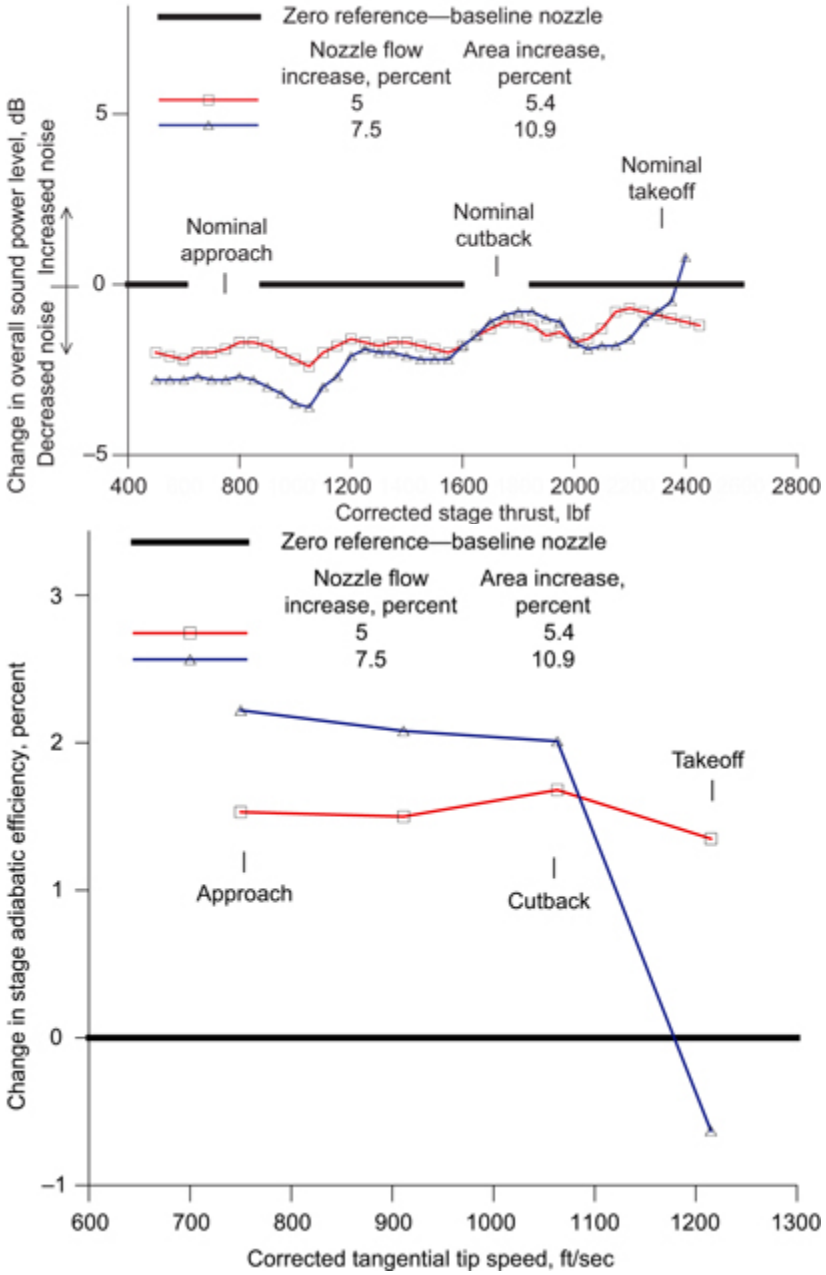
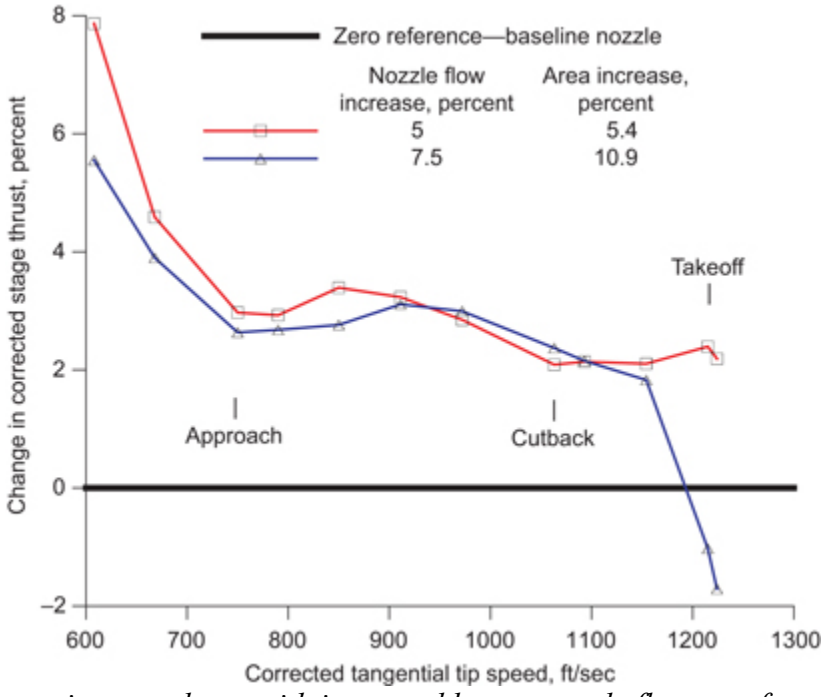
Turbofan Noise Reduction Associated With Increased Bypass Nozzle Flow



Left: Reduction in overall sound power level with increased nozzle flow as a function of corrected stage thrust. Right: Change in fan stage adiabatic efficiency with increased nozzle flow as a function of corrected rotor tip speed.

Long description of figures 1 and 2. Left: Graph for zero reference and for nozzle flow increase of 5 and 7.5 percent and area increase of 5.4 and 10.9 percent, respectively, showing nominal approach, cutback, and takeoff. Right: Graph for zero reference and for nozzle flow increase of 5 and 7.5 percent and area increase of 5.4 and 10.9 percent, respectively, showing approach, cutback, and takeoff.

An advanced 22-in. scale model turbofan, typical of a current-generation aircraft engine design by GE Aircraft Engines, was tested in NASA Glenn Research Center's 9- by 15-Foot Low-Speed Wind Tunnel to explore the far-field acoustic effects of an increased bypass nozzle area at simulated aircraft speeds of takeoff, approach, and landing. The wind-tunnel-scale model consisted of the bypass stage fan, stators, and nacelle (including the fan exit nozzle) of a typical turbofan. This fan-stage test was part of the NASA Glenn Fan Broadband Source Diagnostic Test, second entry, which acquired aeroacoustic results over a range of test conditions. A baseline nozzle was selected, and the nozzle area was chosen for maximum performance at sea-level conditions. Two additional nozzles were also tested--one with a 5.4-percent increase in nozzle area over the baseline nozzle (sized for design point conditions), corresponding to a 5-percent increase in fan weight flow, and another nozzle with a 10.9-percent increase in nozzle area over the baseline nozzle (sized for maximum weight flow at sea-level conditions), corresponding to a 7.5 percent increase in fan weight flow. Measured acoustic benefits with increased nozzle area were very encouraging, showing overall sound power level reductions of 2 dB or more (left graph) while the stage adiabatic efficiency (right graph) and thrust (final graph) actually increased by several percentage points. These noise-reduction benefits were seen to include both rotor-interaction tones and broadband noise, and were evident throughout the range of measured sideline angles.



Percent change in stage thrust with increased bypass nozzle flow as a function of rotor tip speed.

Long description of figure 3. Graph for zero reference and for nozzle flow increase of 5 and 7.5 percent and area increase of 5.4 and 10.9 percent, respectively, showing approach, cutback, and takeoff.

These results suggest that, for a typical turbofan engine, a variable-area bypass exhaust nozzle may be an effective way to decrease engine fan-stage noise while increasing aerodynamic performance in terms of adiabatic efficiency and thrust. The baseline fixed-

area bypass nozzle in this test was sized for maximum stage performance at sea-level conditions. However, turbofan engine bypass exhaust nozzles are normally sized for maximum performance at that portion of the aircraft flight profile where most of the flight time is spent--typically at the cruise condition. Increasing the nozzle flow reduced the fan stage noise in this scale model test. Thus, it may be desirable to employ a variable-area engine bypass exhaust nozzle to reduce fan-stage noise levels and optimize performance at all rotor operating speeds. Even the addition of a limited-position variable-area bypass nozzle, to reduce the mechanical complexity and added engine weight of a continuously variable nozzle design, might be an effective retrofit to existing turbofan engines to control fan-stage noise without sacrificing aerodynamic performance.

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