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TECHNICAL MEMORANDUM

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AN EXPERIMENTAL INVESTIGATION AT MACH NUMBERS FROM 2.1 TO 3.0 OF CIRCULAR INTERNAL-COMPRESSION INLETS HAVING TRANSLATABLE CENTERBODIES AND PROVISIONS FOR BOUNDARY-LAYER REMOVAL

By Earl C. Watson

Ames Research Center
Moffett Field, Calif.

[redacted]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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TECHNICAL MEMORANDUM X-156

AN EXPERIMENTAL INVESTIGATION AT MACH NUMBERS FROM 2.1 TO 3.0 OF CIRCULAR INTERNAL-COMPRESSION INLETS HAVING TRANSLATABLE CENTERBODIES AND PROVISIONS FOR BOUNDARY-LAYER REMOVAL*

By Earl C. Watson

SUMMARY

An experimental investigation was conducted to determine the effects of boundary-layer removal on the characteristics of four internal-compression inlets. Each of the inlets had approximately the same shape and differed primarily in the extent of the regions of perforations which were employed in the internal surfaces to permit the removal of boundary-layer air. Each inlet was axially symmetric and had a translatable centerbody which permitted the contraction ratio to be varied to as low as 0.251 for two of the inlets investigated. In addition, the internal surfaces were shaped to provide a nearly constant area throat region for all centerbody positions. The length from the inlet entrance to the compressor station was 4.8 inlet entrance diameters.

Data were obtained at 0° angle of attack for Mach numbers from 2.1 to 3.0 and for corresponding Reynolds numbers (based on inlet-entrance diameter) from 3.6 to 5.1 million. Results showed that boundary-layer removal through a perforated area in the annulus and centerbody having a total open area equal to 0.105 of the inlet entrance area and located downstream of the minimum flow area increased the total-pressure recovery between 3 and 5 percent in the Mach number range from 2.5 to 2.9, the limit for this comparison. The amount of boundary-layer air removed was estimated to be between 7 and 9 percent of the inlet mass flow. By extending the perforated area ahead of and behind the throat region the total-pressure recovery was further increased. However, the amount of flow removed to obtain this improvement could not be determined accurately. For this latter configuration, the total-pressure recovery was 0.87 and 0.75 at Mach numbers of 2.5 and 3.0, respectively.

*Title, Unclassified

INTRODUCTION

Since it was first pointed out in reference 1 that a main advantage of an internal-compression inlet with a translatable centerbody over many types of external-compression inlets was the elimination of external wave drag at high Mach numbers, continuous efforts have been made to improve the pressure-recovery characteristics of internal-compression inlets. Results from one investigation, reference 2, showed that the pressure recovery could be improved considerably if the annulus and centerbody surfaces were perforated to permit the removal of boundary-layer air. Although the inlets of reference 2 were investigated over a range of Mach numbers from 0.85 to 3.50, satisfactory operation could be obtained only for Mach numbers up to 2.5 because the minimum available contraction ratio was restricted. To determine the effects of boundary-layer removal on the performance of inlets designed for operation at Mach numbers up to 3.0, the present investigation was undertaken.

The inlets of the present investigation had internal shapes which differed from and provided lower contraction ratios than the inlets of reference 2, and were designed for operation at Mach numbers up to 3.0. To investigate the effects of boundary-layer removal at the higher Mach numbers, between 2.5 and 3.0, several perforation arrangements were employed. Four inlets were tested, one without and three with perforations in the annulus and centerbody. Tests were conducted with the models at 0° angle of attack over a range of Mach numbers from 2.1 to 3.0 and a corresponding range of Reynolds number (based on inlet-entrance diameter) from 3.6 to 5.1 million in an 8- by 8-inch blowdown wind tunnel.

NOTATION

A_a $\dfrac{\text{internal area of the annulus}}{A_i}$

A_b $\dfrac{\text{cross-sectional area of the centerbody}}{A_i}$

A_c $\dfrac{\text{flow area at the compressor station}}{A_i}$

A_i inlet entrance area, area of the annulus at the leading edge

A_l $\dfrac{\text{local flow area}}{A_i}$

A_{min}	contraction ratio for constant centerbody position, $\frac{\text{minimum internal-flow area}}{A_i}$
A_s	$\frac{\text{cross-sectional area of the sting supporting the centerbody}}{A_i}$
D_a	internal diameter of the annulus
D_b	diameter of the centerbody
D_i	inlet entrance diameter
L	$\frac{\text{distance of the centerbody apex ahead of the annulus leading edge}}{D_i}$
M_∞	free-stream Mach number
$\frac{m_b}{m_\infty}$	ratio of the mass of air removed through the centerbody passage to the free-stream mass of air through an area equal to A_i
P1, P2, P3	inlet configurations (see figs. 3 and 5)
$\frac{p_b}{p_{t_\infty}}$	ratio of the static pressure in the centerbody passage to the free-stream total pressure
$\frac{p_{t_b}}{p_{t_\infty}}$	ratio of total pressure in the centerbody passage to free-stream total pressure
$\frac{p_{t_c}}{p_{t_\infty}}$	ratio of total pressure at the compressor station to free-stream total pressure
$\frac{p_{t_l}}{p_{t_\infty}}$	ratio of local total pressure at the compressor station to free-stream total pressure
r	radius
X	$\frac{\text{distance downstream from the inlet entrance}}{D_i}$
x	distance downstream from the inlet entrance

APPARATUS AND MODELS

Apparatus

Details of the 8- by 8-inch blowdown wind tunnel and the model-supporting and instrumentation systems are described in references 1 and 2. The same equipment and test procedure were used in the present investigation. In addition to measurements of pressures in the main inlet at the compressor station, measurements were also made in the centerbody flow removal passage (see fig. 1).

Models

Four models of internal-compression inlets having translatable centerbodies were tested in the present investigation (see fig. 1 for a typical assembled model). For each model the shape of the annulus and all parts aft of the compressor station were identical. Two models, designated as the unperforated model and model P1, used a long centerbody and two models, designated as models P2 and P3, used a short centerbody with a shape identical to the forward 95-percent portion of the long centerbody. The arrangement of the perforations in the annulus and centerbody which were used for boundary-layer removal differed in each model.

Centerbody and annulus shape.- Coordinates for the shapes of the centerbodies and the inner surface of the annulus are given in figure 2. These shapes differed from those of references 1 and 2 not only because of differences in the operating range, but also because of a difference in design philosophy. The inlets of references 1 and 2 were designed so that the centerbody and annulus were either conical surfaces or would produce a prescribed pressure distribution when the centerbody was fully retracted. With such designs, prescribing the distribution of flow area at off-design positions of the centerbody was not possible. In contrast, the shapes of the centerbodies and annulus of the present inlets were designed so that for all positions of the centerbody except those near the fully extended position, the effective flow area in the throat region would be constant[1] for some distance in order to stabilize the flow in the vicinity of the terminal shock. It was believed that by this design philosophy the pressure recovery for the off-design positions of the centerbody would be improved. To obtain a region of constant flow area for all centerbody positions, the cross-sectional area of the centerbody (A_b) aft of the maximum section and the internal area of the annulus (A_a) forward of the minimum section were made to decrease linearly with length (X). Thus the geometric flow area in the throat region, which is

[1]To account for boundary-layer growth in the throat, the geometric flow area must increase slightly with distance downstream.

the region bounded by the centerbody aft of its maximum section and the annulus ahead of its minimum section, can be constant (or vary linearly with length to account for boundary-layer growth, depending upon the values assigned to $\Delta A_b/\Delta X$ and $\Delta A_a/\Delta X$) since it is the difference between two areas which varies linearly with length.

The nearly constant flow area in the throat region for nearly all centerbody positions is shown in figure 3 which presents the longitudinal distribution of area for the four inlets. The value of 0.03 for $\Delta A_l/\Delta X$ was selected on the basis of a study of the value of this parameter for the inlets of reference 1. One characteristic apparent in figure 3 is that the length of the nearly constant area region decreases with centerbody retraction. Another characteristic resulting from the linear variation of annulus area ahead of the minimum section is that the contraction ratio and minimum-flow area vary linearly with centerbody position as shown in figure 4.

In regard to the portion of the centerbody ahead of the maximum area section, the shape was made conical since reference 2 indicated that the pressure recovery was essentially unaffected by differences between such a shape and one which was curved. Regarding the annulus, the angle of the inner surface at the lip was 0° to eliminate strong shock waves from the lip. Aft of the minimum area section, the internal area of the annulus varied linearly with distance. At the juncture of these various regions with the aforementioned regions having a constant gradient of area, the centerbody and annulus shapes were faired to eliminate discontinuities in the gradient of flow area.

Perforations.- The arrangement of the perforations in the annulus and centerbody differed in each model. One model was unperforated. The remaining three models were perforated in the manner shown in figure 5. These models are designated as P1, P2, and P3, corresponding to the designation of their perforation arrangements. The perforated surfaces for inlet P1 were located so that when the centerbody was retracted to the position for operation at a Mach number of 3, as determined from results of the unperforated inlet, the perforations would extend downstream from the location of minimum flow area (see fig. 3(a)). The area of the perforations was sized to permit removal of an estimated 7 percent of the inlet mass flow at a Mach number of 3; for this condition the total area of the holes amounted to 0.105 of the inlet entrance area. For inlets P2 and P3, the perforated area in the annulus extended both farther upstream and downstream, and that in the centerbody extended farther upstream than in the case of inlet P1, so that the supersonic flow portion of the inlet was also perforated for a wide range of centerbody positions (see fig. 3(b)). In the case of inlets P2 and P3 the total area of the holes amounted to 0.503 and 0.320, respectively, of the inlet entrance area.

Summary of design criteria.- The aerodynamic and geometric design criteria used for the inlets of the present investigation are summarized in the table below. The lengths and areas given in the table have been normalized with respect to the diameter and area of the annulus at the lip. For the tabulation of the perforation arrangements, see figure 5. By consideration of these design criteria and the preceding discussion it is apparent that although the present inlets are similar in type to those of reference 2, they differ considerably in internal proportions and surface shapes.

Quantity	Inlet	
	Unperforated and P1	P2 and P3
Centerbody used	Long	Short
Contraction ratio:		
Centerbody fully extended[1]	0.94	0.94
Centerbody fully retracted	0.314	0.251
Centerbody position, L = 0	---	0.258
Length from annulus lip:		
To compressor station	4.8	4.8
To throat, centerbody fully retracted	2.13	2.54
Compressor area, A_c	0.685	0.685
Sting area, A_s	0.072	0.072
$\Delta A_a/\Delta X$ forward of $A_{a_{min}}$	-0.15	-0.15
$\Delta A_b/\Delta X$ aft of $A_{b_{max}}$	-0.18	-0.18
$\Delta A_l/\Delta X$ in throat	0.03	0.03

[1]The contraction ratio for fully extended centerbody (i.e., L = 2.0) is the minimum theoretical value that permits start of supersonic flow at M = 1.4.

RESULTS AND DISCUSSION

Pressure Recovery

The average total-pressure recovery presented herein was obtained in the same manner as that discussed in references 1 and 2. In this procedure, the Mach number and centerbody position are held fixed and with supersonic flow in the inlet the exit area is progressively reduced until the terminal shock is expelled. The highest value of pressure recovery obtained prior to expulsion of the terminal shock is the total-pressure recovery recorded for the test conditions. Such data are shown in figure 6 presenting the effect of contraction ratio, A_{min}, on the average total-pressure recovery for several values of Mach number. In general, results have been obtained over a sufficient range of contraction ratios to define the optimum values of contraction ratio and total-pressure recovery for each Mach number. In the ranges investigated, the results indicate a sizable effect of contraction ratio on total-pressure recovery. In particular, the results for the unperforated inlet at a Mach number of 3.0 show extremely abrupt variations in pressure recovery within a small range of contraction ratios. These abrupt changes are considerably more severe than the remainder of the data shown in figure 6, so that one is led to suspect the peak value of these data for a Mach number of 3.0.

The variations of maximum values of total-pressure recovery and contraction ratio with Mach number, as obtained from figure 6, are presented in figure 7 for the four inlets of the present investigation together with results from reference 2 for an unperforated and perforated inlet. The results show that the pressure recovery of the unperforated inlet of the present investigation was considerably higher than that for the unperforated inlet of reference 2, justifying therefore the change in design procedure which incorporated a constant-area throat section for all centerbody positions as well as other geometric modifications noted previously. However, both sets of results indicate a rapid decrease in pressure recovery with increasing Mach number above 2.5. For the inlets of reference 2, this rapid decrease was attributed to the limit of contraction ratio as evidenced by figure 7. This reason is not valid for the inlets of the present investigation, however, since figure 7 shows a continual decrease in contraction ratio with Mach number. The reasons for the more rapid reduction of pressure recovery with Mach number above 2.5 are not known.

The effects of boundary-layer removal through perforations in the annulus and centerbody are also shown in figure 7. If the result for the unperforated inlet at a Mach number of 3.0 is discounted since, as previously mentioned, it seems to be high, several trends are apparent in the results. For one, the increment in pressure recovery attributable to the effects of boundary-layer removal was large throughout the Mach number range wherein data were obtained and increased with Mach number.

As an example, a comparison of results for inlet P1 with those for the unperforated inlet show that the increment increased from 3 to 5 percent with increasing Mach number from 2.5 to 2.9, and for inlet P2 the incremental increase was from 4.5 to 7.5 percent. Another trend indicates that a perforated area in the throat region was relatively more effective in improving the pressure recovery than a perforated area which, in addition to being in the throat region, also extended into the supersonic portion of the inlet. For example, the increment in pressure recovery between inlet P1 and the unperforated inlet was as much as 72 percent of the increment between inlet P2 and the unperforated inlet. Inlet P1 is perforated only in the throat (see fig. 3(a)), whereas inlet P2 is perforated ahead of as well as in the throat (see fig. 3(b)). A further result indicated by the single comparison between inlets P2 and P3 at a Mach number of 3.0 was that perforations in the forward portion of the annulus ($0.35 \leq X \leq 1.14$) were completely ineffective.

Figure 7 indicates that A_{min} for inlet P1 was the same as that for the unperforated inlet whereas A_{min} for inlets P2 and P3 were considerably less. This characteristic would be expected in view of the fact that the perforations in inlet P1 are downstream of the minimum section so that the quantity of flow from the entrance to the minimum section, which determines the allowable contraction ratio, is the same for the unperforated inlet and inlet P1. Thus the improvement in pressure recovery of inlet P1 above that for the unperforated inlet occurred as a result of an improvement of the flow in the throat and subsonic portion of the diffuser by the use of the perforations. On the other hand, the perforations in inlets P2 and P3 are ahead of the minimum section. Flow removed through perforations in the supersonic portion of the inlet thus reduces the amount of flow through the minimum section and thereby permits a reduction in contraction ratio. In addition it should be realized that a change in pressure recovery in the supersonic region also affects the contraction ratio.

It is noted that the contraction ratios for inlets P2 and P3 were the same, but with neither inlet could the centerbody be retracted to attain the lowest available contraction ratio. (See table in "Summary of design criteria.") This characteristic would indicate that little, or no flow was removed through the perforations in the forward portion of the annulus ($0.35 \leq X \leq 1.14$), a result which would explain the ineffectiveness of these perforations which was mentioned earlier.

The variation of contraction ratio with Mach number for all inlets was parallel to that for isentropic flow at Mach numbers above 2.5. Inlet P1, the only one tested at lower Mach numbers, did not follow this trend at these lower Mach numbers because the centerbody was sufficiently extended to cause supersonic spillage about the entrance. Less air entered the entrance, therefore, and the minimum area could be reduced.

In addition to the average total-pressure recovery, the distribution of pressure recovery at the compressor face is also of importance to engine performance and such data are presented in figure 8 for the unperforated inlet and inlets P1 and P2. These data correspond to inlet operation at maximum pressure recovery at each Mach number. The results indicate that generally the largest variations in local total pressure recovery were obtained with the unperforated inlet and the perforations reduced considerably the magnitude of these variations. Variations in local total-pressure ratio as large as 0.08 were obtained with the unperforated inlet at Mach numbers of 2.7 and 2.9.

Boundary-Layer-Removal System

Mass-flow ratios for the centerbody flow-removal duct are shown in figure 9 for inlets P1 and P2. Measured data for the flow removed through the annulus are not available since that flow was returned directly to the free stream about the annulus. An estimate of the mass flow removed through the annulus on the basis of the difference between the flow entering the inlet and the sum of the exiting main duct and centerbody flows could not be made because attempts to calibrate the main duct using the total-pressure rake and the movable plug were unsuccessful. Furthermore, since the pressure differences across the perforations in the supersonic portion of the inlet were unknown, calculation of the flow removal through the annulus perforations in the cases of inlets P2 and P3 was not possible. However, with inlet P1 and for choked perforations the pressure difference across the annulus perforations should be approximately the same as that for the centerbody; in such a case, the quantity of flow removed through the annulus in relation to that removed through the centerbody would be in proportion to the ratio of the perforated area in the annulus to that in the centerbody. Consequently, for inlet P1, the total flow removed would be 2-1/2 times that for the centerbody alone as given in figure 9 and would amount to about 9 and 7 percent of the inlet flow for Mach numbers of 2.5 and 3.0, respectively.

For the calculation of the drag penalty resulting from the removal of boundary-layer air the pressure recovery, as well as the mass flow, of the air removed must be known. Figure 10 shows the total- and static-pressure ratios obtained in the centerbody flow-removal duct for inlets P1 and P2 for the mass-flow ratios indicated in figure 9.

Inlet Starting

It is desirable from the viewpoints of restarting an inlet and of determining the size of the centerbody to be able to predict the inlet-starting characteristics at all Mach numbers. To establish supersonic flow in the inlet it is necessary for the contraction ratio and pressure recovery to be compatible for starting. For inlets having all internal compression, the theoretical aerodynamic contraction ratio required for starting is based on the normal-shock pressure recovery occurring at the free-stream Mach number. For the present type of inlets the flow at the inlet entrance differs considerably from the free-stream flow because of the influence of the protruding centerbody, and consequently the starting contraction ratio must be based on the local flow conditions at the entrance station. However, these flow conditions at the instant of starting are not always known or easily determined, but for estimating purposes the Mach number on the surface of the centerbody can be used for determining a starting contraction ratio. Figure 11 shows starting contraction ratios calculated for the present inlets, and the geometric contraction ratios that occurred when the inlets started. It is apparent that there is a lack of agreement between the data and the values calculated for normal-shock pressure recovery at the cone surface Mach number, and that at all Mach numbers the inlets started at a lower contraction ratio, that is, with less centerbody extension. At $M_\infty = 3.0$, for example, the difference in contraction ratio between the data for the unperforated inlet and that calculated for normal-shock pressure recovery corresponds to a difference in centerbody extension of about 1 inch.

At the instant of starting the inlet takes in the entire mass flow captured by the leading edge of the annulus and therefore spillage cannot be used to explain the lack of agreement between the data and the calculated values. A probable explanation is that the shock structure at the instant of starting is not a single normal shock at the inlet entrance, but a more complicated structure which effectively provides a higher pressure recovery than that which would occur across the normal shock. In addition, the effects of mass flow removal ahead of the minimum area station must be considered whenever removal occurs, as for example in the case of inlet P2.

CONCLUSIONS

An experimental investigation of four circular internal-compression inlets having translatable centerbodies and designed for operation at Mach numbers up to 3.0 has indicated the following results in the Mach number range from 2.1 to 3.0, the limit of the investigation:

1. By the inclusion of the design requirement of a nearly constant area section in the throat region for all centerbody positions, the pressure recovery of the unperforated inlet throughout the range of Mach numbers was improved above that for a similar unperforated internal-compression inlet not having such a design requirement.

2. Perforations in the annulus and centerbody surfaces in and ahead of the throat region of the inlet improved considerably the total-pressure recovery at the compressor face; improvements in pressure-recovery ratio over the unperforated inlet ranging from 0.045 to 0.075 were obtained resulting in total-pressure recoveries varying from 0.87 to 0.75 between Mach numbers of 2.5 and 3.0.

3. A perforated area that was only in and downstream of the throat region was nearly as effective in improving pressure recovery as a perforated area which in addition extended both upstream and downstream from the throat region; improvements in pressure recovery of up to 72 percent of those obtained with the latter configuration were obtained with the former.

4. Perforations reduced the flow distortion at the compressor face.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., Aug. 21, 1959

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1. Mossman, Emmet A., and Pfyl, Frank A.: An Experimental Investigation at Mach Numbers From 2.1 to 3.0 of Circular Internal-Contraction Inlets With Translating Centerbodies. NACA RM A56G06, 1956.

2. Pfyl, Frank A., and Watson, Earl C.: An Experimental Investigation of Circular Internal-Compression Inlets With Translating Centerbodies Employing Boundary-Layer Removal at Mach Numbers from 0.85 to 3.50. NASA MEMO 2-19-59A, 1959.

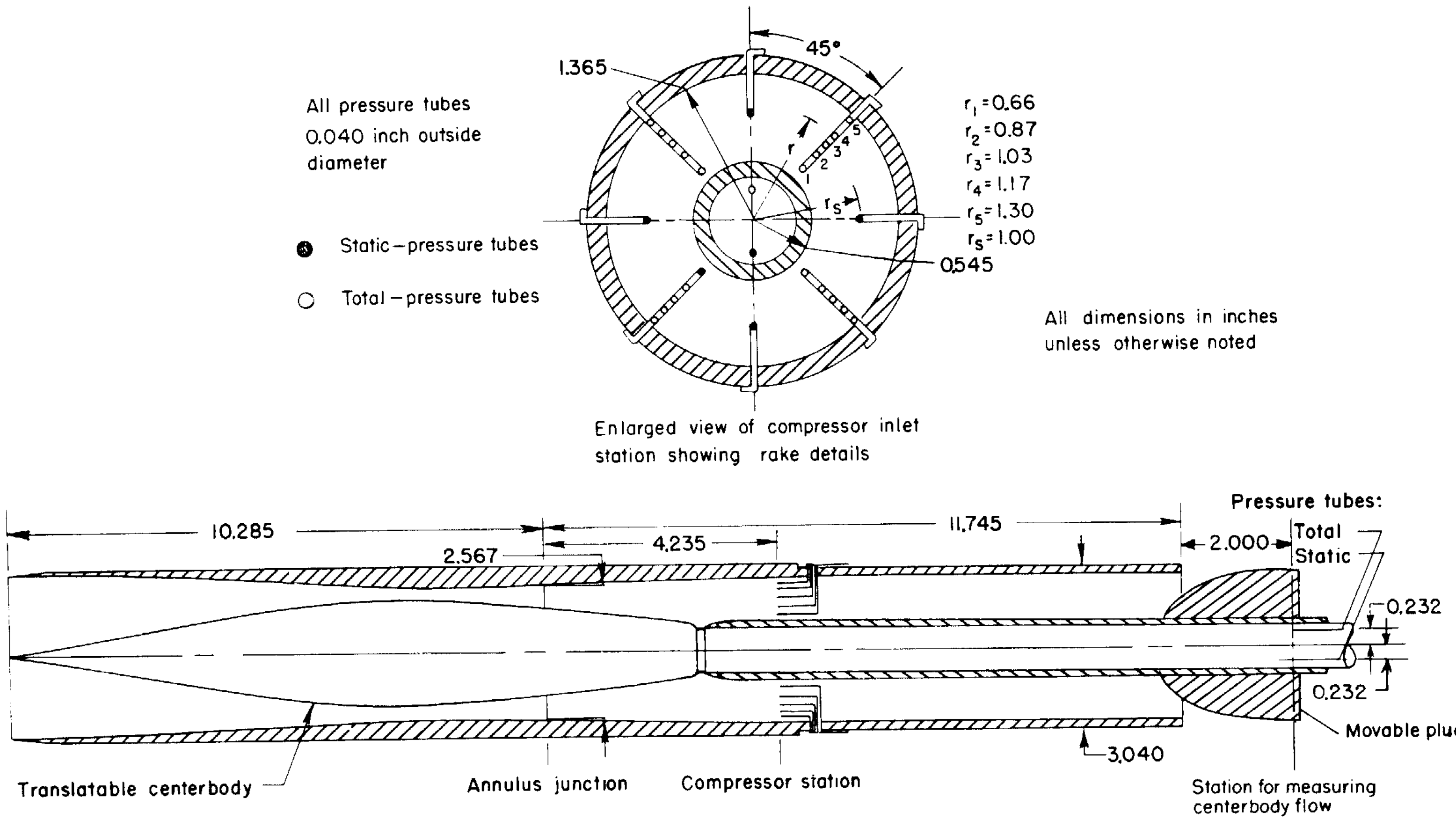
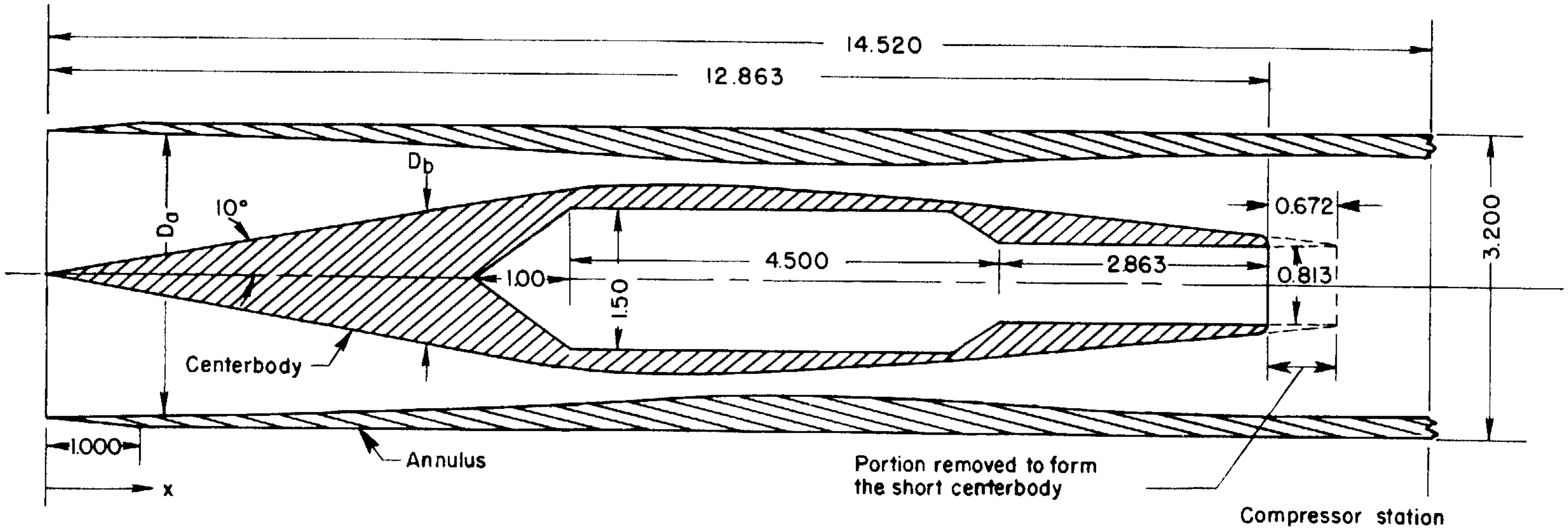


Figure 1.- Typical details of the test models.



Annulus					
x	D_a	x	D_a	x	D_a
0.0	3.025	5.445	2.670	10.891	2.610
.605	3.010	6.050	2.620	11.495	2.661
1.210	2.993	6.655	2.567	12.100	2.696
1.815	2.963	7.260	2.512	12.705	2.730
2.420	2.918	7.865	2.456	14.520	2.730
3.025	2.871	8.470	2.456		
3.630	2.821	9.075	2.465		
4.235	2.772	9.680	2.518		
4.840	2.721	10.285	2.567		

	Centerbody			
	x	D_b	x	D_b
*	0	0	8.705	1.790
*	↓	↓	9.310	1.698
*	4.470	1.571	9.905	1.600
	5.075	1.764	10.510	1.497
	5.680	1.889	11.115	1.386
	6.285	1.960	11.720	1.266
	6.890	1.984	12.325	1.132
	7.495	1.960	12.700	1.040
	8.100	1.877	12.863	.813

* D_b determined as the local dia. of a 20° cone

All dimensions in inches unless otherwise noted

Figure 2.- Details of the annulus and centerbody.

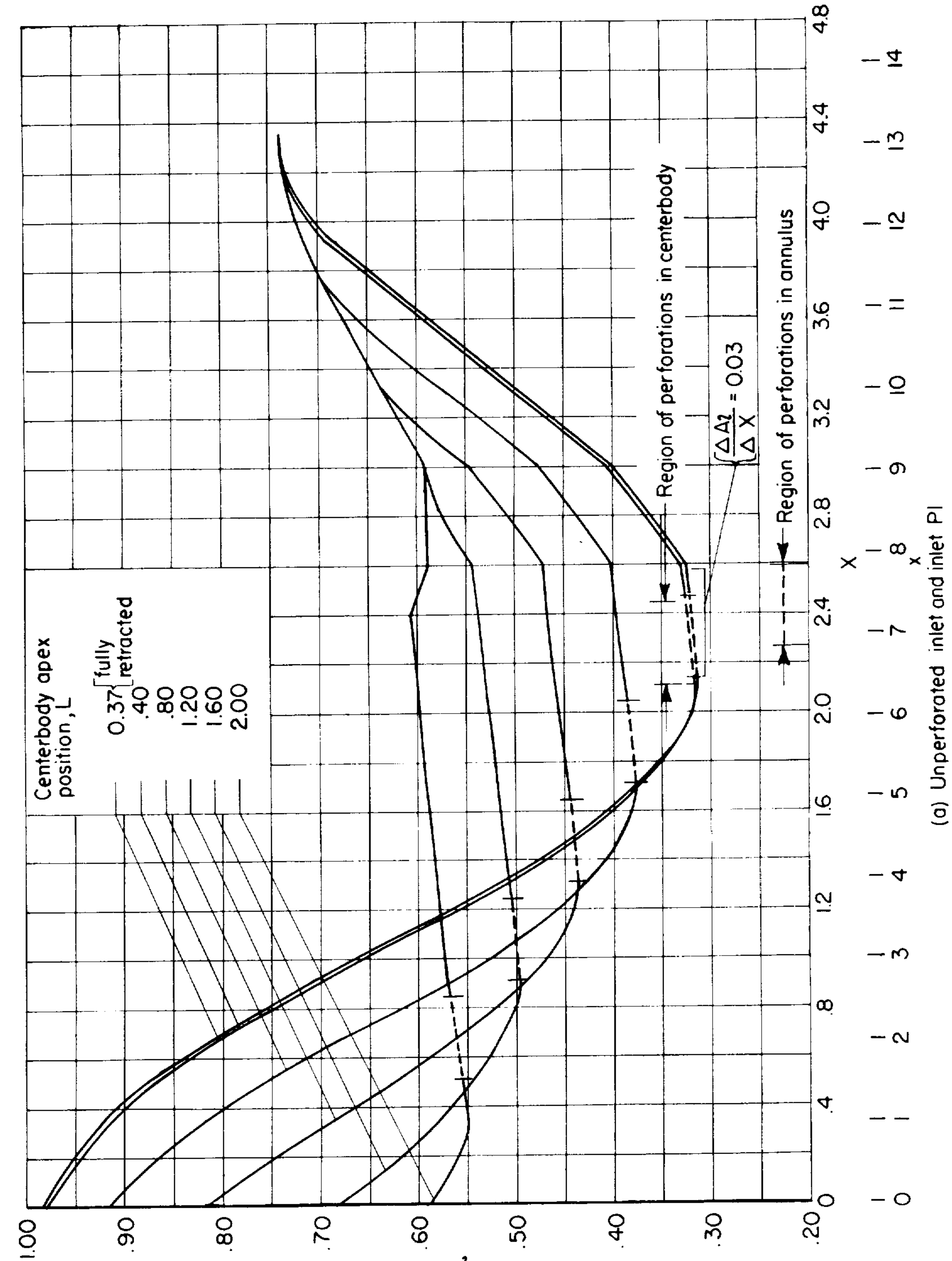
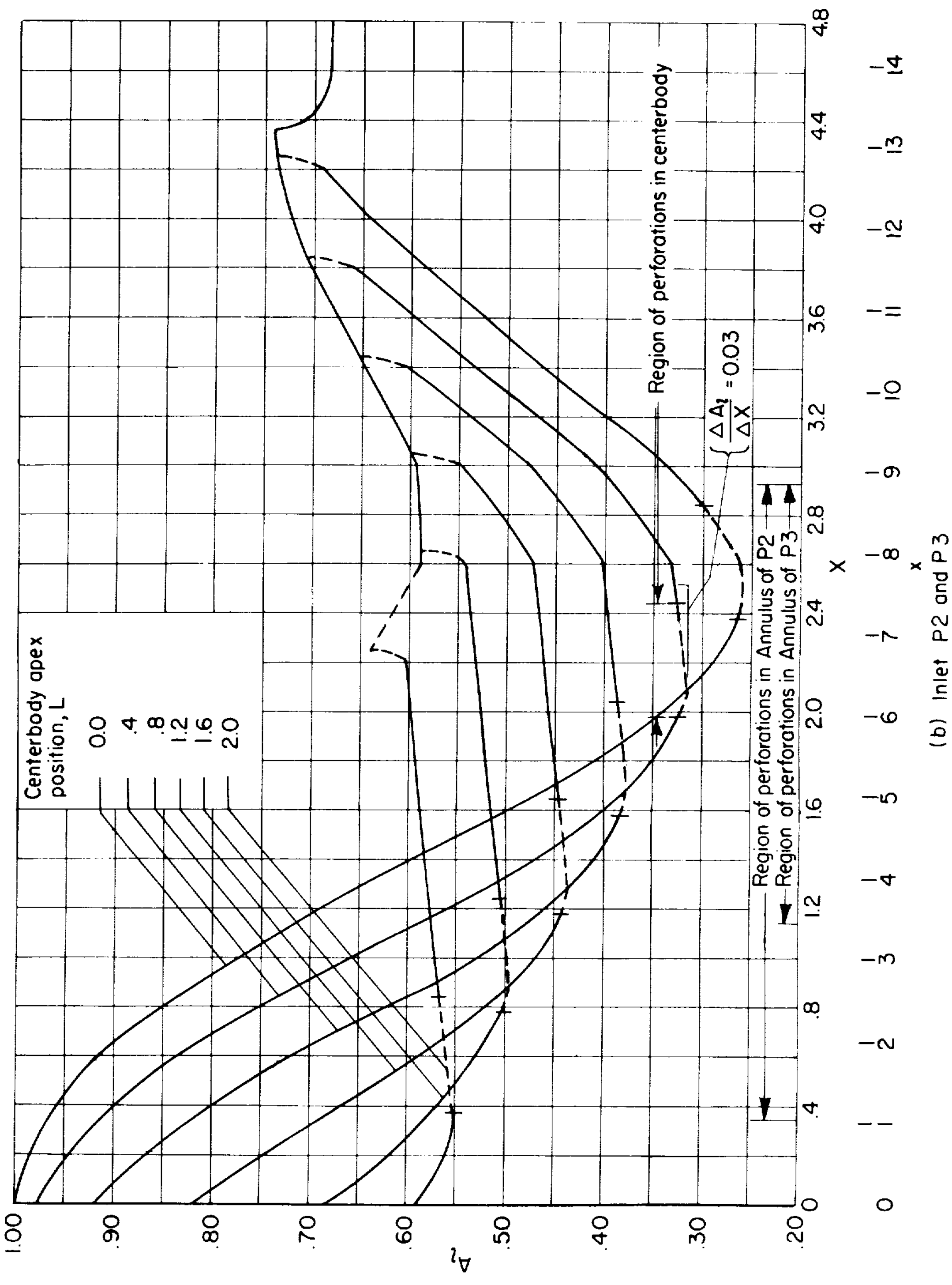


Figure 3.- Longitudinal distribution of area ratio.



(b) Inlet P2 and P3

Figure 3.- Concluded.

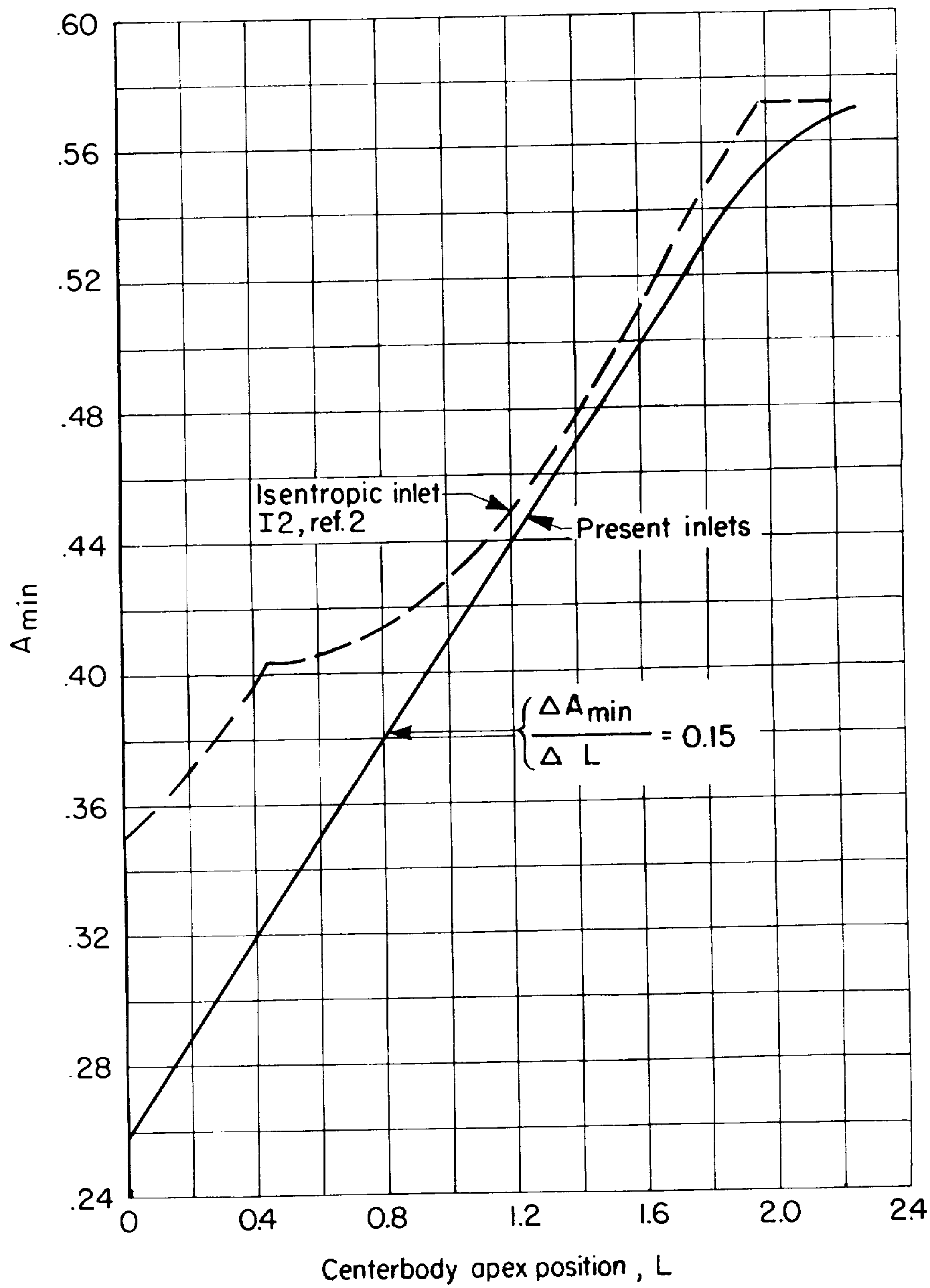
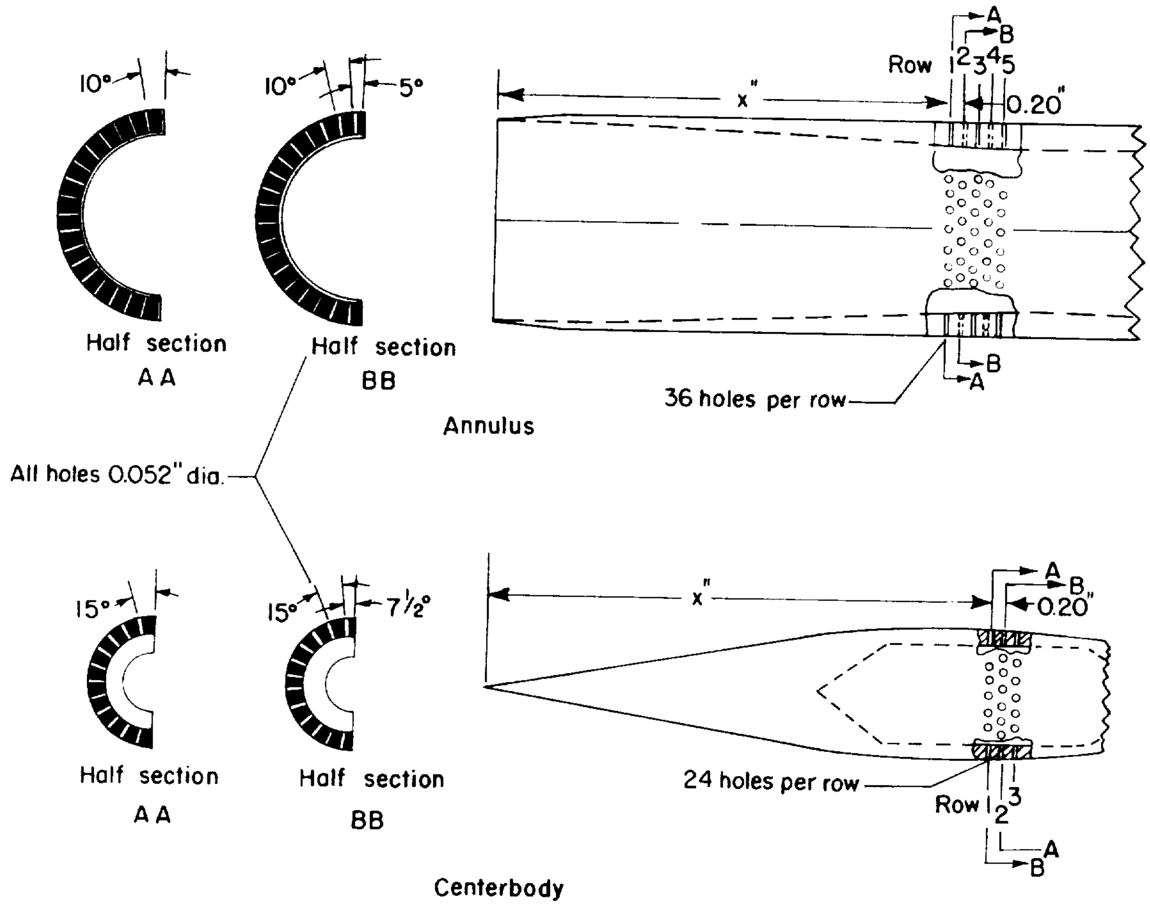


Figure 4.- The variation of contraction ratio with centerbody apex position.



Perforation Arrangements

Designation	x Distance to first row of holes		No. of rows spaced @ 0.20"	
	Annulus	Center-body	Annulus	Center-body
P1	6.85	7.60	6	6
P2	1.05	7.20	40	8
P3	3.45	7.20	20	8

Figure 5.- Details of the perforation arrangements.

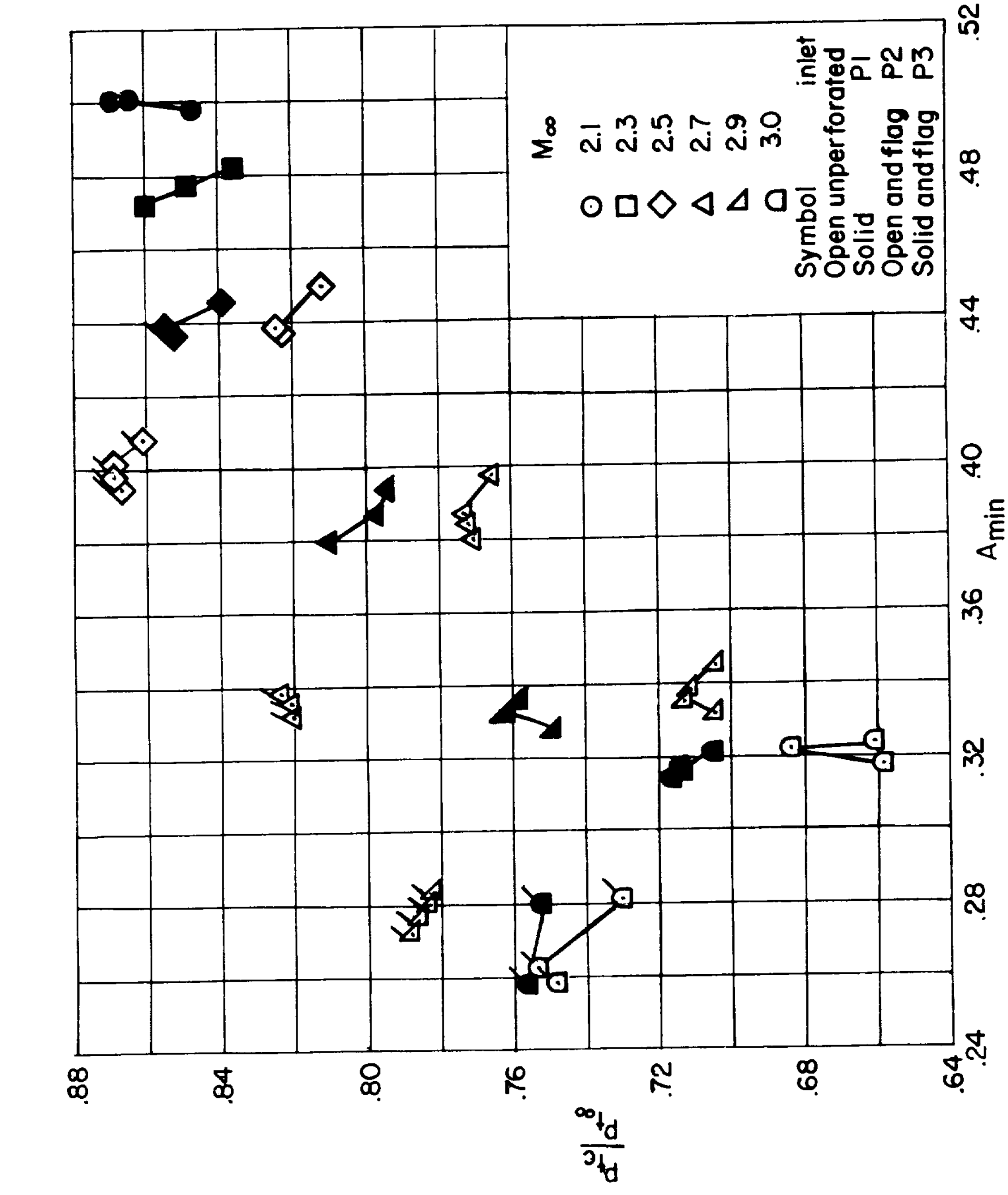


Figure 6.- The variation of total-pressure ratio with contraction ratio.

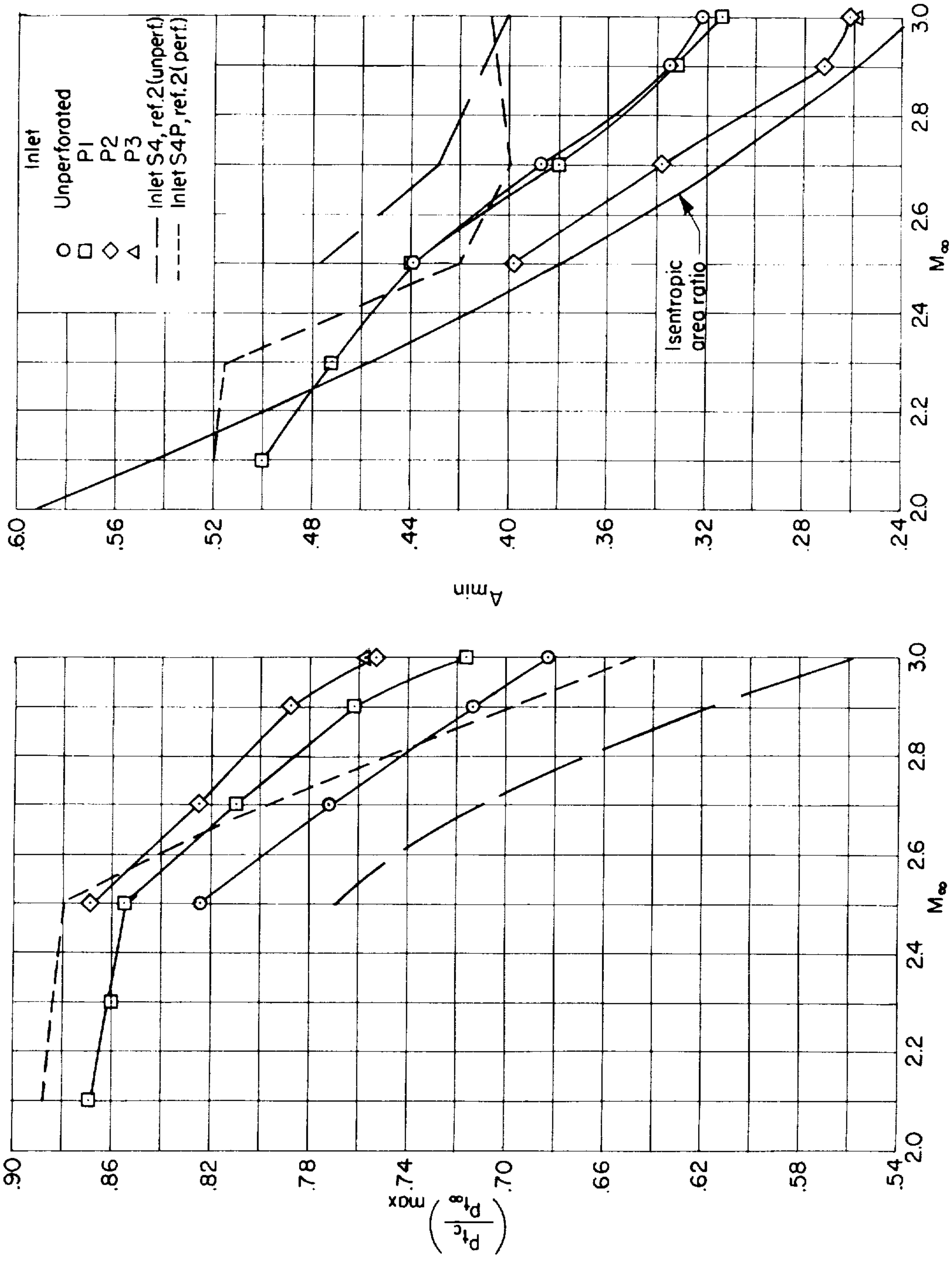
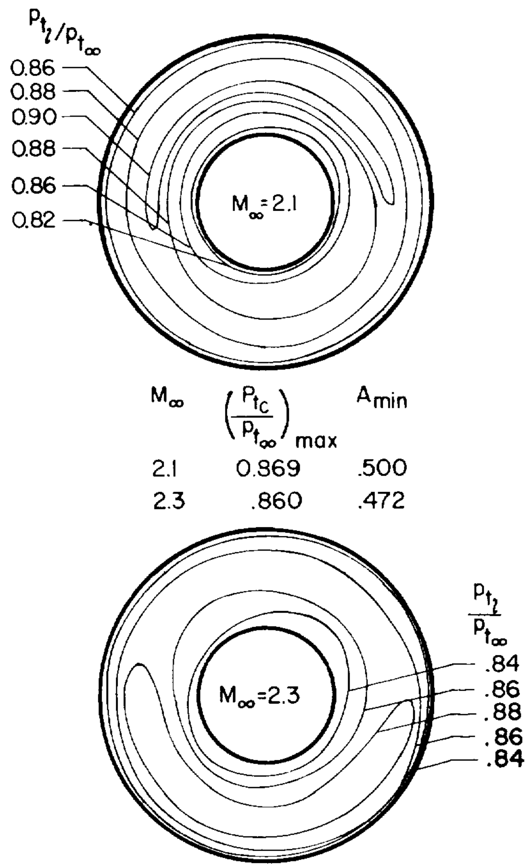
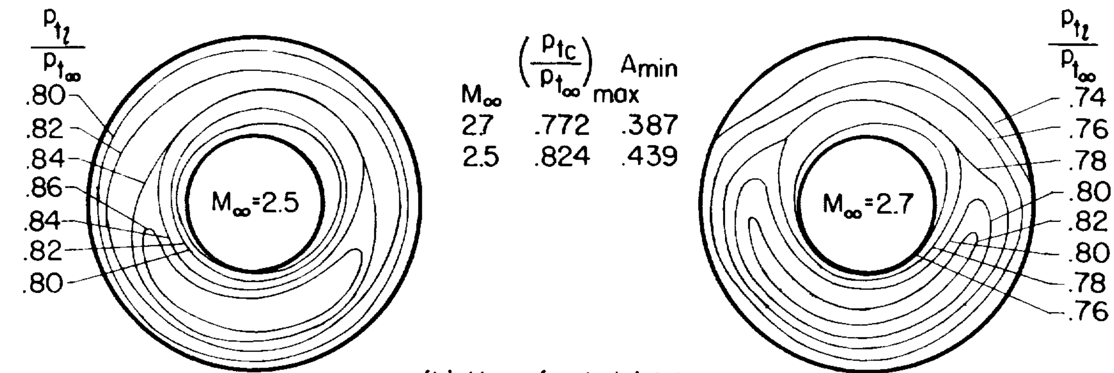


Figure 7.- The variation of maximum total-pressure ratio and contraction ratio with free-stream Mach number.

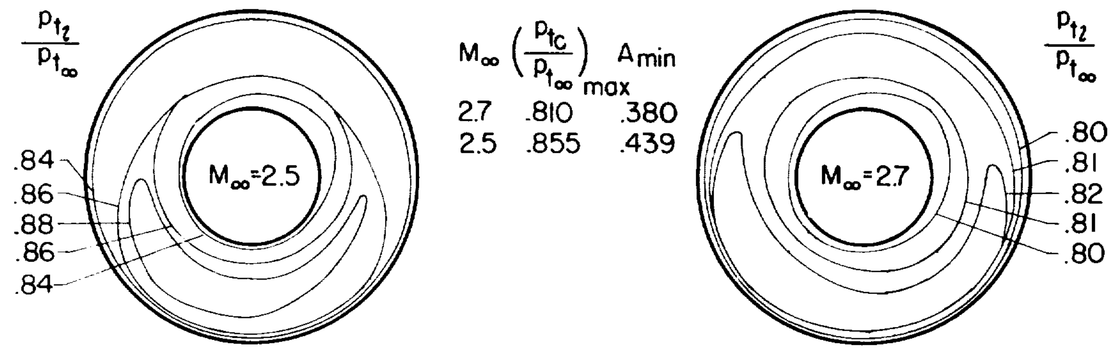


(a) Inlet PI
$M_\infty = 2.1$ and 2.3

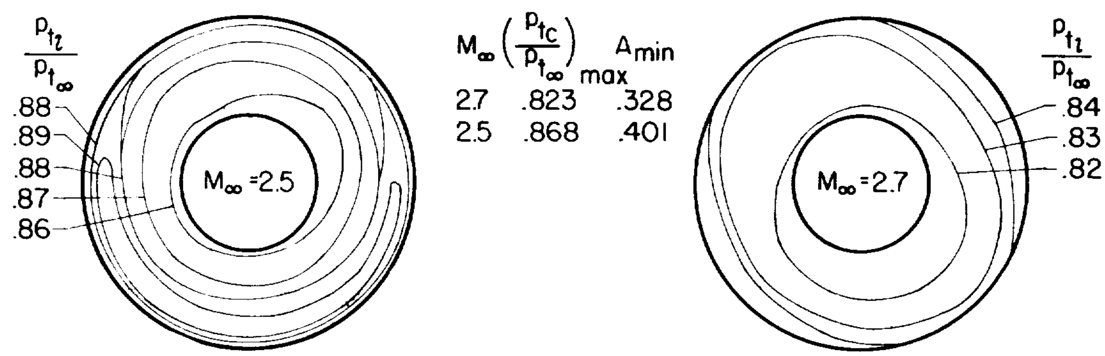
Figure 8.- Contours of total-pressure ratio for maximum pressure-recovery conditions.



(b) Unperforated inlet
M_∞ 2.5 and 2.7

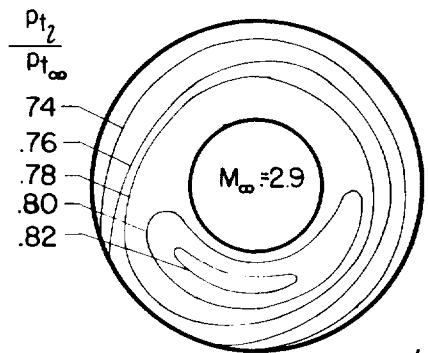


(c) Inlet P1
M_∞ 2.5 and 2.7

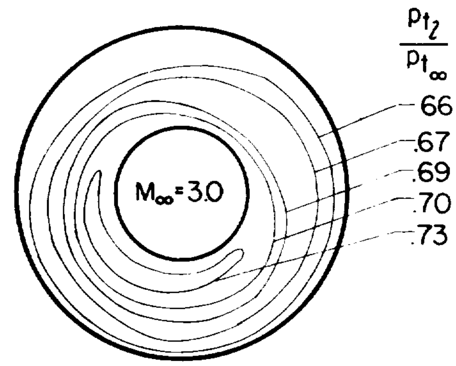


(d) Inlet P2
M_∞= 2.5 and 2.7

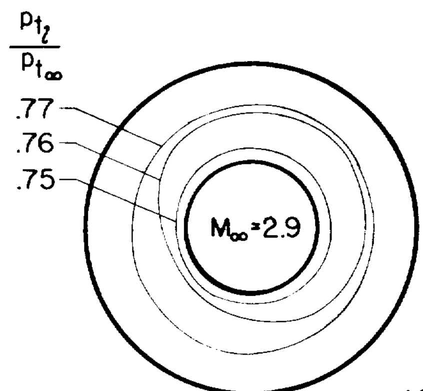
Figure 8.- Continued.



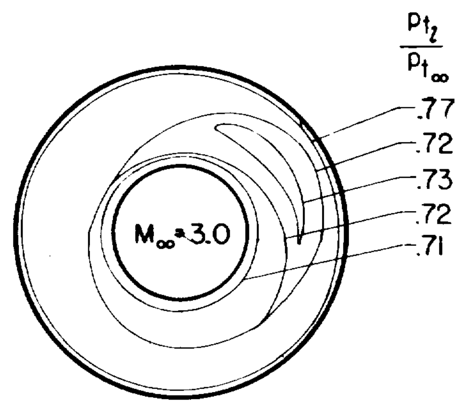
M_∞	$\left(\frac{p_{t_c}}{p_{t_\infty}}\right)_{max}$	A_{min}
3.0	.683	.321
2.9	.713	.335



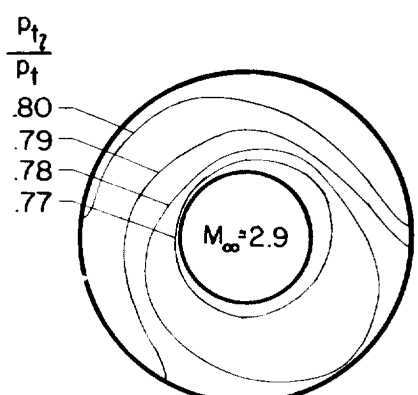
(e) Unperforated inlet
M_∞ 2.9 and 3.0



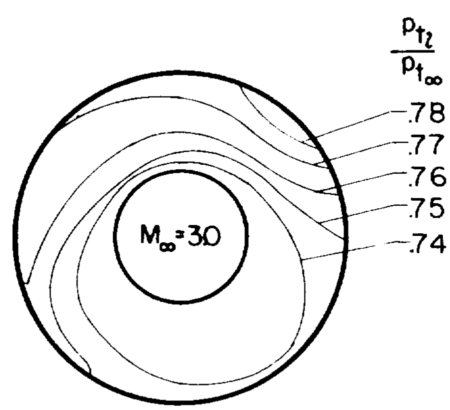
M_∞	$\left(\frac{p_{t_c}}{p_{t_\infty}}\right)_{max}$	A_{min}
3.0	.716	.314
2.9	.762	.332



(f) Inlet P1,
M_∞ 2.9 and 3.0



M_∞	$\left(\frac{p_{t_c}}{p_{t_\infty}}\right)_{max}$	A_{min}
3.0	.753	.262
2.9	.788	.272



(g) Inlet P2
M_∞= 2.9 and 3.0

Figure 8.- Concluded.

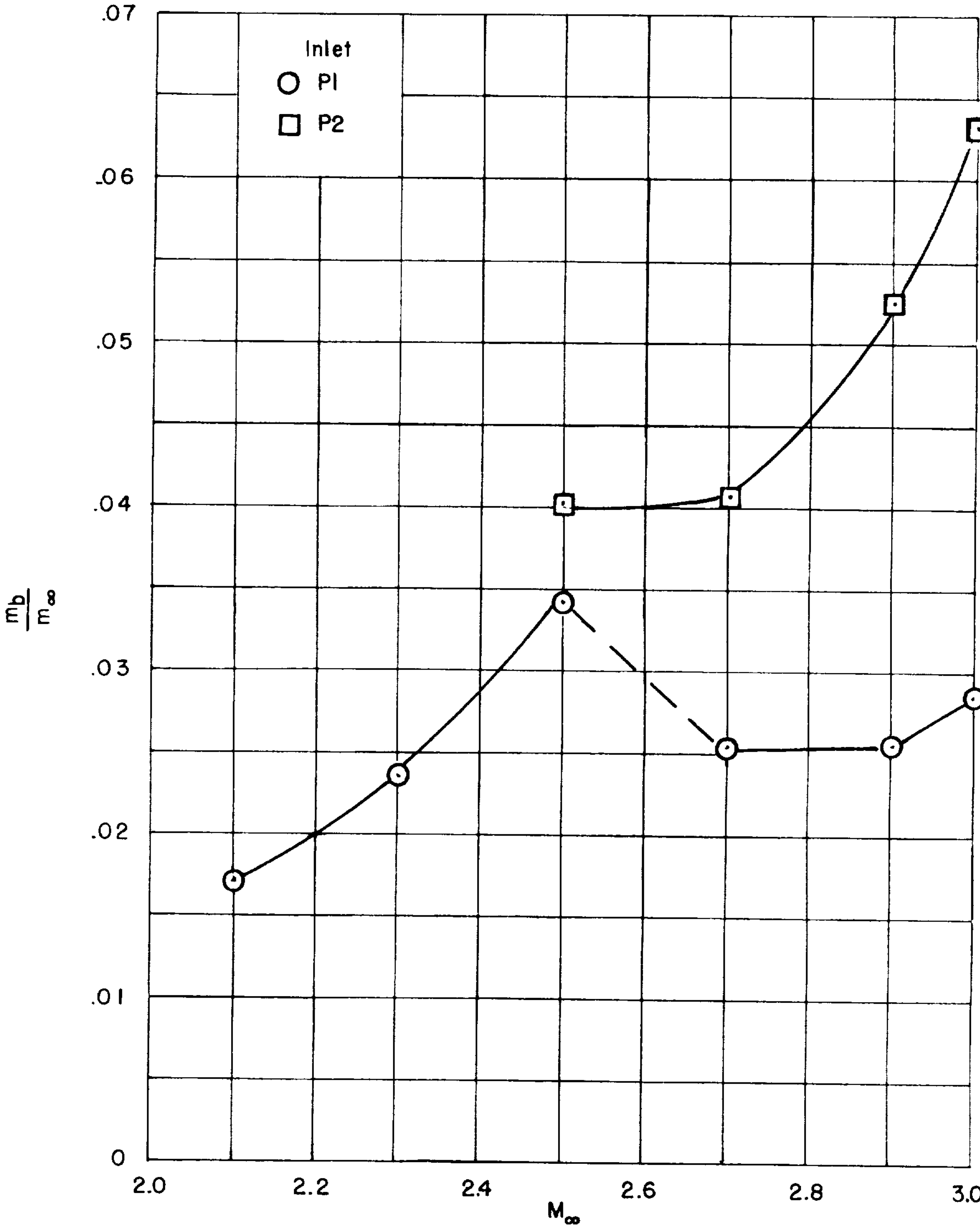


Figure 9.- Centerbody mass-flow ratios for conditions of maximum pressure recovery in the inlet.

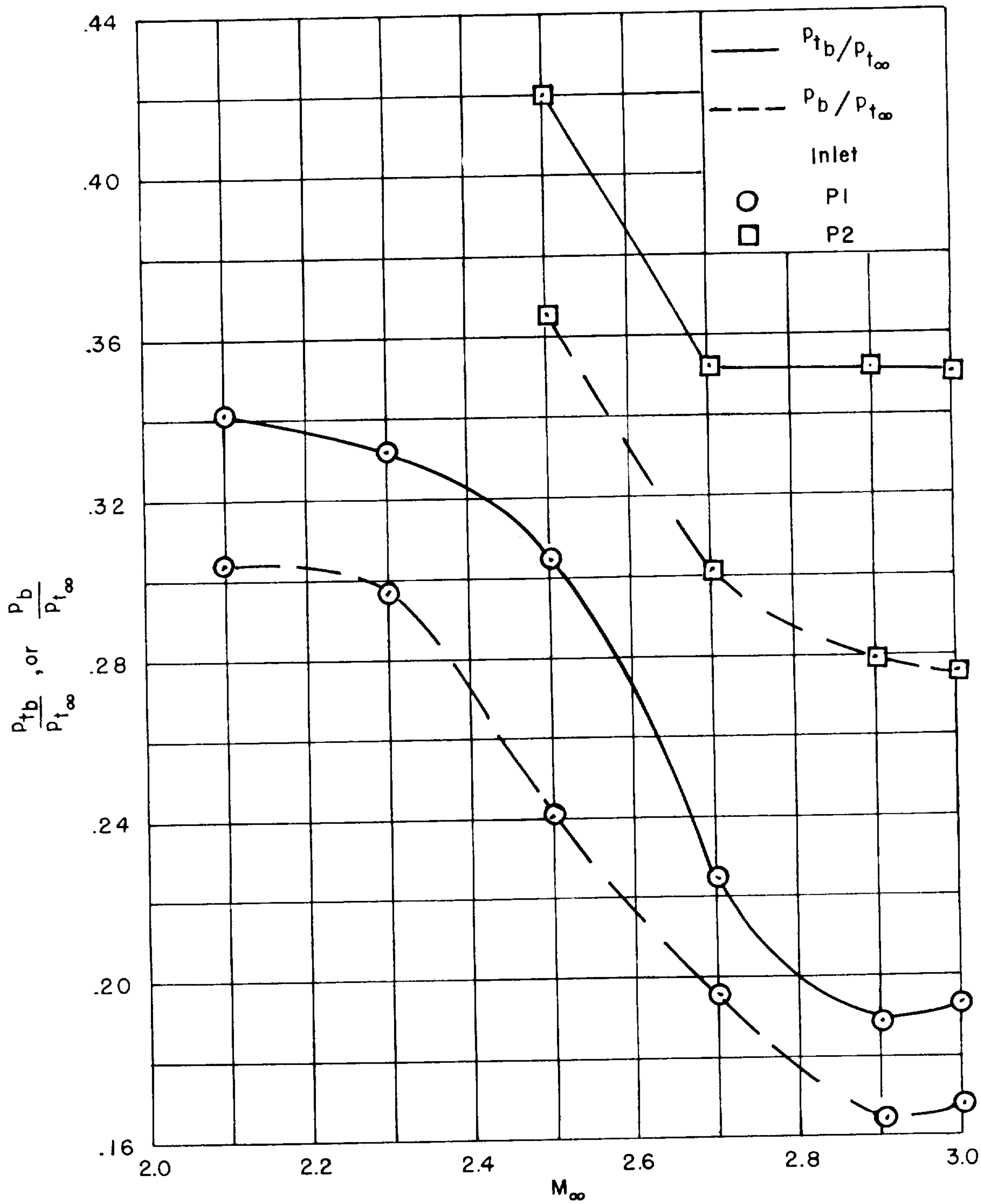


Figure 10.- Pressure recovery in the centerbody flow-removal duct for conditions of maximum pressure recovery in the inlet.

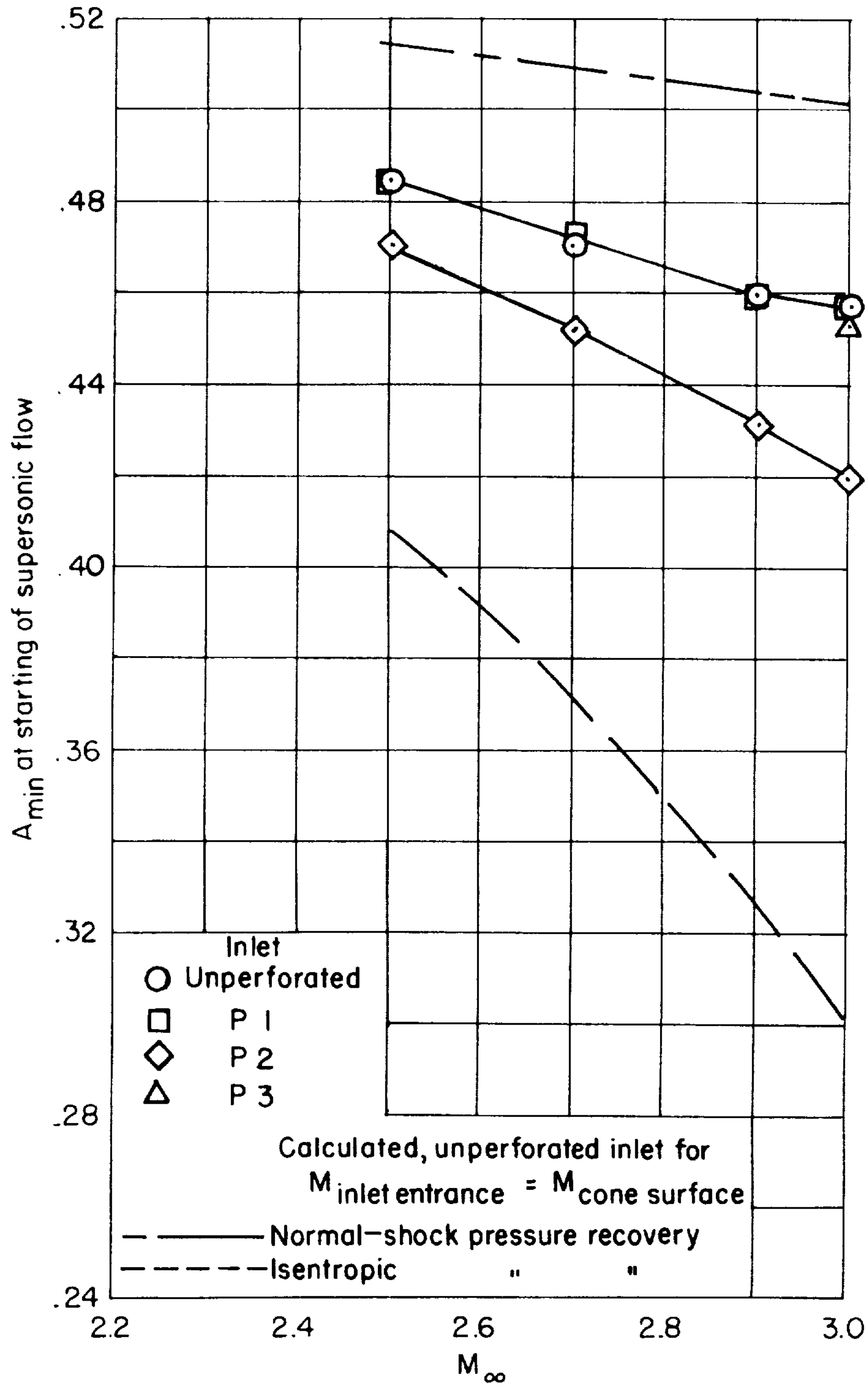


Figure 11.- The variation of the area ratio at the starting of supersonic flow with free-stream Mach number.

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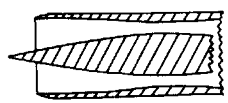
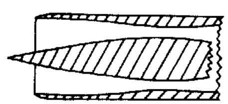
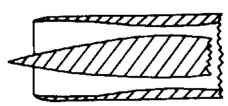
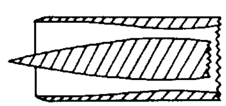
NOTES: (1) Reynolds number is based on the diameter of a circle with the same area as that of the capture area of the inlet.

(2) The symbol * denotes the occurrence of buzz.

Report and facility	Description			Test parameters				Test data				Performance		Remarks
	Configuration	Number of oblique shocks	Type of boundary-layer control	Free-stream Mach number	Reynolds number $\times 10^{-6}$	Angle of attack, deg	Angle of yaw, deg	Drag	Inlet-flow profile	Discharge-flow profile	Flow picture	Maximum total-pressure recovery	Mass-flow ratio	
CONFID. NASA TM X-156 Ames 8- by 8-inch wind tunnel		Multi-ple	Perfo-rations in annulus and center-body	2.1 to 3.0	3.6 to 5.1	0	0	None	None	At com-pressor station	None	0.87 at M = 2.5 0.75 at M = 3.0	1.0 for M > 2.5	Test made with various perforations in annulus and centerbody. Additional data presented include centerbody flow removal and inlet starting characteristics.
CONFID. NASA TM X-156 Ames 8- by 8-inch wind tunnel		Multi-ple	Perfo-rations in annulus and center-body	2.1 to 3.0	3.6 to 5.1	0	0	None	None	At com-pressor station	None	0.87 at M = 2.5 0.75 at M = 3.0	1.0 for M > 2.5	Test made with various perforations in annulus and centerbody. Additional data presented include centerbody flow removal and inlet starting characteristics.
CONFID. NASA TM X-156 Ames 8- by 8-inch wind tunnel		Multi-ple	Perfo-rations in annulus and center-body	2.1 to 3.0	3.6 to 5.1	0	0	None	None	At com-pressor station	None	0.87 at M = 2.5 0.75 at M = 3.0	1.0 for M > 2.5	Test made with various perforations in annulus and centerbody. Additional data presented include centerbody flow removal and inlet starting characteristics.
CONFID. NASA TM X-156 Ames 8- by 8-inch wind tunnel		Multi-ple	Perfo-rations in annulus and center-body	2.1 to 3.0	3.6 to 5.1	0	0	None	None	At com-pressor station	None	0.87 at M = 2.5 0.75 at M = 3.0	1.0 for M > 2.5	Test made with various perforations in annulus and centerbody. Additional data presented include centerbody flow removal and inlet starting characteristics.

Bibliography

These strips are provided for the convenience of the reader and can be removed from this report to compile a bibliography of NASA inlet reports. This page is being added only to inlet reports and is on a trial basis.

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