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RESEARCH MEMORANDUM

A STUDY OF A SYMMETRICAL, CIRCULAR, INTERNAL COMPRESSION INLET

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NATIONAL ADVISORY COMMITTEE
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A STUDY OF A SYMMETRICAL, CIRCULAR, INTERNAL COMPRESSION INLET

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SUMMARY

A preliminary experimental study of symmetrical, circular, internal compression inlets has shown that they attain pressure recovery equal to that measured by conical nose inlets at Mach numbers up to about 2.3. This pressure recovery was obtained with configurations having essentially zero pressure drag of the external surfaces.

INTRODUCTION

Recently, an experimental investigation has been made at Mach numbers up to 2.5 of an inlet which shows promise. The purpose of this paper is to present an interim report describing the development of the inlet and the progress that has been made to date.

SYMBOLS

M	Mach number
m	mass flow, lb-sec/ft
P_t	total pressure, lb/sq ft
A	area, sq ft
p	static pressure, lb/sq ft
X	longitudinal distance, ft
D	diameter, ft

Subscripts:

∞	free stream
1	inlet
max	maximum
min	minimum
c	compressor
t	total
0	entrance

DISCUSSION

Up to the present time, external compression inlets have produced relatively efficient supersonic compression of the induction air, but the wave drag of the external cowls has been high. On a typical airplane this inlet drag is from 10 percent to 20 percent of the total airplane drag at Mach numbers above 2.0. This cowl drag is mainly a function of the initial lip angle. It has been found experimentally that the best overall performance of conical inlets occurs when the lip internal surfaces are nearly alined with the flow direction immediately behind the conical shock wave (fig. 1). This figure shows also the flow angularity behind a 30° cone and the angle of shock detachment. If 3° is added for lip thickness, the external lip angle approaches even closer to the angle of shock detachment. These considerations indicate that the drag of external compression inlets will be large and will probably increase with Mach number because the lip angles must increase.

If the lip angles could be kept low, the pressure drag could be markedly reduced. The internal compression inlet shown in figure 2 is designed for use with a typical jet engine. The resulting external surfaces have very low angularity, approximately 1°; consequently, the wave drag would be negligible. The relative dimensions of the nacelle shown at the bottom of the figure are for a $M = 2.0$ design. As the design Mach number increases, both the inlet and exit diameters increase relative to the engine envelope diameter, and the nacelle will approach even closer to a straight tube. A symmetrical circular configuration was selected which allows the minimum area of the internal duct to be varied by translation of the center body. The photographs at the top of figure 2 show the cone extended for starting, an off-design or transitional position, and the design position with the cone fully retracted. The movement of the center body should be programmed with the flight Mach number. In addition, an automatic control is necessary which can sense the position of the terminal shock wave and actuate the center body to maintain the shock position near the minimum area. Control mechanisms for supersonic inlets which might be adapted to this internal compression inlet are described in reference 1. The angularities of the compression surfaces are low - 8° to 10° for the cone and 1.5° to 2.0° for the lip annulus. These angles are kept low to avoid shock-induced separation during the internal compression process by limiting the pressure rise in an incident wave to less than the value which has been found to cause separation. It would be desirable to reduce the length of the internal ducting. However, in the present design it has not been found necessary to include long stabilizing sections rearward of the minimum-area station. Consequently, the present internal compression inlet is slightly shorter than equivalent conical inlets. The internal compression inlet has been tested only at 0° angle of attack.

Use of the internal compression inlet will result in a net gain only if the pressure recovery is sufficiently high. The conical inlet will be used arbitrarily in the following discussion as a standard for comparison. The maximum pressure recovery of conical inlets is shown in figure 3 for the Mach number range from 1.8 to 2.5. A solid-line curve representing the present state of the art is shown in the figure and will be used for comparison purposes. The experimental pressure recovery of the internal compression inlet as a function of Mach number for four internal shapes is shown in figure 4. Comparison of the data with the best external conical-shock inlets shows that the pressure recovery is about the same over a range of Mach numbers to 2.3. For three of the inlets the compression surfaces were generated by straight lines, the ratio of the minimum area to the inlet area being varied. The fourth case, which gave the highest pressure recovery at Mach numbers greater than 2.1, has a curved center body and a curved lip annulus. It should be noted that the contraction ratio for this inlet corresponds to that for inlets with straight internal elements which gave low pressure recovery for the same Mach number range.

Some idea of why the inlet with the curved center body and curved lip annulus gave higher pressure recovery than the other internal compression inlets was gained by mapping the internal flow field by using the method of characteristics. Figure 5 shows the shock-wave pattern and the computed pressure distribution on the center body and lip annulus for one of the inlets with straight internal elements. The shock waves from the center body and annulus initially had about the same strength. However, the pressure rise at the first reflection of the shock wave from the annulus on the center body was much larger than it was for the first reflection of the center-body shock on the annulus. The pressure gradients behind the shock intersections also were dissimilar. In an effort to equalize both the pressure ratio across each shock-boundary intersection and the pressure gradients behind the intersections, curved compression elements were employed; and as noted previously, the modification was moderately successful. It is thought that further improvements are possible, especially at higher Mach numbers, by shaping the internal surfaces to follow contours derived by the characteristics method.

Of importance to the inlet designer is the off-design performance. On the left-hand side of figure 6 the take-off performance of the internal compression inlet is shown. The take-off characteristics are similar to those for the conventional conical inlet. The curves on the right-hand side of this figure illustrate the "matching" characteristics of the inlet and engine combination. The ordinate of this curve is the ratio of the capture (or entrance) area to the streamtube area supplied by the inlet or required by the engine. The air handling qualities of the inlet are shown by the solid-line curve. The internal compression inlet is assumed to operate as a normal-shock inlet at Mach numbers up to 1.6. Above a Mach number of about 1.8, the inlet operates with the streamtube area equal to the inlet area and has no spillage drag.

The engine air requirements (in terms of the streamtube-area ratio) are shown by the dashed-line curve in figure 6. For this particular engine at M above 1.2, a maximum of 3 percent of the inlet air would have to be bypassed for maximum efficiency. Below a Mach number of 1.2, either the rotational speed of the engine could be reduced slightly or some loss in pressure recovery would be incurred. Many other matching programs could be devised, but figure 6 indicates that the problems should be no more severe with the internal compression inlet than they are with other types of supersonic inlet-engine combinations.

CONCLUDING REMARKS

A preliminary experimental study of symmetrical, circular, internal compression inlets has shown that they attain pressure recovery equal to that measured by conical nose inlets at Mach numbers up to about 2.3. This pressure recovery was obtained with configurations having essentially zero pressure drag of the external surfaces.

Ames Aeronautical Laboratory
National Advisory Committee for Aeronautics
Moffett Field, Calif., Nov. 2, 1955

REFERENCE

1. Wilcox, Fred, and Perchonok, Eugene: Aerodynamic Control of Supersonic Inlets for Optimum Performance. NACA RM E55L14, 1956.

LIP ANGLES OF CONICAL INLETS

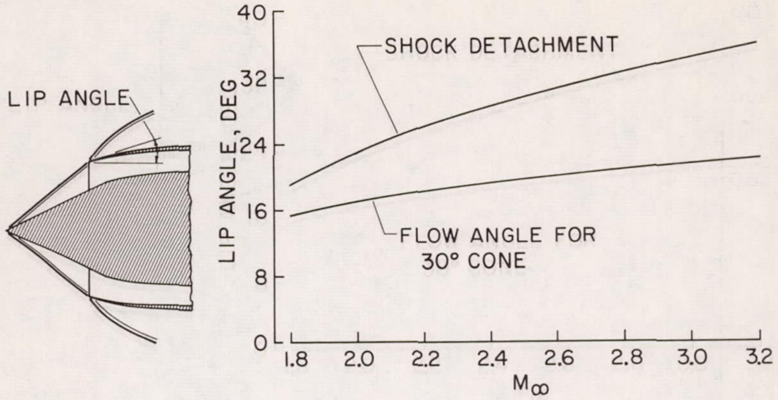

Figure 1

INTERNAL COMPRESSION INLET

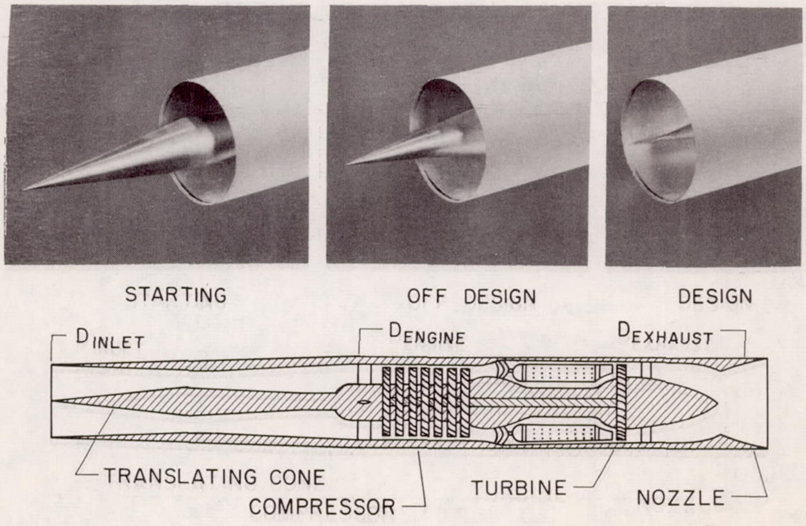
STARTING OFF DESIGN DESIGN

Figure 2

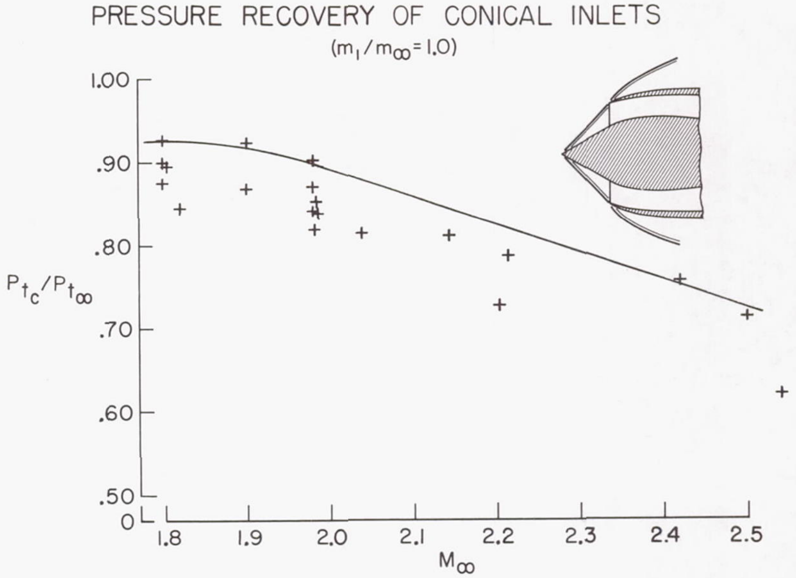

Figure 3

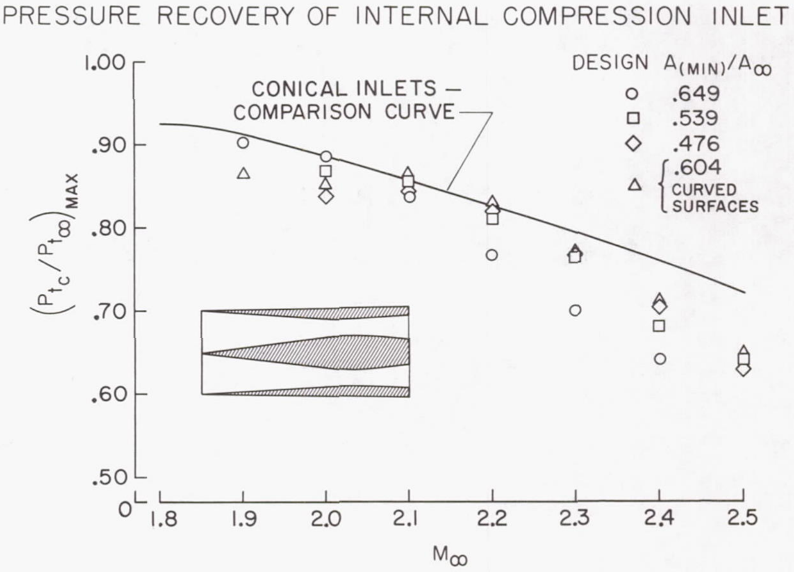

Figure 4

THEORETICAL PRESSURE DISTRIBUTION ON COMPRESSION SURFACES

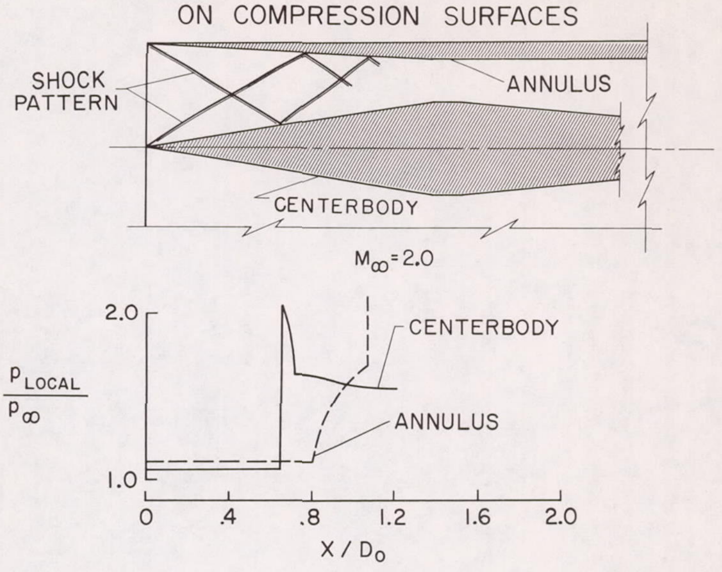

Figure 5

PERFORMANCE OF THE INTERNAL COMPRESSION INLET AT OFF-DESIGN CONDITIONS

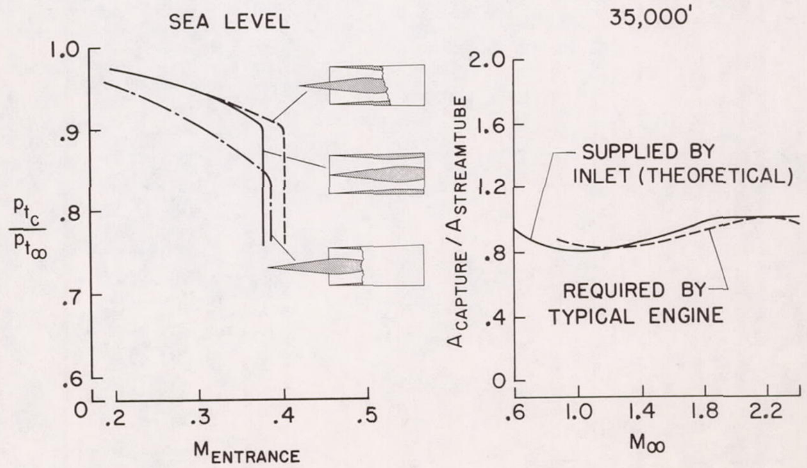

Figure 6