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**CALIBRATION OF MACH 2 NOZZLE BLOCKS
WITH 6% PERFORATED-WALL TEST SECTION**

by

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The speed range of the Sandia 12 x 12-inch transonic wind tunnel was recently increased from Mach 1.35 to Mach 2.0 by the installation of interchangeable fixed Mach 2 nozzle blocks. The installed blocks are shown in Figure 1.

The centerline longitudinal Mach number distribution was determined by the static pipe method. The static pipe was attached to the stagnation instrumentation strut, extended through the nozzle throat, and was anchored, downstream, to the pitching strut pod as shown in Figures 1 and 2. The static pipe has static pressure ports at 2-inch intervals between tunnel Station 0 and 8 inches upstream, and at 1-inch intervals downstream of Station 0.

Two types of test section side walls, metal and plastic, are used in the tunnel. Both types are 6% perforated with 60° inclined holes. The walls have the same hole patterns but differ in that the plastic walls have larger diameter holes with greater spacing between hole centers. The porosity of all walls increases from 0.0% at Station 0.0 to 6.0% at Station 10.0. The top and bottom walls are of the metal type and are hinged upstream to permit varying the wall angle. The metal walls are shown as top and bottom walls in Figure 2. A plastic side-wall is shown in Figure 3.

A 48 port General Design Scanivalve, shown in Figure 4, was used to collect the pressure data from the static pipe.

Stagnation pressure level and test section geometry, ejector flap opening and wall angle were studied to determine settings for optimum flow for both the metal and plastic side walls. Figure 5 presents the results of the stagnation pressure level study. Approximately 25 psia was required to establish flow at approximately Mach 1.9. Further increase in stagnation

pressure produced a minor increase in Mach number. It is of interest to note that there is a decrease in Mach number between tunnel Stations 8 and 10 where the full test section porosity of 6.0% was reached.

The effects of opening the ejector flaps are shown in Figure 6. Run No. 110 was with flaps set to minimum opening. Run Nos. 109 and 106 were with flaps set one-half and full open, respectively. There was a minor increase in Mach number with flaps set one-half open. Further opening of the flaps produced no appreciable change in Mach number.

The effects of wall angle are shown in Figure 7. Converging the top and bottom walls 15 minutes produced a minor reduction in Mach number while diverging the walls 15 minutes produced a minor increase in Mach number.

This paper includes a minimum of the data taken. Evaluation of all data resulted in the conclusion that optimum tunnel settings were a stagnation level of 25 psia, flaps closed to minimum open area and test section walls parallel. A comparison of the centerline longitudinal Mach number distribution for metal and plastic sidewalls is shown in Figure 8. Two aerodynamic test sections were defined: the 'standard' test section (tunnel Stations 18 to 27) and the 'long' test section (tunnel Stations 16 to 32). The average centerline Mach numbers for the 'standard' test section were $\bar{M}_{x_S} = 1.904$ for the metal sidewalls and $\bar{M}_{x_S} = 1.922$ for the plastic sidewalls. The average centerline Mach numbers for the 'long' test section were $\bar{M}_{x_L} = 1.906$ for the metal sidewalls and $\bar{M}_{x_L} = 1.924$ for the plastic sidewalls. The average maximum Mach number deviation, $\left(\frac{\Delta M}{\bar{M}_x}\right)$, was: in the 'standard' test section 1.1% for the metal sidewalls and 0.5% for the plastic sidewalls; in the 'long' test section 1.2% for both metal and plastic sidewalls. The average Mach number gradients for both test sections, $\left(\frac{\Delta M}{\Delta X}\right)_{AV}$, were generally positive (increasing Mach number with length) and were not greater than +0.004 per inch. The plastic sidewalls produced the least gradient, +0.002, in the 'standard' test section and zero gradient in the 'long' test section.

The vertical Mach number distribution, at three tunnel stations, was determined for the plastic sidewalls. Test runs were made utilizing the tunnel settings which produced best longitudinal Mach number distribution.

The tunnel stations selected were Stations 16, 22, and 30. These tunnel stations correspond, respectively, to the start of the 'long' aerodynamic test section, the center of the 'standard' aerodynamic test section, and 2 inches in front of the end of the 'long' aerodynamic test section.

The static pressure probe shown in Figure 9 was used to traverse the test section vertically. Interchangeable sections of the probe support tube were used to locate the static orifices of the probe at tunnel Stations 16, 22, and 30. A transducer was mounted in the upstream end of the probe support to minimize lag time.

The test section was traversed, using the parallel motion gears in the pitching strut, from a point approximately 0.4 inch above the tunnel centerline to within approximately 0.5 inch of the tunnel floor. Traverse rate of the probe was approximately 0.5 inch per second. This slow traverse rate combined with the rapid response of the probe to pressure variations, ensured negligible errors in pressure measurements.

Tunnel stagnation pressure was measured using a pitot tube in the settling chamber. It is assumed that the stagnation pressure in the test section is equal to the stagnation pressure measured in the settling chamber. It is also assumed that the stagnation pressure is constant throughout the test section.

Plenum pressure was measured at a static port in the plenum chamber. Plenum pressure and stagnation pressure were used, with the plenum Mach number relationship determined in the longitudinal Mach number distribution, to compute the centerline Mach number. Since the maximum variation in centerline Mach number was 0.01 or less during each run, the centerline Mach number is assumed constant.

The local static pressure and the stagnation pressure were used to compute the local Mach number. As the centerline Mach number is essentially constant, the local Mach number is plotted directly rather than as a percentage of centerline Mach number.

Figure 10 shows the vertical Mach number distribution at tunnel Stations 16, 22 and 30. The maximum deviation from centerline Mach number is 2.07% and occurs at tunnel Station 16. However, the maximum deviation from centerline Mach number at tunnel Station 30 is only 1.02%. The quality of flow improves considerably from Station 16 to Station 30.

Mach number 1.5 and 2.5 nozzle blocks have been ordered and the possibility of using Mach 3 blocks is under consideration.

FIGURE NO. 1

NOZZLE BLOCKS-MACH NO. ≈ 2.0
SANDIA 12 X 12 INCH TRANSONIC TUNNEL

FIGURE NO. 2

STATIC PIPE INSTALLATION

FIGURE NO. 3

PLASTIC SIDEWALL

FIGURE NO. 4

PRESSURE SCANNER VALVE

FIGURE NO. 5

FIGURE NO. 6

FIGURE NO. 7

COMPARISON OF FLOW, METAL TO PLASTIC WALLS.
 LONGITUDINAL MACH NUMBER DISTRIBUTION.
 MACH 2 NOZZLE BLOCKS.
 SANDIA 12 x 12 INCH TRANSONIC WIND TUNNEL.

SYM.	RUN NO.	TYPE WALLS	OPEN FLAP AREA--SQ. IN.	WALL ANGLE--MINUTES	Pt--PSIA	λ
O	95	METAL	11.29	ZERO	25.00	2.06
□	110	PLASTIC	11.29	ZERO	25.20	2.08

SYM.	M_{xs}	$\left(\frac{\Delta M}{M_{xs}}\right) - \%$	$\left(\frac{\Delta M}{\Delta x_s}\right)_{AV.} \text{ PER IN.}$	M_{xL}	$\left(\frac{\Delta M}{M_{xL}}\right) - \%$	$\left(\frac{\Delta M}{\Delta x_L}\right)_{AV.} \text{ PER IN.}$
O	1.904	1.1	± 0.004	1.906	1.2	± 0.002
□	1.922	0.5	± 0.002	1.924	1.2	0.000

FIGURE NO. 8

FIGURE NO. 9

VERTICAL SURVEY STATIC PROBE,
TUNNEL STATION = 16.0

FIGURE NO. 10