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GENERATION OF FLOW DISTURBANCES IN TRANSONIC WIND TUNNELS

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Abstract

An experimental program, with the objective of identifying sources of flow unsteadiness, has been performed in the T-38 1.5m transonic wind tunnel. A comparison of the sources of flow unsteadiness between the IAR 1.5m and T-38 1.5m wind tunnels has been attempted. These two facilities are known to be the only large transonic wind tunnels in the world which have a perforated test section wall configuration comprised of inclined holes with integral splitter plates for suppression of edge-tones.

Nomenclature

M	Mach number
Tu	turbulence level
Pst	static pressure
Prms	root mean square pressure fluctuations
Cp(rms)	p/q
q	dynamic pressure
f	frequency

Subscripts

∞	free-stream

Superscripts

-	mean value

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I. Introduction

It has been shown through extensive experimental investigations that wind tunnels with slotted walls are generally quieter than those with perforated wall configurations. However Dougherty [1], through an experimental investigation in a 1-ft transonic wind tunnel at AEDC, has shown that the use of splitter-plates inserted in the perforations can be an effective means of suppressing edge-tones.

Based mainly on that experience two large wind tunnels have been built, (IAR and T-38, [2,3]), which have 1.5m x 1.5m test sections whose walls have slanted perforations with integral splitter-plates. Calibrations of these test section configurations have confirmed the effectiveness of splitter-plates in eliminating edge-tones [3,4]. However, as shown in the T-38 case [4], there are other wind tunnel components which generate flow disturbances. Previous measurements in this wind tunnel, have shown the existence of acoustic energy peaks in the low frequency range, below 40 Hz at all subsonic Mach numbers [4].

An experimental program has been performed in the T-38 1.5m transonic wind tunnel to try to identify the origin of these flow disturbances. Three possible sources of the low frequency disturbances were indicated at that time. These were the pressure regulating valve, the test section diffuser, and the perforated test section walls. Although the test section walls were judged the least probable source of the low frequency *static pressure fluctuations*, a new series of measurements, with the solid test section walls, was carried out.

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To prevent possible flow disturbances generated in the test section diffuser from propagating upstream into the test section, a two-dimensional choke system was designed, built, and installed at the very end of the test section. This two-dimensional choke was located upstream of the model support, forming a sonic surface close to the leading edge of the strut.

Some basic flow quality comparisons between the IAR and the T-38 wind tunnels will be presented in the paper. These two transonic wind tunnels have almost identical the test section wall configurations, (see Figure 1), but due to differences in transonic Mach number control, the test section diffuser and plenum chamber geometries are different.

II. Test Description in T-38 Wind Tunnel

Noise and turbulence levels were measured in both the settling chamber and the test section, as shown in Figure 2, the measurements being made both with and without the new test section choke configuration. In order to indicate the direction of propagation of the flow disturbances, two additional noise transducers were installed on the test section side wall, 2.4m apart. The downstream transducer was located 0.8m upstream of the centreline one. The latter was flush mounted on a 10 degree cone probe. A detailed description of the probes and transducers is given in reference [4]. An instrumentation schematic, showing the noise and turbulence measuring equipment, as well as the data reduction systems is presented in Figure 3.

Data reduction was accomplished using a frequency analyzer and a software package ILS installed on the VAX.The Mach number range with the normal second throat configuration was from 0.3 to 0.9; with the test section choke configuration it was from 0.5 to 0.8. The blowing pressure for all test conditions was 3 bars.

III Results and Discussion

Before starting to present the results from the T-38 wind tunnel investigation it should be noted that, due to problems with the data reduction system, it was not possible to cross correlate the signals from the different wind tunnel measurement locations. Consequently, the results are less conclusive than they would have been if the cross correlated signals had been available.

The test section centreline broadband noise level for the two different choke configurations is shown in Figure 4. This indicates that there is no noticeable difference in the noise levels for the Mach number range of 0.5 to 0.65. However, for Mach numbers between 0.65 to 0.8 the difference in the noise levels is quite significant, being reduced from about 1% to about 0.5% with the test section choke configuration. This demonstrates the effectiveness of the sonic surface in preventing flow disturbances from propagating upstream into the test section.

A comparison of the noise levels at the test section side wall, for the two wind tunnel configurations, is given in Figure 5. The difference between the two side wall signals was within the measurement accuracy. It is seen that the normal choke configuration has slightly better characteristics in terms of the noise level. Comparison of these two figures suggests an upstream propagation of the acoustic disturbances, starting at about $M = 0.65$. The upstream propagating acoustic wave is pronounced at the centreline location, but attenuated at the test section wall downstream location. It appears that flow disturbances propagating downstream dominate up to a Mach number about 0.65, with the upstream propagating acoustic disturbances becoming more dominant at higher Mach numbers.

The turbulence level in the settling chamber, together with the noise level in the test section, is presented in Figure 6. The hot film probe was located between the acoustic baffles and the first of the six screens in the settling chamber. The turbulence level recorded upstream of the first screen is reasonably low, considering the highly unsteady flow conditions existing downstream of the pressure regulating valve. Several runs were made with the probe in the settling chamber located in two alternate positions, about 2 meters to both left and right of the centreline. These results showed no significant variation of the level between the three different probe locations, indicating a very good spatial distribution of turbulence in the settling chamber. This appears to be a very good indication that the flow conditioning devices between the control valve and the first screen are chosen properly.

The similarity of the two curves presented in Figure 6 is interesting. It appears that the turbulence contribution to the noise level in the test section is significant.

The turbulence level measured with the two different choke configurations is shown in Figure 7. As expected, the different choke configurations do not affect the turbulence level. However, the level in the test section is very high compared to that in the settling chamber, considering that the contraction ratio for the wind tunnel is 8.7:1. A preliminary analysis, not shown here, suggests an improper choice of the six screens in the settling chamber.

Figure 8 shows a comparison of the free stream static pressure fluctuations for the four different wind tunnel locations, with the conventional (second throat) choke configuration. A very high level of the upstream travelling acoustic disturbances is noticeable at the higher Mach numbers.

The same type of comparison, but this time with the test section choke configuration, is given in Figure 9. The test section choke is shown to be quite effective at the higher Mach numbers. However, the above two figures show the test section choke to be ineffective at the lower Mach numbers, at the downstream side wall location, indicative of the downstream nature of the acoustic wave propagation.

The noise levels with both the conventional and the test section choke configurations are given in Figure 10, as a function of Mach number. The noise level in the settling chamber appears to be insensitive to Mach number, but the level at the centreline test section location is significantly affected by the upstream propagating wave beyond M = 0.65. It is seen that this effect is significantly attenuated by the test section choke. Finally, the side wall transducer location appears to be unaffected by the upstream propagating waves.

A comparison between the perforated and solid test section wall configurations for the T-38 wind tunnel is given in Figure 11. The differences between the low Mach number (0.4 to 0.6) and high Mach number (0.75 to 1.0) conditions can be explained by interference between the perforations and the turbulent boundary layer. However, a sharp peak of the acoustic energy is experienced between Mach numbers 0.6 and 0.75, and is caused by some other flow phenomenon.

Frequency spectra for the perforated and solid test section wall configurations are presented in Figures 12, 13 and 14, where it is seen that the low frequency acoustic energy peaks are present for both wall configurations. Moreover, the disturbances exist even with the test section choke configuration. It appears that the locations of the acoustic energy peaks are not changed with the two different test section wall configurations.

Taking into account the analysis shown so far, and the similar nature of the acoustic energy distribution with frequency at all Mach numbers, the flow disturbances should originate from both upstream and downstream sources. The first logical choice for the upstream sources would be the pressure regulating valve, but other sources in the settling chamber are possible also.

As for the upstream travelling flow disturbances being more pronounced with the higher Mach numbers, it is believed that the possible source of these could be a combination of the strut leading edge and the aerodynamically complicated pitching mechanism. Although the sonic surface should have been located slightly upstream of the strut leading edge, the combination noted above could cause separation and consequent degradation of the test section diffuser flow quality.

Some basic flow quality comparisons between the IAR and the T-38 tunnels will be given here. It is of interest to compare the flow quality characteristics of these two wind tunnels, because of the similarities between them in regard to wind tunnel type, test section size, and test section wall configuration.

Figure 15 shows the noise levels in the three-dimensional test sections of the two wind tunnels. The noise level in the T-38 wind tunnel was measured at 4% porosity up to M = 0.9. It is seen that there is really no similarity between the two wind tunnels at 4%. Beyond M = 0.7, the two different test section diffusers obviously influence the noise level differently in the same type of the test section.

The sharp degradation in the flow quality of the T-38 wind tunnel in the Mach number range of 0.6 to 0.7 remains questionable, as no similar trend exists in the IAR wind tunnel three-dimensional test section.

However, it is very interesting to note that a similar, but much less pronounced, acoustic energy peak existed with the original test section of the IAR wind tunnel, which had a porosity of 20.5% with normal holes. The same effect was experienced with the original two-dimensional test section (see Figure 16) [5], which had solid sidewalls and perforated floor and ceiling, again with normal holes and a porosity of 20.5%. It should be noted here that the two blow-off valves in the T-38 wind tunnel, represent the only essential difference between the two test section configurations. The valves in the T-38 wind tunnel were not active, but were fully open during the measurement.

As already shown, low frequency flow disturbances exist with all test section configurations, yet the acoustic energy peak exists only with the perforated test section. If the low frequency acoustic waves exist along the main wind tunnel stream, one can presume that at certain flow conditions there may be interference between these and other disturbances of a similar nature produced by the valves. Of course, such a hypothesis can be proven only by performing additional measurements.

IV Concluding Remarks

Tests have been carried out in the T-38 1.5m transonic wind tunnel to try to identify the sources of flow unsteadiness.

A series of runs were performed with a choke fitted at the downstream end of the test section, to prevent acoustic disturbances from propagating upstream into the test region.

Low frequency flow disturbances, previously found with the perforated test section configuration, were shown to be present with solid walls also.

A comparison of the flow quality between the IAR and T-38 wind tunnels shows that the different diffuser geometries produce different results with the very similar perforated test section wall configurations.

References

[1] Dougherty N. S., Anderson C. F., and Parker R.L., An Experimental Study on Suppression of Edgetones from Perforated Wind Tunnel Walls, AIAA Paper 76-50, 1976.

[2] Medved L. B., Elfstrom G. M., The Yugoslav 1.5 m Trisonic Blowdown Wind Tunnel, AIAA Paper-86-0746-CP, March 1986.

[3] Ohman L. and Brown D., Performance of the New Roll-In-Roll-Out Transonic Test Sections of the NAE 1.5 m X 1.5 m Blowdown Wind Tunnel, ICAS-90-6.2.2, September 1990.

[4] Medved L. B., Vitic A., Elfstrom G. M., Broadband Noise Measurement in the Transonic Test Section of the VTI T-38 Wind Tunnel, AIAA Paper, June 1990.

[5] Khalid M., Ellis F., and Ohman H. L., Private Communication, 1988.

[6] Elsenaar A., Reynolds Number Effects and Wind Tunnel Environment, AGARD-AR-224, 1988.

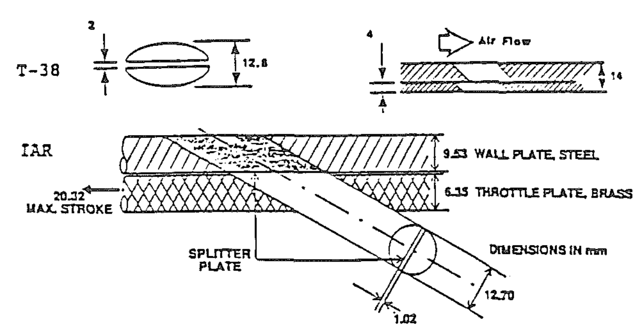

Fig. 1. Perforated test section geoetry with splitter-plates.

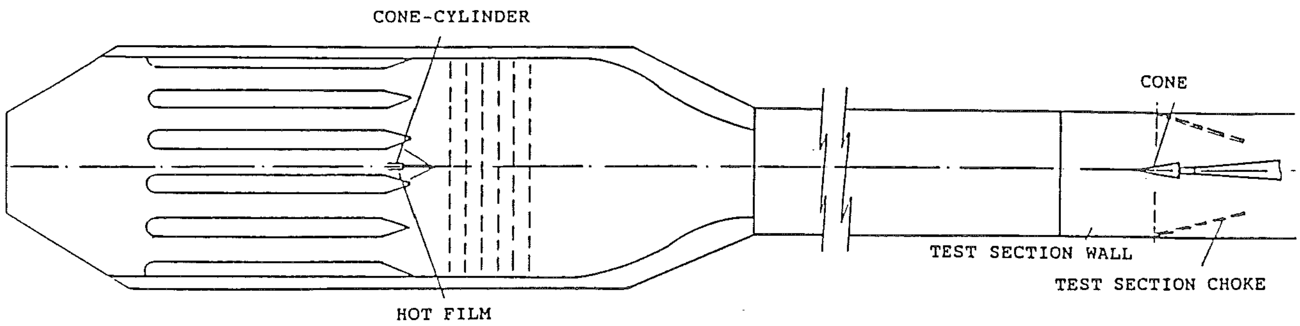

Fig. 2. Sketch of T-38 wind tunnel and measuring locations.

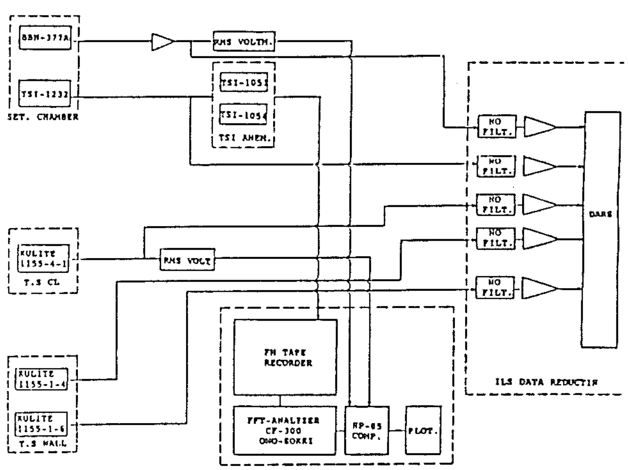

Fig. 3. Instrumentation schematic in T-38 wind tunnel.

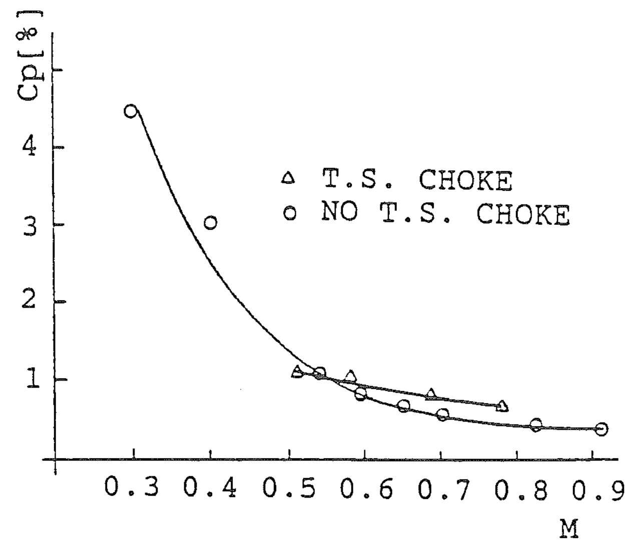

Fig. 5. Static pressure fluctuations at test section wall.

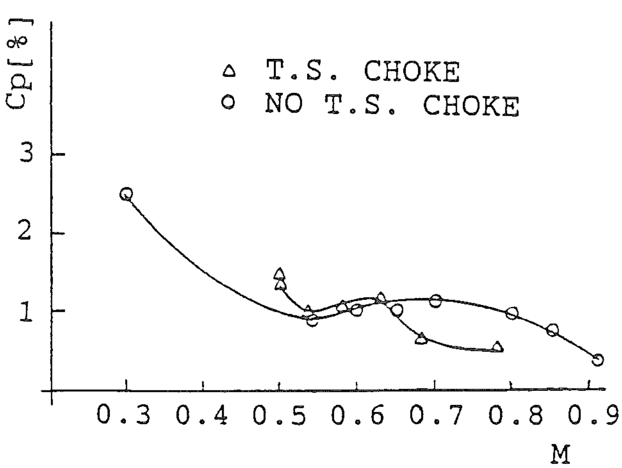

Fig. 4. Static pressure fluctuations at test section centreline.

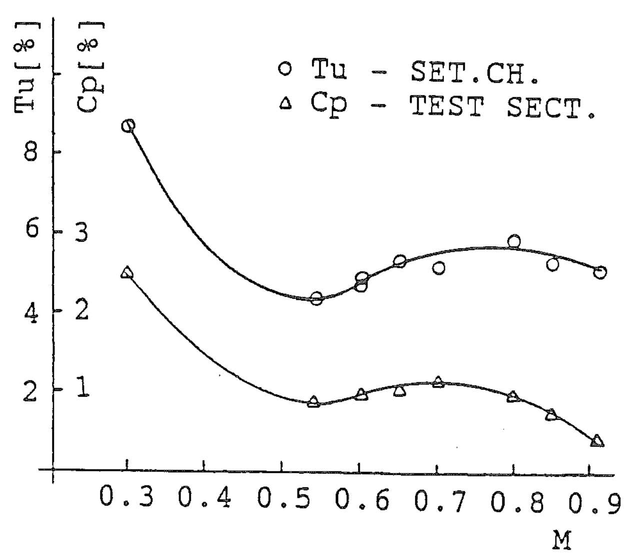

Fig. 6. Turbulence level in settling chamber along with noise level in test section.

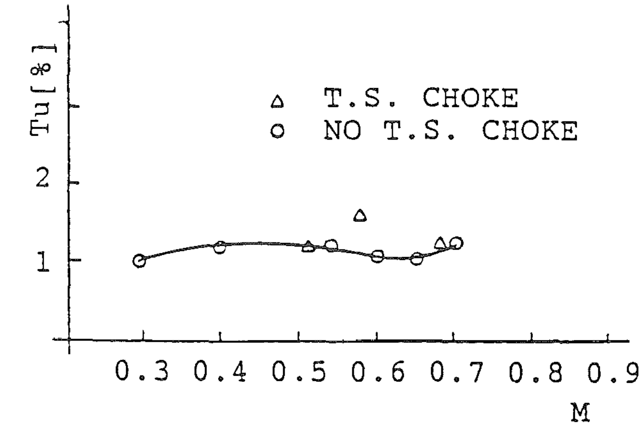

Fig. 7. Turbulence level in test section.

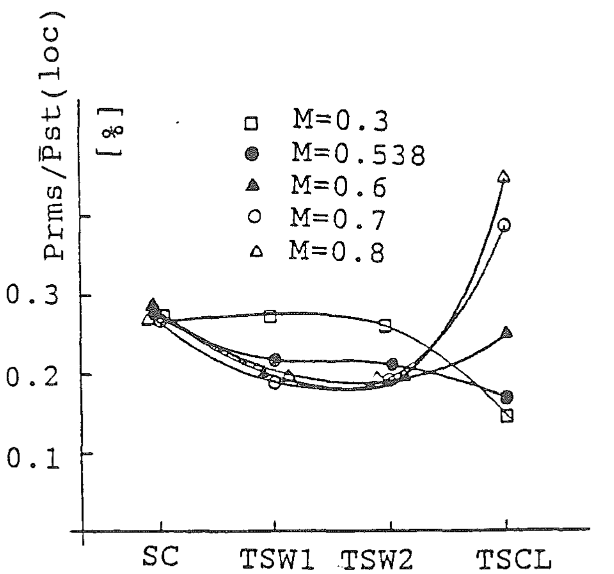

Fig. 8. Noise levels at different wind tunnel locations.

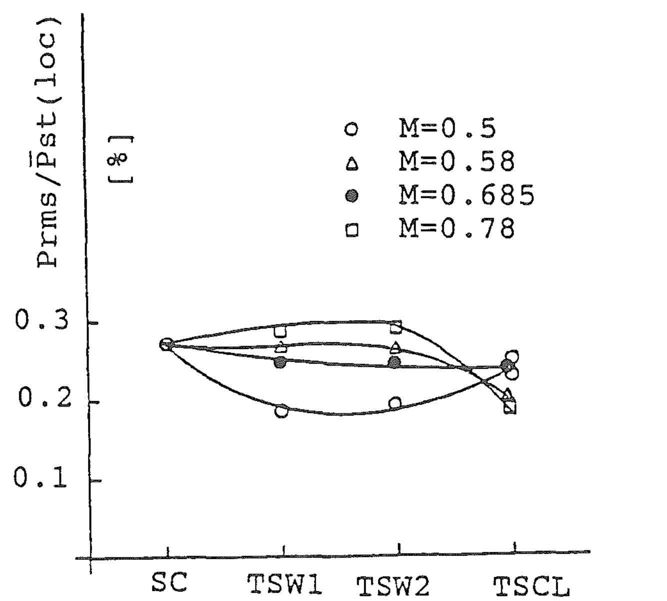

Fig. 9. Static pressure fluctuations at different wind tunnel locations with test section choke.

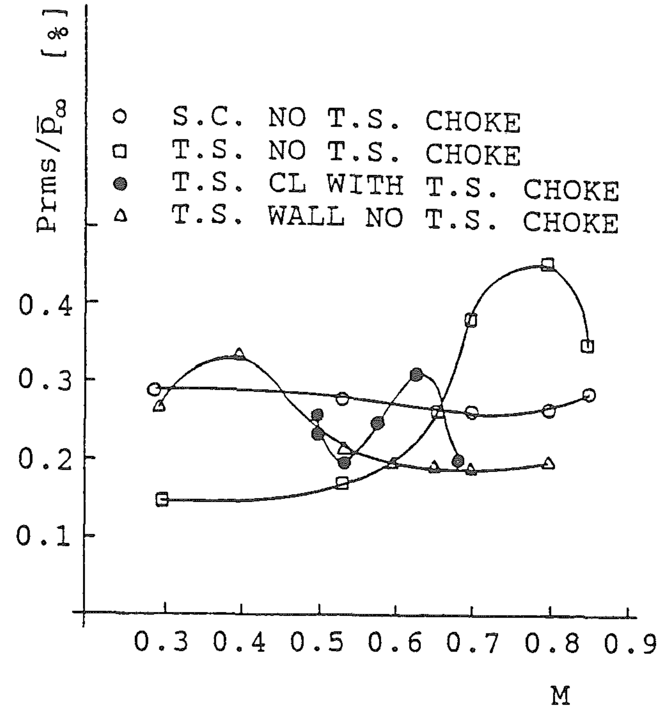

Fig. 10. Static pressure fluctuations with different wind tunnel configurations.

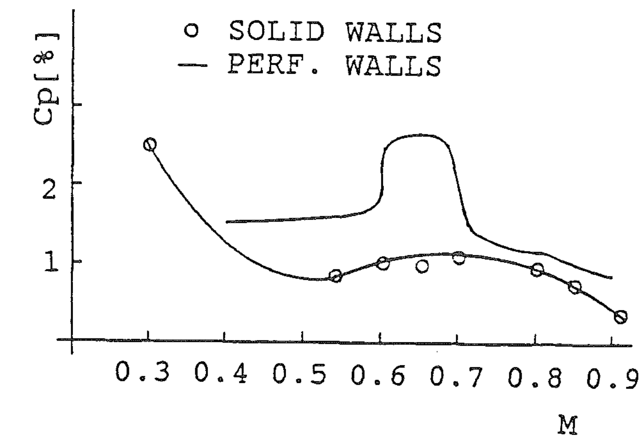

Fig. 11. Static pressure fluctuations with perforated and solid walls in T-38.

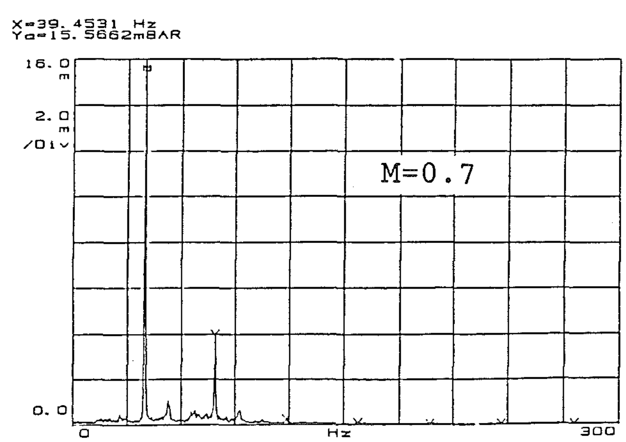

Fig. 12. Frequency spectrum with perforated walls: T-38.

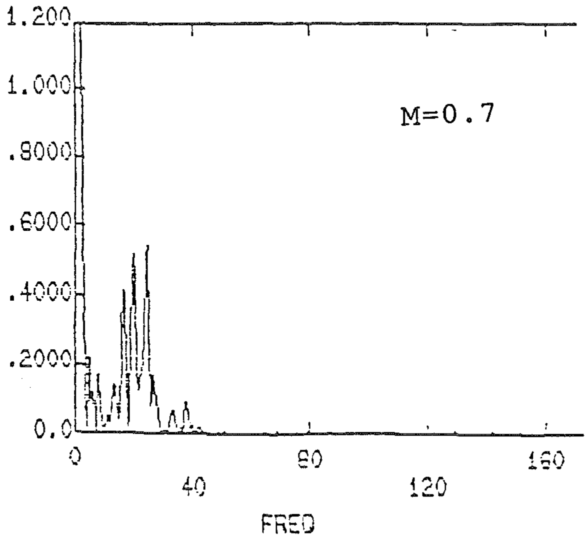

Figure 13. Frequency spectrum with solid walls: T-38.

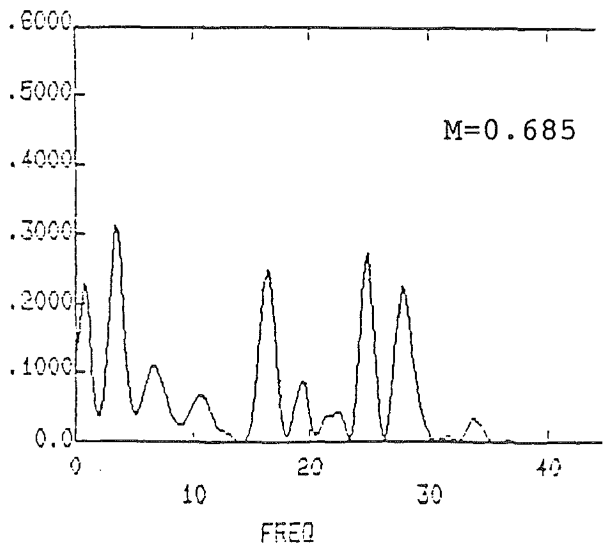

Fig. 14. Frequency spectrum with solid walls and test section choke: T-38.

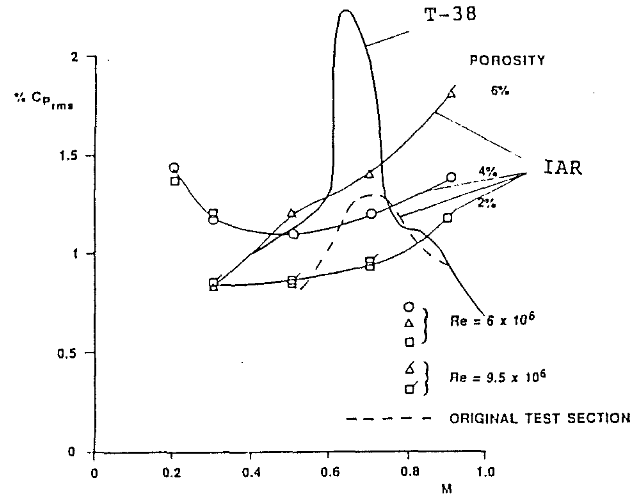

Fig. 15. Static pressure fluctuations level comparison between IAR and T-38 wind tunnels.

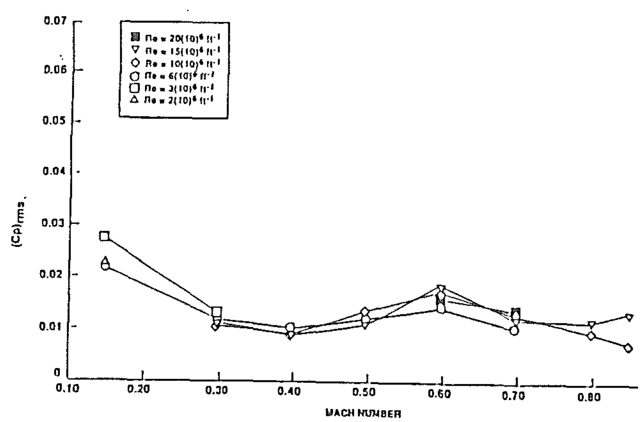

Fig. 16. Static pressure fluctuations in IAR 2D old test section.