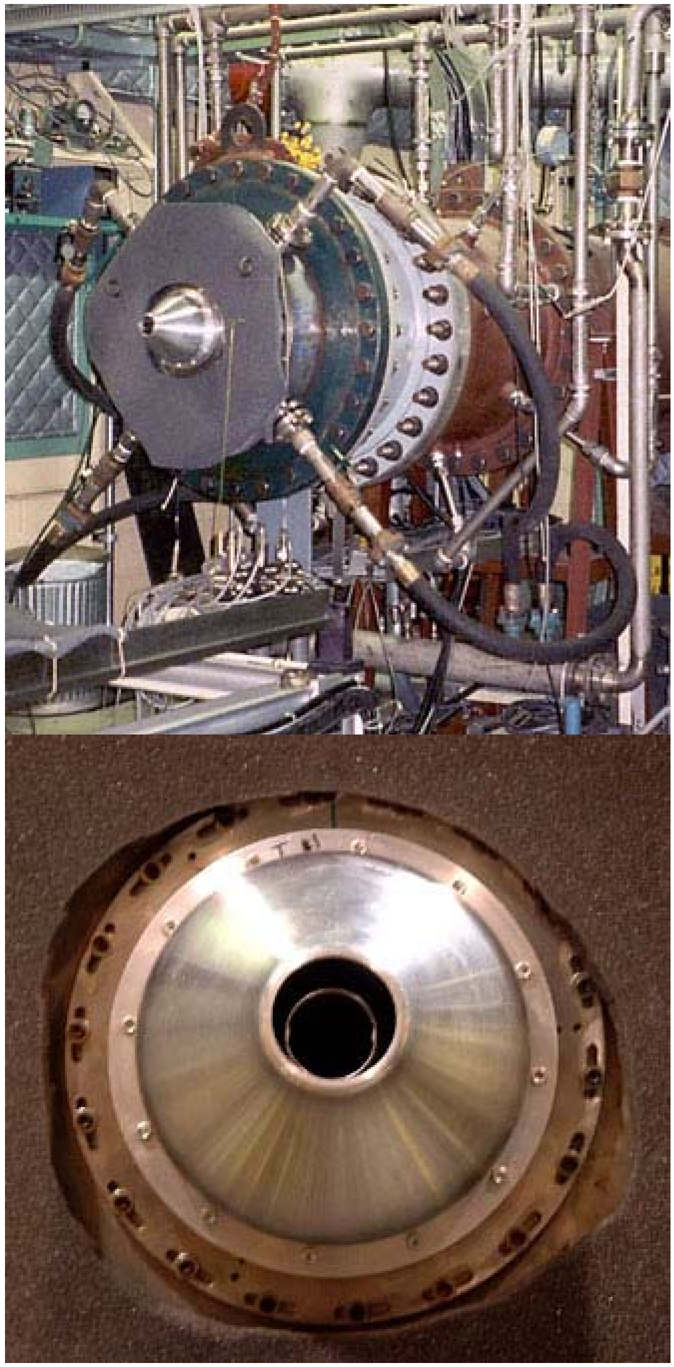
Directional Attenuation of Jet Noise With Eccentric Coannular Nozzle Investigated

Jet noise and flow field were measured to follow up on observations made by Professor D. Papamoschou of the University of California at Irvine (NASA Grant NAG3-2345). When a dual-stream coannular nozzle was arranged nonconcentrically, noise was attenuated significantly on the side where the annulus was thicker (ref. 1). A similar observation was also made in reference 2. The practical significance is obvious. If the bypass flow of a jet exhaust in flight could be diverted to form a thicker layer underneath, then less noise would be heard by an observer on the ground. In view of the current emphasis on jet noise abatement, researchers felt that the effect deserved further attention. This prompted an experiment to confirm the phenomenon in a larger facility and to obtain flow-field data to advance understanding of the mechanism.

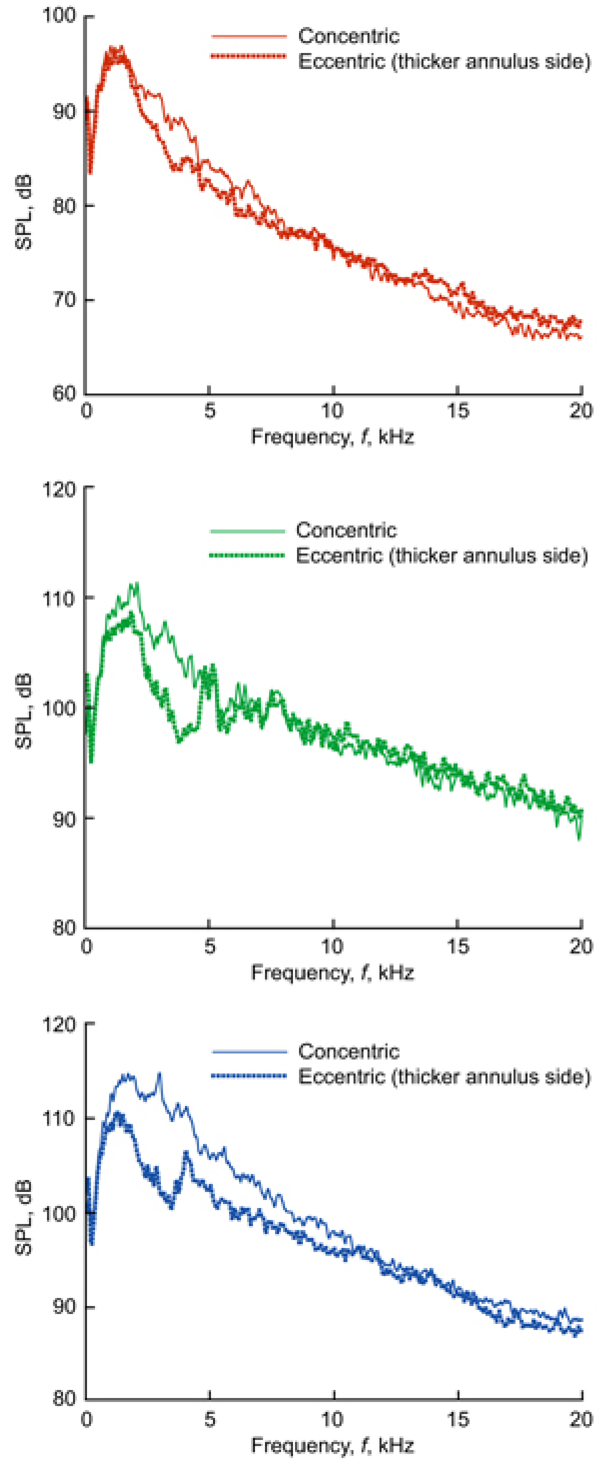


Left: Coannular jet facility. Right: Closeup view of nozzle.

The experiment was conducted in an open-jet facility at the NASA Glenn Research Center, shown in the preceding photographs. The photograph on the right shows a closeup view of the nozzles in the eccentric configuration. The eccentricity was achieved by placing a beveled gasket at the junction of the outer nozzle and the plenum chamber. The outer nozzle nearly touched the inner nozzle on the narrow side, and the axis of the outer nozzle tilted approximately 2.6° with respect to the axis of the inner nozzle.

Three primary (inner) nozzles were used: one convergent nozzle and two convergent-divergent nozzles with design Mach numbers of 1.3 and 1.5. Each had an exit diameter D_i of 1.485 in. and a lip thickness of 0.030 in. The outer nozzle had an exit diameter D_o of 2.1 in. Thus, the ratio of the primary-to-annular exit area was about 0.92. The annular outer passage was conver-gent. All data were taken for "cold" flow; that is, the total temperature was constant through-out and equal to that of the ambient temperature. Noise was measured with a microphone located at a distance of about 40 D_i.

Sound-pressure-level spectra, measured at 25° relative to the downstream jet axis, are compared in the following figure for the thicker annulus side of the eccentric configuration and the corresponding concentric configuration. There are data for three inner-jet Mach numbers M_{JI}, as indicated. All data are for an outer-to-inner jet Mach number ratio of approximately 0.5. Clear noise attenuation is observed. The overall sound pressure level dropped by 1.3, 2.0, and 4.9 dB at M_{JI} = 0.94, 1.3, and 1.5, respectively. This confirmed the noise attenuation and also the trend that the attenuation increased with increasing jet Mach number. The effect was found to be most pronounced in the direction of peak noise radiation: that is, at shallow angles relative to the jet axis. Further measurements indicated insignificant change in the noise on the thinner annulus side as well as at 90° relative to the jet axis.



Sound-pressure-level (SPL) spectra at 25° relative to downstream jet axis. ΔOASPL, difference in overall sound pressure level between the concentric and eccentric cases. Top: M_{JI} = 0.94; ΔOASPL = -1.30 dB. Center: M_{JI} = 1.30; ΔOASPL = -2.00 dB. Bottom: M_{JI} = 1.50; ΔOASPL = -4.9 dB.

Details of the flow field were obtained by pitot-probe and hot-wire surveys. These data showed that the low-speed annular fluid congregated on the thicker annulus side, where a pair of streamwise vortices formed. The flow on that side was also characterized by remarkably low turbulence intensities, commensurate with the observed attenuation in the radiated noise. Further details of this work are provided in reference 3.

References

1. Papamoschou, Dimitri; and Debiasi, M.: Directional Suppression of Noise From a High-Speed Jet. AIAA J., vol. 39, no. 3, 2001, pp. 380-387.
2. Harper-Bourne, Marcus: Physics of Jet Noise Suppression. Proceedings of Jet Noise Workshop, NASA/CP--2001-211152, 2001, pp. 701-719. http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?2001/CP-2001-211152.html
3. Zaman, K.: Noise- and Flow-Field of Jets From an Eccentric Coannular Nozzle. AIAA-2004-0005, 2004.

Glenn contacts: Dr. Khairul B. Zaman, 216-433-5888, Khairul.B.Zaman@nasa.gov; and Dr. James E. Bridges, 216-433-2693, James.E.Bridges@nasa.gov
Author: Dr. Khairul B. Zaman

Headquarters program office: OAT
Programs/Projects: UEET, QAT