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DATA REPORT FOR APOLLO PS-4 MODEL IN THE AEDC HOTSHOT II WIND TUNNEL (U)

NAS 9-150

4.5.5.1

13 August 1962

Approved by

[redacted]

D. J. Gildea
D. J. Gildea - Manager
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FOREWORD

The tests described herein were conducted under NASA Apollo Contract NAS-9-150, during the period from 18 June 1962 to 29 June 1962.

This report was prepared by H. C. Smith of the Wind Tunnel Projects Group, Los Angeles Division.

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ABSTRACT

This report contains results of pressure tests of the 0.04 scale Apollo model PS-4. The tests were conducted in the Arnold Center VKF Hotshot II tunnel at a Mach number of 19.5.

Pressure coefficients and pressure ratio data are given for all valid runs. This report presents basic wind tunnel test data only, in order to make the test results available at the earliest possible date. Analysis and summary of results will be reported later under separate cover.

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I. INTRODUCTION

Hypersonic wind tunnel tests of the 0.04 scale Apollo pressure model PS-4 were conducted to investigate the pressure distributions on the command module for determining aerodynamic loads during entry at a Mach number of 19.

The command module was tested through an angle of attack range of 120° to 180°.

Pretest information was given in Reference (b).

[redacted]

[redacted]

II. REMARKS

In order to obtain pressure distributions on the Apollo command module, pressures were measured at 35 locations on the surface of the model. Since the command module is symmetrical about the pitch plane the pressure orifices were primarily located on one half of the model. Transducers installed in the model at each orifice were used to measure the pressures. One transducer was inoperative during six runs of the test, however, due to the spacing of the pressure orifices, this one pressure reading was not considered critical to the final results of the data.

Accuracy of the final data is ±5%.

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[redacted]

III. MODEL DESCRIPTION

A. General

The model is a 0.04 scale representation of the Apollo command module mounted on a sting in a position so as to place the blunt face forward. In order to cover the desired range of angle of attack of 120° to 180° the sting which is an integral part of the model is at an angle of approximately 10° to the center line of the model. Through the use of a straight sting adapter, a 30° offset adapter, and the sector pitch range of 30°, one model was used to cover the desired angle of attack range.

The model had 35 pressure orifices distributed over its surface on both the blunt face and the conical section.

The structural integrity of the model is analyzed in Reference (a), and the model design drawings are listed in Section V of this report.

[redacted]

III. MODEL DESCRIPTION - continued

B. Instrumentation

Pressures were measured at each orifice using low impedance, variable reluctance, wafer gage transducers installed in the model. The model is a pressure tight shell capable of being evacuated to provide a reference pressure for the transducers. A Hastings tube-type DV-3 gage was also installed in the model to record the reference pressure which was held constant during a run.

[redacted]

III. MODEL DESCRIPTION - continued

C. Model Nomenclature and Full Scale Dimensions

Command Module C2

Description: Command module with 9.13" nose cone vertex radius

Previous Tests: None

Drawing No.: 7121-01159(-2),(-3)

Full Scale Dimensions:

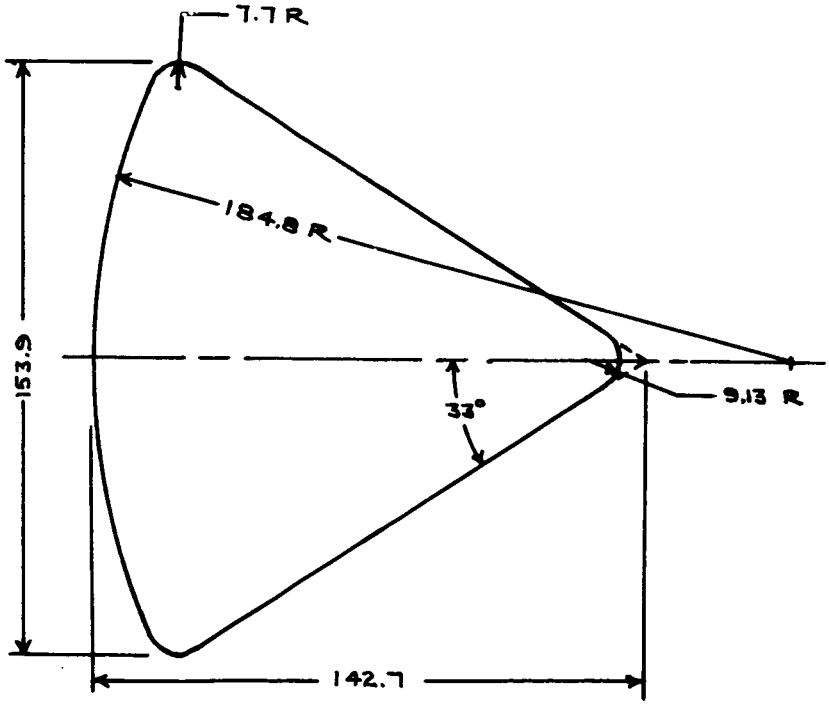
Maximum diameter, in.	153.88
Radius of spherical blunt end, in.	184.80
Corner radius, in.	7.70
Nose cone semi-angle, deg.	33.00
Nose cone vertex radius, in.	9.13

[redacted]

III. MODEL DESCRIPTION - continued

D. Configuration Sketch

Command Module (C2)



Dimensions full scale, inches
Drawing not to scale

[redacted]

[redacted]

IV. TEST PROCEDURE

A. Test Nomenclature

M_o = Free stream Mach number

V_o = Free stream velocity-fps

Re = Model Reynolds number

P = Local orifice pressure-psi

P_o = Free stream static pressure-psi

q_o = Free stream dynamic pressure-psi

H_o = Reservoir pressure (max.)-psi

TT_o = Reservoir temperature (max.)-°K

PT_2 = Total pressure behind a normal shock-psi

C_p = Pressure coefficient = $\frac{P - P_o}{q_o}$

s = Distance to orifice from center of pointed end of model measured along surface of model, positive on windward side

r = Radius of command module at maximum section

λ = Angle of plane of instrumentation relative to pitch plane

α = Angle of attack of model, $\alpha = 0$ when pointed end of command module faces airstream

[redacted]

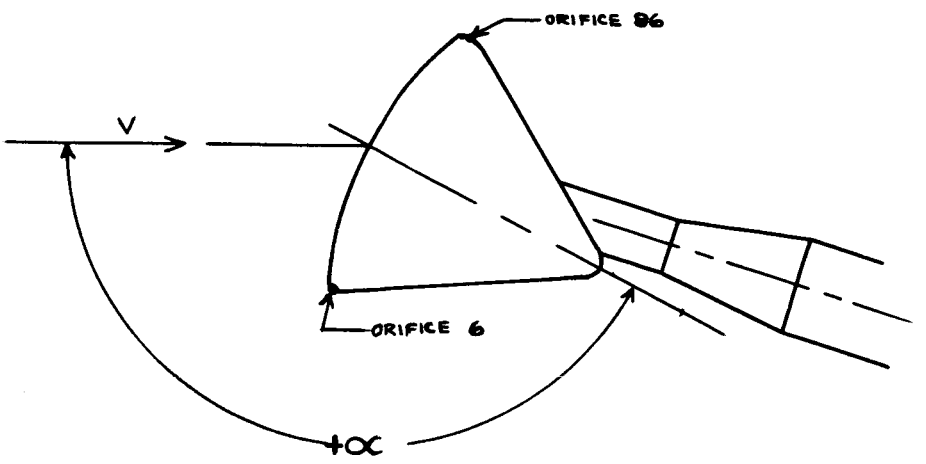
[redacted]

IV. TEST PROCEDURE - continued

B. Model Installation

In order to cover the range of angle of attack of 120° to 180° with one model and a wind tunnel sector with a range of -12° to +20°, use was made of straight and 30° offset sting adapters. The sting, which is and integral part of the model, enters the model at an angle of 10.25° to the model center line.

The sketch below shows the orientation of the pressure orifices with the model at an angle of attack less than 180°.



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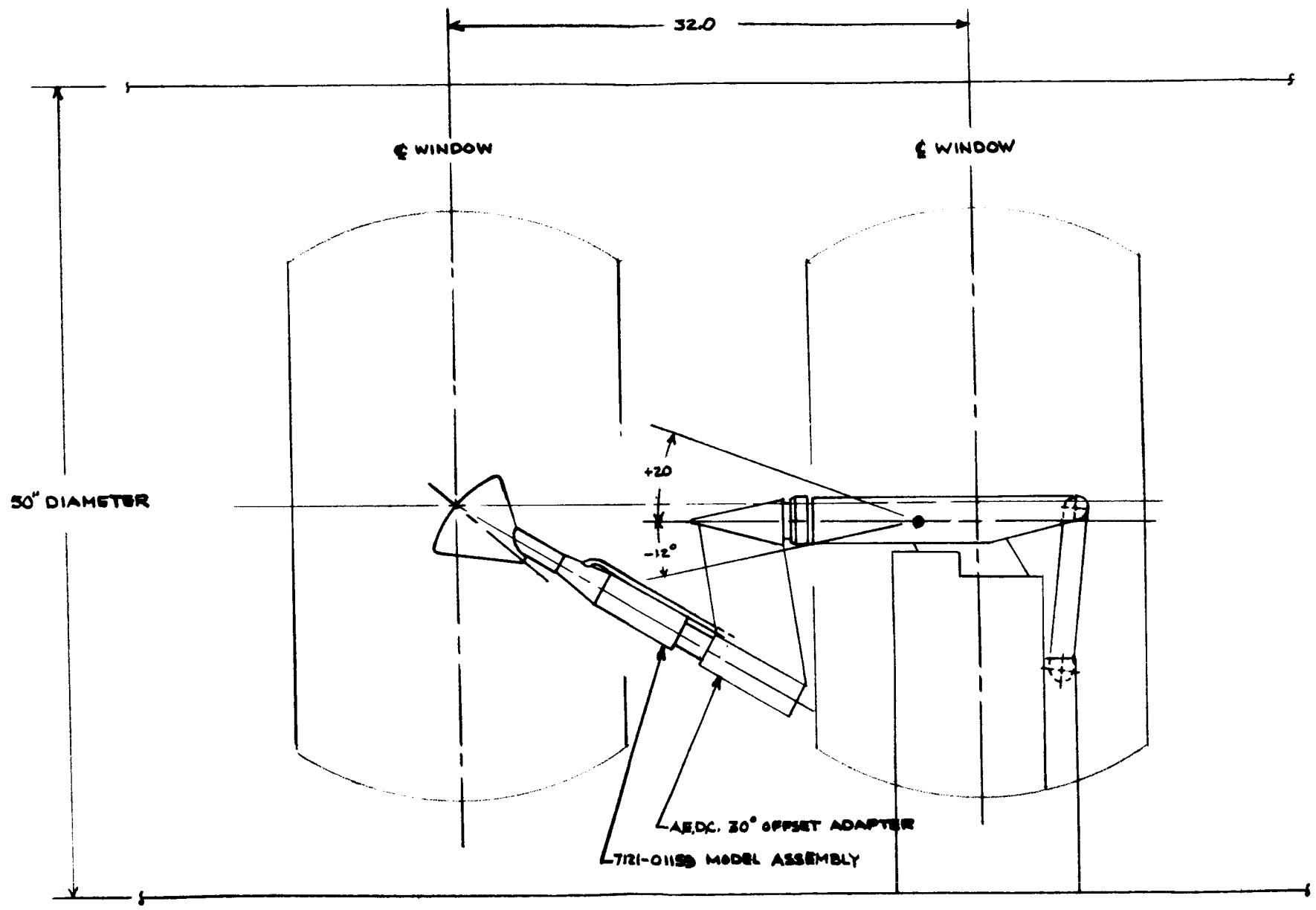

TUNNEL INSTALLATION FOR APOLLO PS-4

IN A.E.D.C. HOTSHOT II

[redacted]

[redacted]

IV. TEST PROCEDURE - continued

C. Instrumentation

Pressures on the surface of the model were measured using wafer gage transducers mounted inside the model. The output of the transducers was recorded on two oscillographs and the pressures were then hand computed. The inside of the model was evacuated and held constant during a run in order to provide a reference pressure for the transducers.

The range of transducers used during the test were 0.5 psi and 3.0 psi. The transducers were calibrated prior to each run. The sketch on the following page shows the location of each pressure orifice and the range of transducer used at each orifice. The transducer at orifice number 67 was inoperative for runs 1240 through 1245.

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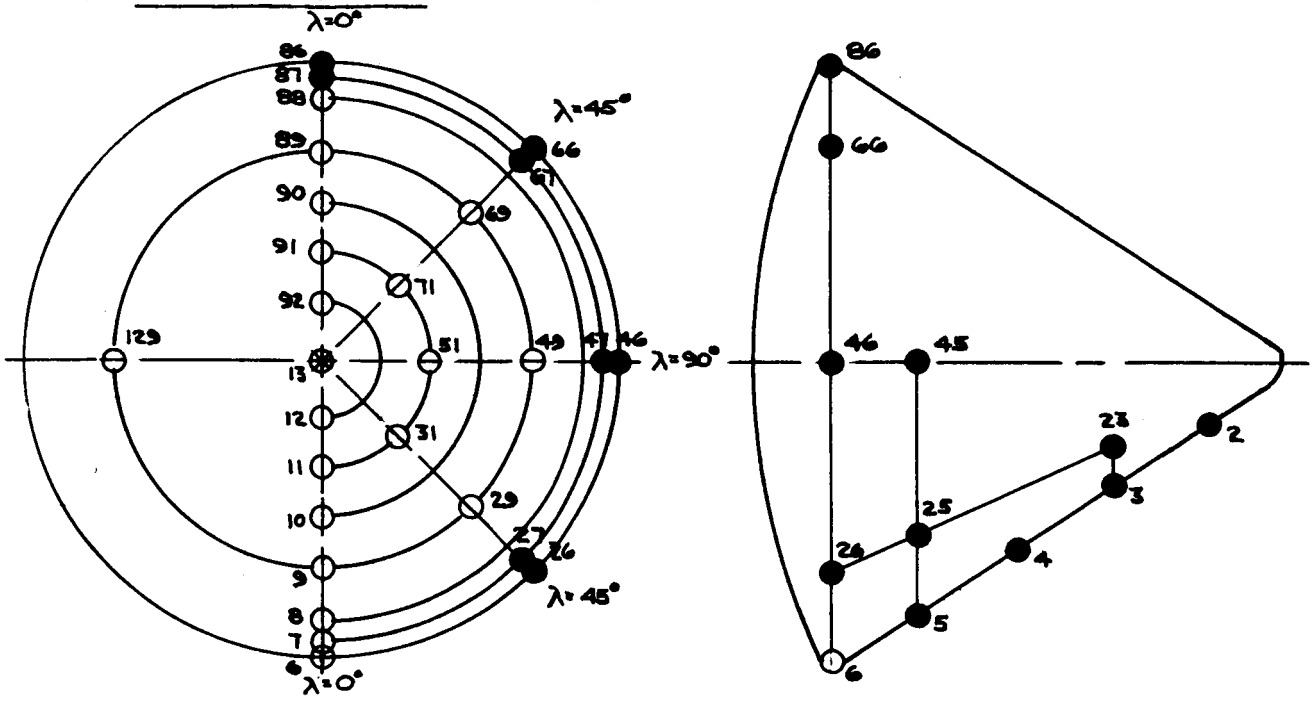
IV. TEST PROCEDURE - continued

C. Instrumentation - continued



○ = 3.0 psi. transducers
● = 0.5 psi. transducers
λ = Angle of plane of instrumentation relative to pitch plane
s = Distance to orifice from center of pointed end measured along surface of module, positive on windward side
r = Radius of command module at maximum section
p# = Pressure orifice number

λ = 0°			
p#	s/r	p#	s/r
2	.317	12	2.708
3	.704	13	2.883
4	1.092	86	-1.799
5	1.479	87	-1.899
6	1.799	88	-1.986
7	1.899	89	-2.171
8	1.986	90	-2.353
9	2.171	91	-2.531
10	2.353	92	-2.708
11	2.531	13	-2.883

λ = 45°	
p#	s/r
23	.704
25	1.479
26	1.799
27	1.899
29	2.171
31	2.531
13	2.883
66	-1.799
67	-1.899
69	-2.171
71	-2.531
13	-2.883

λ = 90°	
p#	s/r
45	1.479
46	1.799
47	1.899
49	2.171
51	2.531
13	2.883
129	-2.171

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IV. TEST PROCEDURE

D. Data Reduction

Oscillograph data were read every 10 to 12 milliseconds and pressures were hand computed. Stagnation pressure behind a normal shock (P_{T2}) was determined by averaging the total pressure measured on two probes near the model and a pressure measured on the model, near the stagnation point, corrected to stagnation conditions using modified Newtonian Theory. The corrected model pressure was used when the average of the three pressure measurements deviated more than one to two per cent from the corrected model pressure. Irregularities in the flow across the test section measured by the probes caused these deviations. It was necessary to use the probe pressures at 120° angle of attack since the location of the orifices on the model and the sharp curvature of the model at the corner did not allow accurate determination of the Newtonian correction factor. The personnel of AEDC at the Hotshot II tunnel feel that the above method is the best to be used in determining P_{T2} because of the irregularities of the flow in the test section and the accuracy of $\pm$ 5 per cent of the data gathering system.

Arc chamber conditions and the stagnation pressure behind a normal shock (P_{T2}) were used in a digital program to compute test section conditions. Free stream dynamic pressure obtained from this program was used to hand compute pressure coefficients for each orifice on the model.

[redacted]

[redacted]

V. REFERENCES

(a) SID-62-331, "Structural Analysis of the 0.04 Scale Apollo Wind Tunnel Models FS-4 and PS-4"

(b) SID-62-538, "Pretest Report for the Apollo Pressure Model (PS-4) in the Arnold Center VKF Hotshot II"

(c) NAA-SID Model Design Dwg. 7121-01159, "Model Assembly, Apollo PS-4 .04 Scale Pressure Model (AEDC Hotshot II)"

(d) NAA-SID Model Design Dwg. 7121-01160, "Wind Tunnel Installation Apollo PS-4 Pressure Model in AEDC Hotshot II Facility"

[redacted]

APPENDIX "A"

RUN INDEX

AEDC HOTSHOT II
Apollo PS-4 (C_2)
0.04 Scale

Run	Angle of Attack deg.	Sting Offset deg.	Free Stream Conditions						Stagnation Conditions		
			M_o	P_o psia	V_o fps	q_o psi	Re	P_{T2}/q_o	H_o psia	T_{T_o} °K	P_{T2}/H_o
1236	179.75	0	18.94	.0014	8599	.344	88,418	1.862	9,679	3,546	$.970 \times 10^{-4}$
1237	169.75	↓	18.99	.0014	8751	.344	84,754	1.862	9,743	3,555	$.938 \times 10^{-4}$
1238	159.50	↓	19.19	.0012	8469	.320	88,702	1.859	9,076	3,315	$.929 \times 10^{-4}$
1239	149.50	↓	18.90	.0014	8844	.352	82,694	1.861	10,000	3,666	$.949 \times 10^{-4}$
1240	149.50	30	18.91	.0013	8737	.331	81,311	1.861	10,075	3,654	$.963 \times 10^{-4}$
1241	140.00	↓	18.87	.0014	8705	.336	83,167	1.862	9,800	3,549	$.977 \times 10^{-4}$
1242	130.00	↓	19.28	.0012	8356	.302	88,402	1.859	9,207	3,332	$.923 \times 10^{-4}$
1243	120.00	↓	19.97	.0009	8498	.257	76,547	1.862	9,397	3,400	$.763 \times 10^{-4}$
1244	147.00	↓	18.75	.0014	8932	.348	78,942	1.863	10,040	3,642	$.976 \times 10^{-4}$
1245	180.00	↓	19.77	.0009	7107	.251	125,573	1.858	8,125	2,935	$.995 \times 10^{-4}$

[redacted]

Run 1236 $\alpha = 179.75°$

$\lambda = 0$

s/r	2.883	2.708	2.531	2.353	2.171	1.986	1.899	1.799
P/PT2	.993	.958	.938	.888	.868	.766	.476	.027
Cp	1.850	1.784	1.748	1.654	1.616	1.428	.887	.045
s/r	1.479	1.092	.704	.317				
P/PT2	.020	.023	.023	.023				
Cp	.033	.038	.040	.038				
s/r	-2.883	-2.708	-2.531	-2.353	-2.171	-1.986	-1.899	-1.799
P/PT2	.993	.994	.938	.927	.914	.727	.446	.034
Cp	1.850	1.850	1.748	1.725	1.700	1.353	.832	.060

$\lambda = 45°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479	.704
P/PT2	.993	1.020	.866	.497	.044	.019	.022
Cp	1.850	1.878	1.612	.925	.077	.032	.036
s/r	-2.883	-2.531	-2.171	-1.899	-1.799		
P/PT2	.993	.945	.873	.493	.035		
Cp	1.850	1.760	1.625	.918	.062		

$\lambda = 90°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479
P/PT2	.993	.995	.875	.516	.040	.017
Cp	1.850	1.852	1.629	.962	.071	.027
s/r	-2.171					
P/PT2	.915					
Cp	1.703					

[redacted]

Run 1237 α = 169.75°

λ = 0

s/r	2.883	2.708	2.531	2.353	2.171	1.986	1.899	1.799
P/PT2	.834	1.006	1.000	.994	1.020	.880	.591	.052
Cp	1.552	1.871	1.861	1.850	1.899	1.638	1.101	.093
s/r	1.479	1.092	.704	.317				
P/PT2	.010	.013	.020	.022				
Cp	.014	.019	.033	.038				
s/r	-2.883	-2.708	-2.531	-2.353	-2.171	-1.986	-1.899	-1.799
P/PT2	.834	.924	.867	.811	.738	.641	.385	.026
Cp	1.552	1.720	1.617	1.510	1.373	1.194	.716	.044

λ = 45°

s/r	2.883	2.531	2.171	1.899	1.799	1.479	.704
P/PT2	.834	1.003	.945	.518	.062	.007	.019
Cp	1.552	1.867	1.760	1.076	.112	.009	.032
s/r	-2.883	-2.531	-2.171	-1.899	-1.799		
P/PT2	.834	.891	.779	.432	.027		
Cp	1.552	1.660	1.450	.804	.047		

λ = 90°

s/r	2.883	2.531	2.171	1.899	1.799	1.479
P/PT2	.834	1.002	.863	.488	.041	.017
Cp	1.552	1.866	1.607	.908	.072	.028
s/r	-2.171					
P/PT2	.874					
Cp	1.627					

[redacted]

Run 1238 $\alpha = 159.5°$

$\lambda = 0$

s/r	2.883	2.708	2.531	2.353	2.171	1.986	1.899	1.799
P/PT2	.824	.911	.959	.956	1.000	.946	.726	.117
Cp	1.534	1.700	1.788	1.782	1.863	1.762	1.354	.218
s/r	1.479	1.092	.704	.317				
P/PT2	.024	.024	.021	.017				
Cp	.040	.040	.035	.028				
s/r	-2.883	-2.708	-2.531	-2.353	-2.171	-1.986	-1.899	-1.799
P/PT2	.824	.797	.714	.649	.574	.483	.305	.015
Cp	1.534	1.486	1.330	1.209	1.069	.900	.569	.024

$\lambda = 45°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479	.704
P/PT2	.824	.913	.908	.627	.092	.015	.016
Cp	1.534	1.700	1.690	1.169	.172	.024	.026
s/r	-2.883	-2.531	-2.171	-1.899	-1.799		
P/PT2	.824	.747	.619	.355	.020		
Cp	1.534	1.391	1.152	.661	.033		

$\lambda = 90°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479
P/PT2	.824	.875	.770	.511	.037	.010
Cp	1.534	1.630	1.434	.952	.064	.015
s/r	-2.171					
P/PT2	.789					
Cp	1.470					

[redacted]

Run 1239 $\alpha = 149.5°$

$\lambda = 0$

s/r	2.883	2.708	2.531	2.353	2.171	1.986	1.899	1.799
P/PT2	.718	.791	.839	.910	.981	.978	.870	.219
Cp	1.338	1.474	1.561	1.694	1.830	1.812	1.620	.408
s/r	1.479	1.092	.704	.317				
P/PT2	.045	.035	.027	.018				
Cp	.079	.061	.047	.031				
s/r	-2.883	-2.708	-2.531	-2.353	-2.171	-1.986	-1.899	-1.799
P/PT2	.718	.631	.545	.477	.406	.331	.200	0
Cp	1.338	1.178	1.015	.889	.756	.616	.373	- .004

$\lambda = 45°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479	.704
P/PT2	.718	.806	.860	.733	.135	.028	.018
Cp	1.338	1.502	1.601	1.366	.248	.048	.030
s/r	-2.883	-2.531	-2.171	-1.899	-1.799		
P/PT2	.718	.590	.458	.252	.012		
Cp	1.338	1.100	.854	.470	.017		

$\lambda = 90°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479
P/PT2	.718	.740	.639	.372	.032	.005
Cp	1.338	1.379	1.190	.694	.056	.002
s/r	-2.171					
P/PT2	.647					
Cp	1.206					

Run 1240 $\alpha = 149.5°$

$\lambda = 0$

s/r	2.883	2.708	2.531	2.353	2.171	1.986	1.899	1.799
P/PT2	.680	.786	.890	.911	.981	.974	.847	.223
Cp	1.265	1.463	1.656	1.695	1.826	1.813	1.576	.415
s/r	1.479	1.092	.704	.317				
P/PT2	.043	.035	.027	.019				
Cp	.075	.061	.046	.031				
s/r	-2.883	-2.708	-2.531	-2.353	-2.171	-1.986	-1.899	-1.799
P/PT2	.680	.633	.537	.472	.430	.328	.194	.009
Cp	1.265	1.178	.999	.878	.800	.610	.361	.014

$\lambda = 45°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479	.704
P/PT2	.680	.826	.881	.662	.138	.027	.017
Cp	1.265	1.537	1.640	1.232	.257	.046	.027
s/r	-2.883	-2.531	-2.171	-1.899	-1.799		
P/PT2	.680	.582	.447	—	.012		
Cp	1.265	1.083	.832	—	.018		

$\lambda = 90°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479
P/PT2	.680	.708	.666	.373	.032	.005
Cp	1.265	1.318	1.239	.694	.056	.006
s/r	-2.171					
P/PT2	.654					
Cp	1.217					

Run 1241 $\alpha = 140.0°$

$\lambda = 0$

s/r	2.883	2.708	2.531	2.353	2.171	1.986	1.899	1.799
P/PT2	.568	.678	.771	.832	.953	1.000	.985	.382
Cp	1.058	1.262	1.436	1.549	1.774	1.862	1.834	.711
s/r	1.479	1.092	.704	.317				
P/PT2	.078	.053	.037	.026				
Cp	.141	.095	.065	.044				
s/r	-2.883	-2.708	-2.531	-2.353	-2.171	-1.986	-1.899	-1.799
P/PT2	.568	.501	.395	.341	.262	.220	.136	.005
Cp	1.058	.933	.735	.635	.488	.410	.253	.006

$\lambda = 45°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479	.704
P/PT2	.568	.701	.795	.720	.204	.045	.022
Cp	1.058	1.305	1.480	1.340	.380	.079	.037
s/r	-2.883	-2.531	-2.171	-1.899	-1.799		
P/PT2	.568	.450	.323	—	.007		
Cp	1.058	.838	.601	—	.010		

$\lambda = 90°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479
P/PT2	.568	.565	.517	.301	.029	.008
Cp	1.058	1.052	.963	.560	.049	.012
s/r	-2.171					
P/PT2	.523					
Cp	.974					

[redacted]

Run 1242 $\alpha = 130.0°$

$\lambda = 0$

s/r	2.883	2.708	2.531	2.353	2.171	1.986	1.899	1.799
P/PT2	.408	.511	.623	.692	.824	.919	1.000	.597
Cp	.758	.950	1.158	1.286	1.532	1.708	1.859	1.110
s/r	1.479	1.092	.704	.317				
P/PT2	.129	.091	.075	.059				
Cp	.240	.165	.135	.105				
s/r	-2.883	-2.708	-2.531	-2.353	-2.171	-1.986	-1.899	-1.799
P/PT2	.408	.358	.258	.219	.163	.126	.074	.003
Cp	.758	.666	.480	.407	.303	.234	.133	.001

$\lambda = 45°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479	.704
P/PT2	.408	.545	.666	.707	.294	.066	.036
Cp	.758	1.013	1.238	1.314	.547	.118	.063
s/r	-2.883	-2.531	-2.171	-1.899	-1.799		
P/PT2	.408	.309	.134	—	.003		
Cp	.758	.574	.249	—	.002		

$\lambda = 90°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479
P/PT2	.408	.411	.384	.234	.028	.013
Cp	.758	.764	.714	.435	.047	.020
s/r	-2.171					
P/PT2	.379					
Cp	.705					

[redacted]

[redacted]

Run 1243 α = 120.0°

λ = 0

s/r	2.883	2.708	2.531	2.353	2.171	1.986	1.899	1.799
P/PT2	.250	.345	.446	.526	.651	.791	.929	.845
Cp	.466	.642	.830	.979	1.212	1.473	1.730	1.573
s/r	1.479	1.092	.704	.317				
P/PT2	.238	.224	.202	.179				
Cp	.443	.417	.376	.333				
s/r	-2.883	-2.708	-2.531	-2.353	-2.171	-1.986	-1.899	-1.799
P/PT2	.250	.219	.161	.126	.084	.068	.038	.002
Cp	.466	.408	.300	.235	.152	.122	.067	0

λ = 45°

s/r	2.883	2.531	2.171	1.899	1.799	1.479	.704
P/PT2	.250	.373	.511	.668	.392	.111	.090
Cp	.466	.695	.951	1.244	.730	.207	.163
s/r	-2.883	-2.531	-2.171	-1.899	-1.799		
P/PT2	.250	.188	.120	—	.002		
Cp	.466	.350	.223	—	- .001		

λ = 90°

s/r	2.883	2.531	2.171	1.899	1.799	1.479
P/PT2	.250	.266	.245	.159	.027	.016
Cp	.466	.495	.456	.296	.046	.025
s/r	-2.171					
P/PT2	.241					
Cp	.449					

[redacted]

Run 1244 $\alpha = 147.0°$

$\lambda = 0$

s/r	2.883	2.708	2.531	2.353	2.171	1.986	1.899	1.799
P/PT2	.669	.771	.867	.896	1.000	.984	.873	.256
Cp	1.246	1.437	1.615	1.670	1.863	1.834	1.626	.477
s/r	1.479	1.092	.704	.317				
P/PT2	.050	.040	.030	.021				
Cp	.089	.071	.051	.035				
s/r	-2.883	-2.708	-2.531	-2.353	-2.171	-1.986	-1.899	-1.799
P/PT2	.669	.606	.499	.434	.353	.301	.178	.009
Cp	1.246	1.129	.929	.808	.658	.561	.328	.012

$\lambda = 45°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479	.704
P/PT2	.669	.788	.828	.689	.159	.032	.019
Cp	1.246	1.469	1.543	1.284	.292	.056	.032
s/r	-2.883	-2.531	-2.171	-1.899	-1.799		
P/PT2	.669	.532	.420	—	.014		
Cp	1.246	.990	.782	—	.023		

$\lambda = 90°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479
P/PT2	.669	.648	.616	.353	.032	.006
Cp	1.246	1.207	1.148	.658	.055	.007
s/r	-2.171					
P/PT2	.580					
Cp	1.080					

[redacted]

Run 1245 $\alpha = 180.0°$

$\lambda = 0$

s/r	2.883	2.708	2.531	2.353	2.171	1.986	1.899	1.799
P/PT2	1.000	1.012	.986	.941	.941	.786	.509	.026
Cp	1.858	1.880	1.832	1.750	1.750	1.460	.944	.044
s/r	1.479	1.092	.704	.317				
P/PT2	.018	.023	.023	.022				
Cp	.029	.038	.038	.037				
s/r	-2.883	-2.708	-2.531	-2.353	-2.171	-1.986	-1.899	-1.799
P/PT2	1.000	1.013	.962	.914	.924	.736	.435	.036
Cp	1.858	1.881	1.789	1.697	1.714	1.369	.808	.063

$\lambda = 45°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479	.704
P/PT2	1.000	.991	.884	.501	.045	.016	.019
Cp	1.858	1.841	1.640	.930	.079	.025	.031
s/r	-2.883	-2.531	-2.171	-1.899	-1.799		
P/PT2	1.000	.984	.886	—	.036		
Cp	1.858	1.825	1.648	—	.063		

$\lambda = 90°$

s/r	2.883	2.531	2.171	1.899	1.799	1.479
P/PT2	1.000	.980	.901	.519	.043	.013
Cp	1.858	1.820	1.674	.962	.076	.020
s/r	-2.171					
P/PT2	.934					
Cp	1.731					

[redacted]

[redacted]

APPENDIX "B"

[redacted]

INDEX OF FIGURES

Photographs	Figure
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Apollo PS-4 Model Installation-Front View	2
Pressure Data	
Command Module Pressure Distributions	3-12

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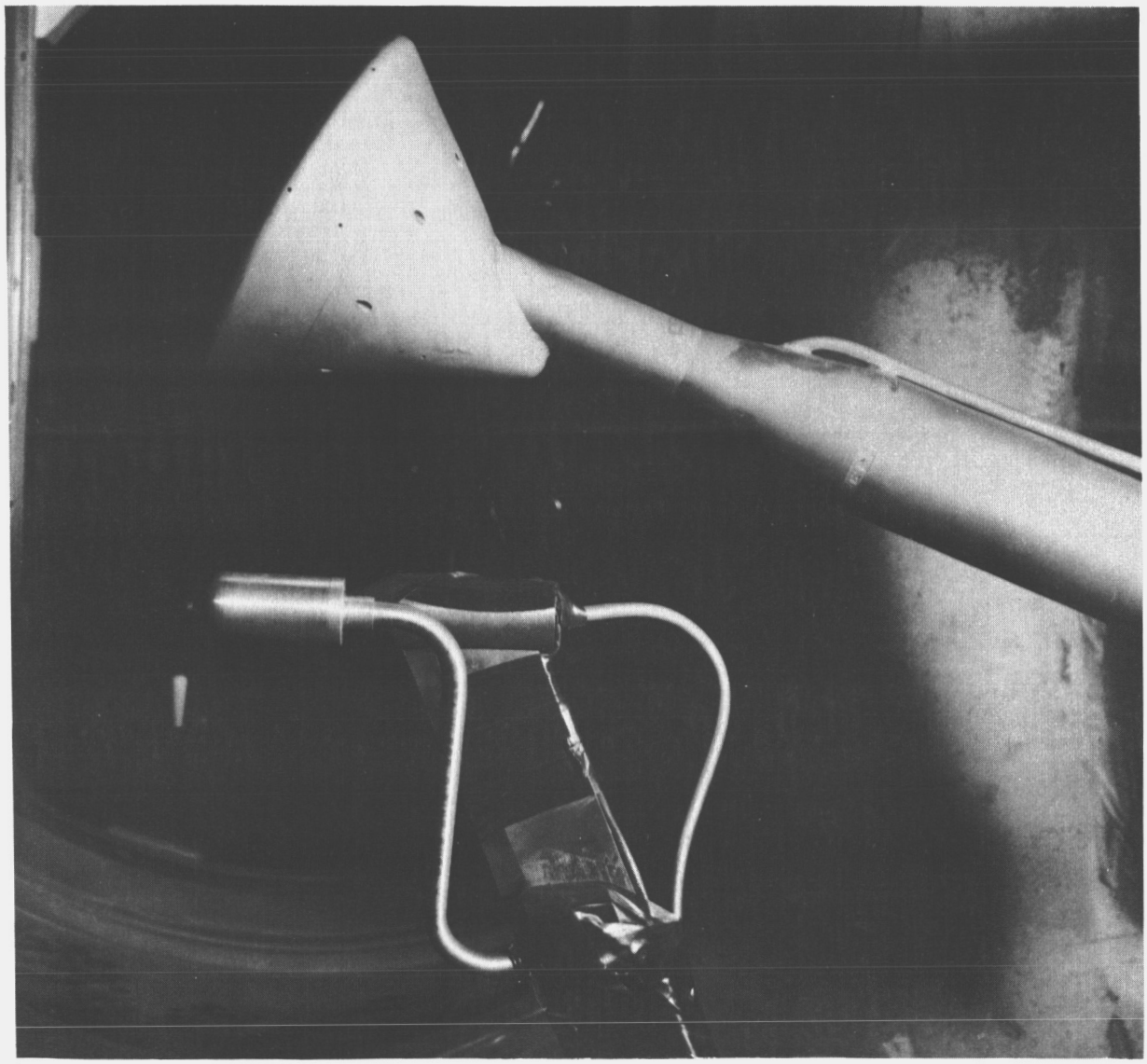

Figure 1. Apollo PS-4 Model Installation-Side View

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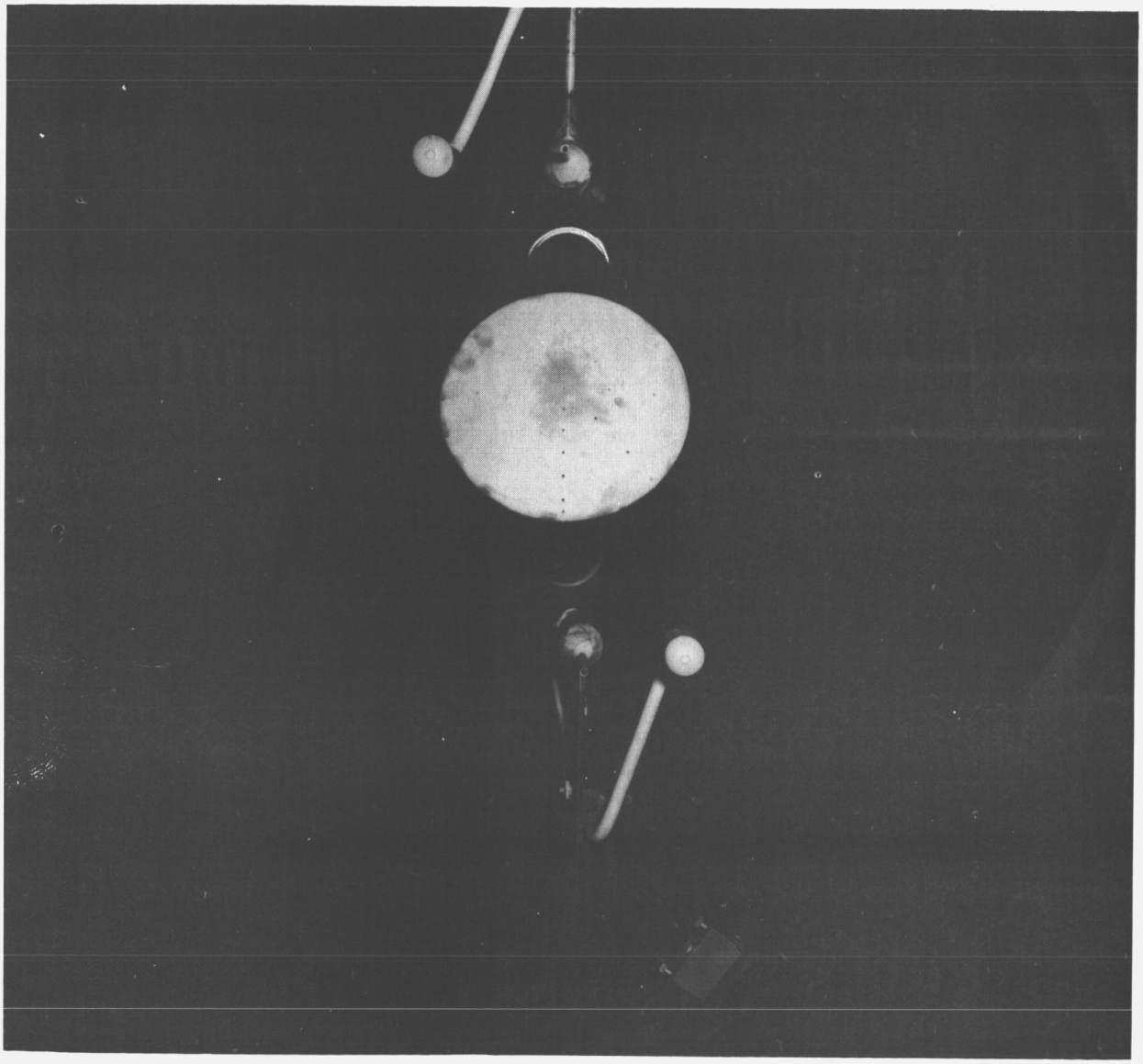

Figure 2. Apollo PS-4 Model Installation-Front View

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FIGURE 3

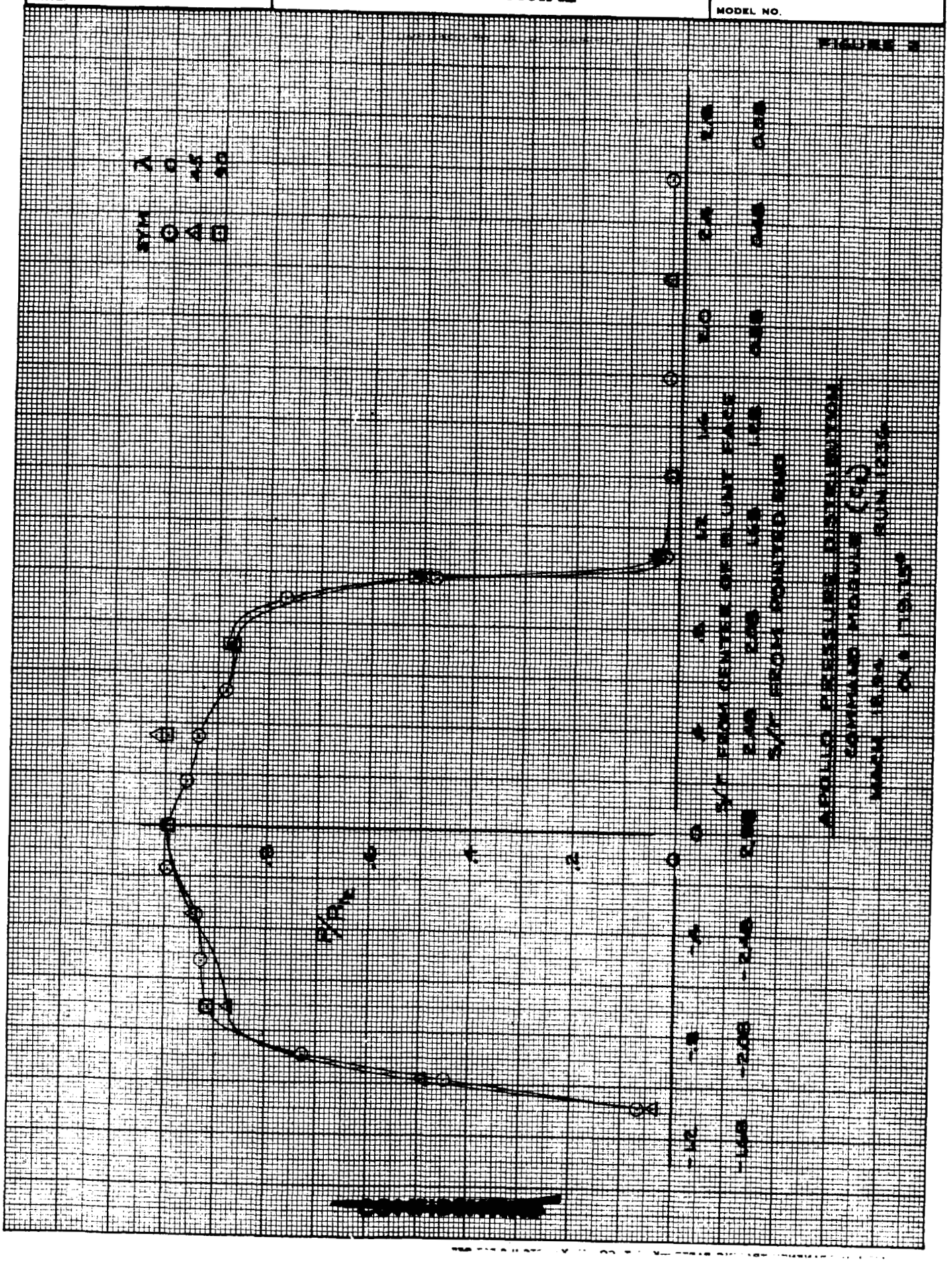

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FIGURE 4

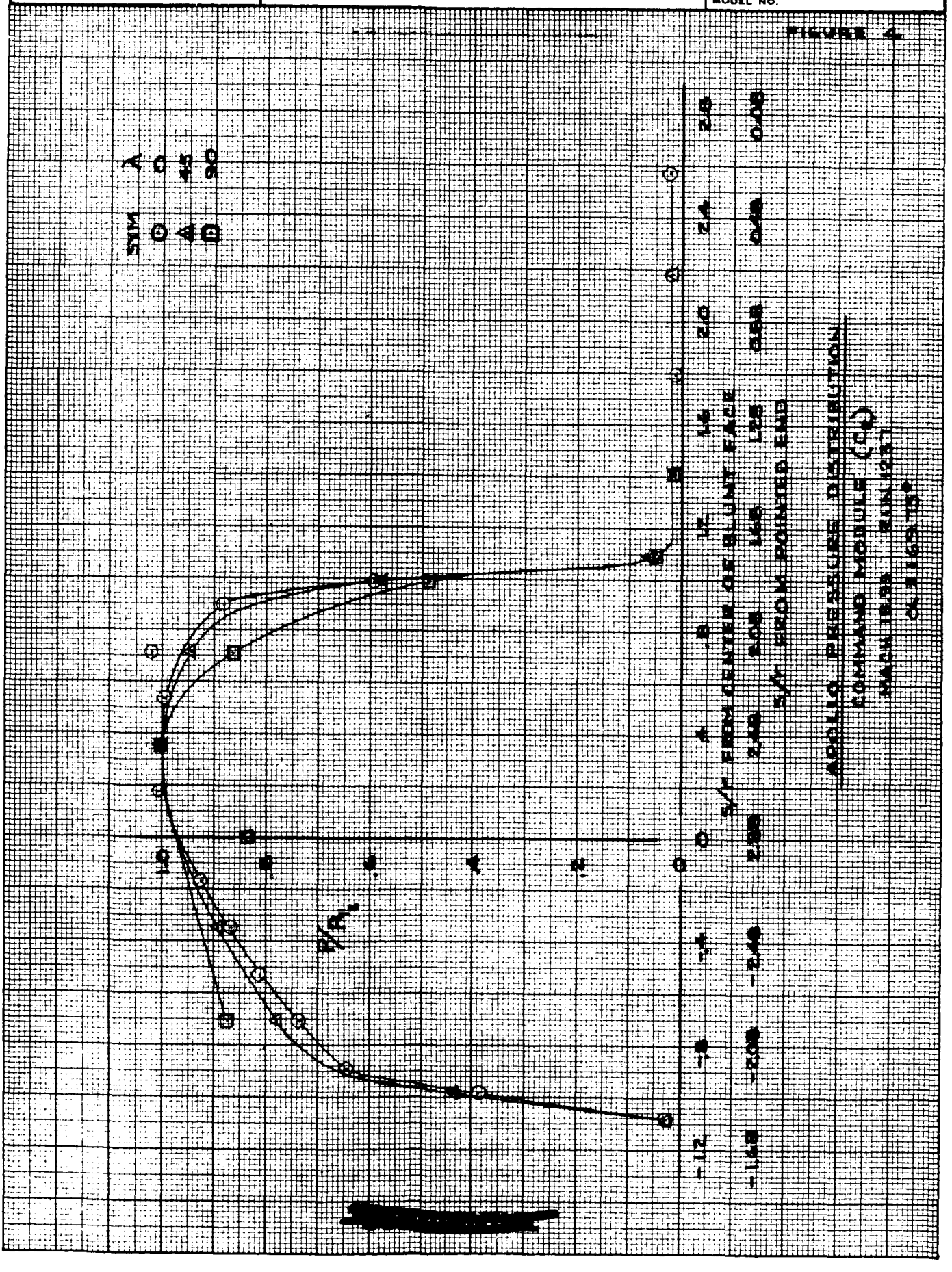

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FIGURE 8

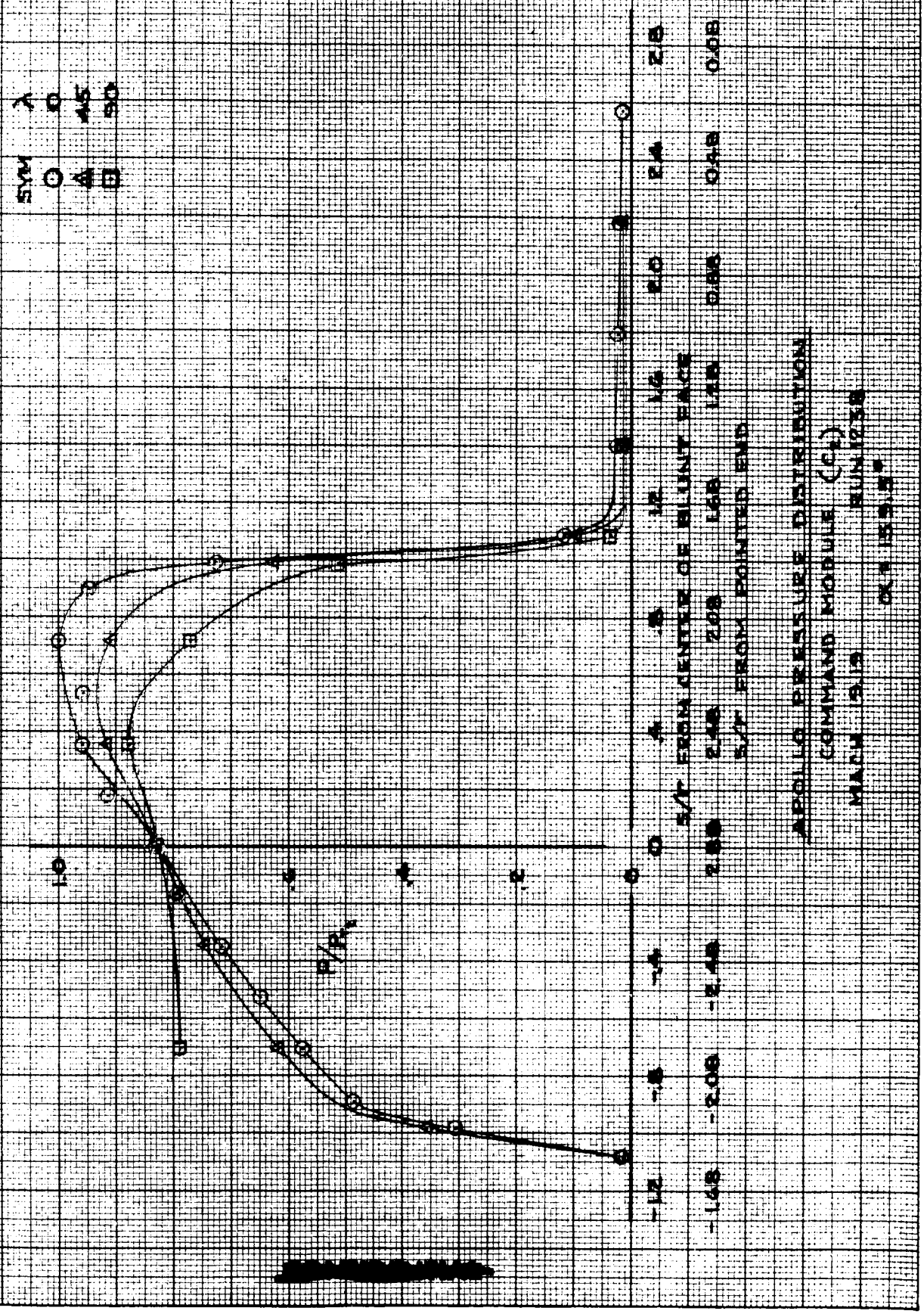

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FIGURE 6

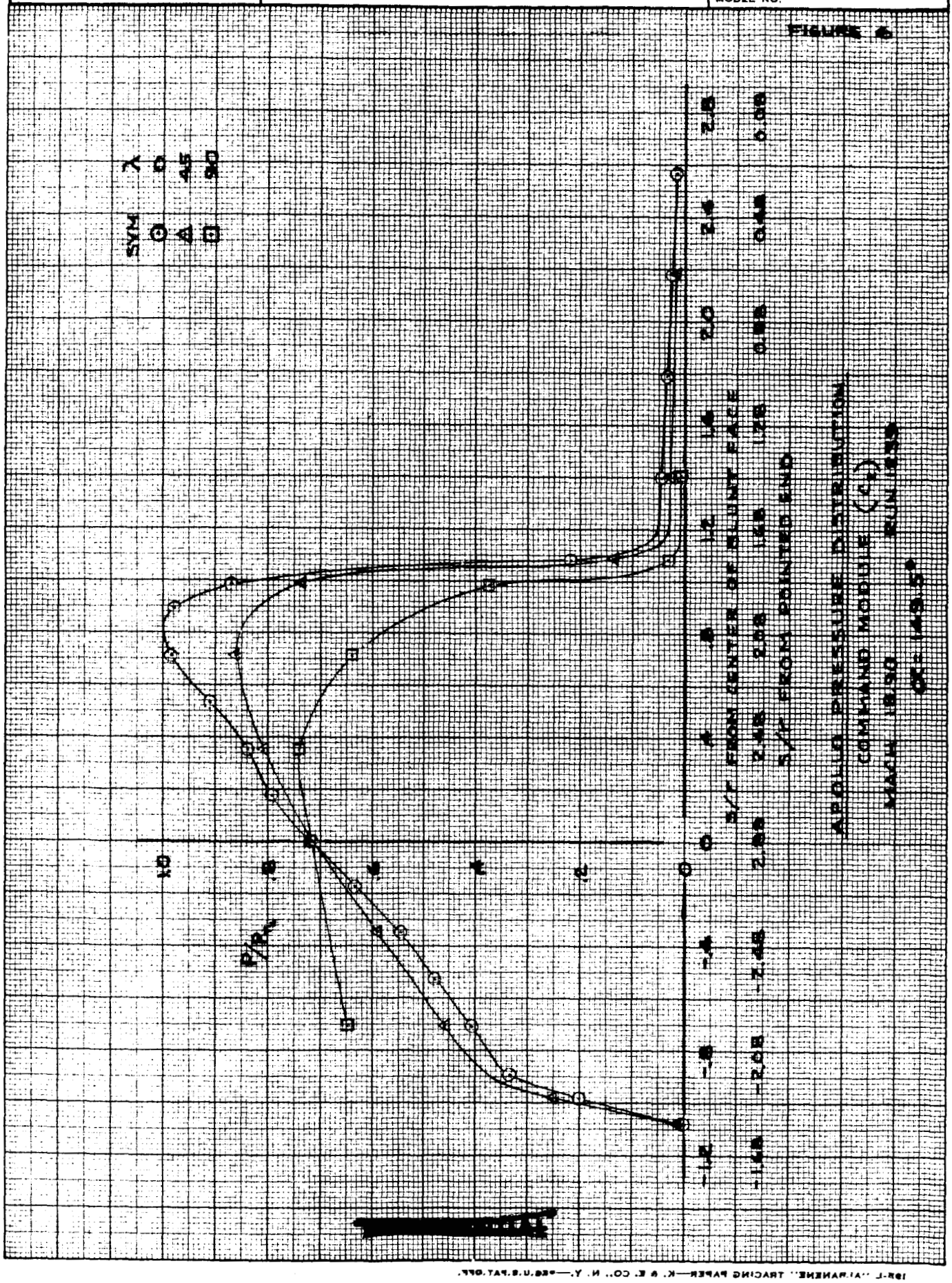

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FIGURE 7

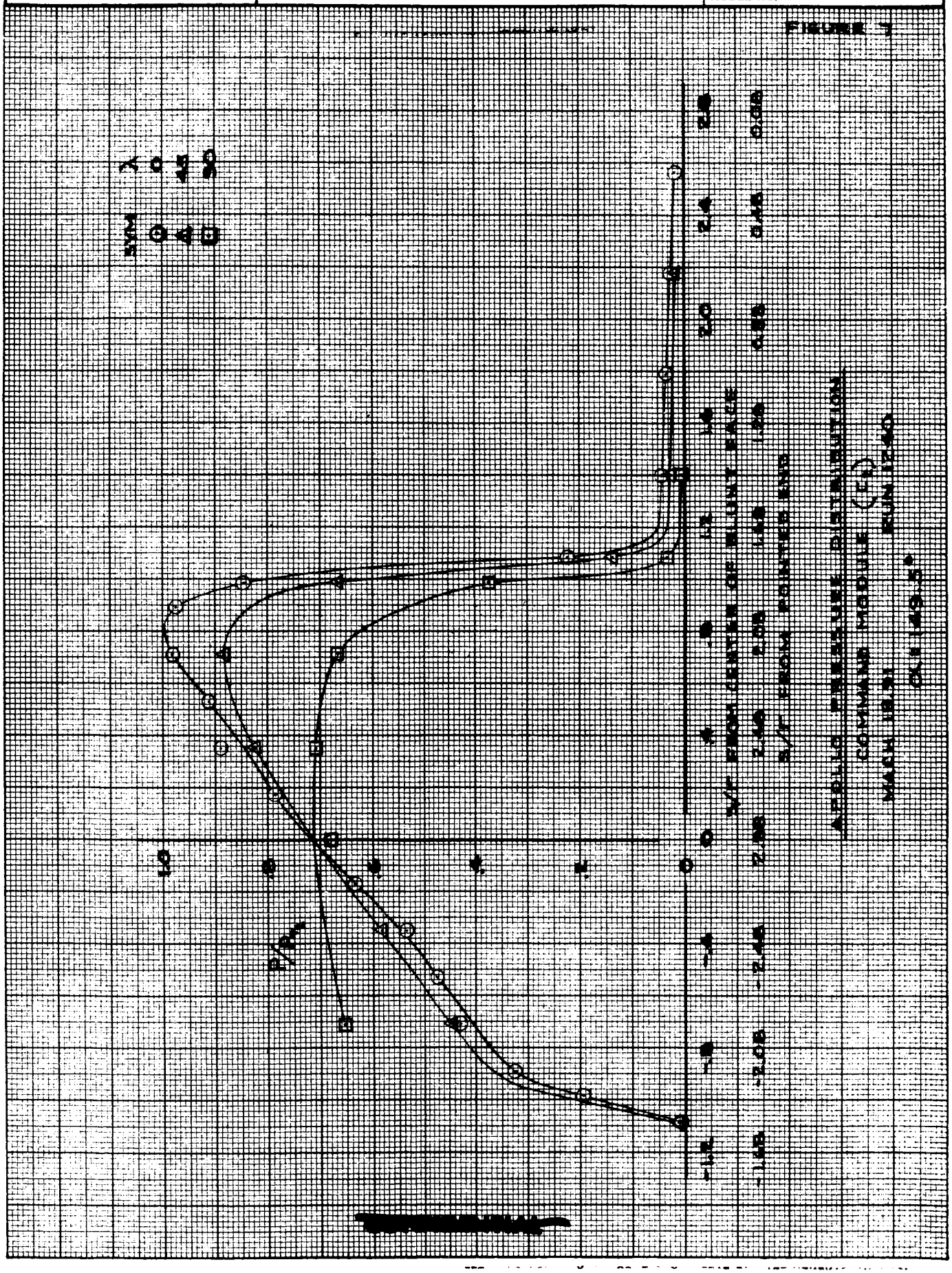

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FIGURE B

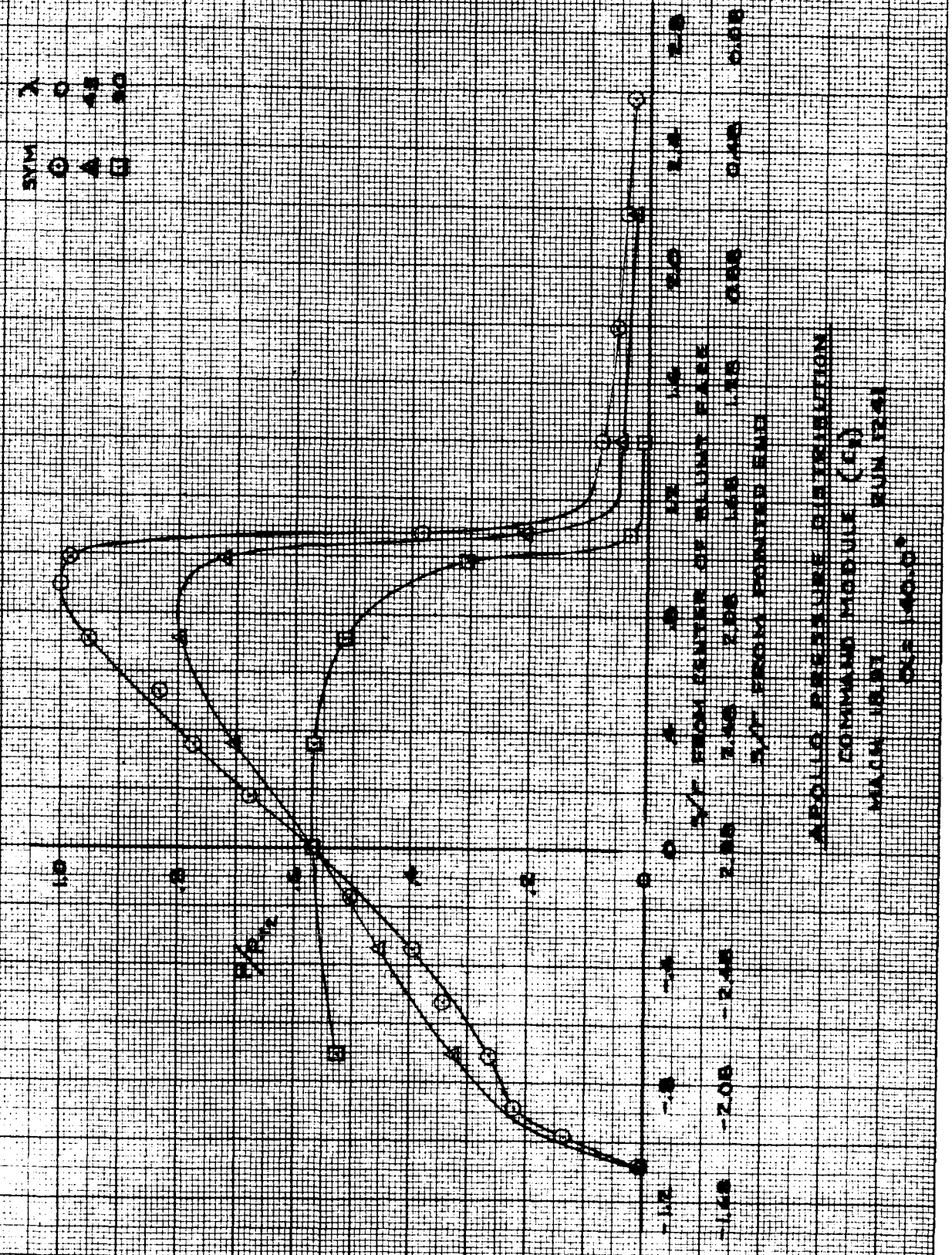

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FIGURE 9

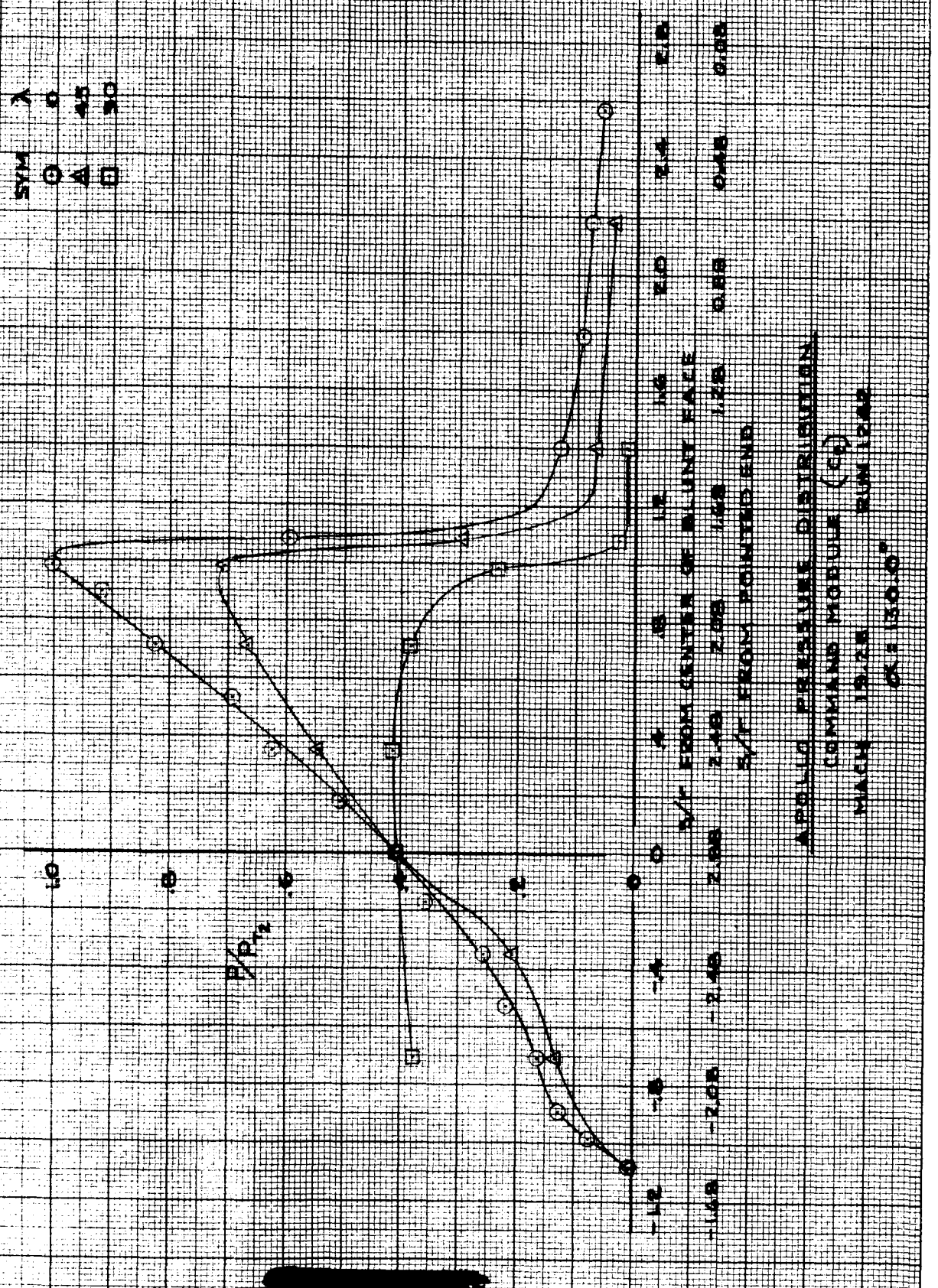

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FIGURE 10

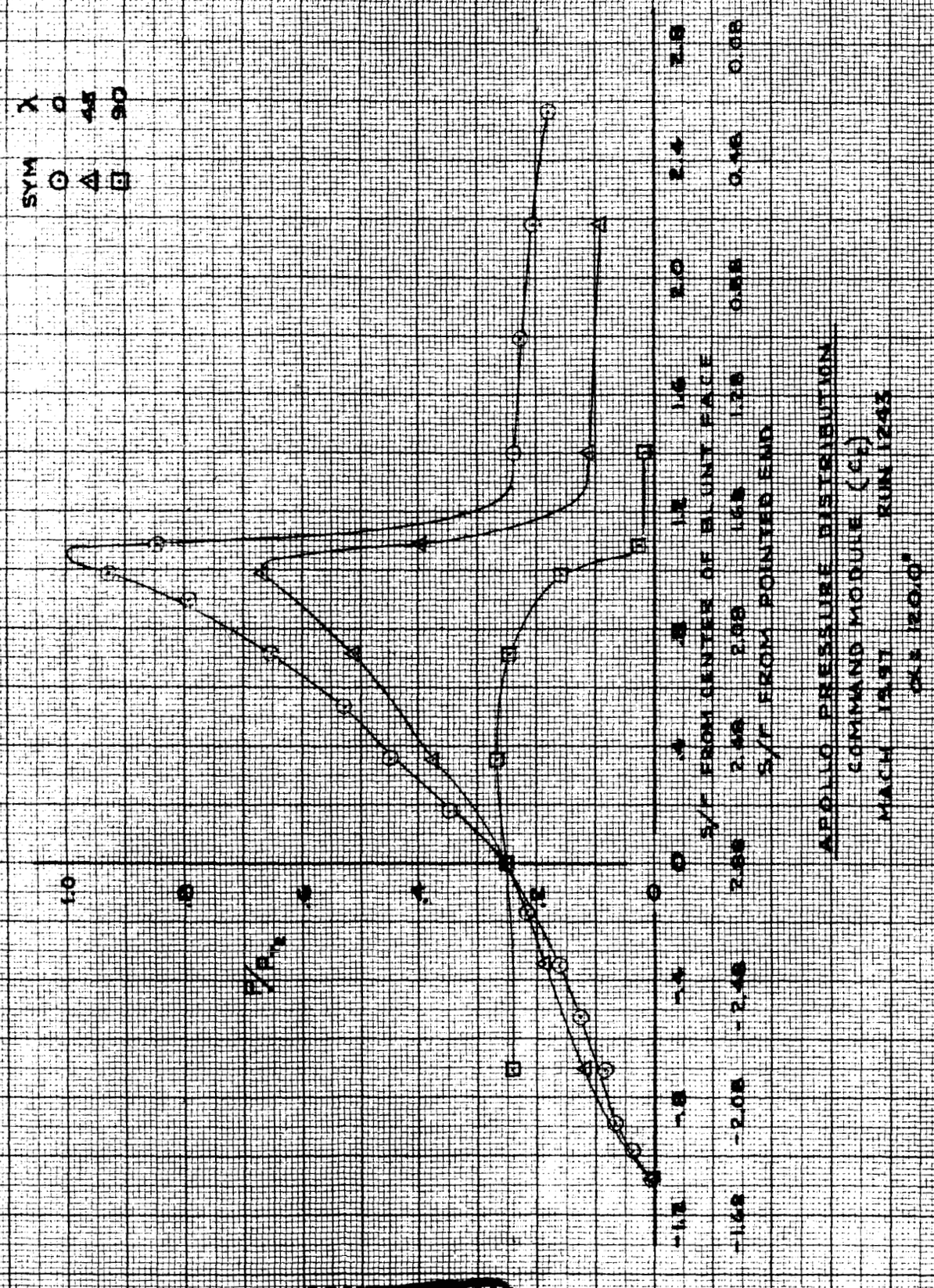

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FIGURE 11

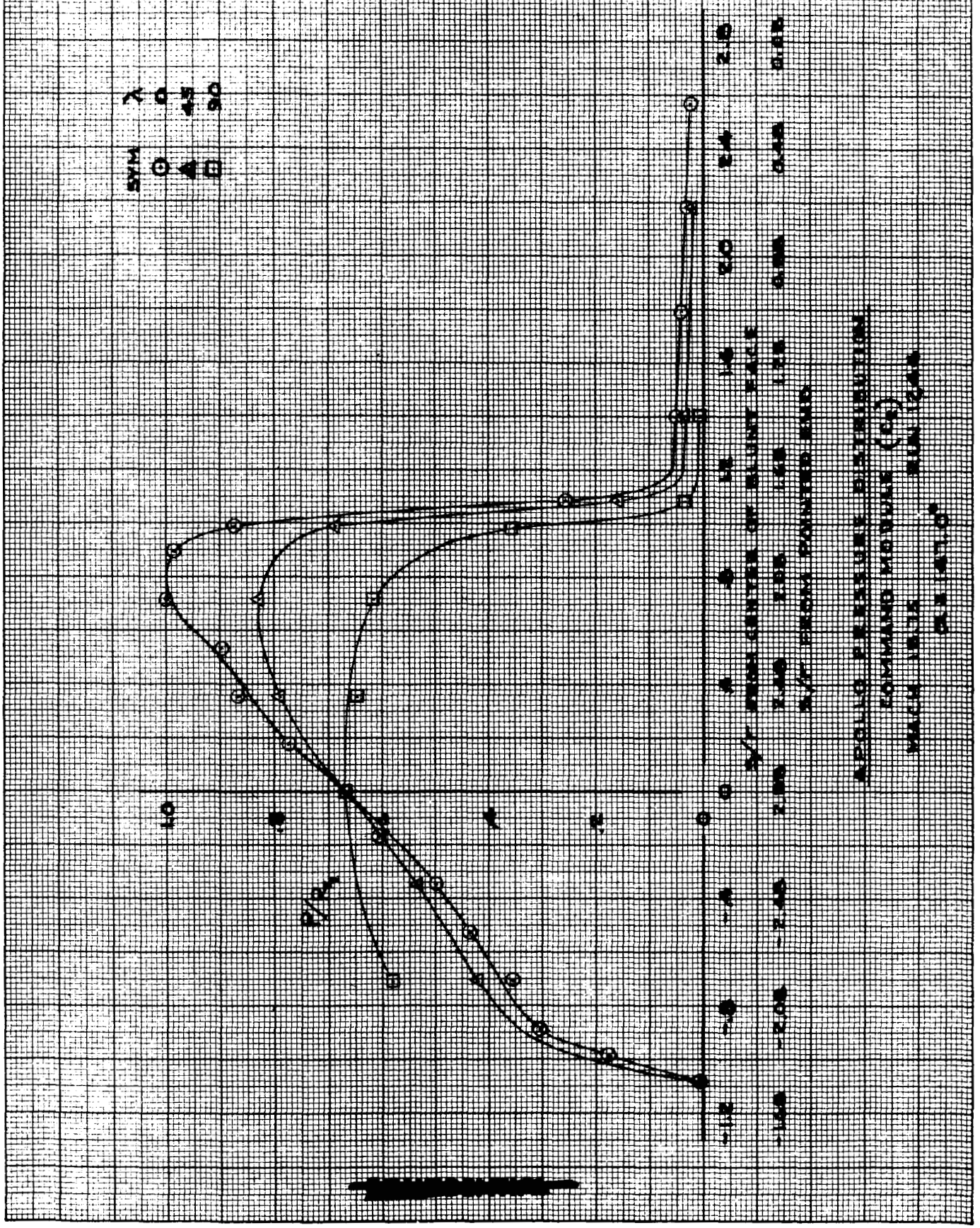

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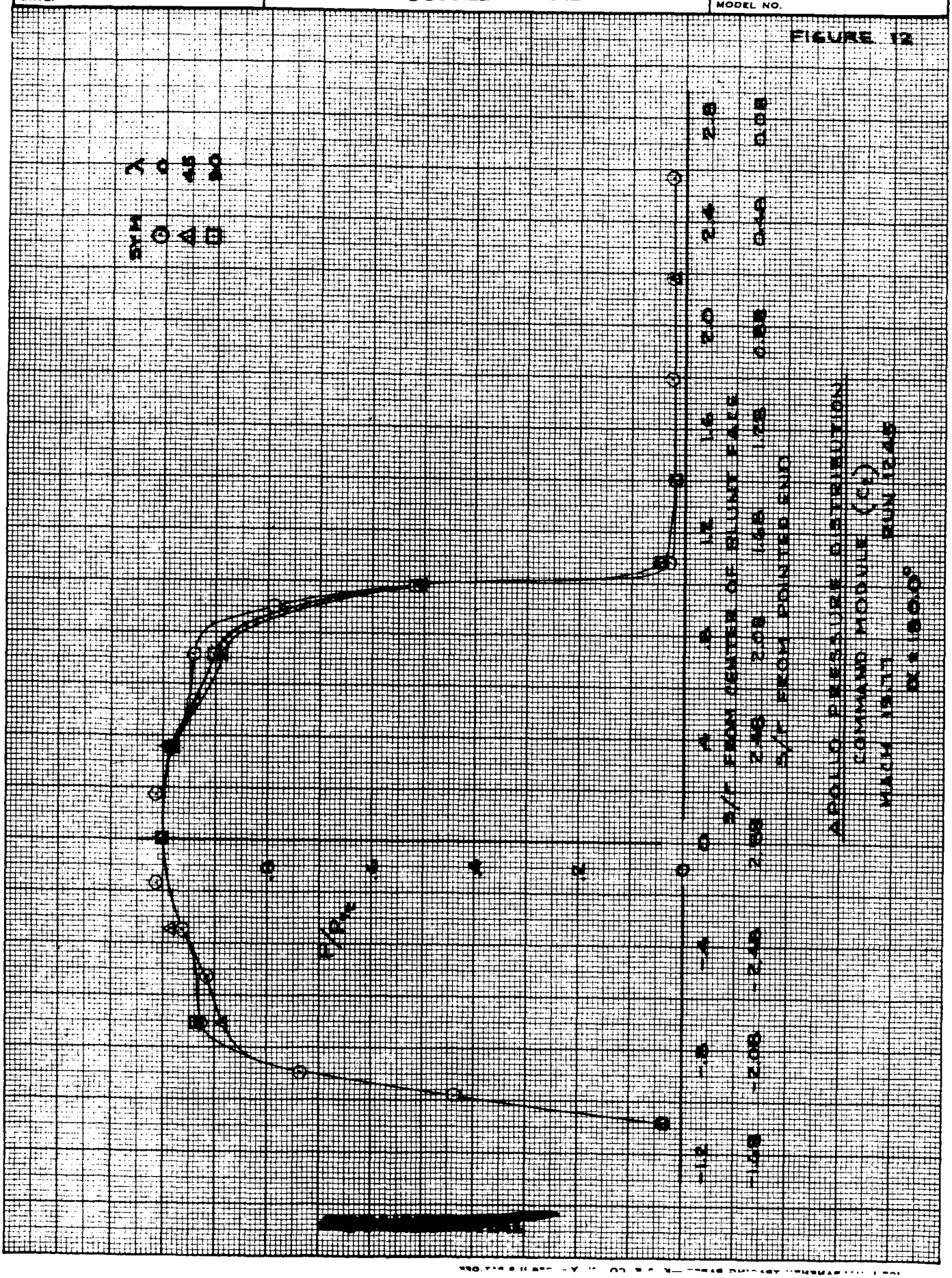
FIGURE 12



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