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The Boeing/AFOSR Mach-6 Quiet Tunnel at Purdue University

A high-Reynolds number hypersonic quiet-flow wind tunnel with low operating costs had to be developed, to enable detailed measurements of the mechanisms of transition under low-noise conditions comparable to flight [5, 6]. The Purdue Mach-6 Quiet-Flow Ludwieg Tube has been developed, with DoD support, to meet this need.

Figure 1 shows a schematic of the facility [7]. The Ludwieg tube is designed to provide a 10-s. runtime about once per hour, at an operating cost estimated at $10 per shot. It is a larger and more sophisticated version of the Mach-4 quiet-flow Ludwieg tube that has been operating at Purdue since 1992 [3]. The driver-tube, contraction, nozzle, and diffuser are pressurized before the run, and the vacuum tank is evacuated. When the double burst-diaphragm breaks, an expansion wave travels upstream into the driver tube. Mach-6 flow begins about 500 ms after the diaphragms break. Every 0.2 s, the expansion wave returns to the contraction, the stagnation pressure drops roughly 1%, and the wave reflects. The flow becomes subsonic after about 6-10 s., when the stagnation pressure has dropped by about 40% and the stagnation temperature by about 9%.

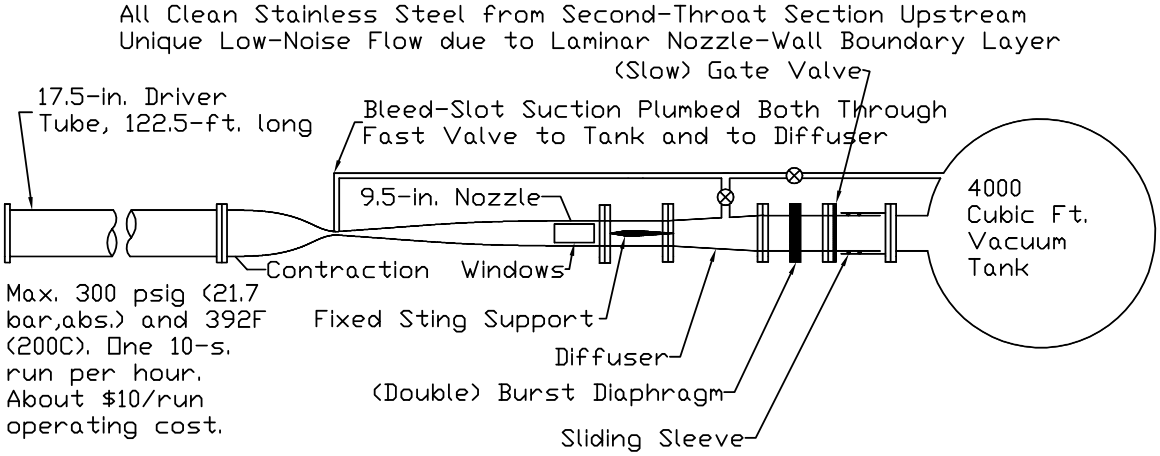

Figure 1: Schematic of Purdue Mach-6 Quiet-Flow Ludwieg Tube

The facility is designed to reach a quiet-flow Reynolds number of about 13 million. Initial operation has been without throat heating, allowing a quiet-flow Reynolds number of roughly 10 million, at the design stagnation pressure of about 150 psia [4]. The maximum quiet-flow Reynolds number that is actually achieved is dependent on fabrication quality and the reliability of the approximate prediction methods that were used. This maximum quiet-flow Reynolds number is likely to occur somewhere between 75 psia and 225 psia. As of October 2005, the tunnel is quiet to 94 psia; from initial operatin in 2001 til early in 2005, quiet flow was only achieved at 8 psia, apparently due to a small flaw in the leading edge of the bleed lip.

Figure 2 shows a schematic of the downstream end of the nozzle, with a 7.5-deg. half-angle cone drawn to scale. The onset of uniform flow is marked in the figure, along with lines indicating the onset of noise radiated from the nozzle walls, according to transition estimates based on the e^N method [4]. A slender cone with a 5.5-inch base diameter has been started successfully.

Quiet length Reynolds numbers of 2-6 million can thus be achieved on models of this slenderness, as can be deduced from the notes on the figure. This is substantially less than the quiet-flow length

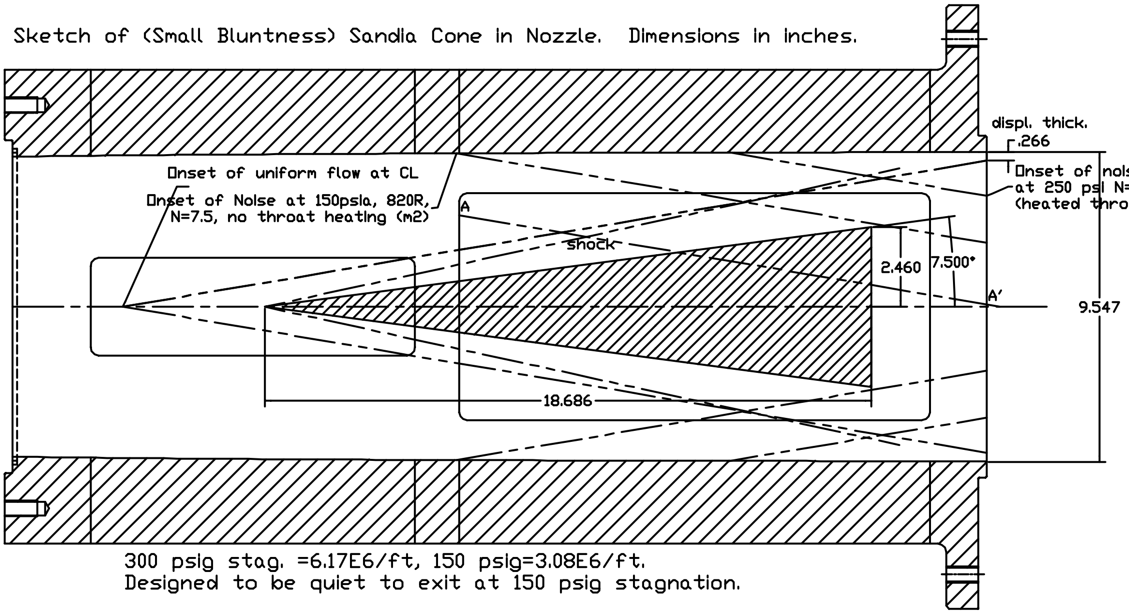

Figure 2: Schematic of Quiet-Flow Nozzle with Cone. Dimensions in Inches.

Reynolds number, which is based on the tip-to-tip length of the quiet and uniform flow region. Larger transition Reynolds numbers were achieved in various Langley tests, at relatively high Reynolds number, under nominally ‘quiet’ conditions, often by ensuring only that the leading portion of the model was in fully quiet flow [1].

References

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