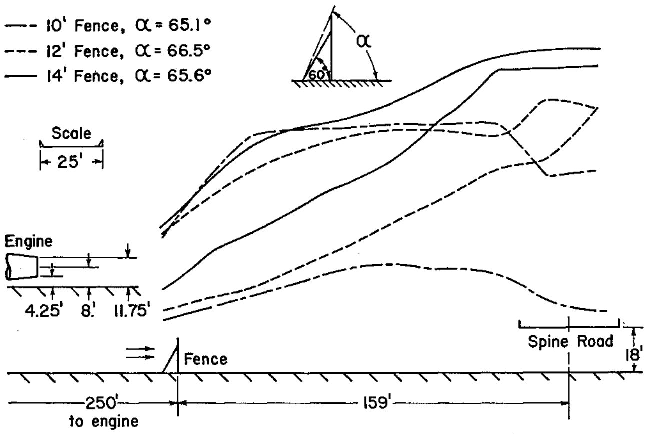

Fig. 2 Single fence 20-mph velocity contours.

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.

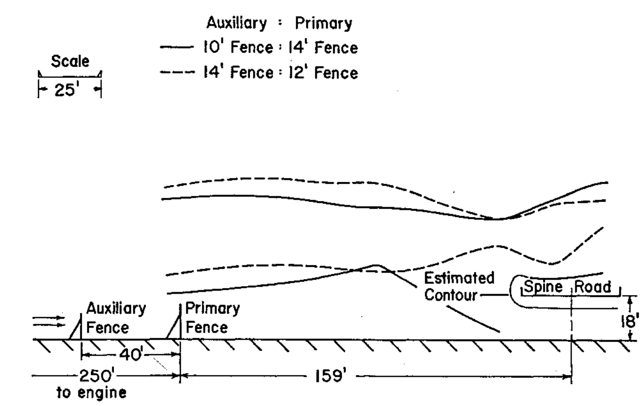

Fig. 3 Double fence 20-mph velocity contours.

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.

[3] Sforza, P. M., Steiger, M. H., and Trentacoste, N.: "Studies on Three-Dimensional Viscous Jets," *AIAA Journal*, Vol. 4, No. 5, May 1966, pp. 800–806.

A Wind-Tunnel Stream Oscillation Apparatus

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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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A semi-open jet wind tunnel or a driven solid wall tunnel is therefore indicated. It also appears that two large chord airfoils at the upstream end of the test section would oscillate the stream and space the wakes far enough apart that the model under test would avoid direct contact with the wakes.

An analytical determination of the effect of vane chord, spacing and reduced frequency was made[4] concurrently with an experimental feasibility study in a 2 ft × 3 ft wind tunnel. The first study used two all moving vanes spaced 1 ft apart across the long tunnel dimension. Equal length vanes were added to the end of the tunnel side walls which were open downstream of these vanes.

Initial tests showed that flow angles were uniform and large, (± 8° could easily be obtained) however the vanes stalled early as they usually do in a grid. These vanes were replaced by 1 ft chord vanes having 50% moveable flaps. It is the preliminary results for this system that are presented in this Note.

Equipment and Tests

A schematic of the flapped vane system is shown in Fig. 1. The four flaps are mechanically linked and are driven by an electric motor. Flap amplitude is variable up to at least ± 15° and frequency is variable up to at least 20 Hz.

Flow velocities were measured using an X hot wire, the two channels of which were added and subtracted on an oscilloscope to obtain longitudinal and transverse velocities. A potentiometer pickoff indicated the flap positions.

Measurements were obtained for four frequency parameters (γ) between 0 and 0.3 at several points in the tunnel between the two central vanes.

Results

Before unsteady measurements were taken static tests indicated that for a given flap angle a uniform change of flow angle occurred in the test section. The changes were not quite symmetrical for positive and negative flap angles but this was probably due to a slight asymmetry in the normal steady flow of the tunnel.

Typical oscilloscope traces for oscillating vane amplitudes of ± 5° are shown in Fig. 2. The lateral velocities are sinusoidal whilst only small perturbations (of the same order as the turbulence in this tunnel) can be seen in the longitudinal velocity. At large vane amplitudes (± 15°) significant oscillatory components occur in the longitudinal velocity.

Oscilloscope data was reduced in terms of flow angle amplitude (θ) (Fig. 3) and its approximate phase lag (ϕ) to the vane motion. Except near the collector, flow amplitude is uniform throughout the test area. It should be noted however that the amplitudes are of the order of ± 7.5° for vane amplitudes of ±5°, this is larger than expected but is probably due to vane linkage setting error. Further tests due to be carried out on a larger scale system should verify this. Phase relations between the flow and vanes are only approximate but they do agree qualitatively with the theoretical results of Ref. 4.

With this system the size of model that can be used is obviously restricted. Regions of the test section that remain unaffected by the wakes of the vanes throughout the oscillatory cycle are superimposed on the schematic of the tunnel in Fig. 1.

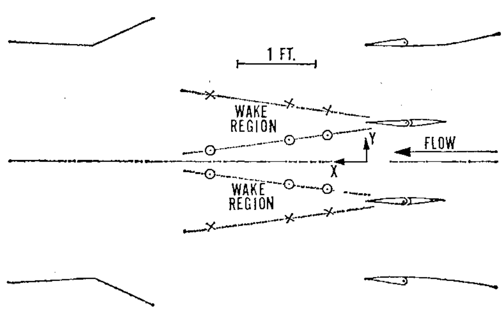

Fig. 1 Schematic of oscillating vanes.

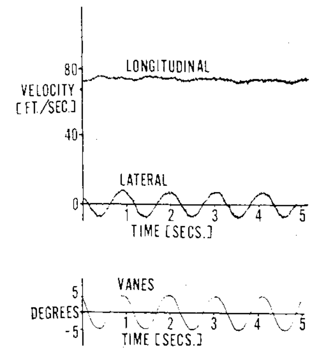

Fig. 2 Typical velocity fluctuations.

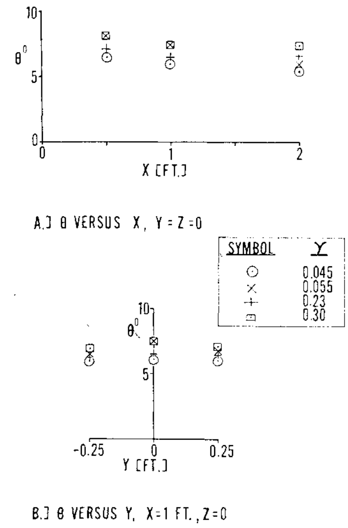

Fig. 3 Variation of gust amplitude in the test section.

Some measurements were obtained for sudden changes in flap angle. The rise times of the flow signals were comparable to the duration of flap motion (approximately 65 msec) but the times between start of flap motion and first perceived flow changes at different points on the tunnel center line indicated that disturbances were being propagated at one-half tunnel velocity. This might have been expected for points between the outer sets of vanes but not for points on the center line. Again further work is necessary in this area.

Conclusions

The results of this preliminary study are very encouraging. Uniform sinusoidal lateral gusts of large amplitude can be generated in a semi-open jet wind tunnel using the oscillating flapped airfoils described.

On the basis of these results a similar system has been designed and built for installation into a 7 ft × 10 ft tunnel where a more detailed calibration will be made. After calibration, experiments on the transient stall of a two dimensional helicopter rotor section will be made as the start of a larger program. This facility should also be useful for the study of model building dynamics.

References

[1] Abbott, F. T., Jr., "Brief Description of the Characteristics of the Langley Transonic Dynamics Tunnel Airstream Oscillator," Paper 6, Sept. 24–25, 1968, NASA.

[2] Buell, D. A., "An Experimental Investigation of the Velocity Fluctuations behind Oscillating Vanes," TN D-5543, Nov. 1969, NASA.

[3] Simmons, J. M. and Platzer, M. F., "Experimental Investigations of Incompressible Flow Past Airfoils with Oscillating Jet Flaps," *Journal of Aircraft*, Vol. 8, No. 8, Aug. 1971, pp. 587–592.

[4] Jones, W. P. and Moore, J. A., Private Communication "Flow in the Wake of a Cascade of Oscillating airfoils," Jan. 1972.