Engineering Notes

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Scale-Model Studies of Blast-Deflection Fences for High Thrust Engines

JOHN J. BERTIN* AND JOHN C. WESTKAEMPER†
The University of Texas, Austin, Texas

1. Introduction

INCREASED thrust levels of commerical jet engines have created the need for better protection against the resultant exhaust wakes. Land acquisition costs and the need for public access to terminals has led to the use of exhaust deflectors, especially for protecting traffic on roads in the vicinity of taxiways and runways. The FAA has published[1] exhaust profile data and deflector-fence design information for contemporary aircraft. However, planners of new airports should anticipate future aircraft whose engines have increased thrust.

In the present work, an 0.02 scale model was constructed to represent a twin-engine aircraft, the proposed fence geometries, and the adjacent service roads requiring traffic protection. Data were obtained to define the flowfield immediately upstream of the fence and downstream to the roads. In addition to a single, long primary fence, flowfield data were obtained for double fences in which a smaller, auxiliary fence was located upstream of the primary fence to provide a sheltered area for ground service equipment. Results of the experimental investigation are presented herein.

2. Description of the experiments

The portion of the Dallas/Ft. Worth Regional Airport included in the model test program is presented in Fig. 1. A range of aircraft breakaway positions were considered (150 ft to 400 ft from the primary fence) with engine centerlines 60 ft apart and 8 ft above the apron. An objective of the study was to identify fence combinations which would protect vehicles using either the service road (at apron elevation) or the spine road (elevated 18 ft. above the apron). The auxiliary 100 ft long fence was located 40 ft upstream of the 250 ft long primary fence.

The jet exhausts of the experimental investigation simulated the exhaust momentum of a turbofan having a breakaway thrust of 33,000 lb. A convergent nozzle supplied a uniform jet (of room temperature air at 766 fps), so that the model momentum was equivalent to that of the two coaxial streams of a turbofan engine. The model scale was 0.02, based on jet exhaust diameter. Three fence heights were studied: a 10-ft fence, a 12-ft fence, and a 14-ft fence. In cross-section, the fences consisted of two linear segments. The lower segment was inclined 30° from the vertical, while the upper segment was vertical.

A variety of measurements and visual observations were made to determine the effect of a particular fence geometry. Upstream of the fence, the velocity measurements were made with a Pitot probe; downstream of the fence a hot-wire anemometer was used. The flow visualization techniques used include: 1) dry talcum powder mixed into the exhaust air to indicate the streakline patterns of the deflected jet; 2) talcum powder mixed with water to indicate the surface velocity directions in regions of high shear; 3) tufts taped to the ground plane to indicate the surface velocity directions in regions of low shear; and 4) smoke exhausted near the ground plane so that the local flow directions could be followed in low-velocity regions. Reference 2 presents additional detailed information regarding the test program.

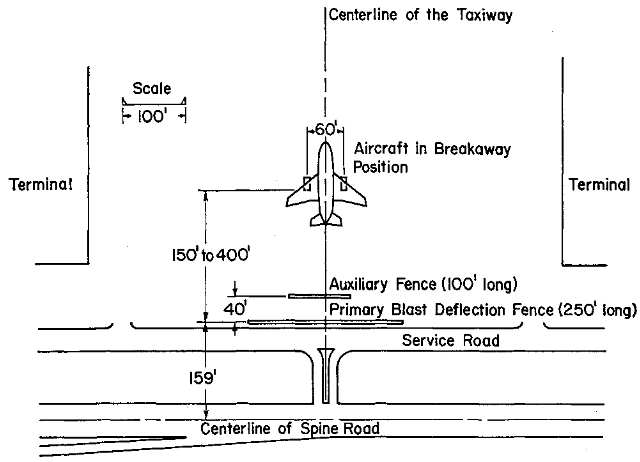

Fig. 1 Blast deflection model of the Dallas/Ft. Worth Regional Airport.

3. Discussion of results

The local streamwise velocity was computed (using Bernoulli's equation) from Pitot-pressure measurements made with three probes located 15 ft upstream of the fence. Within the accuracy of the measurements, these streamwise velocities were not affected by the fence geometry configurations tested. The decay of centerline velocity observed in the present program compares favorably with that presented in Ref. 3. This agreement exists although the current measurements were made two jet diameters upstream of a fence in the presence of a ground plane.

Since crosswind gusts averaging more than 20 mph on a moving vehicle are considered hazardous,[1] the location of the 20-mph velocity contour was considered a most important criterion in the evaluation of the effectiveness of a particular fence geometry. A hot-wire anemometer was used to define the 20-mph and the 40-mph velocity contours downstream of the primary fence in a vertical plane containing the centerline of the left engine. The effectiveness of the different single fence configurations tested can be seen by referring to the 20-mph velocity contours presented in Fig. 2. Clearly the least jet deflection was given by the 10-ft fence, whereas the 14-ft fence was the most effective. Because of the difference in the angle of jet deflection for each of the three fences, the differences between the minimum height of the 20-mph velocity contour became more pronounced further downstream. The relative ineffectiveness of the 10-ft fence occurred because its height is less than the top of the jet exhaust flow. Heights of the other, and more effective, fences extended above the jet exhaust.

Additional velocity measurements were obtained for the 10-ft fence and for the 14-ft fence with the distance from the

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* Associate Professor, Department of Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin. Member AIAA.

† Associate Professor, Department of Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin. Associate Fellow AIAA.

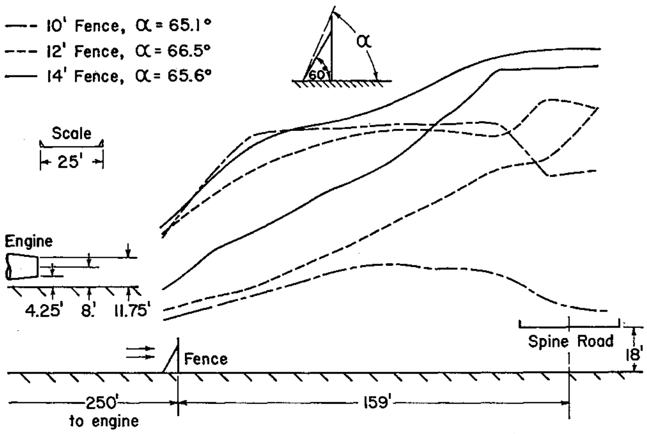

Fig. 2 Single fence 20-mph velocity contours.

jet to the fence ranging from 150 ft to 400 ft in 50 ft increments. Although Ref. 1 states "generally, the closer the fence is to the source of the blast the better it performs, provided the extended centerline of the blast falls below the top of the fence," such was not the case for the 10-ft fence, whose performance was essentially unaffected by the distance to the jet. However, the 14-ft fence did perform as expected.

Flow visualization studies clearly indicated that the flow downstream of the fence was a low-speed, recirculating flow. Smoke and tuft patterns for the entire region from the fence to the spine road depicted a low-velocity flow along the ground plane directed toward the fence.

The 20-mph velocity contours for the double-fence configurations indicate that the flow was significantly different from the single-fence configurations, as shown in Fig. 3. For many of the double-fences tested, the lower limit of the 20-mph velocity contour returned to the ground plane downstream of the primary fence. From this reattachment point, the flow near the ground plane proceeded toward the spine road at high speed. Thus, it was clear that, for certain conditions, a 20-mph velocity contour wraps closely around the spine road. Since velocity measurements were not made under the spine road, the location of the contour in this region is an estimation.

Flow visualization results also indicated that the double-fences were not as effective as the single-fences. Tufts located 15 ft downstream of the primary fence were directed upstream while those located 50 ft downstream were aligned with the jet exhaust direction. Thus, flow reattachment occurred within 50 ft of the primary fence. Flow continued downstream toward the spine road as could be seen from the tuft patterns and from the quick dispersion of the smoke in the high velocity flow under the spine road.

No clear trends regarding "fence efficiency" for double-fence configurations were evident in the velocity contour data. Configurations employing the tallest (14-ft) fence tended to be best. The most effective double-fence tested employed the 14-ft fence in the upstream (or auxiliary fence) position as shown in Fig. 3.

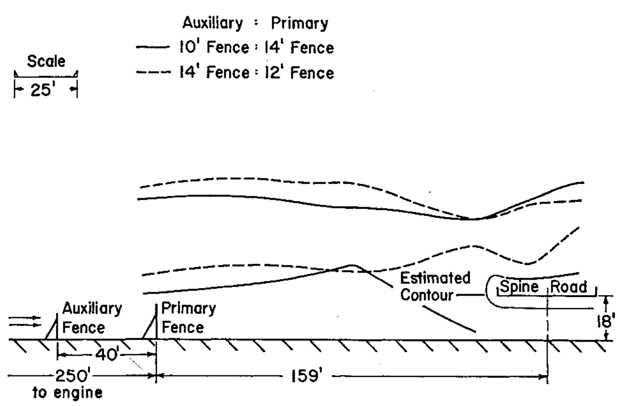

Fig. 3 Double fence 20-mph velocity contours.

4. Conclusions

Although the jet exhaust momentum simulated in this experiment was high, the data exhibited trends reported previously in the literature, e.g., that the velocity at the jet centerline varied inversely with distance from the exhaust plane and that, for a single fence, improved jet-deflection characteristics were obtained as the ratio of the fence height to jet height was increased. As expected, jet deflection was improved as the 14-ft fence was moved closer to the jet exhaust. However, jet-deflection with the 10-ft fence was almost independent of jet distance because the jet exhaust spilled over the top of the fence.

When an auxiliary fence was employed to provide a protected area for service equipment, the jet-deflection performance for the spine road decreased markedly. For many configurations, the flow reattached within 50 ft of the primary fence and the downstream velocity was potentially hazardous to vehicles traveling on the nearby roads.

References

[1] "Effects of Jet Blast," Advisory Circular 150/5325-6, April 1965, Federal Aviation Agency, Washington, D.C.

[2] Bertin, J. J., Westkaemper, J. C., Gregson, T. W., and Stone, C. M. "An Aerodynamic Study of the Jet Blast Protection Structures for the Dallas/Ft. Worth Regional Airport," Aerospace Engineering Rept. 71003, March 1971, University of Texas at Austin.

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A Wind-Tunnel Stream Oscillation Apparatus

J. Bicknell* and A. G. Parker†
Texas A & M University, College Station, Texas

Nomenclature

U = mean tunnel velocity, fps
v = amplitude of lateral velocity, fps
x = distance downstream from the trailing edge of the vanes, ft
y = transverse distance measured from tunnel center line, ft
z = vertical distance measured from tunnel center line, ft
θ = amplitude of flow angle changes, deg
ϕ = phase lag in degrees between flow and vanes
γ = frequency parameter per foot ($=\omega/U$)
ω = frequency of oscillator, rad/sec

Introduction

The development of a harmonically varying airstream (in direction or magnitude) has received the attention of several investigators.[1–4] In Ref. 1, wall mounted vanes were used; in 2, rows of vanes were oscillated to simulate large-scale atmospheric type gustiness. The tunnel of Ref. 1 was slotted, that of Ref. 2 closed. In Ref. 3, varying lift was produced by modulating jet flaps, also in a closed tunnel.

An analytical examination shows that the tunnel walls exert a most powerful control over attempts at stream bending, and that the removal of this constriction is most necessary.

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* Visiting Professor, Aerospace Engineering Department. Member AIAA.

† Assistant Professor, Aerospace Engineering Department. Associate Member AIAA.