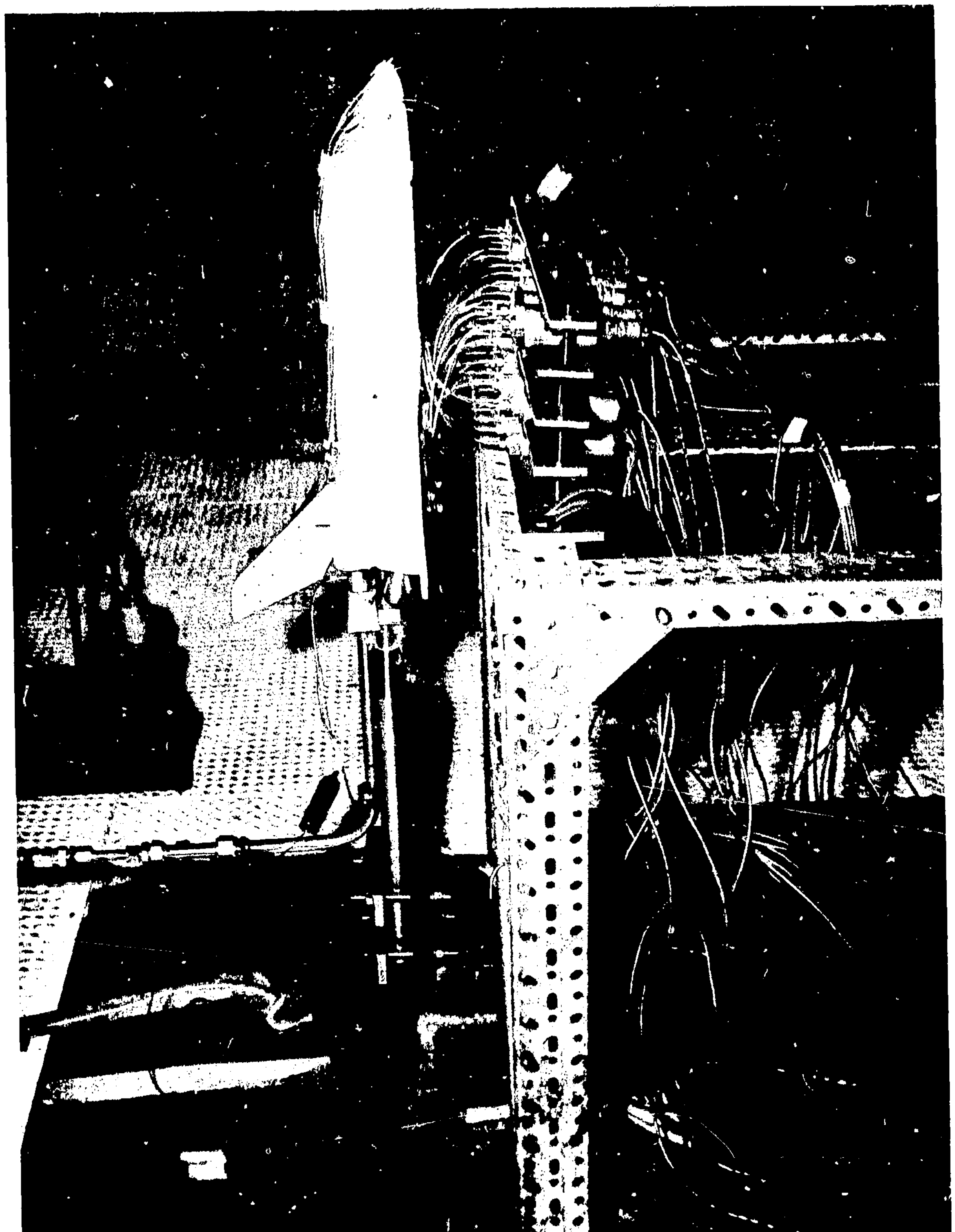
b. RCS Nozzle Block Installation

Figure 3. - Continued.



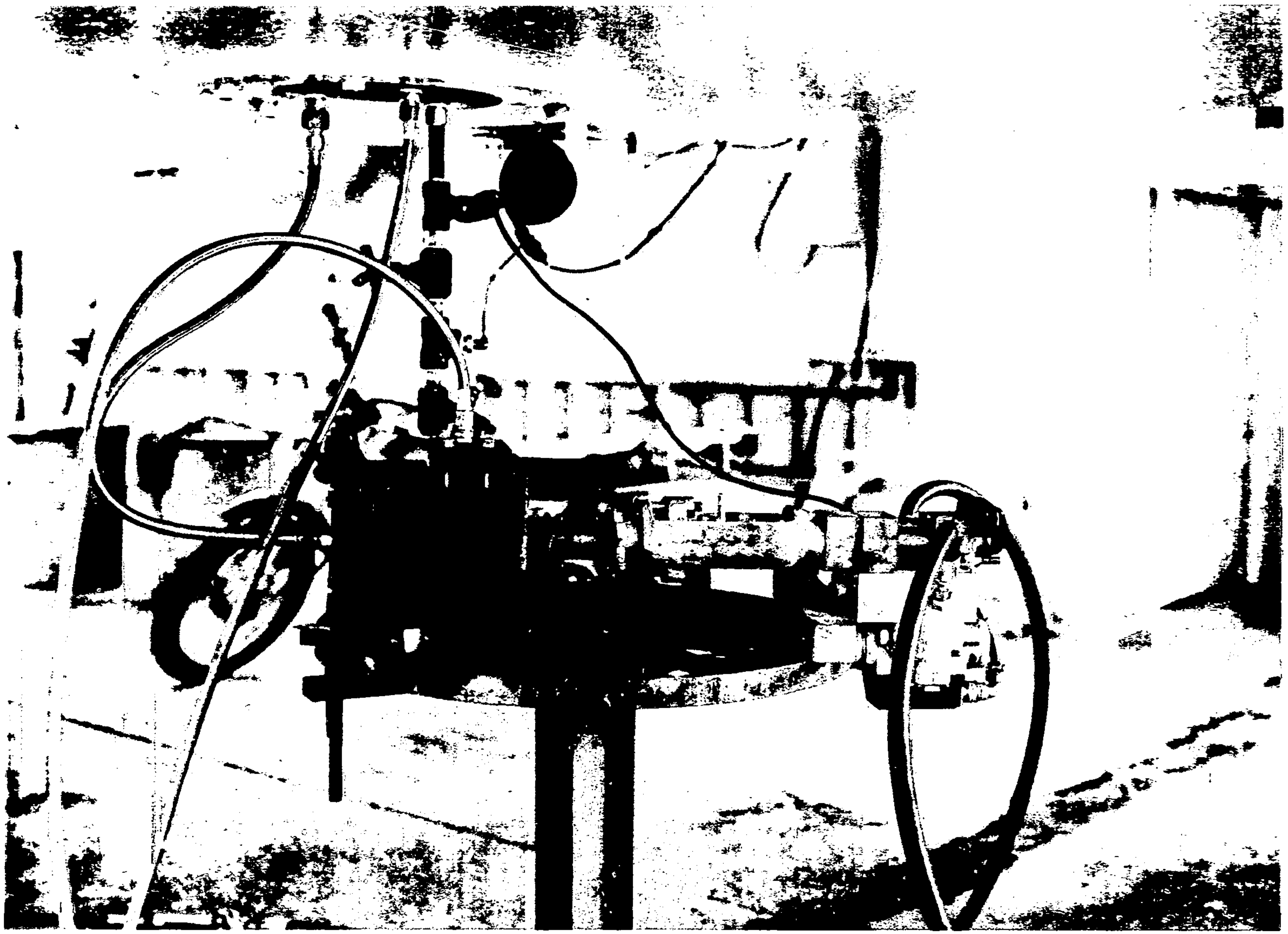
c. Pressure Tap and Transducer Installation Photograph-Plan View

Figure 3. - Continued.



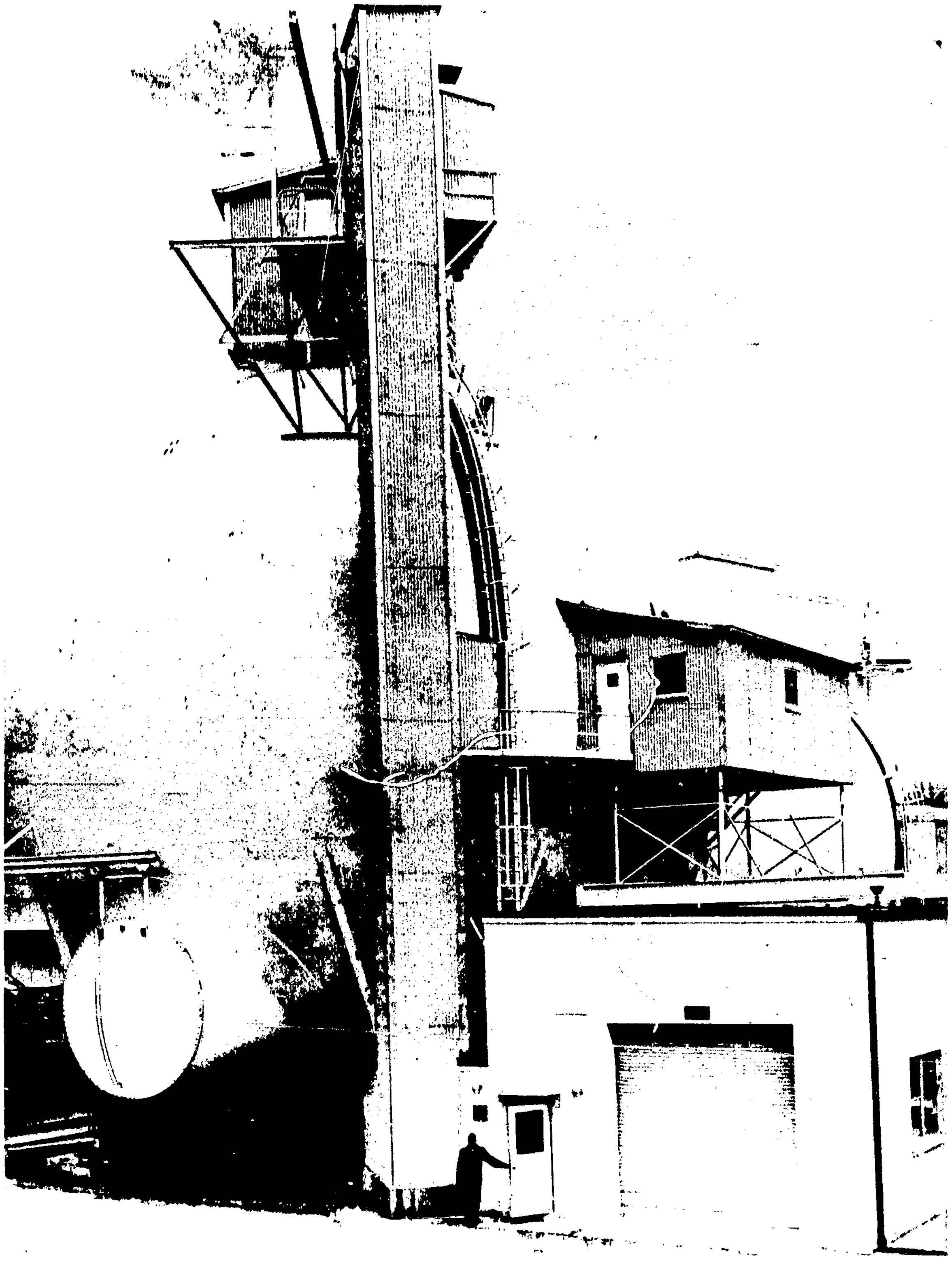
d. Pressure Tap and Transducer Installation Photograph-Side View

Figure 3. - Continued.



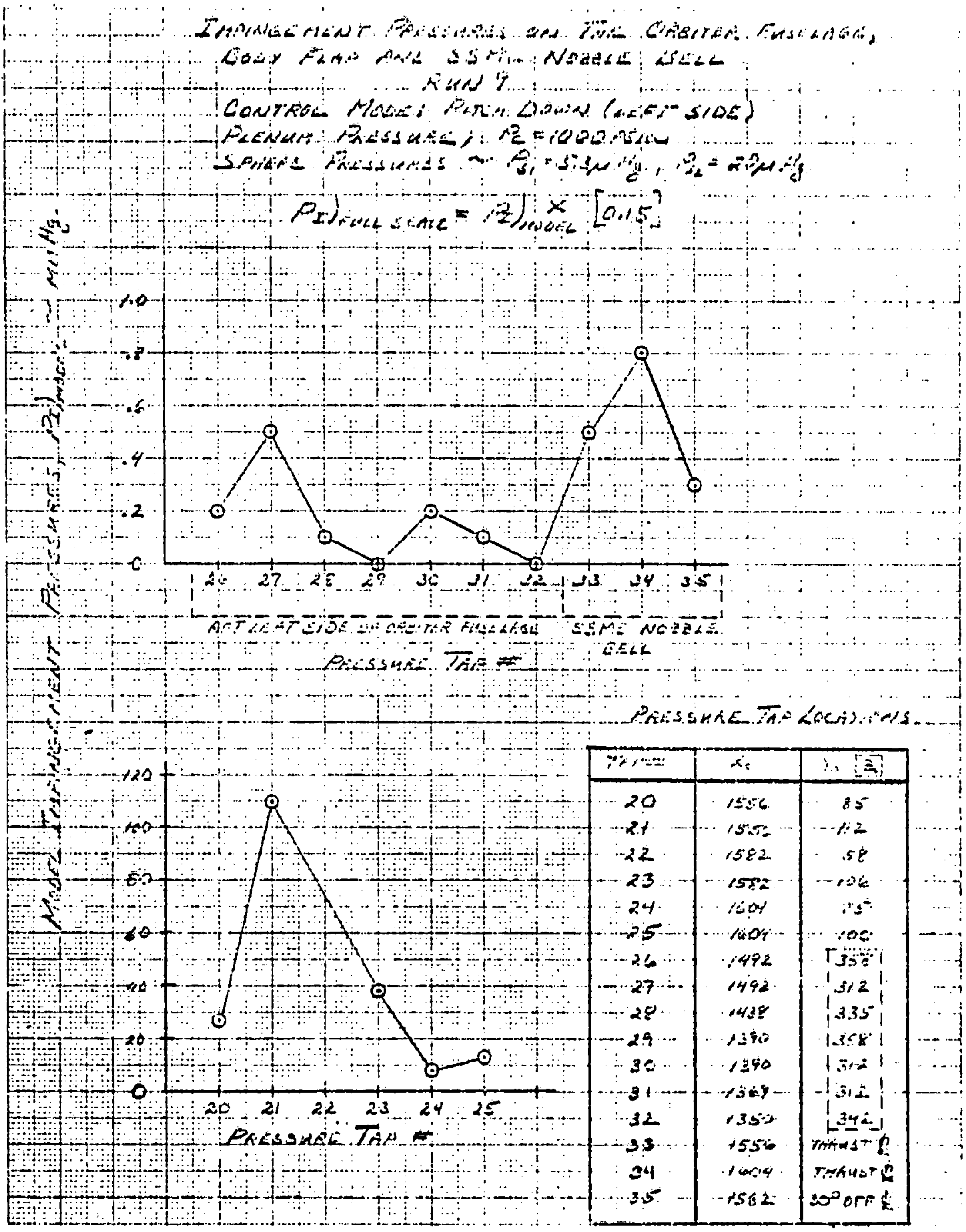
e. Hyd. Valve System Installation

Figure 3. - Continued.



f. LaRC 60-foot Vacuum Sphere Facility

Figure 3. - Concluded.



[illegible]	x_c	y_c [illegible]
20	1556	85
21	1556	112
22	1582	58
23	1582	106
24	1604	[illegible]
25	1604	100
26	1492	[illegible]
27	1492	312
28	1438	335
29	1390	358
30	1390	312
31	1369	312
32	1350	342
33	1556	THRUST ℄
34	1604	THRUST ℄
35	1562	30° OFF ℄

Figure 4. - Impingement Pressures on the Orbiter Fuselage, Body Flap and SSME Nozzle Bell.

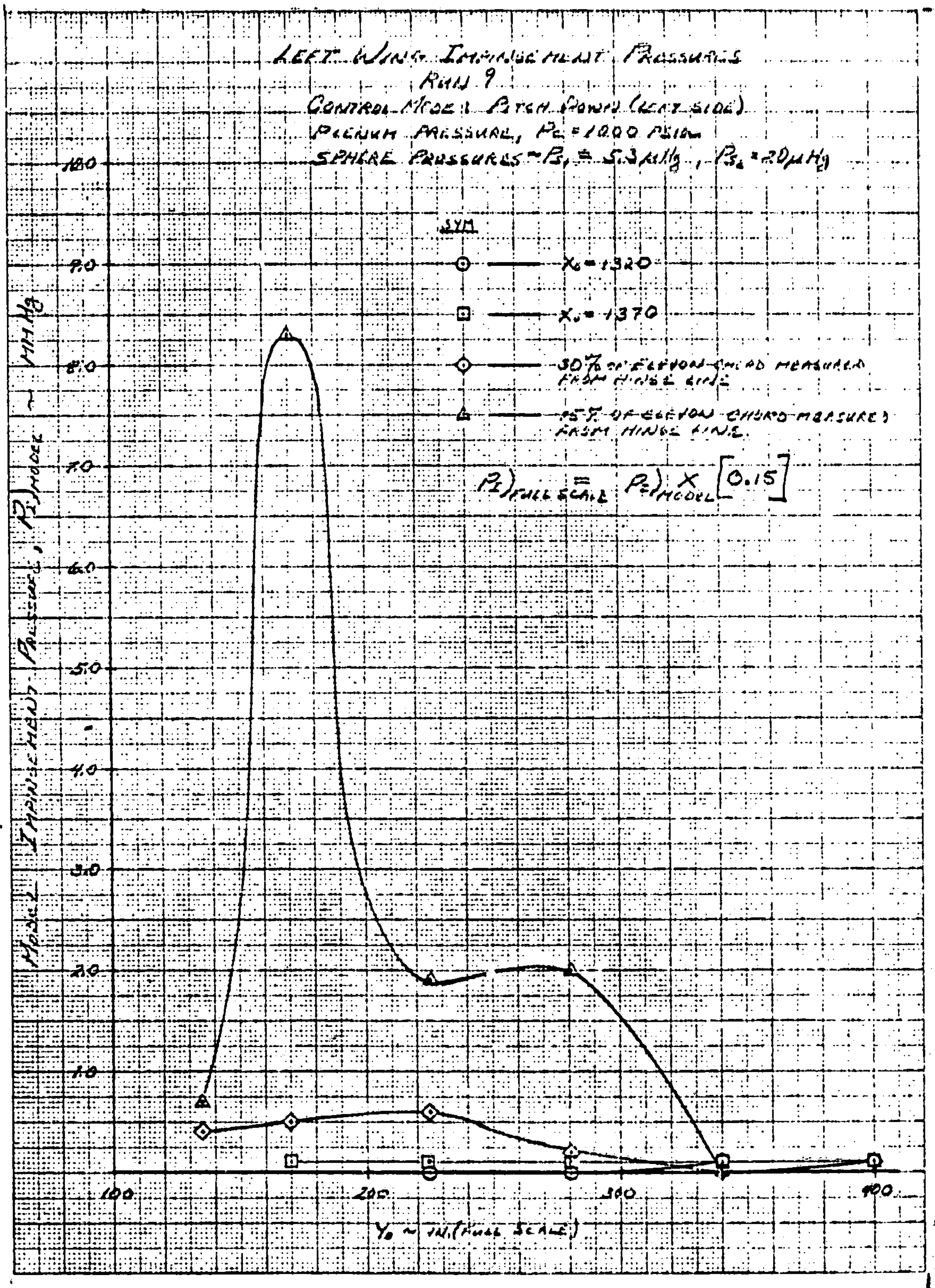


Figure 5. - Left Wing Impingement Pressures.

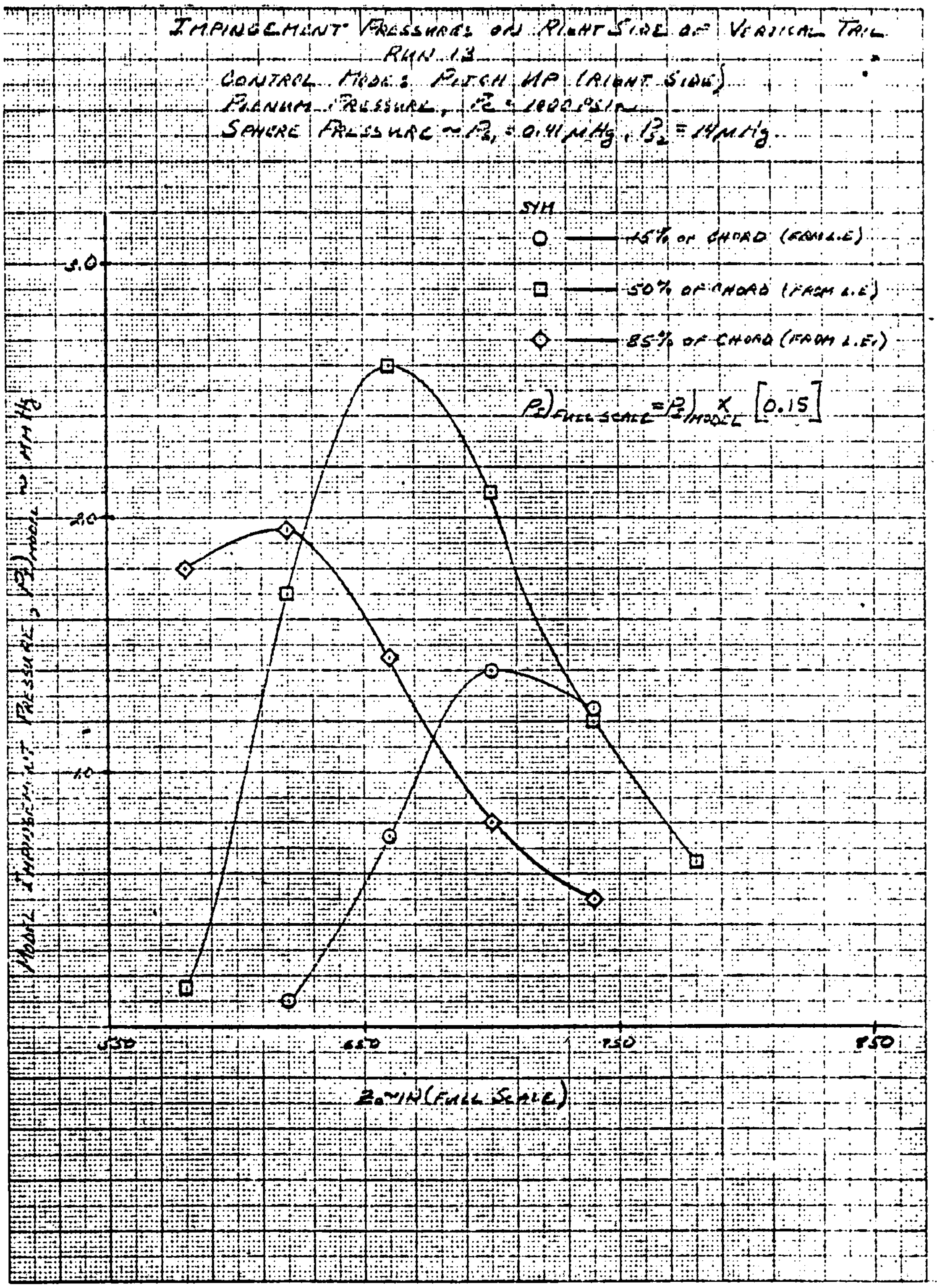


Figure 6. - Impingement Pressures on Right Side of Vertical Tail.