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TRANSONIC PRESSURE DISTRIBUTIONS OVER PROTUBERANCES AND ADJACENT AREAS IN PROXIMITY TO THE NOSE OF A LAUNCH VEHICLE

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TRANSONIC PRESSURE DISTRIBUTIONS OVER PROTUBERANCES AND ADJACENT AREAS IN PROXIMITY TO THE NOSE OF A LAUNCH VEHICLE

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SUMMARY

A wind-tunnel investigation was conducted over a Mach number range from 0.40 to 1.20 to determine the pressure distributions over protuberances and adjacent areas in proximity to the nose of a launch vehicle. The Reynolds number of the investigation varied with Mach number over a range of 2.30×10^6 per foot to 3.17×10^6 per foot $(0.701 \times 10^6$ per meter to 0.966×10^6 per meter$)$. The angle of attack varied from about -10° to 10°.

The results of the investigation indicate that the variation in pressure coefficient over the forward portion of the protuberance mounted closest to the nose is similar to the variation over the forward portion of the protuberance mounted farthest from the nose; however, there is some variation in the pressure coefficient distribution over the rearward portion of the protuberances. Also, there is an extremely rapid buildup of a negative pressure-coefficient peak of large magnitude rearward of the protuberance cone-cylinder juncture over a small Mach number range as the surface pressure coefficients approach and exceed sonic values.

INTRODUCTION

The National Aeronautics and Space Administration has undertaken a general research program to evaluate various control-system concepts used to stabilize and control launch vehicles in a near-space environment. One such system has been described in reference 1. Since the control system will generally operate only in a near-space environment, fairings are used to protect vulnerable portions of the control system during atmospheric flight. These fairings create protuberances near the nose of the launch vehicle and result in a very unusual configuration. A theoretical analysis of the aerodynamic effects of the protuberances would be difficult to obtain. In addition, only limited experimental data are available for use in analyzing the aerodynamic effects of the protuberances. Therefore, in support of a study of a particular control-system concept, an investigation has been conducted at transonic speeds by using the second stage of the two-stage launch vehicle described in reference 1. The purpose of this investigation was to determine the pressure coefficient distributions over the control fairings and areas adjacent to the control fairings as an aid in the evaluation of the structural loadings in the proximity of the nose. The static aerodynamic characteristics of the complete two-stage launch vehicle have been reported in reference 2.

This investigation was conducted in the Langley 8-foot transonic pressure tunnel over a Mach number range of 0.40 to 1.20. The Reynolds number of the investigation varied with Mach number over a range of 2.30×10^6 per foot to 3.17×10^6 per foot $\left(0.701 \times 10^6\right.$ per meter to $\left.0.966 \times 10^6 \text{ per meter}\right)$. The angle of attack varied from about -10° to 10°.

SYMBOLS

The units used for the physical quantities defined in this paper are given in both U.S. Customary Units and in the International System of Units (SI). The values of the physical quantities in SI Units are in parentheses. Factors relating the two systems are given in reference 3.

x	model station, inches (centimeters) (see fig. 1(a))
l	protuberance station, inches (centimeters) (see fig. 1(b))
M	Mach number
R	Reynolds number per unit length, foot^{-1} $\left(\text{meter}^{-1}\right)$
α	nominal angle of attack of model center line (does not include corrections for deflection of model and support system due to load), degrees
p	local static pressure, pounds per square foot $\left(\text{kilonewtons per meter}^2\right)$
p_∞	free-stream static pressure, pounds per square foot $\left(\text{kilonewtons per meter}^2\right)$
q_∞	free-stream dynamic pressure, pounds per square foot $\left(\text{kilonewtons per meter}^2\right)$
C_p	pressure coefficient, $\dfrac{p - p_\infty}{q_\infty}$

MODEL AND APPARATUS

Model

Geometrical details of the second stage of the two-stage launch vehicle are presented in figure 1(a). The details of the control fairings are given in figure 1(b), and the arrangement of the pressure orifices on the control fairings and areas adjacent to the control fairings are shown in figure 1(c).

The control fairings will be referred to hereinafter as protuberances. A photograph of the model of the entire two-stage launch vehicle investigated in reference 2 is provided in figure 2. A detailed photograph of the instrumented portion of the second stage used in the present investigation is given in figure 3. All longitudinal orifice locations, which are indicated in the table of results, are referenced to model station 0. (See fig. 1(a).)

Apparatus

The investigation was conducted in the Langley 8-foot transonic pressure tunnel. This facility is a single-return, rectangular, slotted-throat tunnel having controls that allow for the independent variation of Mach number, density, temperature, and humidity and is designed to obtain aerodynamic data through the speed of sound while minimizing the usual effects of blockage.

Model surface pressures were measured by using multiple-tube manometer boards and were recorded on photographic film.

TEST CONDITIONS AND TECHNIQUES

Range of Investigation

The test conditions are summarized in the following table:

M	q_∞		R	
	psf	kN/m^2	ft^{-1}	m^{-1}
0.40	214	10.25	2.30×10^6	0.701×10^6
.60	422	20.21	3.17	.966
.65	407	19.49	2.84	.866
.70	443	21.21	2.97	.905
.75	493	23.60	3.10	.945
.80	462	22.12	2.81	.856
.85	506	24.23	2.89	.881
.90	534	25.57	2.96	.902
.95	560	26.81	3.02	.920
1.00	585	28.01	3.06	.933
1.20	655	31.36	3.14	.957

Results were obtained for the model upright and for the model rolled 90° counterclockwise as viewed from the front over an angle-of-attack range from about -10° to 10° at Mach numbers of 0.40, 0.60, 0.80, 1.00, and 1.20. In addition, results were obtained at an angle of attack of 0° at Mach numbers of 0.65, 0.70, 0.75, 0.85, 0.90, and 0.95.

Transition Strips

The investigation was conducted with boundary-layer transition fixed. The transition point was fixed by a transition strip 0.100 inch (0.254 cm) wide composed of No. 60 carborundum grains set in a plastic adhesive. The transition strip was located with the forward edge at model station 1.500 (3.810).

CORRECTIONS AND ACCURACY

Angles of attack not corrected for deflection of the model and support system under load will be referred to as nominal angles of attack. The nominal angles of attack have been corrected for tunnel airflow angularity. The accuracy of the nominal angles of attack presented herein is estimated to be $\pm 0.1^\circ$. Since the true angle of attack is the nominal angle of attack plus the correction for deflection of the model and support system under load, an approximation of the model deflection under load has been made from results presented in reference 2. It is estimated that an additional deflection (in the direction of the resultant normal force) of less than 0.25° would be expected for the condition of maximum loading for the present investigation.

Effects of subsonic boundary interference in the slotted test section of the Langley 8-foot transonic pressure tunnel are considered to be negligible and no corrections for these effects have been applied. At supersonic speeds, the experimental results are generally affected by boundary-reflected disturbances that occur at Mach numbers from slightly above 1.00 to those at which the disturbances are reflected downstream of the model base. For the present investigation, all results are free from boundary-reflected disturbances.

A consideration of factors affecting the results of this investigation has indicated general accuracies in pressure coefficient to be of the order of ± 0.01 and ± 0.005 at Mach numbers of 0.40 and 1.20, respectively. However, in regions of rapidly varying pressures or for conditions where the pressures are noticeably sensitive to small Mach number changes, such accuracies may not be expected. Based upon unpublished tunnel calibrations, local deviations from the quoted free-stream Mach numbers did not exceed ± 0.003 at subsonic speeds and did not become greater than ± 0.010 as the Mach number was increased to 1.20.

RESULTS AND DISCUSSION

Results

Results obtained in the present investigation are presented in the form of surface pressure coefficients which are given in table I.

Representative plots of these results are presented in figures 4 and 5 to show the effects of Mach number and angle of attack on the surface pressure coefficient distributions over the protuberances and the adjacent areas in proximity to the nose of the launch vehicle. Shown in figure 6 is the effect of the location of the protuberance, with respect to the nose and the other protuberances, on the protuberance surface pressure coefficients. It should be noted in figures 4 to 7 that the sketch preceding each plot is shown for the model upright irrespective of whether the data are presented for the model upright or the model rolled 90°. In figure 7, the effect of Mach number on the local pressure coefficients rearward of the cone-cylinder juncture of the protuberances is indicated. Figure 8 presents schlieren photographs of the flow over the protuberance region of the second stage.

Discussion

The effects of varying Mach number on the surface pressure coefficient distributions over the protuberances and the areas adjacent to the protuberances are presented in figure 4. Comparison of the surface pressure coefficients over the protuberances (rows B and D) indicates that the main effects of increasing Mach number are to increase the magnitude of the negative pressure-coefficient peaks associated with the cone-cylinder juncture of the protuberance up to a Mach number of approximately 0.70 and a subsequent decrease for Mach numbers greater than approximately 0.70. In addition, there is a general broadening of the negative pressure-coefficient peaks associated with the cone-cylinder juncture of the protuberance as Mach number is increased. It is also evident from the results in figure 4 that, as the Mach number approaches 0.85, the pressure coefficients aft of the cone-cylinder juncture of the protuberances become more negative (rows B and D). It is conjectured that this is a result of the flow separating from the aft portion of the protuberances due to the large boattailing of the protuberances. The effects of increasing Mach number on the pressure coefficients of the areas adjacent to the protuberances (rows A and C) are an overall general increase in the value of the negative pressure coefficients up to a Mach number of approximately 0.85. The increase is most noticeable in the region from approximately model station 4.900 (12.446) to 7.300 (18.542), a region which includes the part of the model from the nose of the rearward protuberance to the base of the forward protuberance. For Mach numbers greater than approximately 0.85, the apparent separated flow behind the aft portion of the protuberances can be seen to have a dominating effect on the pressure coefficients associated with the rearward orifices of rows A and C.

From figure 4, a comparison of results for rows A and C shows that the areas adjacent to the protuberances experience interference pressure variations which are associated with their proximity to the protuberances. Examination of the results indicates that the closer the protuberances are circumferentially, the more negative the pressure coefficients on the surface between them.

The effects of angle of attack on the surface pressure coefficients of the protuberances and areas adjacent to the protuberances are shown in figure 5(a) for the model upright and in figure 5(b) for the model rolled 90°. These results indicate that the general effect of variation of angle of attack to be a decrease in pressure coefficient (more negative) for orifices on the leeward side of the model and an increase in pressure coefficient (more positive) for orifices on the windward side of the model.

From a comparison of row B (model upright) with row D (model rolled 90°) and row B (model rolled 90°) with row D (model upright), an indication of the effect of location of the protuberance with respect to the nose of the launch vehicle and with respect to the other protuberances on the surface pressure coefficients of the protuberances can be seen. (See fig. 6.) The variations of pressure coefficient over the forward portion of the forward- and rearward-mounted protuberances are similar and show no effect due to location of the protuberances. However, there is some variation in the pressure coefficient distribution over the rearward portion of the protuberances.

Figure 7 illustrates the rapid changes in local pressure coefficient which occur just downstream of the cone-cylinder juncture of the protuberances. Shown are the variations in pressure coefficient with Mach number for four orifice locations immediately behind the protuberance cone-cylinder junctures. Examination of the results in figure 7 indicates that there is an extremely rapid buildup of a negative pressure-coefficient peak of large magnitude over a small Mach number range as the local pressure coefficients approach and exceed sonic values. This buildup is probably a result of the flow around the shoulder of the conical portion of the protuberances improving progressively between Mach numbers of 0.70 and 1.00 by means of a Prandtl-Meyer type of supersonic expansion, so that the pressure coefficient becomes more negative accordingly. Also of interest is the sudden increase (more positive) in pressure coefficient occurring at a Mach number of approximately 0.80 for the orifices on row B (rearward protuberance) at protuberance stations rearward of $l = 1.524$ (3.871). This is a probable result of the orifices in row B lying within a local compression region at Mach numbers from approximately 0.80 to 0.95. (See fig. 8.) It is conjectured that the orifices in row D for the same location on the protuberance do not experience the compression seen in row B because of the reduced pressure region created by the rearward-protuberance cone-cylinder juncture.

CONCLUDING REMARKS

An investigation has been conducted at transonic speeds to determine the pressure coefficient distributions over protuberances and adjacent areas located in proximity to the nose of a launch vehicle.

The results of the investigation indicate the variation in pressure coefficient over the forward portion of the protuberance mounted closest to the nose is similar to that over the forward portion of the protuberance mounted farthest from the nose; however, there is some variation in the pressure coefficient distribution over the rearward portion of the protuberances. Also, there is an extremely rapid buildup of a negative pressure-coefficient peak of large magnitude rearward of the protuberances cone-cylinder juncture over a small Mach number range as the surface pressure coefficients approach and exceed sonic values.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., October 8, 1965.

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TABLE I.- PRESSURE COEFFICIENTS

(a) $M = 0.65$ to 0.95; $\alpha = 0^{o}$

Orifice	x, in.	x, cm	C_p for M of - 0.65	0.70	0.75	0.85	0.90	0.95
Row A								
1	3.855	9.792	-0.021	0.046	0.013	0.031	0.073	0.117
2	4.244	10.780	-.089	-.025	-.064	-.058	-.028	.010
3	4.550	11.557	-.142	-.081	-.120	-.109	-.082	-.085
4	4.863	12.352	-.184	-.123	-.157	-.126	-.078	-.029
5	5.611	14.252	-.293	-.245	-.308	-.298	-.227	-.156
6	6.011	15.268	-.271	-.234	-.313	-.432	-.350	-.267
7	6.230	15.824	-.271	-.237	-.319	-.557	-.494	-.422
8	6.630	16.840	-.214	-.166	-.223	-.373	-.558	-.591
9	7.151	18.164	-.104	-.041	-.078	-.126	-.212	-.632
10	7.770	19.736	-.019	.050	.018	-.038	-.106	-.299
11	8.020	20.371	.001	.072	.038	-.006	-.066	-.216
12	8.270	21.006	.010	.081	.048	.016	-.032	-.163
Row B								
13	3.697	9.390	-0.016	0.055	0.023	0.048	0.093	0.135
14	3.947	10.025	-.106	-.038	-.069	-.033	.019	.071
15	4.244	10.780	-.568	-.541	-.617	-.754	-.752	-.676
16	4.550	11.557	-.083	-.019	-.056	-.038	-.018	-.042
17	4.863	12.352	.225	.290	.248	.239	.270	.287
18	4.915	12.484	.683	.765	.722	.674	.731	.756
19	5.020	12.751	-.124	-.063	-.098	-.039	.040	.143
20	5.237	13.302	.001	.069	.035	.062	.120	.179
21	5.611	14.252	-.062	.006	-.026	.003	.061	.122
22	5.811	14.760	-.130	-.063	-.087	-.046	.018	.084
23	6.011	15.268	-.280	-.206	-.211	-.136	-.062	.012
24	6.230	15.824	-1.097	-1.168	-1.099	-.849	-.732	-.621
25	6.430	16.332	-.483	-.454	-.834	-.600	-.574	-.805
26	6.630	16.840	-.449	-.393	-.414	-.488	-.433	-.620
27	6.890	17.501	-.500	-.452	-.462	-.424	-.382	-.392
28	7.151	18.164	-.331	-.267	-.275	-.389	-.388	-.370
29	7.460	18.948	.012	.067	.025	-.335	-.419	-.411
30	7.770	19.736	.072	.133	.086	-.161	-.321	-.376
31	8.020	20.371	.136	.211	.165	-.108	-.318	-.431
32	8.270	21.006	.197	.265	.204	.016	-.213	-.397
Row C								
33	3.605	9.157	0.028	0.098	0.065	0.080	0.116	0.159
34	3.855	9.792	.007	.074	.040	.053	.093	.132
35	4.244	10.780	-.037	.028	-.008	-.003	.027	.061
36	4.550	11.557	-.075	-.009	-.043	-.034	-.003	.017
37	4.863	12.352	-.114	-.048	-.076	-.045	.005	.049
38	5.237	13.302	-.246	-.178	-.198	-.135	-.068	-.007
39	5.611	14.252	-.365	-.328	-.391	-.331	-.247	-.168
40	5.811	14.760	-.374	-.331	-.403	-.465	-.378	-.296
41	6.011	15.268	-.471	-.445	-.512	-.594	-.502	-.409
42	6.230	15.824	-.486	-.479	-.609	-.714	-.717	-.714
43	6.430	16.332	-.369	-.321	-.391	-.653	-.687	-.716
44	6.630	16.840	-.249	-.186	-.214	-.353	-.484	-.668
45	6.890	17.501	-.144	-.085	-.119	-.301	-.395	-.470
46	7.151	18.164	-.069	-.010	-.054	-.219	-.390	-.417
47	7.460	18.948	-.024	.034	-.021	-.138	-.360	-.444
48	7.770	19.736	-.023	.034	-.013	-.080	-.278	-.436
49	8.020	20.371	-.021	.038	-.002	-.033	-.194	-.393
50	8.270	21.006	-.016	.046	.013	.009	-.099	-.327
Row D								
51	3.697	9.390	0.024	0.092	0.060	0.073	0.114	0.151
52	3.947	10.025	.008	.073	.039	.049	.087	.122
53	4.244	10.780	.297	.370	.335	.344	.376	.413
54	4.290	10.897	.579	.672	.649	.683	.731	.772
55	4.395	11.163	-.283	-.231	-.271	-.291	-.282	-.264
56	4.550	11.557	-.062	.005	-.027	-.011	.032	.072
57	4.863	12.352	-.048	.023	-.003	.032	.083	.129
58	5.237	13.302	-.174	-.100	-.110	-.041	.025	.085
59	5.611	14.252	-1.236	-1.335	-1.259	-.973	-.834	-.714
60	5.811	14.760	-.512	-.513	-.897	-1.091	-.961	-.844
61	6.011	15.268	-.477	-.419	-.460	-.928	-.819	-.773
62	6.230	15.824	-.569	-.528	-.543	-.528	-.432	-.717
63	6.430	16.332	-.478	-.425	-.447	-.394	-.362	-.546
64	6.630	16.840	-.303	-.244	-.268	-.311	-.347	-.502
65	6.890	17.501	-.135	-.084	-.134	-.219	-.366	-.491
66	7.151	18.164	-.011	.044	-.010	-.136	-.303	-.446
67	7.460	18.948	.255	.294	.204	-.016	-.230	-.280
68	7.770	19.736	.239	.293	.230	.133	-.057	-.147
69	8.020	20.371	.162	.231	.190	.154	.023	-.099
70	8.270	21.006	.111	.183	.152	.140	.056	-.074

TABLE I.- PRESSURE COEFFICIENTS - Continued

(b) M = 0.40; $\alpha = -10^{\circ}$ to 10°; model upright

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row A									
1	3.855	9.792	0.037	0.013	-0.001	-0.042	-0.084	-0.116	-0.185
2	4.244	10.780	-.013	-.043	-.059	-.096	-.137	-.166	-.235
3	4.550	11.557	-.068	-.094	-.106	-.147	-.178	-.212	-.274
4	4.863	12.352	-.104	-.138	-.150	-.185	-.222	-.245	-.298
5	5.611	14.252	-.270	-.270	-.262	-.269	-.282	-.284	-.308
6	6.011	15.268	-.278	-.253	-.233	-.234	-.235	-.226	-.242
7	6.230	15.824	-.287	-.256	-.229	-.227	-.226	-.214	-.224
8	6.630	16.840	-.264	-.227	-.193	-.193	-.184	-.169	-.192
9	7.151	18.164	-.189	-.145	-.114	-.116	-.119	-.116	-.136
10	7.770	19.736	-.111	-.072	-.042	-.044	-.053	-.054	-.087
11	8.020	20.371	-.090	-.053	-.022	-.027	-.036	-.038	-.078
12	8.270	21.006	-.085	-.043	-.015	-.016	-.025	-.030	-.065
Row B									
13	3.697	9.390	0.129	0.055	0.013	-0.039	-0.085	-0.117	-0.175
14	3.947	10.025	.059	-.021	-.064	-.120	-.168	-.199	-.262
15	4.244	10.780	-.289	-.389	-.442	-.507	-.559	-.593	-.636
16	4.550	11.557	.053	-.010	-.043	-.088	-.126	-.147	-.193
17	4.863	12.352	.374	.309	.272	.222	.176	.143	.075
18	4.915	12.484	.789	.741	.707	.643	.577	.517	.416
19	5.020	12.751	.007	-.057	-.088	-.124	-.143	-.146	-.159
20	5.237	13.302	.107	.051	.027	-.012	-.041	-.052	-.096
21	5.611	14.252	.048	-.010	-.032	-.072	-.104	-.113	-.147
22	5.811	14.760	-.018	-.077	-.106	-.142	-.171	-.179	-.212
23	6.011	15.268	-.158	-.219	-.246	-.288	-.313	-.320	-.350
24	6.230	15.824	-.735	-.801	-.831	-.871	-.884	-.875	-.874
25	6.430	16.332	-.403	-.437	-.447	-.466	-.469	-.451	-.452
26	6.630	16.840	-.381	-.411	-.415	-.432	-.432	-.410	-.402
27	6.890	17.501	-.461	-.477	-.470	-.469	-.460	-.426	-.406
28	7.151	18.164	-.388	-.383	-.364	-.347	-.325	-.284	-.263
29	7.460	18.948	.000	.007	.014	.019	-.005	-.014	-.030
30	7.770	19.736	.094	.087	.087	.075	.074	.080	.068
31	8.020	20.371	.158	.146	.145	.127	.150	.191	.199
32	8.270	21.006	.211	.187	.187	.171	.194	.210	.205

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row C									
33	3.605	9.157	0.100	0.065	0.045	0.006	-0.028	-0.060	-0.137
34	3.855	9.792	.083	.047	.027	-.010	-.049	-.081	-.157
35	4.244	10.780	.060	.019	-.007	-.050	-.093	-.131	-.207
36	4.550	11.557	.034	-.015	-.042	-.085	-.130	-.165	-.241
37	4.863	12.352	-.016	-.062	-.093	-.133	-.172	-.204	-.270
38	5.237	13.302	-.155	-.199	-.223	-.264	-.291	-.311	-.360
39	5.611	14.252	-.286	-.311	-.317	-.334	-.334	-.324	-.337
40	5.811	14.760	-.352	-.355	-.344	-.345	-.333	-.324	-.339
41	6.011	15.268	-.433	-.423	-.403	-.407	-.379	-.347	-.353
42	6.230	15.824	-.483	-.455	-.427	-.419	-.439	-.411	-.365
43	6.430	16.332	-.465	-.407	-.362	-.355	-.360	-.333	-.292
44	6.630	16.840	-.394	-.327	-.279	-.270	-.261	-.239	-.221
45	6.890	17.501	-.262	-.191	-.163	-.162	-.177	-.166	-.184
46	7.151	18.164	-.144	-.083	-.072	-.080	-.103	-.106	-.159
47	7.460	18.948	-.052	-.007	-.007	-.019	-.055	-.092	-.108
48	7.770	19.736	-.017	.022	.011	-.005	-.047	-.107	-.127
49	8.020	20.371	-.008	.023	.018	-.005	-.063	-.104	-.115
50	8.270	21.006	-.010	.023	.022	-.004	-.070	-.060	-.069
Row D									
51	3.697	9.390	-0.029	0.001	0.014	0.001	-0.009	-0.028	-0.097
52	3.947	10.025	-.062	-.022	-.007	-.010	-.015	-.030	-.090
53	4.244	10.780	.086	.200	.251	.270	.285	.282	.183
54	4.290	10.897	.213	.389	.469	.515	.534	.528	.448
55	4.395	11.163	-.534	-.386	-.310	-.265	-.244	-.261	-.355
56	4.550	11.557	-.335	-.196	-.124	-.078	-.082	-.112	-.213
57	4.863	12.352	-.271	-.158	-.097	-.072	-.082	-.108	-.208
58	5.237	13.302	-.345	-.258	-.211	-.196	-.209	-.228	-.315
59	5.611	14.252	-1.048	-1.000	-.969	-.964	-.964	-.958	-1.023
60	5.811	14.760	-.572	-.517	-.491	-.489	-.489	-.536	-.668
61	6.011	15.268	-.551	-.490	-.455	-.453	-.451	-.460	-.551
62	6.230	15.824	-.612	-.561	-.529	-.521	-.532	-.550	-.636
63	6.430	16.332	-.539	-.503	-.465	-.456	-.465	-.484	-.583
64	6.630	16.840	-.346	-.358	-.325	-.307	-.324	-.340	-.461
65	6.890	17.501	-.046	-.111	-.110	-.100	-.112	-.106	-.133
66	7.151	18.164	-.004	-.044	-.007	.005	.016	.031	-.015
67	7.460	18.948	.094	.121	.229	.249	.240	.238	.124
68	7.770	19.736	-.005	.101	.196	.205	.179	.160	.063
69	8.020	20.371	-.054	.060	.121	.127	.102	.090	.015
70	8.270	21.006	-.077	.034	.079	.075	.054	.050	-.011

TABLE I.- PRESSURE COEFFICIENTS - Continued

(c) M = 0.60; α = -10° to 10°; model upright

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row A									
1	3.855	9.792	0.083	0.052	0.029	-0.006	-0.044	-0.100	-0.161
2	4.244	10.780	.029	-.008	-.032	-.071	-.108	-.164	-.221
3	4.550	11.557	-.022	-.058	-.086	-.124	-.160	-.213	-.265
4	4.863	12.352	-.063	-.101	-.129	-.167	-.201	-.251	-.295
5	5.611	14.252	-.243	-.255	-.260	-.269	-.273	-.293	-.299
6	6.011	15.268	-.276	-.255	-.245	-.239	-.235	-.248	-.237
7	6.230	15.824	-.289	-.261	-.244	-.237	-.224	-.230	-.216
8	6.630	16.840	-.258	-.223	-.199	-.187	-.170	-.174	-.171
9	7.151	18.164	-.155	-.122	-.099	-.086	-.083	-.098	-.107
10	7.770	19.736	-.063	-.032	-.011	-.006	-.011	-.032	-.054
11	8.020	20.371	-.040	-.012	.010	.013	.009	-.014	-.044
12	8.270	21.006	-.035	-.004	.020	.022	.018	-.003	-.029
Row B									
13	3.697	9.390	0.179	0.097	0.049	-0.003	-0.047	-0.097	-0.148
14	3.947	10.025	.101	.018	-.035	-.091	-.136	-.190	-.241
15	4.244	10.780	-.283	-.397	-.465	-.536	-.587	-.652	-.685
16	4.550	11.557	.092	.021	-.022	-.065	-.100	-.146	-.184
17	4.863	12.352	.405	.333	.289	.240	.192	.141	.078
18	4.915	12.484	.877	.823	.777	.708	.644	.563	.456
19	5.020	12.751	.040	-.034	-.073	-.108	-.123	-.147	-.144
20	5.237	13.302	.151	.091	.054	.020	-.005	-.042	-.068
21	5.611	14.252	.090	.029	-.008	-.044	-.068	-.102	-.120
22	5.811	14.760	.019	-.042	-.079	-.115	-.140	-.170	-.189
23	6.011	15.268	-.128	-.193	-.231	-.267	-.289	-.319	-.335
24	6.230	15.824	-.837	-.915	-.958	-.997	-1.004	-1.027	-.995
25	6.430	16.332	-.402	-.437	-.451	-.465	-.460	-.469	-.450
26	6.630	16.840	-.385	-.414	-.424	-.430	-.422	-.422	-.397
27	6.890	17.501	-.476	-.485	-.483	-.476	-.451	-.437	-.395
28	7.151	18.164	-.367	-.360	-.342	-.319	-.289	-.267	-.225
29	7.460	18.948	.033	.034	.031	.029	.016	.003	-.006
30	7.770	19.736	.073	.090	.090	.088	.091	.080	.087
31	8.020	20.371	.162	.147	.151	.155	.192	.198	.226
32	8.270	21.006	.264	.215	.219	.219	.249	.253	.262

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row C									
33	3.605	9.157	0.145	0.108	0.081	0.043	0.009	-0.042	-0.103
34	3.855	9.792	.126	.089	.059	.024	-.012	-.064	-.127
35	4.244	10.780	.103	.058	.023	-.022	-.062	-.121	-.191
36	4.550	11.557	.077	.027	-.011	-.058	-.099	-.159	-.225
37	4.863	12.352	.033	-.018	-.056	-.100	-.140	-.194	-.255
38	5.237	13.302	-.108	-.162	-.193	-.232	-.263	-.308	-.354
39	5.611	14.252	-.274	-.304	-.318	-.333	-.331	-.348	-.352
40	5.811	14.760	-.358	-.363	-.353	-.345	-.329	-.341	-.352
41	6.011	15.268	-.460	-.450	-.434	-.433	-.404	-.400	-.379
42	6.230	15.824	-.539	-.502	-.464	-.449	-.478	-.496	-.439
43	6.430	16.332	-.498	-.428	-.369	-.354	-.348	-.374	-.333
44	6.630	16.840	-.405	-.318	-.258	-.239	-.235	-.257	-.229
45	6.890	17.501	-.247	-.158	-.125	-.127	-.142	-.179	-.155
46	7.151	18.164	-.119	-.043	-.038	-.050	-.073	-.107	-.108
47	7.460	18.948	-.029	.041	.014	.002	-.036	-.047	-.077
48	7.770	19.736	.011	.060	.024	.002	-.038	-.043	-.048
49	8.020	20.371	.029	.063	.031	.003	-.048	-.037	-.035
50	8.270	21.006	.030	.061	.036	.005	-.036	-.013	-.027
Row D									
51	3.697	9.390	0.013	0.044	0.048	0.039	0.027	-0.007	-0.066
52	3.947	10.025	-.015	.017	.028	.021	.014	-.014	-.064
53	4.244	10.780	.146	.251	.299	.315	.327	.307	.222
54	4.290	10.897	.307	.471	.546	.590	.606	.600	.542
55	4.395	11.163	-.532	-.385	-.309	-.263	-.236	-.266	-.347
56	4.550	11.557	-.321	-.169	-.093	-.045	-.042	-.097	-.188
57	4.863	12.352	-.244	-.116	-.059	-.035	-.038	-.087	-.180
58	5.237	13.302	-.319	-.223	-.180	-.162	-.165	-.208	-.290
59	5.611	14.252	-1.198	-1.155	-1.125	-1.117	-1.111	-1.120	-1.117
60	5.811	14.760	-.592	-.529	-.499	-.494	-.491	-.526	-.743
61	6.011	15.268	-.566	-.500	-.466	-.456	-.454	-.487	-.551
62	6.230	15.824	-.628	-.583	-.548	-.539	-.546	-.593	-.674
63	6.430	16.332	-.518	-.507	-.471	-.456	-.460	-.509	-.596
64	6.630	16.840	-.249	-.334	-.307	-.287	-.285	-.326	-.413
65	6.890	17.501	-.045	-.093	-.112	-.108	-.099	-.069	-.071
66	7.151	18.164	-.017	-.053	-.004	.010	.017	-.015	-.074
67	7.460	18.948	.188	.129	.259	.288	.262	.095	.012
68	7.770	19.736	.140	.146	.249	.265	.239	.107	-.022
69	8.020	20.371	.074	.115	.177	.175	.159	.076	-.031
70	8.270	21.006	.039	.097	.134	.122	.107	.049	-.031

TABLE I.- PRESSURE COEFFICIENTS - Continued

(d) M = 0.80; α = -10° to 10°; model upright

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row A									
1	3.855	9.792	0.153	0.117	0.082	0.049	0.010	-0.034	-0.104
2	4.244	10.780	.094	.048	.004	-.035	-.078	-.122	-.192
3	4.550	11.557	.048	-.003	-.048	-.090	-.130	-.173	-.244
4	4.863	12.352	.016	-.036	-.080	-.120	-.160	-.197	-.261
5	5.611	14.252	-.197	-.239	-.280	-.312	-.337	-.304	-.336
6	6.011	15.268	-.361	-.391	-.413	-.409	-.379	-.285	-.292
7	6.230	15.824	-.470	-.468	-.439	-.401	-.353	-.304	-.298
8	6.630	16.840	-.323	-.303	-.280	-.244	-.215	-.237	-.230
9	7.151	18.164	-.136	-.101	-.077	-.051	-.050	-.105	-.099
10	7.770	19.736	-.010	.020	.038	.050	.039	.010	-.008
11	8.020	20.371	.017	.049	.062	.072	.059	.037	.014
12	8.270	21.006	.026	.061	.073	.081	.070	.055	.029
Row B									
13	3.697	9.390	0.255	0.174	0.110	0.062	0.018	-0.021	-0.075
14	3.947	10.025	.173	.087	.021	-.028	-.072	-.113	-.168
15	4.244	10.780	-.294	-.444	-.560	-.660	-.729	-.787	-.843
16	4.550	11.557	.158	.080	.022	-.024	-.067	-.108	-.175
17	4.863	12.352	.479	.401	.337	.283	.229	.170	.085
18	4.915	12.484	.962	.899	.832	.748	.657	.557	.447
19	5.020	12.751	.106	.026	-.028	-.058	-.066	-.064	-.059
20	5.237	13.302	.232	.161	.110	.071	.036	.010	-.025
21	5.611	14.252	.171	.100	.047	.008	-.025	-.047	-.071
22	5.811	14.760	.109	.041	-.012	-.048	-.078	-.092	-.115
23	6.011	15.268	-.012	-.075	-.122	-.155	-.180	-.192	-.214
24	6.230	15.824	-.852	-.905	-.942	-.966	-.985	-.989	-.986
25	6.430	16.332	-.983	-1.084	-1.134	-1.148	-1.105	-.876	-.673
26	6.630	16.840	-.505	-.768	-.794	-.709	-.557	-.511	-.469
27	6.890	17.501	-.502	-.417	-.369	-.343	-.292	-.259	-.238
28	7.151	18.164	-.299	-.243	-.189	-.152	-.089	-.102	-.113
29	7.460	18.948	.009	.013	.052	.070	.045	-.031	-.059
30	7.770	19.736	.040	.049	.093	.099	.077	.032	.011
31	8.020	20.371	.154	.132	.184	.184	.156	.078	.045
32	8.270	21.006	.276	.219	.227	.235	.222	.179	.145

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row C									
33	3.605	9.157	0.215	0.176	0.133	0.100	0.066	0.029	-0.039
34	3.855	9.792	.193	.150	.107	.073	.038	.001	-.066
35	4.244	10.780	.171	.116	.065	.020	-.026	-.078	-.160
36	4.550	11.557	.154	.093	.035	-.014	-.066	-.118	-.202
37	4.863	12.352	.120	.063	.008	-.039	-.084	-.131	-.207
38	5.237	13.302	.006	-.053	-.106	-.147	-.185	-.224	-.287
39	5.611	14.252	-.207	-.269	-.325	-.366	-.401	-.420	-.444
40	5.811	14.760	-.350	-.404	-.463	-.485	-.490	-.446	-.411
41	6.011	15.268	-.424	-.445	-.520	-.563	-.545	-.498	-.440
42	6.230	15.824	-.645	-.644	-.683	-.677	-.722	-.766	-.624
43	6.430	16.332	-.795	-.817	-.690	-.482	-.455	-.526	-.465
44	6.630	16.840	-.617	-.488	-.265	-.201	-.210	-.296	-.270
45	6.890	17.501	-.346	-.258	-.109	-.096	-.092	-.162	-.163
46	7.151	18.164	-.181	-.127	-.018	-.035	-.027	-.080	-.090
47	7.460	18.948	-.029	-.011	.031	-.005	.011	.005	-.014
48	7.770	19.736	.042	.060	.055	.010	.010	.043	.025
49	8.020	20.371	.078	.098	.070	.031	.005	.054	.039
50	8.270	21.006	.090	.117	.080	.055	.009	.063	.048
Row D									
51	3.697	9.390	0.088	0.110	0.102	0.095	0.082	0.055	-0.011
52	3.947	10.025	.066	.087	.076	.071	.060	.040	-.017
53	4.244	10.780	.247	.327	.353	.368	.384	.375	.302
54	4.290	10.897	.493	.621	.664	.703	.727	.746	.707
55	4.395	11.163	-.529	-.383	-.314	-.261	-.234	-.243	-.317
56	4.550	11.557	-.285	-.117	-.050	.006	.004	-.037	-.136
57	4.863	12.352	-.169	-.036	.010	.039	.038	-.001	-.101
58	5.237	13.302	-.212	-.107	-.076	-.053	-.056	-.093	-.176
59	5.611	14.252	-1.128	-1.123	-1.118	-1.102	-1.105	-1.113	-1.125
60	5.811	14.760	-.815	-.851	-1.180	-1.184	-1.161	-1.050	-1.012
61	6.011	15.268	-.552	-.515	-.878	-.877	-.857	-.781	-.733
62	6.230	15.824	-.475	-.440	-.497	-.453	-.429	-.452	-.535
63	6.430	16.332	-.293	-.295	-.427	-.407	-.382	-.332	-.345
64	6.630	16.840	-.240	-.215	-.251	-.249	-.209	-.163	-.244
65	6.890	17.501	-.205	-.183	-.108	-.114	-.110	-.090	-.198
66	7.151	18.164	-.172	-.152	-.022	.017	.012	-.053	-.075
67	7.460	18.948	-.036	-.091	.194	.259	.243	.078	.025
68	7.770	19.736	.049	.064	.247	.293	.280	.180	.103
69	8.020	20.371	.073	.114	.218	.243	.230	.172	.107
70	8.270	21.006	.081	.125	.188	.196	.184	.151	.095

TABLE I.- PRESSURE COEFFICIENTS - Continued

(e) M = 1.0; α = -10° to 10°; model upright

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row A									
1	3.855	9.792	0.263	0.230	0.210	0.181	0.146	0.109	0.049
2	4.244	10.780	.202	.142	.107	.077	.043	.006	-.051
3	4.550	11.557	.168	.108	.042	-.035	-.062	-.096	-.163
4	4.863	12.352	.165	.116	.082	.044	-.117	-.174	-.185
5	5.611	14.252	.034	.000	-.030	-.074	-.118	-.149	-.301
6	6.011	15.268	-.107	-.129	-.154	-.176	-.192	-.222	-.332
7	6.230	15.824	-.238	-.249	-.274	-.318	-.355	-.346	-.393
8	6.630	16.840	-.468	-.459	-.457	-.500	-.567	-.586	-.596
9	7.151	18.164	-.547	-.561	-.568	-.581	-.592	-.568	-.548
10	7.770	19.736	-.552	-.534	-.468	-.409	-.299	-.240	-.285
11	8.020	20.371	-.523	-.444	-.371	-.292	-.227	-.209	-.254
12	8.270	21.006	-.402	-.332	-.287	-.237	-.212	-.215	-.235
Row B									
13	3.697	9.390	0.364	0.292	0.244	0.200	0.161	0.124	0.078
14	3.947	10.025	.294	.225	.181	.140	.103	.069	.026
15	4.244	10.780	-.323	-.487	-.541	-.573	-.599	-.621	-.637
16	4.550	11.557	.285	.211	.112	-.010	-.136	-.274	-.426
17	4.863	12.352	.568	.483	.416	.329	.234	.150	.036
18	4.915	12.484	.990	.941	.908	.796	.721	.714	.630
19	5.020	12.751	.260	.231	.206	.230	.207	.103	-.029
20	5.237	13.302	.378	.318	.282	.252	.217	.176	.080
21	5.611	14.252	.335	.273	.234	.196	.158	.130	.062
22	5.811	14.760	.293	.234	.195	.158	.121	.094	.033
23	6.011	15.268	.214	.162	.127	.094	.058	.030	-.025
24	6.230	15.824	-.427	-.461	-.486	-.509	-.529	-.546	-.571
25	6.430	16.332	-.635	-.680	-.708	-.736	-.761	-.781	-.801
26	6.630	16.840	-.555	-.615	-.652	-.684	-.707	-.707	-.714
27	6.890	17.501	-.643	-.594	-.600	-.602	-.559	-.510	-.483
28	7.151	18.164	-.513	-.464	-.475	-.479	-.456	-.434	-.428
29	7.460	18.948	-.451	-.449	-.470	-.486	-.473	-.453	-.443
30	7.770	19.736	-.425	-.420	-.434	-.451	-.440	-.425	-.418
31	8.020	20.371	-.420	-.446	-.465	-.473	-.471	-.451	-.434
32	8.270	21.006	-.317	-.371	-.389	-.396	-.407	-.396	-.379

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row C									
33	3.605	9.157	0.316	0.282	0.251	0.220	0.183	0.149	0.089
34	3.855	9.792	.293	.255	.224	.195	.162	.130	.078
35	4.244	10.780	.273	.211	.164	.126	.088	.054	-.005
36	4.550	11.557	.268	.199	.139	.061	-.023	-.064	-.142
37	4.863	12.352	.256	.204	.160	.115	.054	-.094	-.177
38	5.237	13.302	.189	.141	.108	.069	.025	-.024	-.179
39	5.611	14.252	.045	-.003	-.039	-.081	-.129	-.181	-.280
40	5.811	14.760	-.106	-.141	-.171	-.204	-.243	-.286	-.377
41	6.011	15.268	-.199	-.238	-.270	-.313	-.346	-.368	-.407
42	6.230	15.824	-.347	-.392	-.516	-.636	-.702	-.691	-.635
43	6.430	16.332	-.598	-.599	-.643	-.701	-.754	-.773	-.787
44	6.630	16.840	-.692	-.692	-.701	-.738	-.758	-.749	-.735
45	6.890	17.501	-.683	-.692	-.695	-.714	-.767	-.730	-.646
46	7.151	18.164	-.645	-.591	-.528	-.497	-.588	-.485	-.393
47	7.460	18.948	-.508	-.358	-.360	-.377	-.332	-.317	-.250
48	7.770	19.736	-.282	-.280	-.293	-.290	-.293	-.262	-.245
49	8.020	20.371	-.223	-.251	-.250	-.239	-.258	-.248	-.268
50	8.270	21.006	-.166	-.204	-.209	-.203	-.230	-.242	-.279
Row D									
51	3.697	9.390	0.203	0.222	0.220	0.211	0.193	0.169	0.107
52	3.947	10.025	.196	.205	.196	.183	.165	.142	.088
53	4.244	10.780	.387	.440	.459	.466	.472	.469	.407
54	4.290	10.897	.686	.766	.794	.822	.836	.868	.865
55	4.395	11.163	-.352	-.263	-.218	-.191	-.169	-.147	-.148
56	4.550	11.557	-.282	-.101	.069	.136	.116	.038	-.081
57	4.863	12.352	.000	.111	.165	.192	.181	.128	.047
58	5.237	13.302	-.019	.077	.135	.158	.146	.096	-.008
59	5.611	14.252	-.696	-.648	-.612	-.599	-.605	-.623	-.687
60	5.811	14.760	-.786	-.760	-.733	-.724	-.731	-.741	-.790
61	6.011	15.268	-.716	-.692	-.670	-.666	-.677	-.687	-.739
62	6.230	15.824	-.733	-.737	-.727	-.742	-.662	-.640	-.767
63	6.430	16.332	-.867	-.784	-.752	-.685	-.641	-.634	-.727
64	6.630	16.840	-.784	-.778	-.738	-.651	-.563	-.638	-.733
65	6.890	17.501	-.736	-.665	-.577	-.532	-.513	-.601	-.737
66	7.151	18.164	-.720	-.653	-.527	-.452	-.469	-.529	-.646
67	7.460	18.948	-.688	-.525	-.354	-.218	-.316	-.379	-.512
68	7.770	19.736	-.590	-.315	-.148	-.048	-.165	-.248	-.449
69	8.020	20.371	-.504	-.223	-.082	-.026		-.221	-.446
70	8.270	21.006	-.417	-.176	-.070	-.045		-.220	-.423

TABLE I.- PRESSURE COEFFICIENTS - Continued

(f) M = 1.20; α = -10° to 10°; model upright

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row A									
1	3.855	9.792	0.366	0.357	0.344	0.323	0.284	0.252	0.189
2	4.244	10.780	.298	.292	.278	.257	.216	.186	.133
3	4.550	11.557	.192	.172	.151	.136	.116	.095	.044
4	4.863	12.352	.227	.036	.038	.017	-.014	-.043	-.089
5	5.611	14.252	.175	.165	.130	.071	-.001	-.060	-.115
6	6.011	15.268	.097	.085	.054	.037	.003	-.025	-.104
7	6.230	15.824	-.001	-.043	-.101	-.100	-.093	-.114	-.169
8	6.630	16.840	-.187	-.181	-.190	-.207	-.244	-.278	-.294
9	7.151	18.164	-.295	-.294	-.302	-.311	-.326	-.339	-.353
10	7.770	19.736	-.333	-.352	-.344	-.342	-.342	-.265	-.239
11	8.020	20.371	-.340	-.349	-.321	-.305	-.214	-.203	-.235
12	8.270	21.006	-.347	-.333	-.290	-.195	-.161	-.180	-.219
Row B									
13	3.697	9.390	0.465	0.410	0.368	0.329	0.279	0.250	0.195
14	3.947	10.025	.420	.374	.339	.306	.260	.228	.175
15	4.244	10.780	-.217	-.244	-.265	-.280	-.301	-.316	-.345
16	4.550	11.557	.286	.034	-.095	-.153	-.195	-.213	-.237
17	4.863	12.352	.622	.501	.424	.365	.308	.268	.213
18	4.915	12.484	1.159	1.131	1.072	.987	.874	.796	.587
19	5.020	12.751	.430	.310	.209	.166	.153	.121	.092
20	5.237	13.302	.522	.453	.388	.306	.224	.164	.094
21	5.611	14.252	.492	.429	.372	.320	.260	.197	.129
22	5.811	14.760	.465	.410	.359	.311	.259	.201	.143
23	6.011	15.268	.409	.365	.324	.286	.242	.196	.145
24	6.230	15.824	-.139	-.163	-.187	-.204	-.229	-.251	-.276
25	6.430	16.332	-.336	-.366	-.392	-.410	-.435	-.451	-.470
26	6.630	16.840	-.283	-.325	-.359	-.382	-.412	-.430	-.457
27	6.890	17.501	-.409	-.443	-.469	-.481	-.481	-.474	-.477
28	7.151	18.164	-.386	-.409	-.423	-.430	-.436	-.431	-.424
29	7.460	18.948	-.369	-.404	-.418	-.417	-.408	-.395	-.386
30	7.770	19.736	-.327	-.378	-.398	-.395	-.380	-.367	-.358
31	8.020	20.371	-.240	-.311	-.343	-.352	-.356	-.355	-.359
32	8.270	21.006	-.105	-.184	-.230	-.236	-.256	-.254	-.265

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row C									
33	3.605	9.157	0.401	0.382	0.357	0.332	0.290	0.256	0.182
34	3.855	9.792	.380	.369	.349	.328	.289	.257	.186
35	4.244	10.780	.344	.338	.322	.306	.275	.246	.192
36	4.550	11.557	.312	.240	.206	.176	.133	.094	.023
37	4.863	12.352	.361	.216	.089	.052	.033	.023	-.012
38	5.237	13.302	.336	.289	.229	.165	.081	.017	-.044
39	5.611	14.252	.245	.196	.141	.082	.019	-.040	-.104
40	5.811	14.760	.123	.088	.043	.002	-.049	-.106	-.175
41	6.011	15.268	-.009	-.045	-.066	-.087	-.124	-.153	-.201
42	6.230	15.824	-.156	-.235	-.334	-.400	-.395	-.355	-.335
43	6.430	16.332	-.305	-.344	-.393	-.450	-.500	-.514	-.516
44	6.630	16.840	-.388	-.390	-.428	-.459	-.484	-.489	-.492
45	6.890	17.501	-.406	-.409	-.430	-.468	-.507	-.490	-.467
46	7.151	18.164	-.435	-.446	-.458	-.448	-.512	-.488	-.444
47	7.460	18.948	-.434	-.417	-.365	-.292	-.297	-.249	-.230
48	7.770	19.736	-.286	-.274	-.232	-.191	-.210	-.155	-.174
49	8.020	20.371	-.148	-.172	-.148	-.133	-.139	-.146	-.214
50	8.270	21.006	-.056	-.115	-.112	-.112	-.130	-.165	-.256
Row D									
51	3.697	9.390	0.282	0.323	0.330	0.329	0.305	0.279	0.203
52	3.947	10.025	.292	.324	.325	.318	.293	.266	.186
53	4.244	10.780	.509	.563	.579	.587	.591	.576	.472
54	4.290	10.897	.873	.923	.933	.967	.979	.989	1.026
55	4.395	11.163	-.119	-.033	.024	.060	.077	.087	.058
56	4.550	11.557	-.140	-.053	-.002	.060	.079	.068	.032
57	4.863	12.352	.011	.143	.241	.270	.269	.233	.138
58	5.237	13.302	.132	.249	.258	.243	.237	.221	.191
59	5.611	14.252	-.378	-.333	-.311	-.306	-.320	-.324	-.365
60	5.811	14.760	-.473	-.446	-.435	-.430	-.443	-.443	-.471
61	6.011	15.268	-.427	-.410	-.408	-.405	-.418	-.421	-.448
62	6.230	15.824	-.476	-.462	-.482	-.493	-.425	-.429	-.514
63	6.430	16.332	-.556	-.516	-.518	-.487	-.406	-.409	-.483
64	6.630	16.840	-.588	-.586	-.534	-.490	-.380	-.417	-.483
65	6.890	17.501	-.576	-.471	-.410	-.389	-.348	-.414	-.493
66	7.151	18.164	-.579	-.481	-.395	-.326	-.308	-.358	-.453
67	7.460	18.948	-.568	-.437	-.294	-.124	-.156	-.219	-.214
68	7.770	19.736	-.530	-.306	-.098	.078	-.039	-.111	-.121
69	8.020	20.371	-.473	-.223	-.017	.080	-.014	-.108	-.151
70	8.270	21.006	-.399	-.167	.003	.047	-.026	-.128	-.185

TABLE I.- PRESSURE COEFFICIENTS - Continued

(g) M = 0.40; α = -10° to 10°; model rolled 90°

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row A									
1	3.855	9.792	-0.190	-0.130	-0.082	-0.042	-0.004	-0.003	0.026
2	4.244	10.780	-.234	-.181	-.131	-.096	-.063	-.062	-.035
3	4.550	11.557	-.268	-.225	-.182	-.147	-.114	-.113	-.091
4	4.863	12.352	-.303	-.257	-.216	-.185	-.157	-.163	-.142
5	5.611	14.252	-.387	-.344	-.305	-.269	-.250	-.260	-.252
6	6.011	15.268	-.350	-.304	-.266	-.234	-.210	-.220	-.203
7	6.230	15.824	-.331	-.291	-.256	-.227	-.205	-.214	-.200
8	6.630	16.840	-.271	-.243	-.210	-.193	-.174	-.197	-.197
9	7.151	18.164	-.164	-.150	-.125	-.116	-.115	-.151	-.169
10	7.770	19.736	-.080	-.073	-.050	-.044	-.045	-.090	-.132
11	8.020	20.371	-.060	-.057	-.036	-.027	-.026	-.070	-.115
12	8.270	21.006	-.108	-.051	-.027	-.016	-.016	-.062	-.106
Row B									
13	3.697	9.390	-0.210	-0.071	-0.041	-0.039	-0.045	-0.093	-0.142
14	3.947	10.025	-.803	-.160	-.129	-.120	-.119	-.157	-.200
15	4.244	10.780	-.216	-.666	-.578	-.507	-.448	-.441	-.402
16	4.550	11.557	.130	-.158	-.117	-.088	-.066	-.087	-.084
17	4.863	12.352	.565	.191	.214	.222	.237	.206	.149
18	4.915	12.484	-.330	.629	.656	.643	.631	.630	.582
19	5.020	12.751	-.244	-.219	-.158	-.124	-.113	-.172	-.242
20	5.237	13.302	-.266	-.118	-.052	-.012	-.021	-.080	-.178
21	5.611	14.252	-.316	-.160	-.106	-.072	-.083	-.144	-.239
22	5.811	14.760	-.441	-.223	-.172	-.142	-.152	-.216	-.302
23	6.011	15.268	-.983	-.357	-.313	-.288	-.294	-.353	-.433
24	6.230	15.824	-.684	-.912	-.883	-.871	-.866	-.909	-.971
25	6.430	16.332	-.559	-.611	-.486	-.466	-.469	-.608	-.686
26	6.630	16.840	-.615	-.464	-.438	-.432	-.435	-.475	-.569
27	6.890	17.501	-.514	-.522	-.486	-.469	-.482	-.529	-.618
28	7.151	18.164	-.144	-.401	-.359	-.347	-.362	-.407	-.519
29	7.460	18.948	-.074	-.048	.000	.019	.004	-.041	-.126
30	7.770	19.736	.045	.031	.059	.075	.071	.027	-.026
31	8.020	20.371	.001	.128	.127	.127	.121	.161	.011
32	8.270	21.006	.060	.125	.164	.171	.158	.163	-.008

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row C									
33	3.605	9.157	0.035	0.047	0.034	0.006	-0.015	-0.070	-0.119
34	3.855	9.792	-.020	.025	.014	-.010	-.028	-.087	-.134
35	4.244	10.780	-.068	-.027	-.033	-.050	-.064	-.111	-.149
36	4.550	11.557	-.107	-.070	-.072	-.085	-.094	-.140	-.175
37	4.863	12.352	-.213	-.114	-.117	-.133	-.143	-.186	-.222
38	5.237	13.302	-.229	-.235	-.241	-.264	-.274	-.320	-.356
39	5.611	14.252	-.243	-.271	-.300	-.334	-.357	-.408	-.451
40	5.811	14.760	-.287	-.293	-.311	-.345	-.376	-.433	-.483
41	6.011	15.268	-.324	-.341	-.365	-.407	-.422	-.469	-.524
42	6.230	15.824	-.300	-.405	-.437	-.419	-.427	-.463	-.530
43	6.430	16.332	-.249	-.352	-.376	-.355	-.353	-.388	-.453
44	6.630	16.840	-.218	-.278	-.292	-.270	-.264	-.280	-.341
45	6.890	17.501	-.206	-.220	-.201	-.162	-.150	-.153	-.207
46	7.151	18.164	-.171	-.167	-.133	-.080	-.066	-.076	-.104
47	7.460	18.948	-.124	-.127	-.062	-.019	-.005	-.020	-.017
48	7.770	19.736	-.118	-.097	-.040	-.005	.009	-.002	.025
49	8.020	20.371	-.124	-.077	-.035	-.005	.015	.005	.032
50	8.270	21.006	-.078	-.077	-.035	-.004	.016	.012	.018
Row D									
51	3.697	9.390	0.142	0.089	0.049	0.001	-0.025	-0.085	-0.124
52	3.947	10.025	.434	.077	.039	-.010	-.037	-.096	-.129
53	4.244	10.780	.627	.362	.322	.270	.225	.169	.114
54	4.290	10.897	-.053	.573	.553	.515	.459	.396	.316
55	4.395	11.163	.085	-.146	-.205	-.265	-.306	-.376	-.415
56	4.550	11.557	.082	.014	-.032	-.078	-.123	-.182	-.226
57	4.863	12.352	-.047	.017	-.024	-.072	-.101	-.156	-.192
58	5.237	13.302	-.807	-.112	-.152	-.196	-.230	-.280	-.306
59	5.611	14.252	-.415	-.881	-.928	-.964	-.982	-1.023	-1.017
60	5.811	14.760	-.390	-.451	-.474	-.489	-.498	-.527	-.520
61	6.011	15.268	-.507	-.424	-.443	-.453	-.452	-.478	-.455
62	6.230	15.824	-.476	-.529	-.530	-.521	-.511	-.521	-.486
63	6.430	16.332	-.359	-.484	-.475	-.456	-.437	-.437	-.393
64	6.630	16.840	-.082	-.352	-.338	-.307	-.292	-.296	-.251
65	6.890	17.501	.054	-.101	-.101	-.100	-.115	-.127	-.079
66	7.151	18.164	.292	.029	.011	.005	.013	-.013	-.017
67	7.460	18.948	.226	.267	.250	.249	.258	.254	.253
68	7.770	19.736	.137	.215	.209	.205	.205	.191	.227
69	8.020	20.371	.084	.124	.124	.127	.125	.119	.152
70	8.270	21.006	-.070	.076	.075	.075	.078	.071	.097

TABLE I.- PRESSURE COEFFICIENTS - Continued

(h) $M = 0.60$; $\alpha = -10^{\circ}$ to 10°; model rolled 90°

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
				Row A					
1	3.855	9.792	-0.147	-0.084	-0.045	-0.006	0.028	0.055	0.073
2	4.244	10.780	-.195	-.141	-.106	-.071	-.039	-.014	.005
3	4.550	11.557	-.236	-.187	-.152	-.124	-.095	-.071	-.057
4	4.863	12.352	-.268	-.221	-.191	-.167	-.141	-.120	-.111
5	5.611	14.252	-.374	-.331	-.300	-.269	-.244	-.227	-.221
6	6.011	15.268	-.350	-.301	-.273	-.239	-.220	-.192	-.181
7	6.230	15.824	-.324	-.285	-.262	-.237	-.217	-.194	-.183
8	6.630	16.840	-.243	-.223	-.205	-.187	-.178	-.174	-.180
9	7.151	18.164	-.122	-.109	-.096	-.086	-.096	-.110	-.145
10	7.770	19.736	-.024	-.022	-.012	-.006	-.016	-.037	-.097
11	8.020	20.371	-.008	-.004	.008	.013	.005	-.016	-.077
12	8.270	21.006	-.003	.006	.018	.022	.018	-.006	-.067
				Row B					
13	3.697	9.390	-0.053	-0.008	0.006	-0.003	-0.010	-0.039	-0.109
14	3.947	10.025	-.150	-.104	-.087	-.091	-.092	-.117	-.176
15	4.244	10.780	-.844	-.700	-.614	-.536	-.469	-.429	-.395
16	4.550	11.557	-.179	-.124	-.088	-.065	-.045	-.036	-.046
17	4.863	12.352	.142	.213	.237	.240	.253	.248	.179
18	4.915	12.484	.662	.721	.740	.708	.692	.729	.665
19	5.020	12.751	-.295	-.184	-.135	-.108	-.093	-.130	-.203
20	5.237	13.302	-.203	-.077	-.014	.020	.012	-.027	-.134
21	5.611	14.252	-.224	-.120	-.069	-.044	-.054	-.094	-.202
22	5.811	14.760	-.276	-.179	-.133	-.115	-.126	-.168	-.270
23	6.011	15.268	-.402	-.317	-.282	-.267	-.275	-.311	-.406
24	6.230	15.824	-1.049	-1.004	-1.003	-.997	-.997	-.994	-1.066
25	6.430	16.332	-.716	-.547	-.466	-.465	-.463	-.533	-.670
26	6.630	16.840	-.531	-.445	-.432	-.430	-.439	-.460	-.570
27	6.890	17.501	-.598	-.502	-.481	-.476	-.484	-.509	-.621
28	7.151	18.164	-.458	-.336	-.315	-.319	-.321	-.345	-.468
29	7.460	18.948	-.051	.013	.040	.029	.044	.022	-.040
30	7.770	19.736	-.054	.053	.073	.088	.075	.049	-.002
31	8.020	20.371	.043	.130	.150	.155	.114	.100	.027
32	8.270	21.006	.030	.181	.217	.219	.166	.156	.025

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
				Row C					
33	3.605	9.157	0.117	0.103	0.083	0.043	0.022	-0.020	-0.088
34	3.855	9.792	.092	.077	.059	.024	.001	-.039	-.103
35	4.244	10.780	.029	.021	.009	-.022	-.036	-.063	-.114
36	4.550	11.557	-.022	-.027	-.034	-.058	-.068	-.092	-.138
37	4.863	12.352	-.066	-.071	-.076	-.100	-.112	-.135	-.182
38	5.237	13.302	-.170	-.190	-.203	-.232	-.244	-.272	-.323
39	5.611	14.252	-.194	-.243	-.285	-.333	-.361	-.395	-.457
40	5.811	14.760	-.211	-.269	-.297	-.345	-.391	-.429	-.511
41	6.011	15.268	-.270	-.336	-.389	-.433	-.451	-.473	-.564
42	6.230	15.824	-.347	-.437	-.479	-.449	-.456	-.466	-.571
43	6.430	16.332	-.306	-.350	-.376	-.354	-.349	-.349	-.444
44	6.630	16.840	-.226	-.246	-.265	-.239	-.229	-.218	-.321
45	6.890	17.501	-.185	-.178	-.166	-.127	-.114	-.108	-.184
46	7.151	18.164	-.171	-.124	-.091	-.050	-.039	-.040	-.080
47	7.460	18.948	-.131	-.092	-.029	.002	.019	.022	.014
48	7.770	19.736	-.076	-.073	-.017	.002	.031	.046	.070
49	8.020	20.371	-.071	-.062	-.018	.003	.039	.063	.082
50	8.270	21.006	-.082	-.052	-.021	.005	.042	.068	.069
				Row D					
51	3.697	9.390	0.210	0.145	0.095	0.039	0.005	-0.037	-0.094
52	3.947	10.025	.196	.127	.080	.021	-.010	-.050	-.104
53	4.244	10.780	.492	.429	.377	.315	.267	.227	.152
54	4.290	10.897	.701	.672	.638	.590	.519	.483	.367
55	4.395	11.163	-.012	-.115	-.189	-.263	-.305	-.361	-.421
56	4.550	11.557	.142	.065	.010	-.045	-.088	-.132	-.196
57	4.863	12.352	.142	.069	.020	-.035	-.071	-.108	-.162
58	5.237	13.302	.015	-.061	-.110	-.162	-.197	-.232	-.283
59	5.611	14.252	-.879	-.991	-1.057	-1.117	-1.141	-1.160	-1.175
60	5.811	14.760	-.385	-.439	-.469	-.494	-.503	-.508	-.519
61	6.011	15.268	-.371	-.416	-.440	-.456	-.457	-.452	-.453
62	6.230	15.824	-.502	-.534	-.537	-.539	-.525	-.508	-.484
63	6.430	16.332	-.464	-.478	-.472	-.456	-.435	-.409	-.372
64	6.630	16.840	-.315	-.321	-.307	-.287	-.267	-.247	-.208
65	6.890	17.501	-.033	-.075	-.086	-.108	-.106	-.106	-.063
66	7.151	18.164	.050	.031	.018	.010	.015	.007	-.016
67	7.460	18.948	.295	.304	.286	.288	.292	.292	.258
68	7.770	19.736	.296	.288	.280	.265	.256	.250	.279
69	8.020	20.371	.202	.190	.186	.175	.178	.175	.209
70	8.270	21.006	.146	.134	.131	.122	.127	.132	.156

TABLE I.- PRESSURE COEFFICIENTS - Continued

(i) $M = 0.80$; $\alpha = -10^{\circ}$ to 10°; model rolled 90°

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row A									
1	3.855	9.792	-0.100	-0.031	0.011	0.049	0.094	0.117	0.148
2	4.244	10.780	-.157	-.101	-.067	-.035	.011	.034	.067
3	4.550	11.557	-.189	-.138	-.114	-.090	-.050	-.032	-.003
4	4.863	12.352	-.209	-.162	-.137	-.120	-.086	-.076	-.058
5	5.611	14.252	-.362	-.342	-.324	-.312	-.270	-.252	-.218
6	6.011	15.268	-.415	-.459	-.440	-.409	-.328	-.276	-.222
7	6.230	15.824	-.388	-.393	-.398	-.401	-.333	-.298	-.241
8	6.630	16.840	-.299	-.253	-.229	-.244	-.239	-.242	-.223
9	7.151	18.164	-.158	-.115	-.079	-.051	-.073	-.111	-.156
10	7.770	19.736	-.027	.006	.028	.050	.030	-.015	-.075
11	8.020	20.371	.012	.042	.058	.072	.053	.012	-.052
12	8.270	21.006	.034	.064	.077	.081	.067	.027	-.036
Row B									
13	3.697	9.390	0.030	0.069	0.077	0.062	0.058	0.015	-0.059
14	3.947	10.025	-.051	-.019	-.010	-.028	-.032	-.073	-.149
15	4.244	10.780	-.965	-.863	-.756	-.660	-.562	-.534	-.488
16	4.550	11.557	-.209	-.081	-.040	-.024	.008	.007	.003
17	4.863	12.352	.121	.257	.287	.283	.310	.314	.275
18	4.915	12.484	.634	.728	.765	.748	.732	.780	.722
19	5.020	12.751	-.107	-.113	-.078	-.058	-.026	-.062	-.098
20	5.237	13.302	-.122	-.018	.041	.071	.079	.044	-.033
21	5.611	14.252	-.142	-.053	-.012	.008	.015	-.024	-.098
22	5.811	14.760	-.179	-.094	-.057	-.048	-.043	-.083	-.160
23	6.011	15.268	-.266	-.189	-.159	-.155	-.152	-.190	-.264
24	6.230	15.284	-1.020	-.981	-.968	-.966	-.966	-.993	-1.029
25	6.430	16.332	-.941	-.809	-.986	-1.148	-.936	-.804	-.868
26	6.630	16.840	-.594	-.531	-.552	-.709	-.533	-.515	-.520
27	6.890	17.501	-.409	-.355	-.320	-.343	-.320	-.362	-.401
28	7.151	18.164	-.223	-.203	-.145	-.152	-.151	-.204	-.226
29	7.460	18.948	-.119	-.110	-.058	.070	-.065	-.105	-.152
30	7.770	19.736	-.034	-.053	-.012	.099	.016	-.039	-.076
31	8.020	20.371	.036	.040	.086	.184	.101	.015	-.026
32	8.270	21.006	.127	.156	.179	.235	.182	.112	.075

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row C									
33	3.605	9.157	0.195	0.171	0.147	0.100	0.077	0.027	-0.046
34	3.855	9.792	.170	.146	.120	.073	.051	.000	-.070
35	4.244	10.780	.096	.076	.059	.020	.012	-.024	-.071
36	4.550	11.557	.030	.020	.012	-.014	-.011	-.040	-.077
37	4.863	12.352	-.005	-.007	-.014	-.039	-.036	-.064	-.105
38	5.237	13.302	-.106	-.110	-.120	-.147	-.148	-.175	-.213
39	5.611	14.252	-.254	-.300	-.330	-.366	-.365	-.386	-.405
40	5.811	14.760	-.260	-.333	-.393	-.485	-.520	-.562	-.588
41	6.011	15.268	-.317	-.405	-.460	-.563	-.574	-.625	-.668
42	6.230	15.824	-.541	-.748	-.758	-.677	-.616	-.597	-.606
43	6.430	16.332	-.447	-.565	-.560	-.482	-.417	-.415	-.425
44	6.630	16.840	-.261	-.266	-.249	-.201	-.239	-.346	-.397
45	6.890	17.501	-.186	-.142	-.103	-.096	-.121	-.277	-.366
46	7.151	18.164	-.161	-.077	-.036	-.035	-.043	-.153	-.217
47	7.460	18.948	-.137	-.069	-.013	-.005	.011	-.046	-.092
48	7.770	19.736	-.091	-.064	-.015	.010	.039	.019	-.010
49	8.020	20.371	-.079	-.066	-.014	.031	.061	.055	.038
50	8.270	21.006	-.075	-.046	-.003	.055	.077	.083	.076
Row D									
51	3.697	9.390	0.282	0.212	0.159	0.095	0.062	0.010	-0.047
52	3.947	10.025	.263	.189	.135	.071	.040	-.010	-.066
53	4.244	10.780	.574	.501	.444	.368	.321	.272	.193
54	4.290	10.897	.830	.799	.767	.703	.636	.587	.442
55	4.395	11.163	.022	-.088	-.170	-.261	-.302	-.374	-.429
56	4.550	11.557	.204	.128	.069	.006	-.037	-.088	-.153
57	4.863	12.352	.219	.147	.097	.039	.006	-.038	-.090
58	5.237	13.302	.114	.046	-.001	-.053	-.085	-.130	-.172
59	5.611	14.252	-.984	-1.035	-1.067	-1.102	-1.119	-1.145	-1.161
60	5.811	14.760	-.902	-1.033	-1.112	-1.184	-1.199	-1.219	-.940
61	6.011	15.268	-.304	-.446	-.663	-.877	-.815	-.786	-.651
62	6.230	15.824	-.600	-.543	-.487	-.453	-.428	-.426	-.474
63	6.430	16.332	-.540	-.510	-.467	-.407	-.354	-.323	-.329
64	6.630	16.840	-.285	-.272	-.258	-.249	-.210	-.198	-.232
65	6.890	17.501	-.037	-.083	-.107	-.114	-.085	-.090	-.141
66	7.151	18.164	.037	.017	.013	.017	.025	-.007	-.065
67	7.460	18.948	.249	.257	.261	.259	.249	.238	.092
68	7.770	19.736	.311	.306	.303	.293	.268	.262	.176
69	8.020	20.371	.256	.252	.248	.243	.227	.226	.184
70	8.270	21.006	.204	.199	.199	.196	.192	.192	.179

TABLE I.- PRESSURE COEFFICIENTS - Continued

(j) M = 1.0; α = -10° to 10°; model rolled 90°

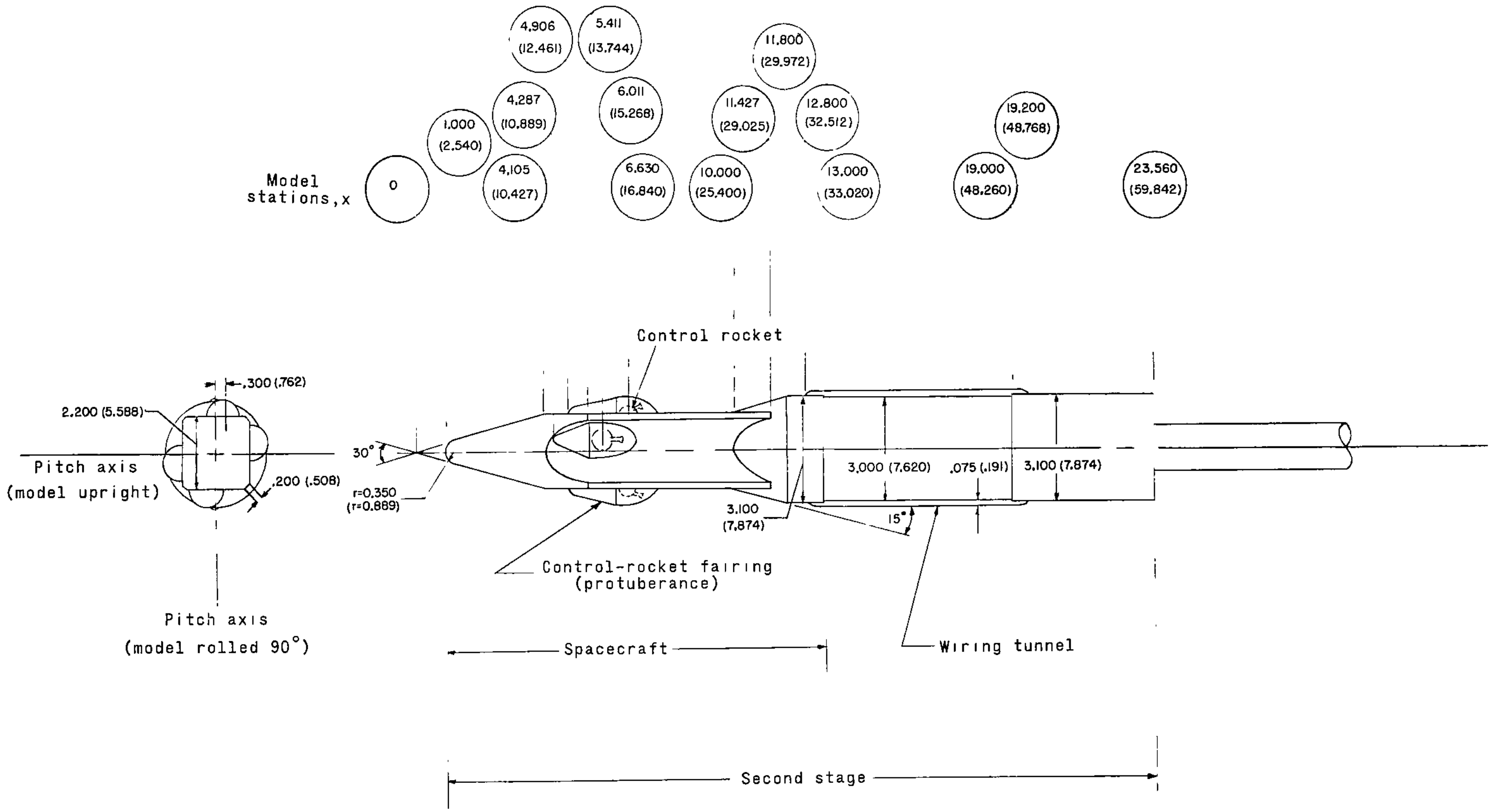
Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row A									
1	3.855	9.792	0.024	0.094	0.139	0.181	0.218	0.247	0.279
2	4.244	10.780	-.096	-.022	.026	.077	.123	.164	.210
3	4.550	11.557	-.234	-.172	-.105	-.035	.023	.075	.136
4	4.863	12.352	-.125	.029	.040	.044	.051	.018	.051
5	5.611	14.252	-.163	-.117	-.085	-.074	-.061	-.065	-.087
6	6.011	15.268	-.271	-.202	-.191	-.176	-.148	-.140	-.145
7	6.230	15.824	-.399	-.333	-.310	-.318	-.304	-.255	-.228
8	6.630	16.840	-.653	-.565	-.522	-.500	-.503	-.460	-.324
9	7.151	18.164	-.770	-.693	-.636	-.581	-.542	-.470	-.370
10	7.770	19.736	-.596	-.551	-.481	-.409	-.385	-.357	-.329
11	8.020	20.371	-.362	-.365	-.340	-.292	-.272	-.275	-.284
12	8.270	21.006	-.204	-.223	-.241	-.237	-.224	-.250	-.282
Row B									
13	3.697	9.390	0.175	0.208	0.215	0.200	0.186	0.151	0.085
14	3.947	10.025	.127	.154	.158	.140	.125	.090	.027
15	4.244	10.780	-.612	-.584	-.574	-.573	-.565	-.575	-.586
16	4.550	11.557	-.350	-.187	-.086	-.010	.057	.059	.015
17	4.863	12.352	-.092	.109	.227	.329	.366	.365	.317
18	4.915	12.484	.236	.461	.605	.796	.839	.903	.848
19	5.020	12.751	.314	.339	.316	.230	.197	.154	.125
20	5.237	13.302	.054	.178	.228	.252	.245	.218	.142
21	5.611	14.252	.008	.119	.171	.196	.192	.163	.096
22	5.811	14.760	-.017	.084	.135	.158	.155	.120	.049
23	6.011	15.268	-.056	.030	.075	.094	.089	.056	-.018
24	6.230	15.824	-.591	-.541	-.517	-.509	-.514	-.538	-.583
25	6.430	16.332	-.798	-.766	-.747	-.736	-.737	-.746	-.759
26	6.630	16.840	-.731	-.708	-.697	-.684	-.669	-.663	-.659
27	6.890	17.501	-.670	-.645	-.640	-.602	-.563	-.596	-.593
28	7.151	18.164	-.618	-.548	-.497	-.479	-.436	-.517	-.553
29	7.460	18.948	-.588	-.528	-.495	-.486	-.451	-.503	-.542
30	7.770	19.736	-.531	-.483	-.464	-.451	-.422	-.454	-.499
31	8.020	20.371	-.458	-.474	-.472	-.473	-.462	-.474	-.480
32	8.270	21.006	-.309	-.362	-.381	-.396	-.395	-.386	-.372

Orifice	x, in.	x, cm	C_p for α, deg, of - -10	-6	-3	0	3	6	10
Row C									
33	3.605	9.157	0.311	0.287	0.262	0.220	0.188	0.141	0.075
34	3.855	9.792	.295	.268	.239	.195	.156	.107	.038
35	4.244	10.780	.233	.202	.172	.126	.087	.036	-.045
36	4.550	11.557	.150	.114	.091	.061	.059	.027	-.013
37	4.863	12.352	.081	.105	.120	.115	.112	.089	.026
38	5.237	13.302	.034	.071	.080	.069	.061	.037	-.001
39	5.611	14.252	-.144	-.098	-.080	-.081	-.078	-.095	-.136
40	5.811	14.760	-.260	-.220	-.200	-.204	-.214	-.226	-.249
41	6.011	15.268	-.245	-.268	-.297	-.313	-.310	-.343	-.408
42	6.230	15.824	-.369	-.516	-.616	-.636	-.575	-.534	-.538
43	6.430	16.332	-.524	-.629	-.677	-.701	-.665	-.686	-.744
44	6.630	16.840	-.535	-.631	-.697	-.738	-.680	-.730	-.820
45	6.890	17.501	-.580	-.629	-.686	-.714	-.561	-.657	-.763
46	7.151	18.164	-.472	-.521	-.498	-.497	-.445	-.555	-.588
47	7.460	18.948	-.459	-.330	-.348	-.377	-.460	-.491	-.451
48	7.770	19.736	-.311	-.275	-.262	-.290	-.425	-.409	-.349
49	8.020	20.371	-.306	-.268	-.221	-.239	-.366	-.327	-.278
50	8.270	21.006	-.316	-.278	-.209	-.203	-.294	-.249	-.215
Row D									
51	3.697	9.390	0.387	0.318	0.268	0.211	0.169	0.124	0.066
52	3.947	10.025	.367	.295	.243	.183	.140	.093	.032
53	4.244	10.780	.665	.592	.532	.466	.408	.361	.278
54	4.290	10.897	.945	.916	.883	.822	.754	.732	.574
55	4.395	11.163	.112	-.019	-.118	-.191	-.225	-.269	-.288
56	4.550	11.557	.314	.237	.182	.136	.030	-.184	-.318
57	4.863	12.352	.346	.283	.237	.192	.155	.127	.051
58	5.237	13.302	.283	.233	.196	.158	.123	.091	.057
59	5.611	14.252	-.528	-.558	-.578	-.599	-.612	-.630	-.647
60	5.811	14.760	-.622	-.668	-.698	-.724	-.744	-.765	-.782
61	6.011	15.268	-.538	-.595	-.631	-.666	-.686	-.708	-.723
62	6.230	15.824	-.636	-.687	-.722	-.742	-.751	-.760	-.760
63	6.430	16.332	-.559	-.622	-.666	-.685	-.708	-.748	-.777
64	6.630	16.840	-.432	-.556	-.635	-.651	-.647	-.704	-.744
65	6.890	17.501	-.392	-.462	-.506	-.532	-.520	-.592	-.634
66	7.151	18.164	-.339	-.386	-.418	-.452	-.461	-.501	-.562
67	7.460	18.948	-.129	-.219	-.205	-.218	-.256	-.209	-.144
68	7.770	19.736	.014	-.005	-.012	-.048	-.081	-.061	-.021
69	8.020	20.371	.022	.009	-.004	-.026	-.057	-.041	-.007
70	8.270	21.006	-.010	-.023	-.034	-.045	-.069	-.041	-.001

TABLE I.- PRESSURE COEFFICIENTS - Concluded

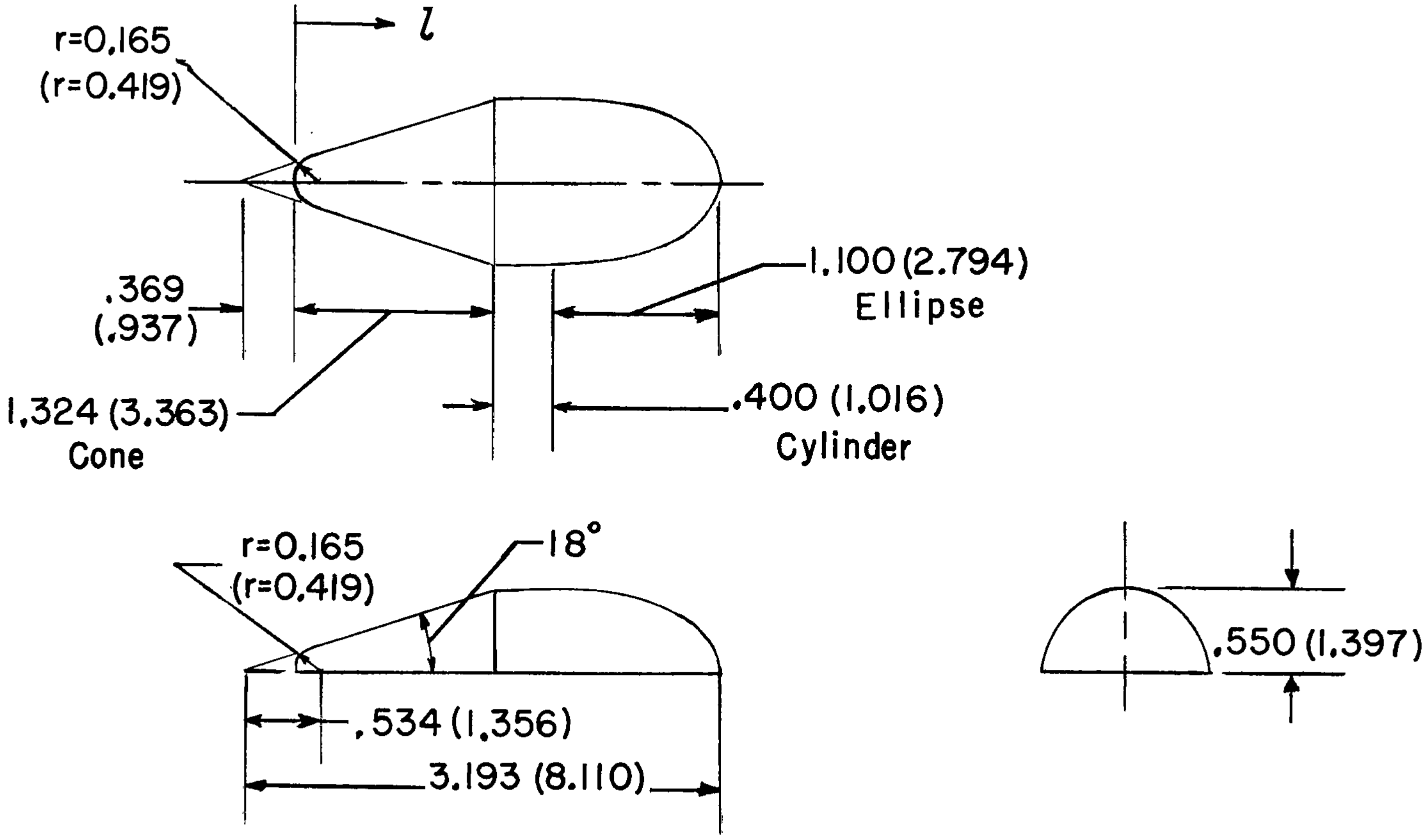
(k) $M = 1.2$; $\alpha = -10^{\circ}$ to 10°; model rolled 90°

Orifice	x		C_p for α, deg, of -						
	in.	cm	-10	-6	-3	0	3	6	10
Row A									
1	3.855	9.792	0.177	0.249	0.280	0.323	0.343	0.366	0.391
2	4.244	10.780	.104	.180	.217	.257	.277	.303	.346
3	4.550	11.557	-.014	.050	.087	.136	.178	.220	.300
4	4.863	12.352	-.104	-.091	-.039	.017	.067	.158	.233
5	5.611	14.252	-.059	.017	.048	.071	.062	.047	.020
6	6.011	15.268	-.103	-.027	-.014	.037	.042	.065	.040
7	6.230	15.824	-.195	-.086	-.080	-.100	-.068	-.026	-.015
8	6.630	16.840	-.387	-.274	-.236	-.207	-.216	-.225	-.122
9	7.151	18.164	-.496	-.416	-.363	-.311	-.277	-.236	-.175
10	7.770	19.736	-.484	-.440	-.413	-.342	-.321	-.279	-.236
11	8.020	20.371	-.457	-.399	-.372	-.305	-.297	-.280	-.236
12	8.270	21.006	-.338	-.275	-.254	-.195	-.205	-.244	-.217
Row B									
13	3.697	9.390	0.291	0.334	0.335	0.329	0.300	0.270	0.203
14	3.947	10.025	.277	.316	.315	.306	.278	.251	.192
15	4.244	10.780	-.314	-.287	-.281	-.280	-.286	-.293	-.304
16	4.550	11.557	-.282	-.199	-.195	-.153	-.116	-.104	-.100
17	4.863	12.352	.045	.197	.317	.365	.362	.364	.333
18	4.915	12.484	.492	.713	.989	.987	.901	.940	.889
19	5.020	12.751	.240	.295	.211	.166	.208	.203	.214
20	5.237	13.302	.067	.212	.272	.306	.289	.274	.183
21	5.611	14.252	.151	.255	.290	.320	.321	.293	.227
22	5.811	14.760	.129	.236	.280	.311	.304	.272	.205
23	6.011	15.268	.102	.207	.248	.286	.280	.232	.163
24	6.230	15.824	-.316	-.254	-.228	-.204	-.215	-.246	-.298
25	6.430	16.332	-.499	-.459	-.434	-.410	-.419	-.431	-.470
26	6.630	16.840	-.483	-.437	-.409	-.382	-.389	-.405	-.445
27	6.890	17.501	-.489	-.469	-.463	-.481	-.489	-.505	-.493
28	7.151	18.164	-.481	-.454	-.443	-.430	-.443	-.457	-.467
29	7.460	18.948	-.496	-.476	-.463	-.417	-.454	-.470	-.478
30	7.770	19.736	-.482	-.439	-.409	-.395	-.434	-.458	-.472
31	8.020	20.371	-.376	-.342	-.351	-.352	-.365	-.365	-.418
32	8.270	21.006	-.192	-.171	-.194	-.236	-.248	-.238	-.320
Row C									
33	3.605	9.157	0.407	0.397	0.364	0.332	0.286	0.251	0.191
34	3.855	9.792	.408	.396	.363	.328	.279	.244	.186
35	4.244	10.780	.378	.365	.338	.306	.254	.204	.130
36	4.550	11.557	.312	.252	.202	.176	.143	.114	.067
37	4.863	12.352	.247	.198	.130	.052	.014	.019	.065
38	5.237	13.302	.161	.185	.178	.165	.142	.112	.065
39	5.611	14.252	.032	.087	.093	.082	.072	.054	.015
40	5.811	14.760	-.076	-.020	.002	.002	-.008	-.026	-.062
41	6.011	15.268	-.077	-.068	-.074	-.087	-.125	-.183	-.185
42	6.230	15.824	-.156	-.265	-.369	-.400	-.308	-.271	-.281
43	6.430	16.332	-.295	-.365	-.441	-.450	-.412	-.403	-.447
44	6.630	16.840	-.313	-.358	-.427	-.459	-.451	-.475	-.532
45	6.890	17.501	-.346	-.388	-.458	-.468	-.464	-.508	-.552
46	7.151	18.164	-.367	-.447	-.437	-.448	-.485	-.521	-.550
47	7.460	18.948	-.308	-.312	-.310	-.292	-.355	-.364	-.427
48	7.770	19.736	-.317	-.261	-.202	-.191	-.209	-.214	-.236
49	8.020	20.371	-.255	-.196	-.164	-.133	-.145	-.157	-.177
50	8.270	21.006	-.211	-.187	-.151	-.112	-.121	-.122	-.127
Row D									
51	3.697	9.390	0.484	0.431	0.377	0.329	0.275	0.244	0.197
52	3.947	10.025	.473	.421	.369	.318	.266	.234	.188
53	4.244	10.780	.773	.714	.649	.587	.511	.460	.393
54	4.290	10.897	1.096	1.076	1.026	.967	.869	.795	.675
55	4.395	11.163	.197	.127	.084	.060	.032	.015	-.006
56	4.550	11.557	.440	.297	.132	.060	-.002	-.045	-.092
57	4.863	12.352	.490	.427	.342	.270	.198	.140	.080
58	5.237	13.302	.451	.391	.317	.243	.177	.127	.081
59	5.611	14.252	-.229	-.253	-.280	-.306	-.334	-.359	-.387
60	5.811	14.760	-.336	-.372	-.405	-.430	-.458	-.483	-.499
61	6.011	15.268	-.288	-.332	-.374	-.405	-.435	-.462	-.471
62	6.230	15.824	-.389	-.427	-.464	-.493	-.512	-.523	-.515
63	6.430	16.332	-.345	-.376	-.469	-.487	-.504	-.508	-.529
64	6.630	16.840	-.316	-.334	-.469	-.490	-.491	-.492	-.524
65	6.890	17.501	-.278	-.300	-.360	-.389	-.422	-.436	-.468
66	7.151	18.164	-.244	-.273	-.310	-.326	-.343	-.327	-.365
67	7.460	18.948	-.154	-.170	-.185	-.124	-.106	-.090	-.023
68	7.770	19.736	-.005	-.028	.119	.078	.034	.030	.046
69	8.020	20.371	.064	.035	.112	.080	.048	.031	.017
70	8.270	21.006	.075	.045	.069	.047	.017	-.004	-.010



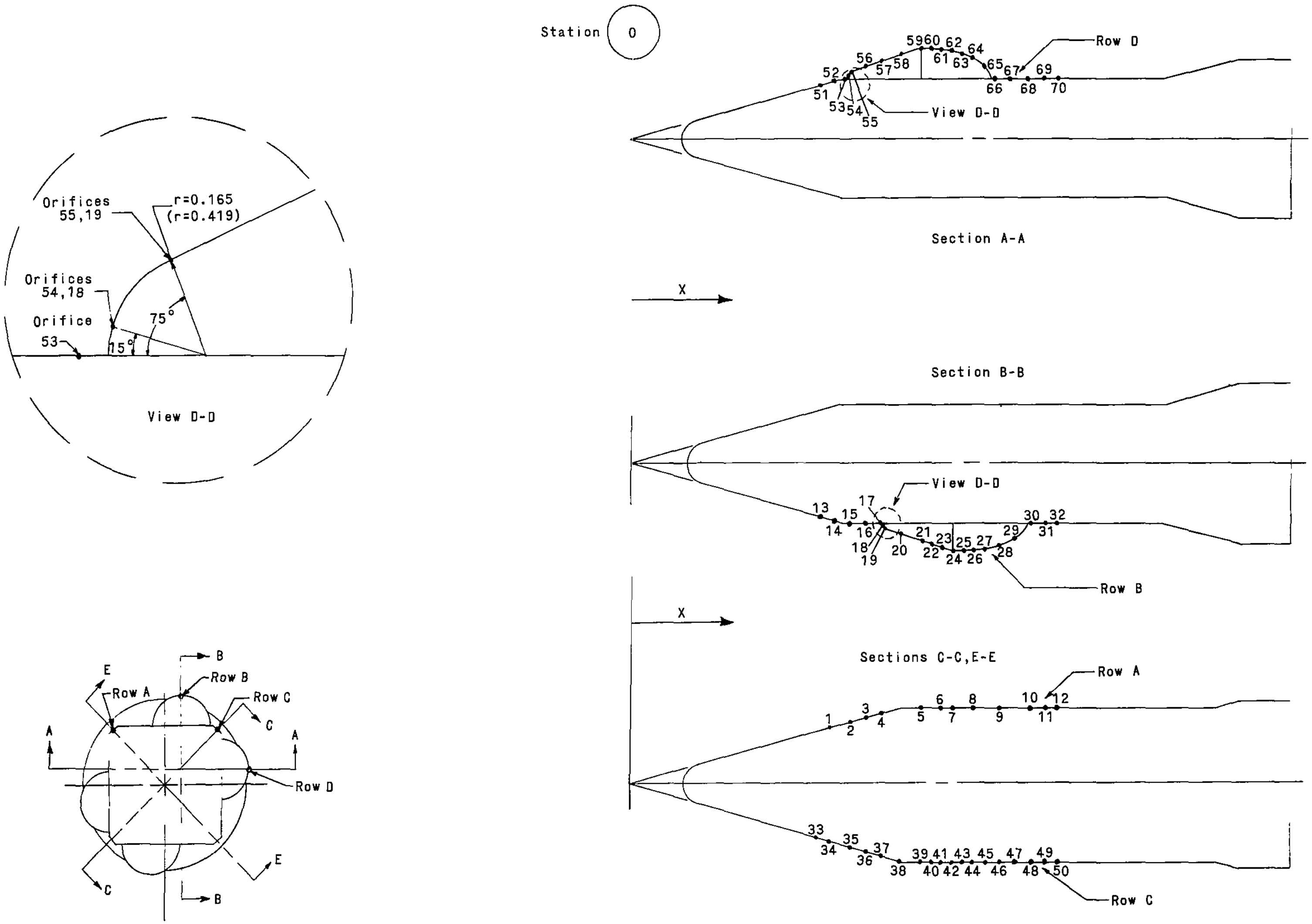
(a) Geometric details of second stage.

Figure 1.- Details of models. Linear dimensions are in inches (centimeters).



(b) Geometric details of protuberance.

Figure 1.- Continued.



(c) Location of orifices on second stage.

Figure 1.- Concluded.

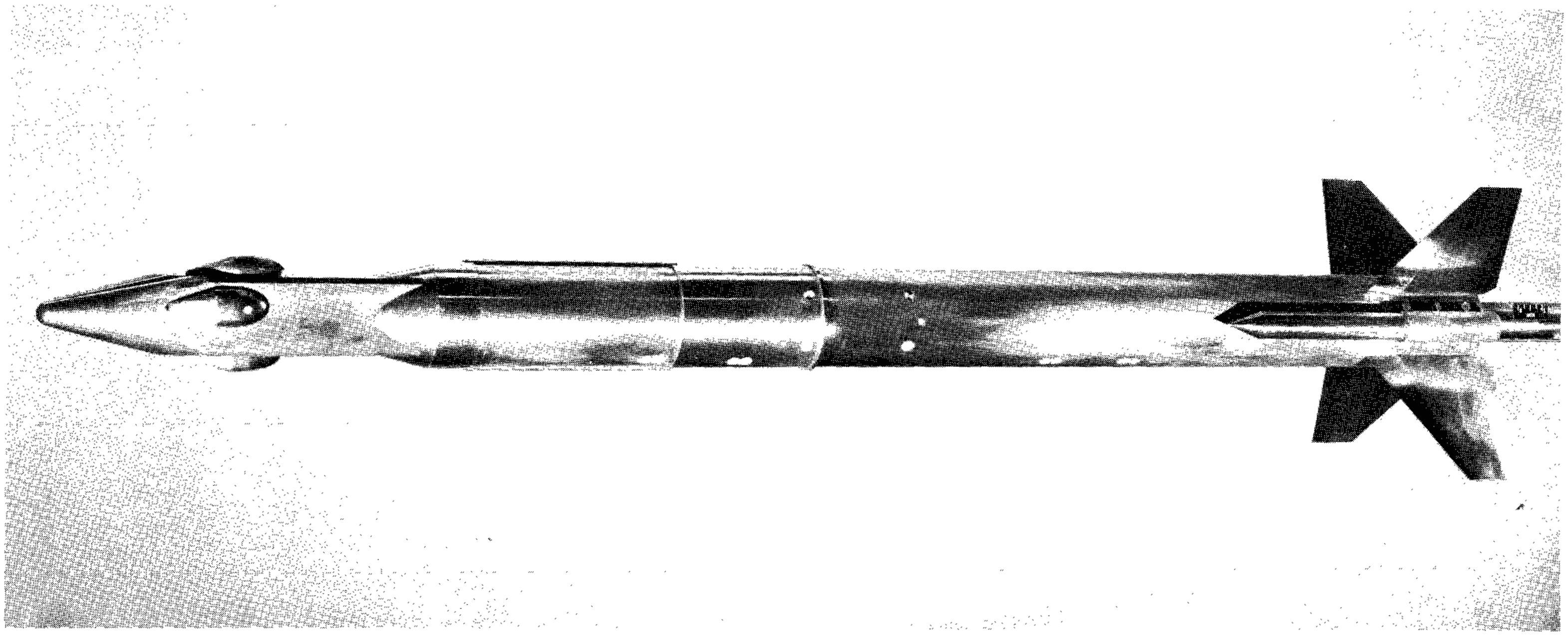


Figure 2.- Complete two-stage launch vehicle

L-62-6675

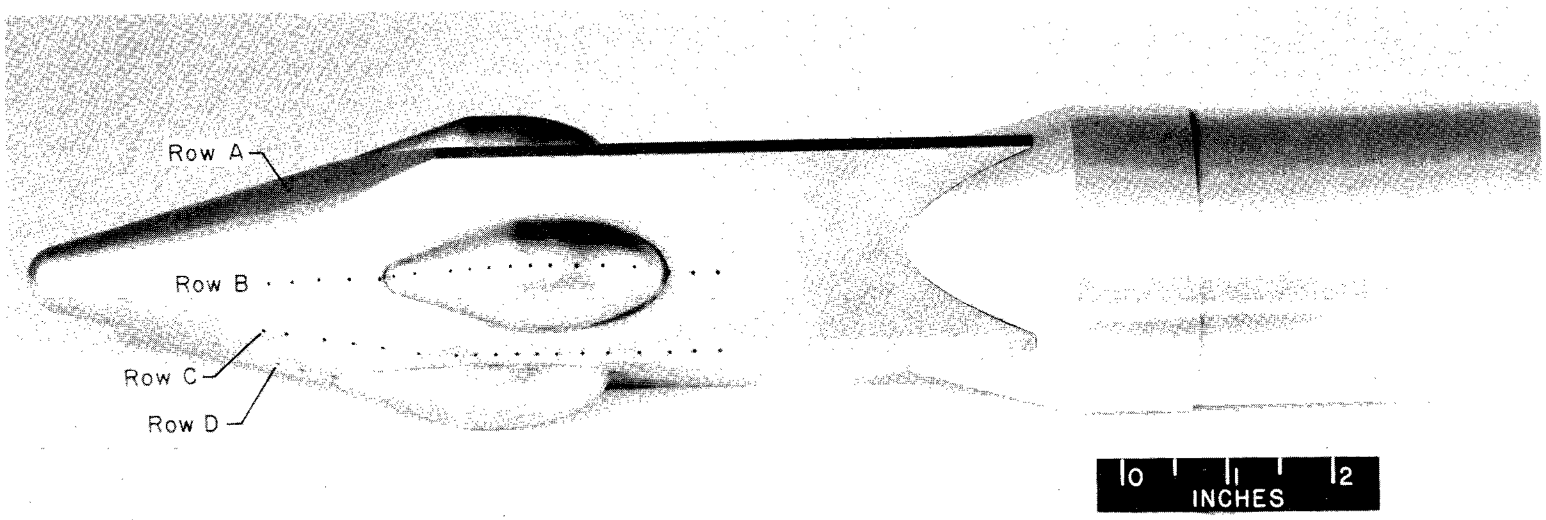
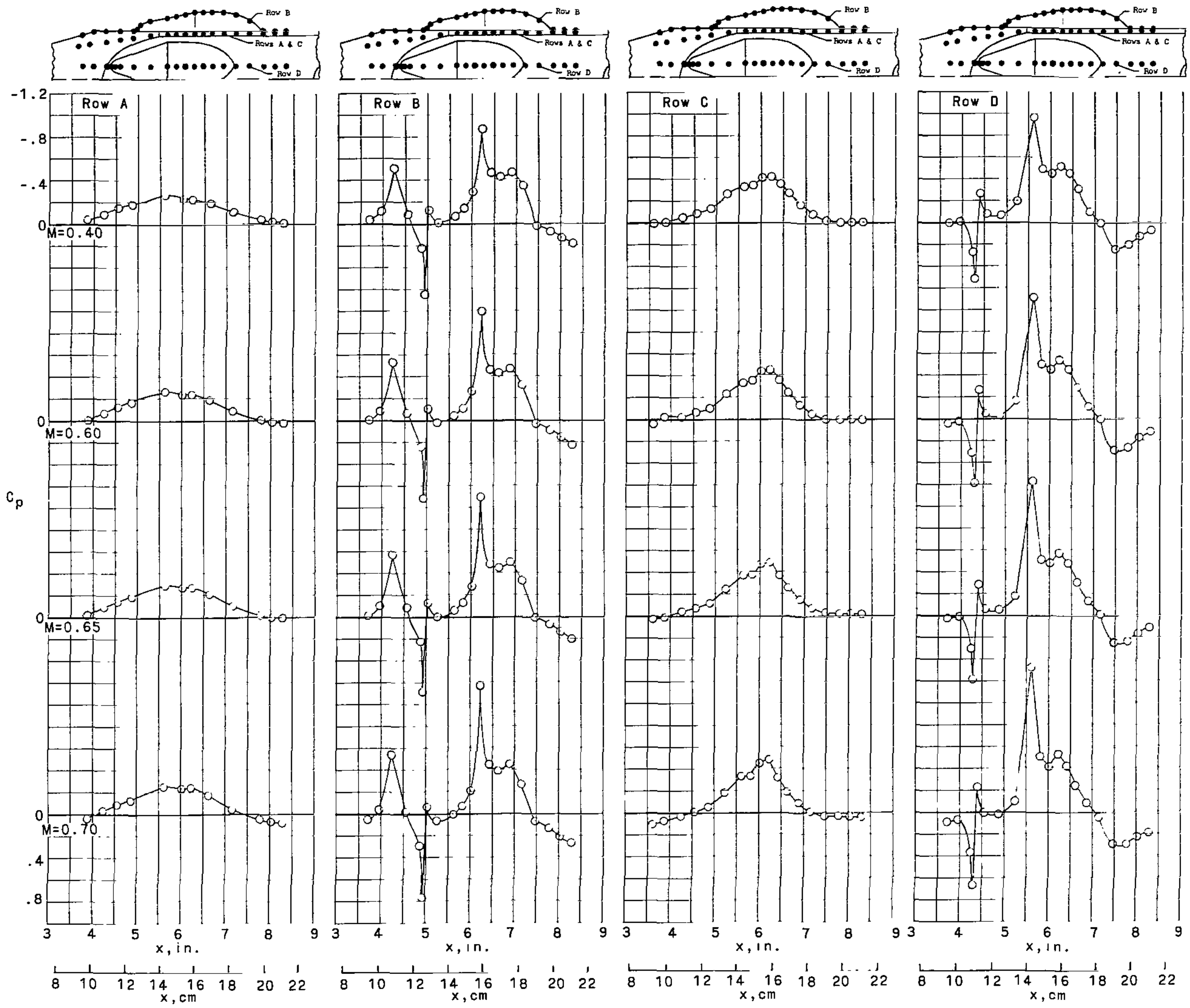


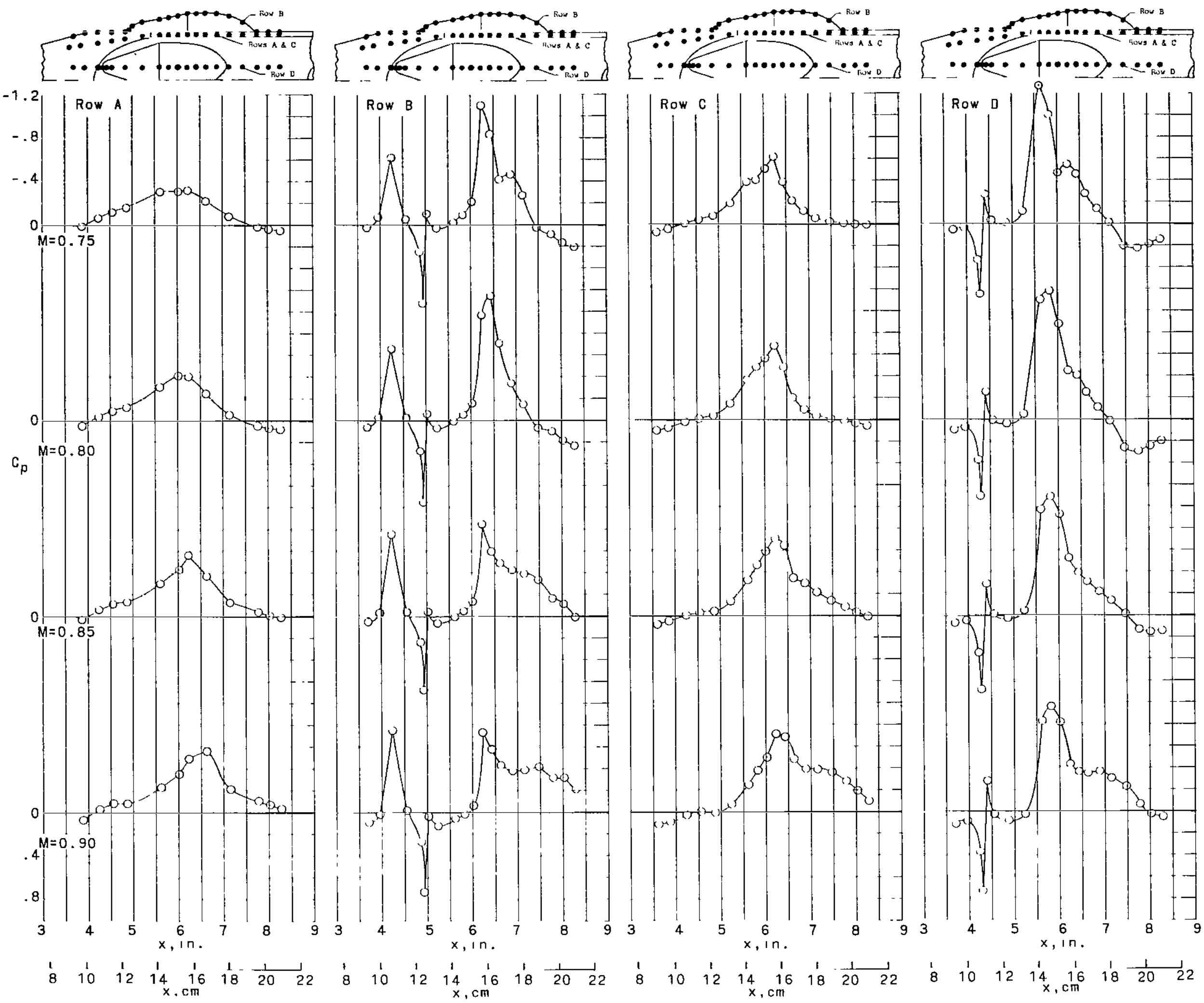
Figure 3.- Model of present investigation.

L-64-6431.1



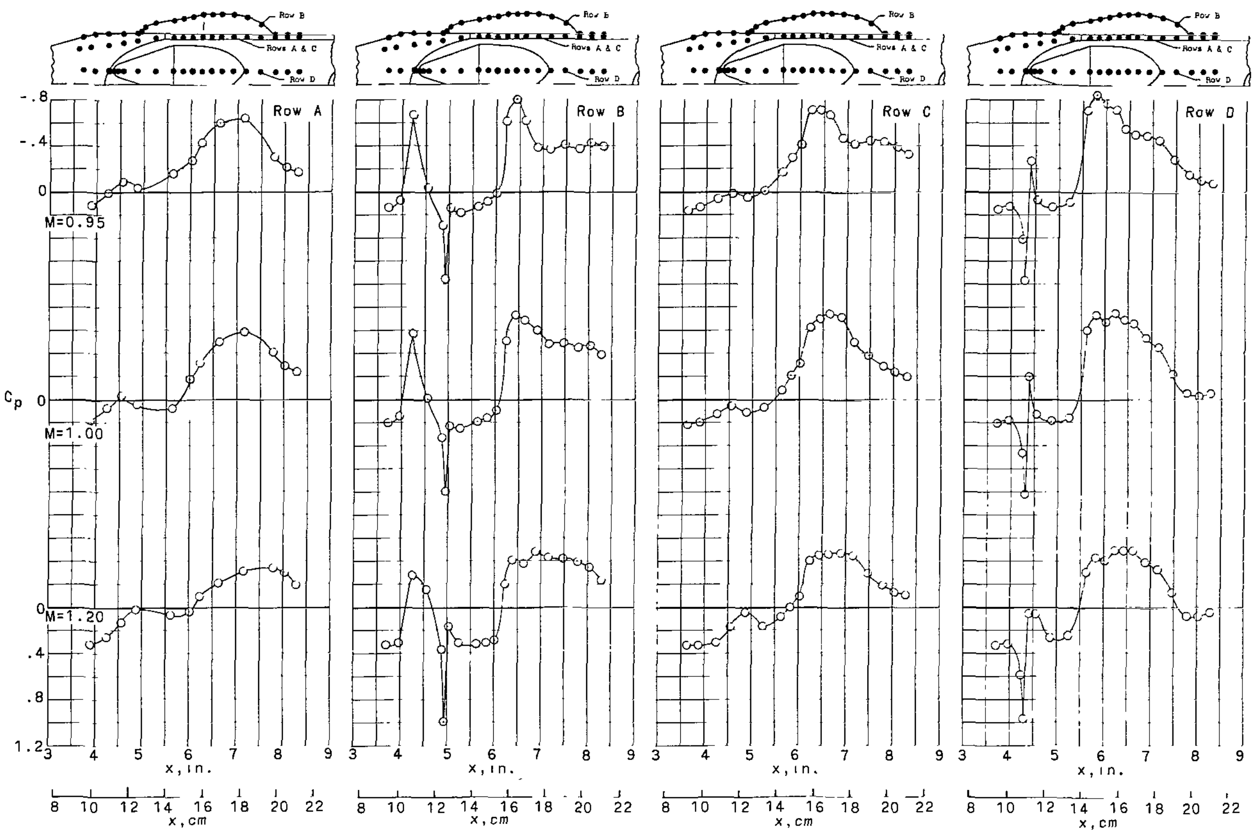
(a) Mach numbers 0.40 to 0.70.

Figure 4.- Effect of Mach number on surface pressure coefficients on protuberances and areas adjacent to protuberances. $\alpha = 0^0$.



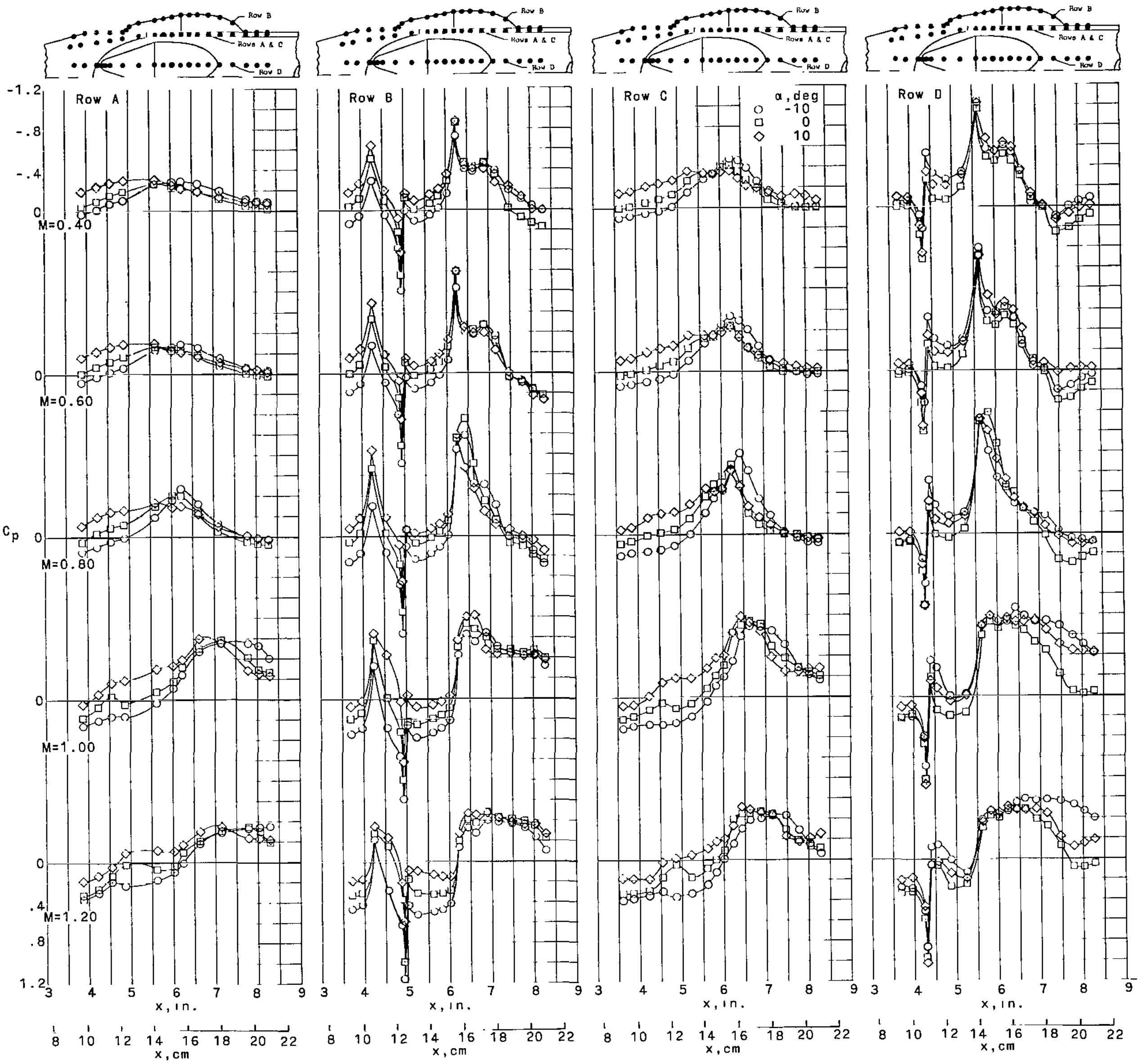
(b) Mach numbers 0.75 to 0.90.

Figure 4.- Continued.



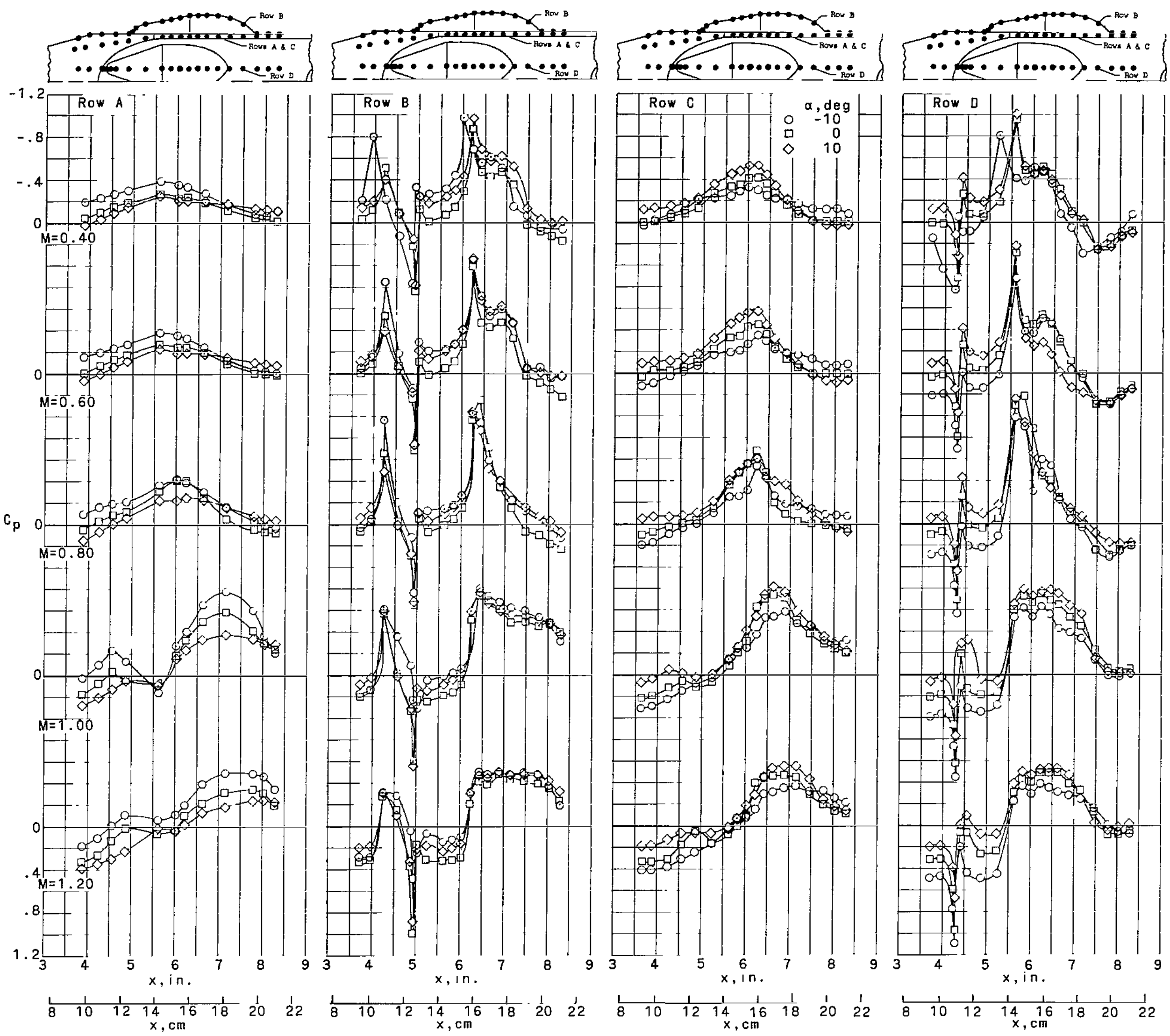
(c) Mach numbers 0.95 to 1.20.

Figure 4.- Concluded.



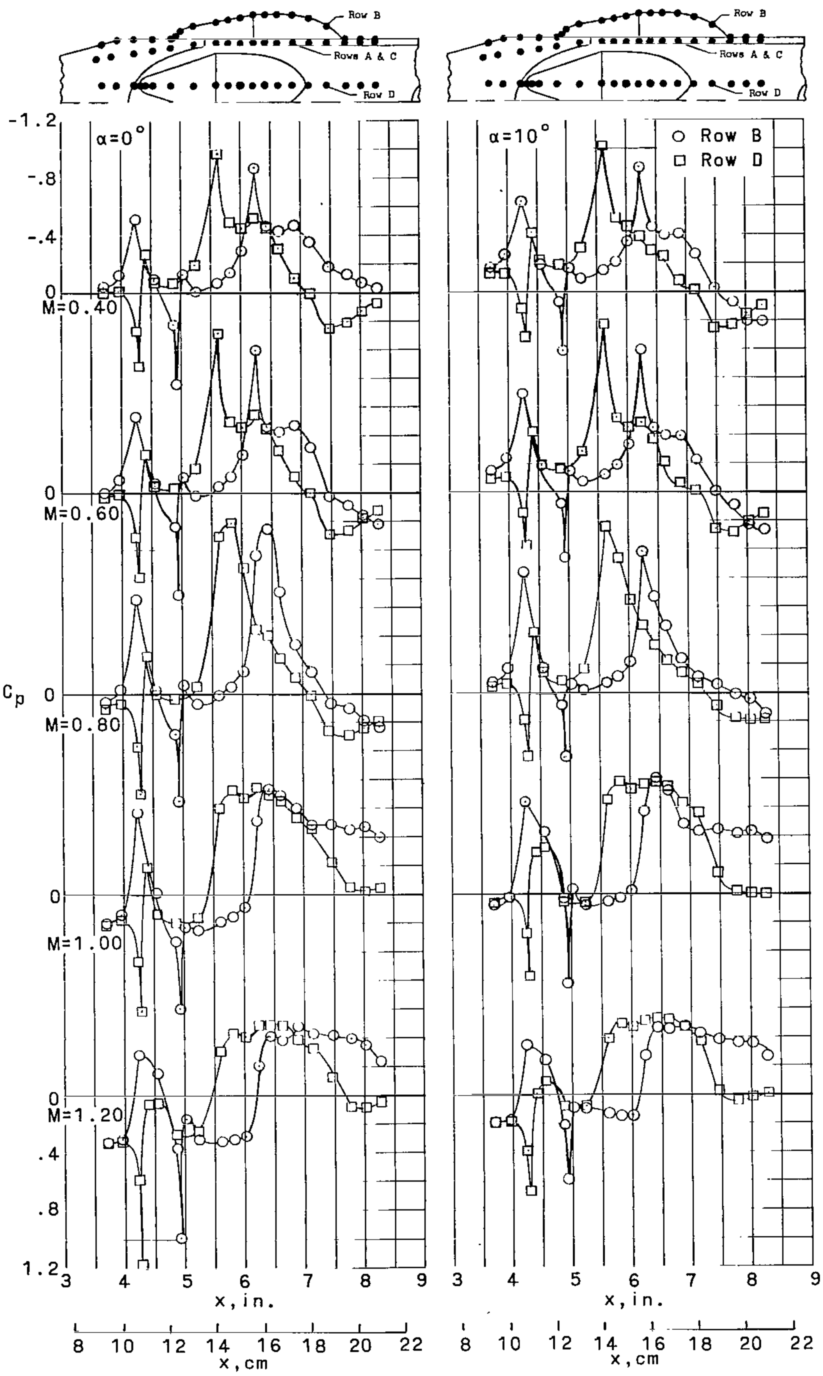
(a) Model upright.

Figure 5.- Effect of angle of attack on surface pressure coefficients on protuberances and areas adjacent to protuberances.



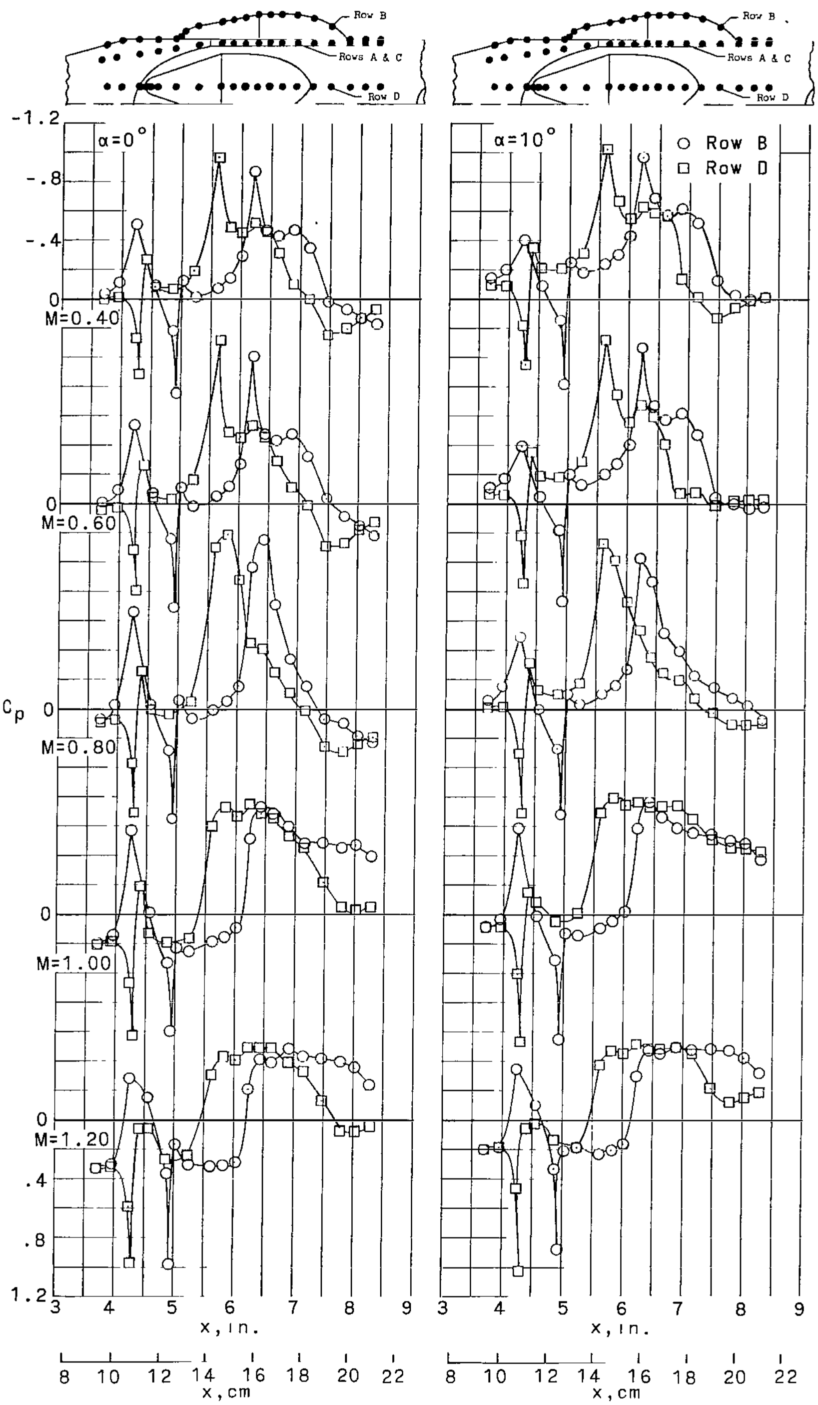
(b) Model rolled 90°.

Figure 5.- Concluded.



(a) Row B (model upright); row D (model rolled 90°).

Figure 6.- Effect of longitudinal location of protuberances with respect to nose of launch vehicle and other protuberances.



(b) Row B (model rolled 90°); row D (model upright).

Figure 6.- Concluded.

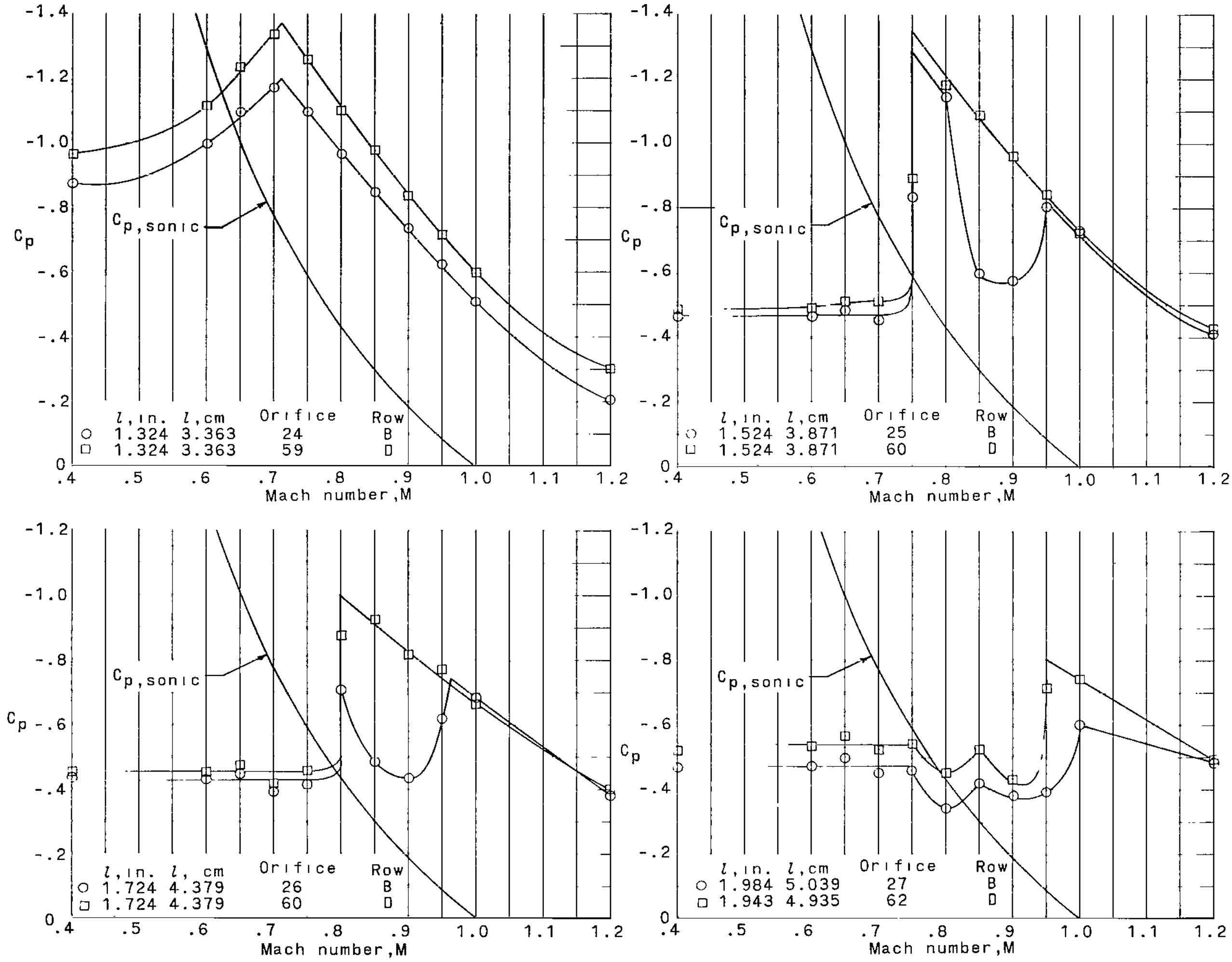


Figure 7.- Effect of Mach number on surface pressure coefficients for four orifice locations immediately behind cone-cylinder juncture of forward and rearward protuberances. $\alpha = 0^0$.

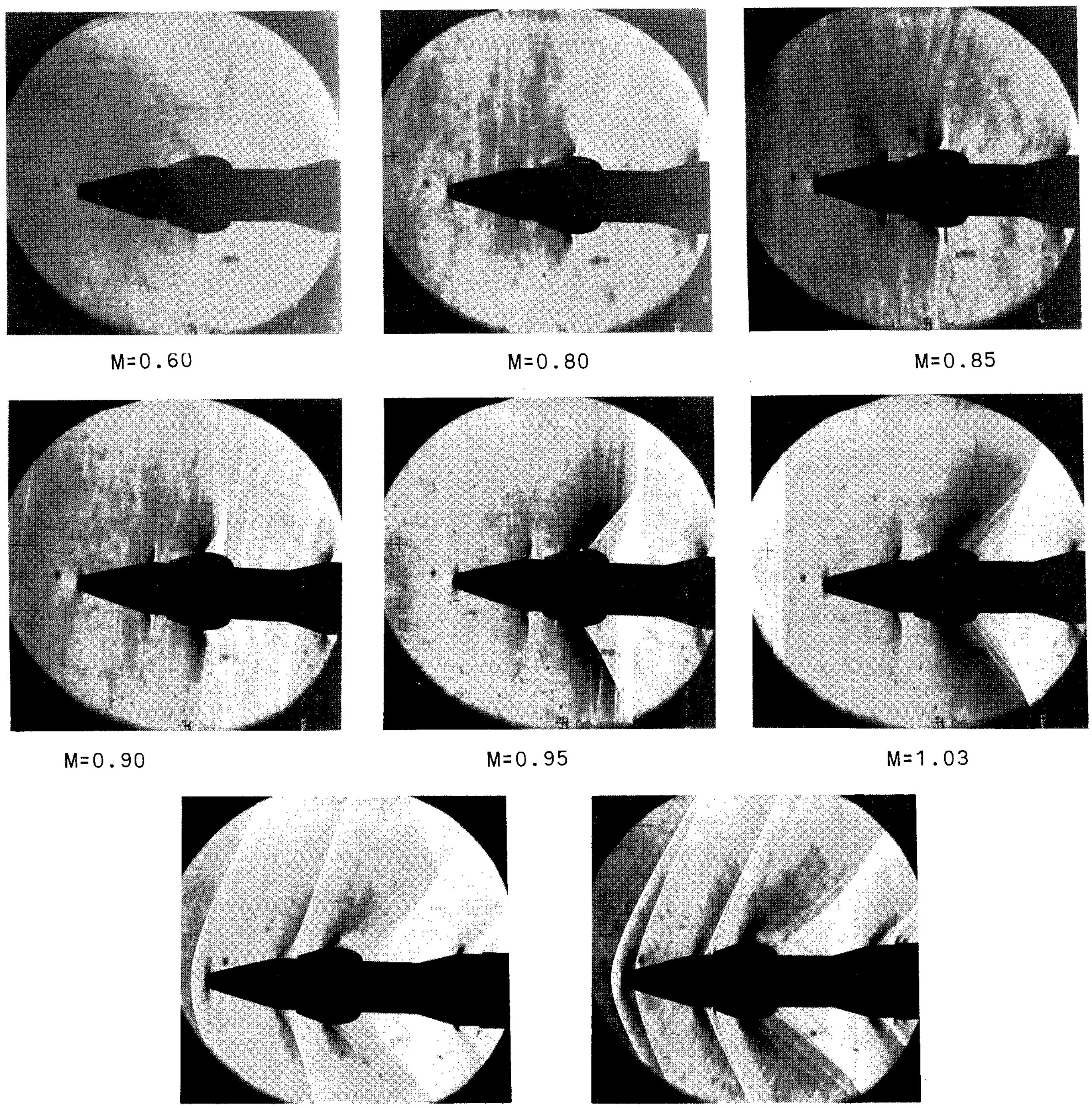


Figure 8.- Schlieren photographs of transonic flow over nose section. Model upright; $\alpha = 0^{0}$. L-65-7960

NASA-Langley, 1966 L-4538

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