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# PRELIMINARY TESTS OF THE MIXER NOZZLE CONCEPT FOR REDUCING BLOWN FLAP NOISE

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# PRELIMINARY TESTS OF THE MIXER NOZZLE CONCEPT FOR REDUCING BLOWN FLAP NOISE

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## INTRODUCTION

One method to increase the lift capability of a STOL aircraft during takeoff and landing is to incorporate an externally blown flap system. With this method large trailing edge wing flaps are lowered directly into the fan-jet engine exhaust. Unfortunately, the impingement of this high velocity airstream on the flap surfaces causes a substantial increase in the noise level of the engine exhaust jet. In order to meet the commonly considered goal for STOL aircraft of 95 EPNdB at 500 ft. the additional noise generated by the interaction of the jet exhaust with the flaps must be considerably reduced.

The flap interaction noise appears to be proportional to the surface area of the flaps scrubbed by the jet exhaust and to the sixth power of the jet exhaust impingement velocity. Reducing this impingement velocity (while maintaining acceptable lift characteristics) appears to offer promise of substantial reduction in flap interaction noise.

The impingement velocity can be reduced by employing a mixer nozzle at the fan-jet engine exhaust. A mixer nozzle is a multi-element nozzle designed in such a way that the velocity of the individual small jets making up the exhaust decays rapidly by turbulent mixing with the surrounding low velocity airstream.

The purpose of this report is to present some preliminary findings on the noise reduction effectiveness of a mixer nozzle. Noise measurements were made with a small scale (32.4 cm wing chord) externally blown flap model using the mixing nozzle concept to reduce the velocity of impingement at the flaps. To simplify the apparatus the mixer nozzle was simulated by a multi-lobed orifice plate.

Data are presented comparing the results obtained with a single orifice and an eight lobe orifice, both having the same total area of discharge.

## APPARATUS

The data were obtained from the experimental set-up shown in figure 1. Cold air (294 K) flows through the simulated mixer nozzle (orifice plate) and impinges on the wing flaps as shown. Two different orifice plates were used. One had a single 6.1 cm orifice in the center and the other had eight orifices shaped as shown in figure 1. The total areas, flow rates, discharge coefficients and pressure ratios across the orifices were approximately the same. Consequently, the jet velocity at the exit was the same for both orifices (296 m/sec).

Free stream velocities with the wing removed were calculated from total pressures measured downstream of the orifices by a traversing probe. The velocity measurements and the sound measurements were taken at the same orifice pressure ratio (1.74).

Sound data were taken for the orifices alone and with the wing in place (flaps at the $30^{\circ}$-$60^{\circ}$ position). The microphones were placed at various intervals on a 3.05 meters radius circle centered at the orifice exit (fig. 2).

The microphone horizontal plane and jet centerline were located 4 feet above a smooth flat asphalt surface.

Noise data were analyzed by a 1/3 octave band spectrum analyzer. The analyzer determined sound pressure level spectrums referenced to 0.0002 microbar. Overall sound pressure levels were computed from the SPL data.

## RESULTS

### Peak Velocity Degradation

Results of the velocity decay measurements are shown in figure 3. The ordinate is the ratio of the local peak velocity as measured at various axial positions to the velocity at the exit plane of the orifice. The abscissa is a correlating parameter. The curves, solid and dashed, represent unpublished NASA data. As the distance downstream of the nozzle increases, for a given diameter and Mach number the peak velocity decreases. The eight-lobe nozzle (dashed curves) shows a faster rate of velocity degradation than does the single nozzle. The lower dashed curve is for the results obtained when alternate lobes are canted outward $10^{\circ}$ from the nozzle centerline.

The velocity data obtained for the work reported herein with the single orifice and eight-lobe orifice agrees reasonably well with this correlation. Thus, the eight-lobe orifice satisfactorily simulated an eight lobed mixing nozzle.

### Sound Measurements

A comparison of the noise data for the single orifice only and eight-lobe orifice only is shown in figure 4. Figure 4(a) gives the OASPL at a distance of 3.05 m at the various microphone angular positions. The OASPL is plotted as a function of the angle from the air supply line (or engine inlet direction). The orifice pressure ratio was 1.74 for both configurations. The results show that the differences in OASPL between the single and eight lobe orifice are small. The eight lobed orifice had a smaller peak OASPL (at $160^{\circ}$) but was about 2 dB louder at the $80^{\circ}$ microphone position.

The sound pressure level 1/3 octave spectra for the orifices are shown in figure 4(b). These measurements were made at $80^{\circ}$ from the air supply line. Although, again, the difference in the results between the two orifices is small the 8-lobe orifice shows an increase in high frequency noise content which is characteristic of multi-element nozzles.

A comparison of the noise data for the eight-lobe orifice only and the eight lobe orifice with the wing in place is shown in figure 5. Figure 5(a) compares the two OASPL directivity patterns. The patterns show that the presence of the wing causes a substantial increase in the noise level of the system up to about $100^{\circ}$. The SPL spectra at $80^{\circ}$ are compared in figure 5(b). Figure 5(b) shows that the wing is the dominating noise source up to a frequency of about 8 kHz.

A comparison of the sound data for the single and 8-lobed orifices with the wing in place and the flaps in the $30^{\circ}$-$60^{\circ}$ position is shown in figure 6. Figure 6(a) gives the OASPL directivity patterns. The SPL spectra at $80^{\circ}$ are shown in figure 6(b). It is evident from figure 6 that the single orifice blowing on the flap is noisier, especially below the wing, and the peak frequency is about the same for both cases (2.5 kHz) for this small scale model.

## CONCLUSION

Noise data obtained with a multi-element orifice used to simulate a mixer nozzle indicate that blown flap noise can be reduced by this method. Comparison of the noise levels measured with a single orifice and with the multi-element orifice blowing on the wing flaps shows that the noise was reduced about 6 dB below the wing when the flaps were blown with the multi-element orifice.

## SYMBOL LIST

| | |
|---|---|
| $C_e$ | orifice (nozzle) discharge coefficient |
| $D_{et}$ | equivalent diameter = $\frac{4 \text{ Total Area}}{}$, cm |
| $M_j$ | Mach number at orifice (nozzle) exit plane |
| OASPL | overall sound pressure level referenced to 0.0002 microbar, dB |
| $R_m$ | microphone radius, m |
| SPL | sound pressure level referenced to 0.0002 microbar, dB |
| V | free stream peak jet velocity, m/sec |
| $V_j$ | peak velocity at orifice (nozzle) exit plane, m/sec |
| X | axial distance from orifice (nozzle) exit plane, m |

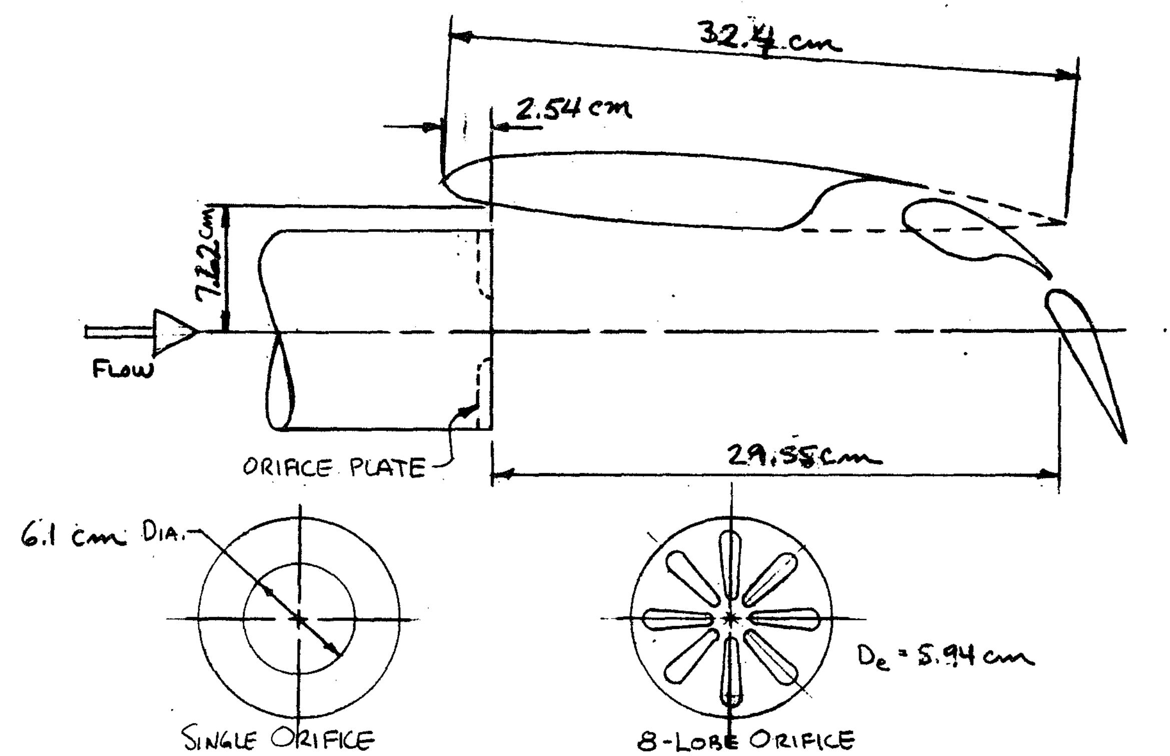



Figure 1. Small scale externally blown flap model with single and 8-lobe orifice plates.

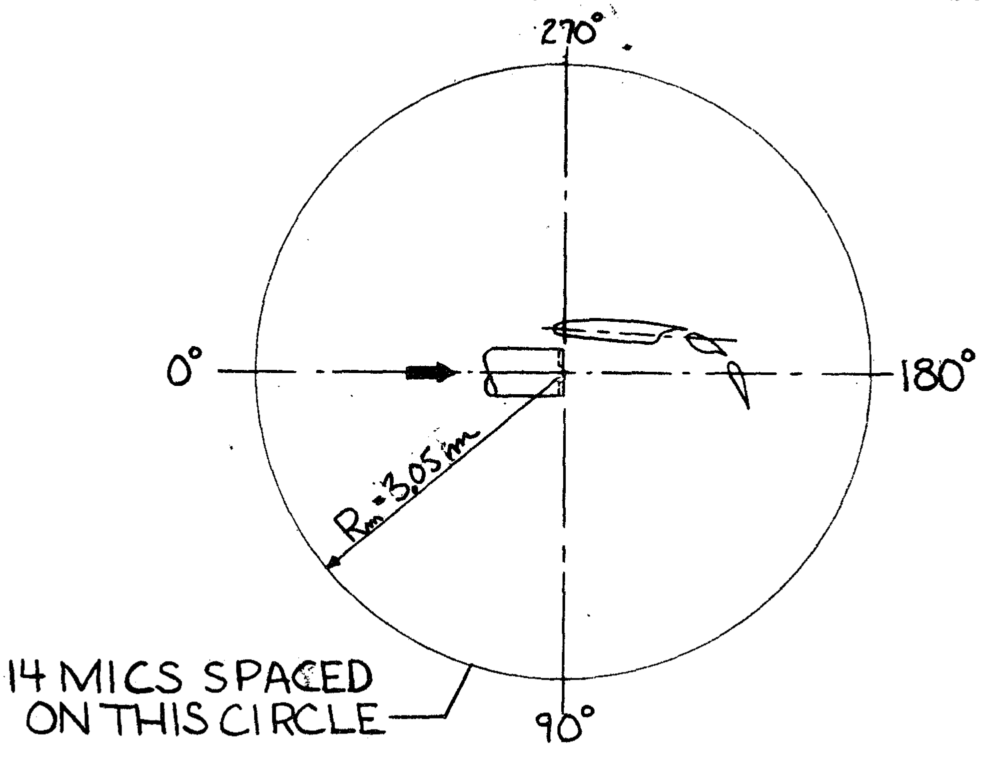



Figure 2. Microphone location for small scale externally blown flap model.

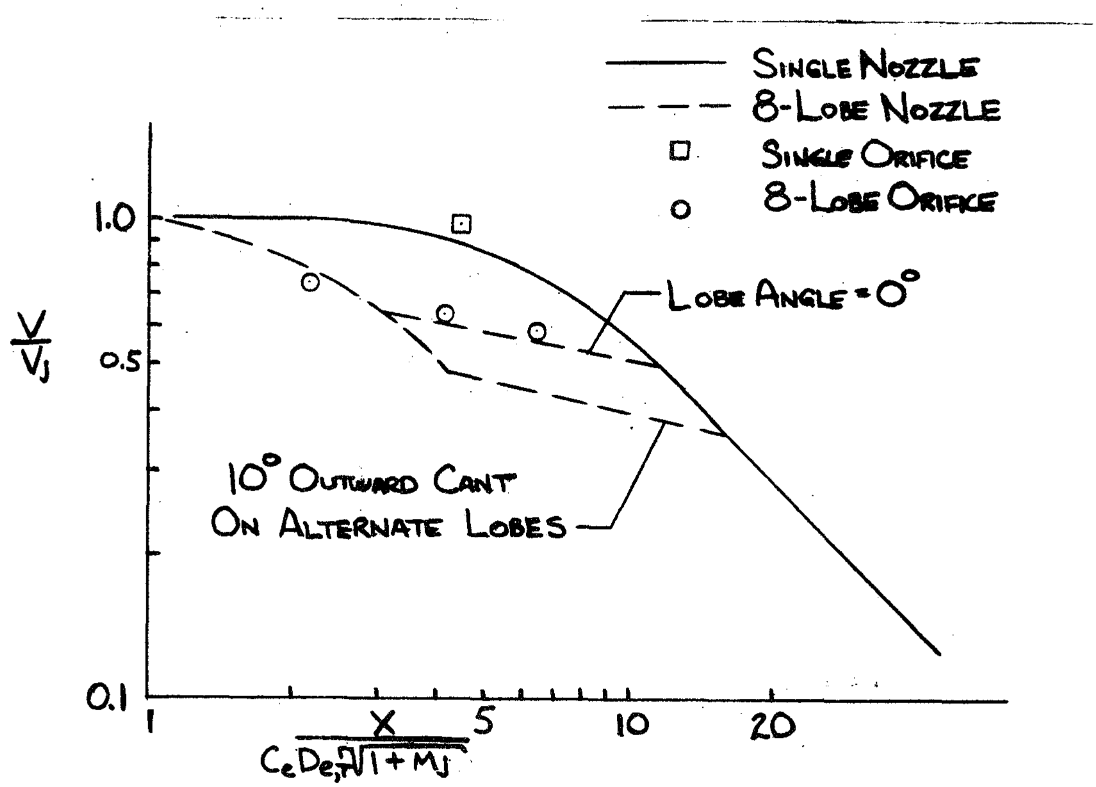
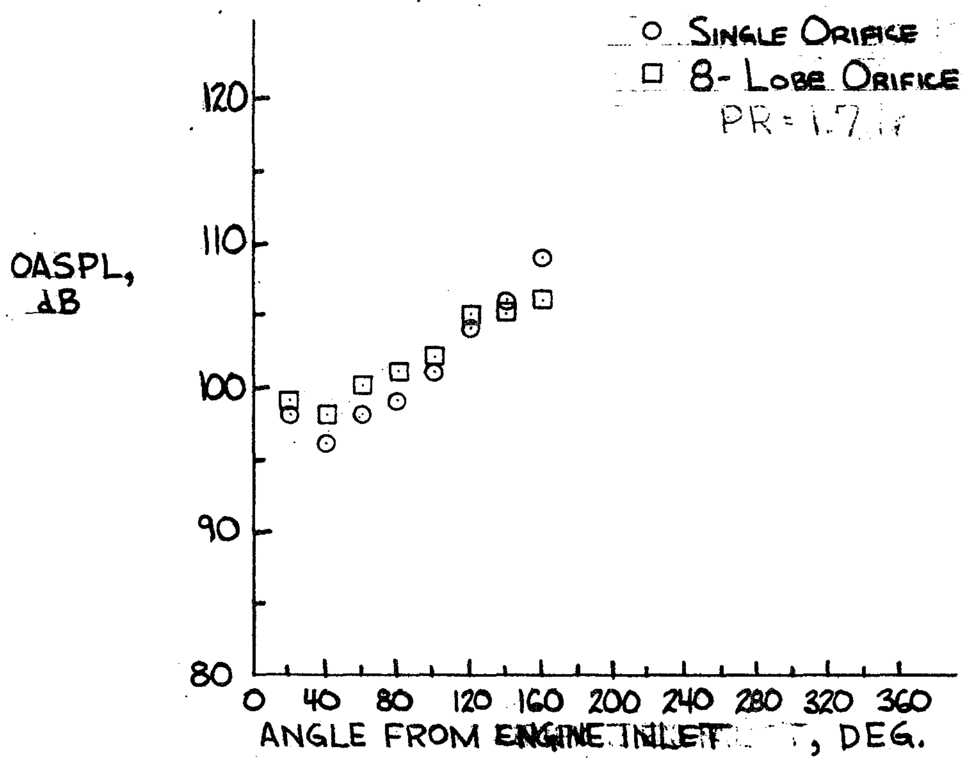
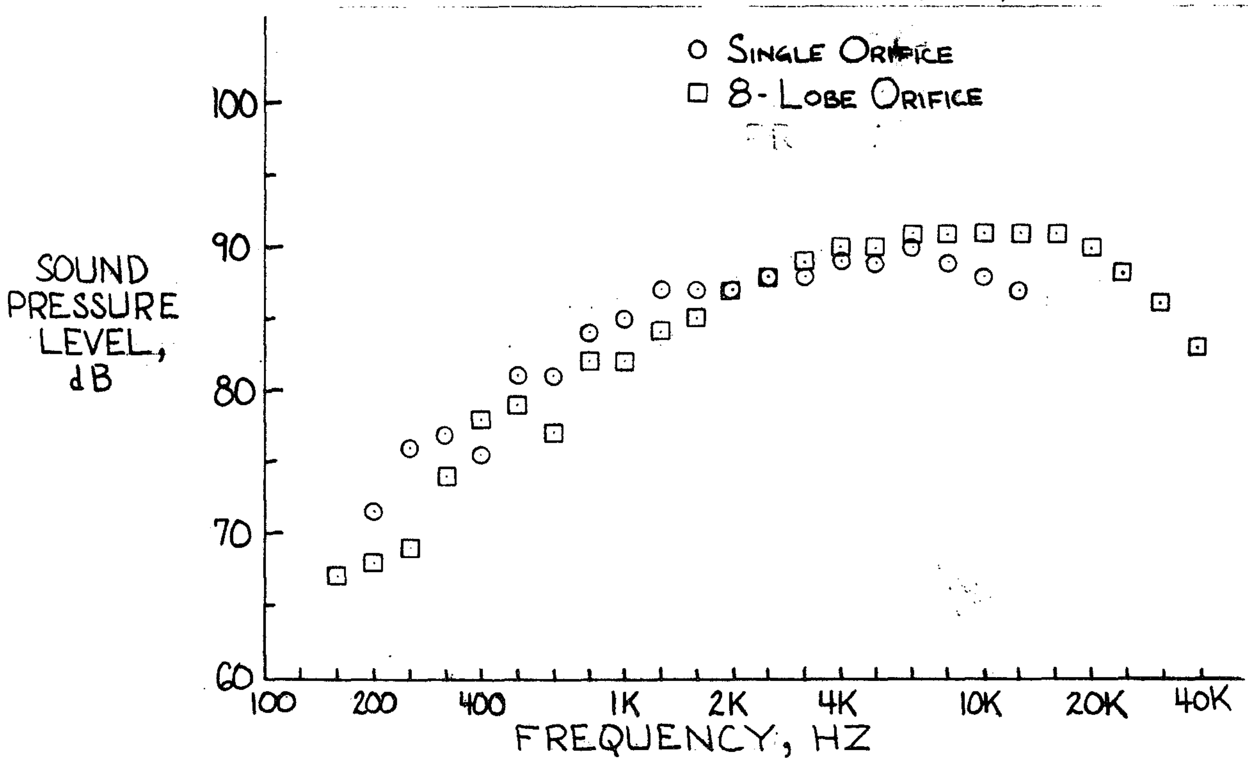



**Figure 3.** Comparison of velocity decay for single nozzle and 8-lobe nozzle. Also shown are data points for simulated nozzles (orifice plates).



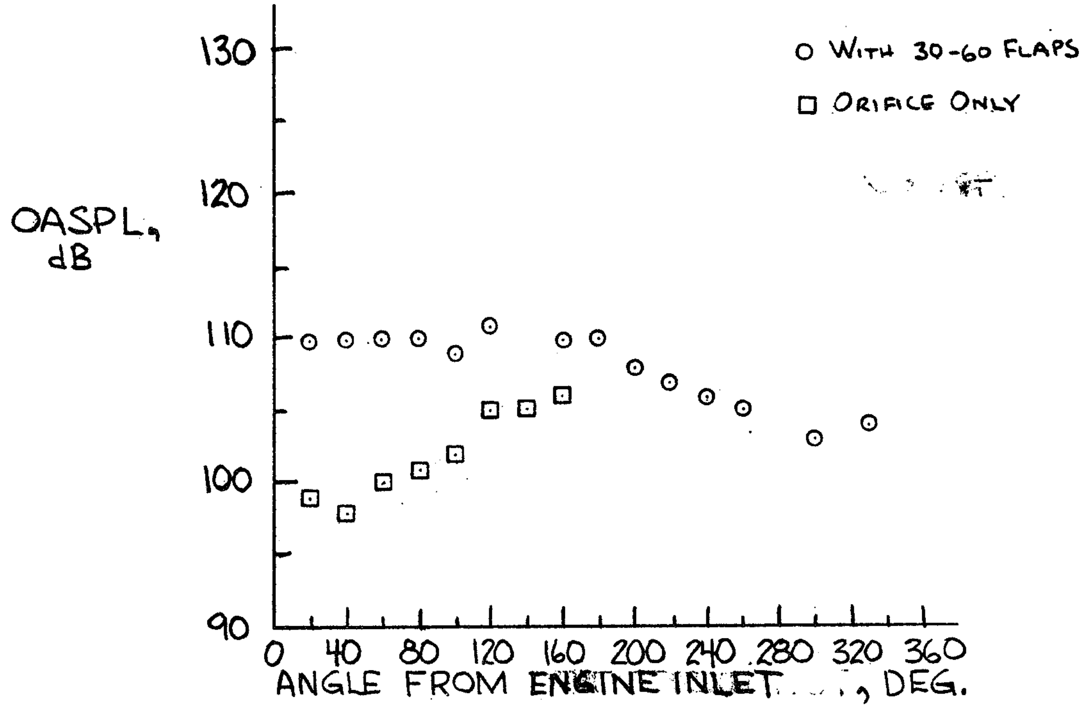

(a) Overall sound pressure level directivity pattern.

Figure 4. Comparison of noise data for single orifice only and 8-lobe orifice only. Orifice pressure ratio, 1.74; orifice exhaust velocity, 296 m/sec.



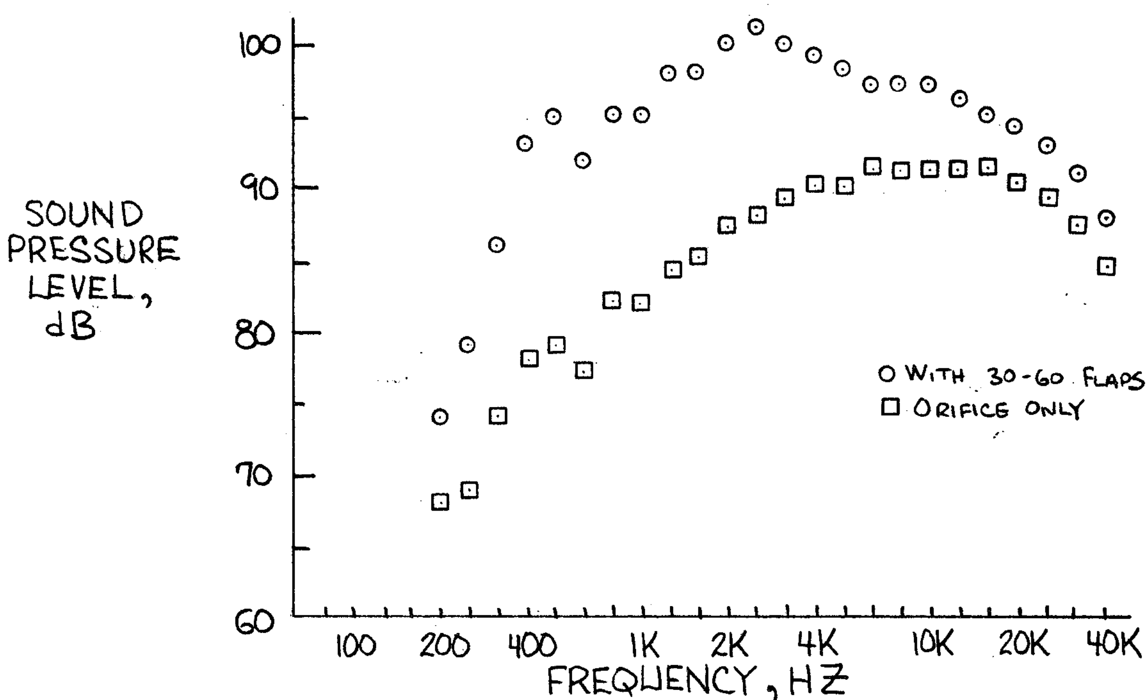

(b) SPL 1/3-octave spectra below wing at 80° microphone.

Figure 4. Cont.



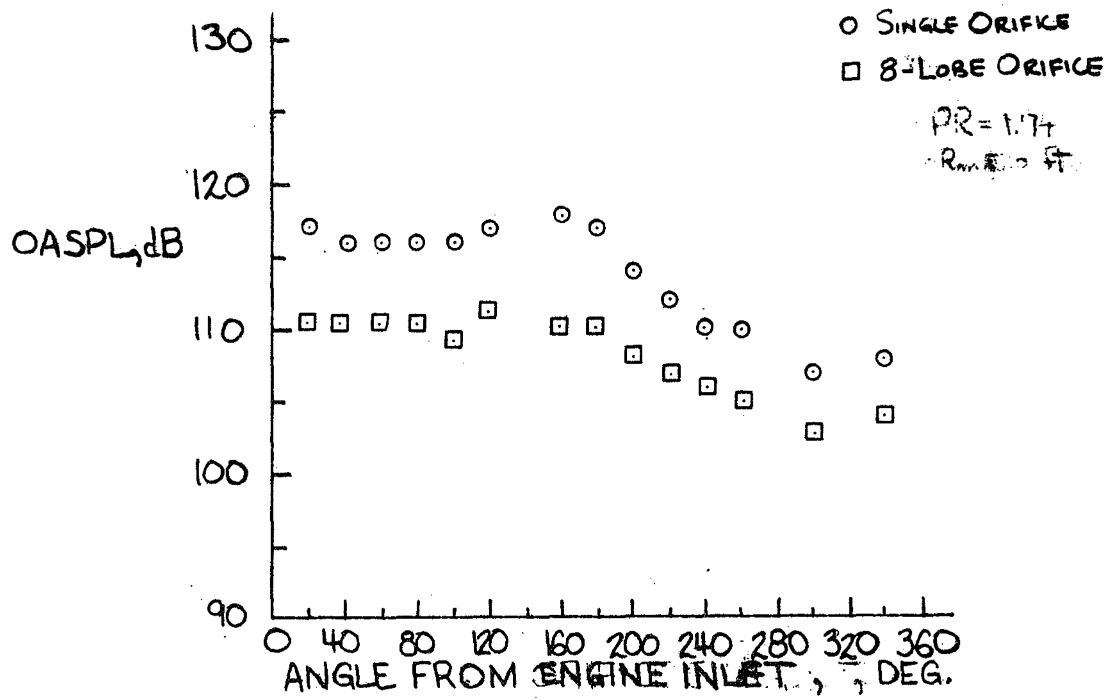

(a) Overall sound pressure level directivity pattern.

**Figure 5.** Comparison of noise data for 8-lobe orifice with 30-60° flaps and 8-lobe orifice only. Orifice pressure ratio, 1.74; orifice exhaust velocity, 296 m/sec.



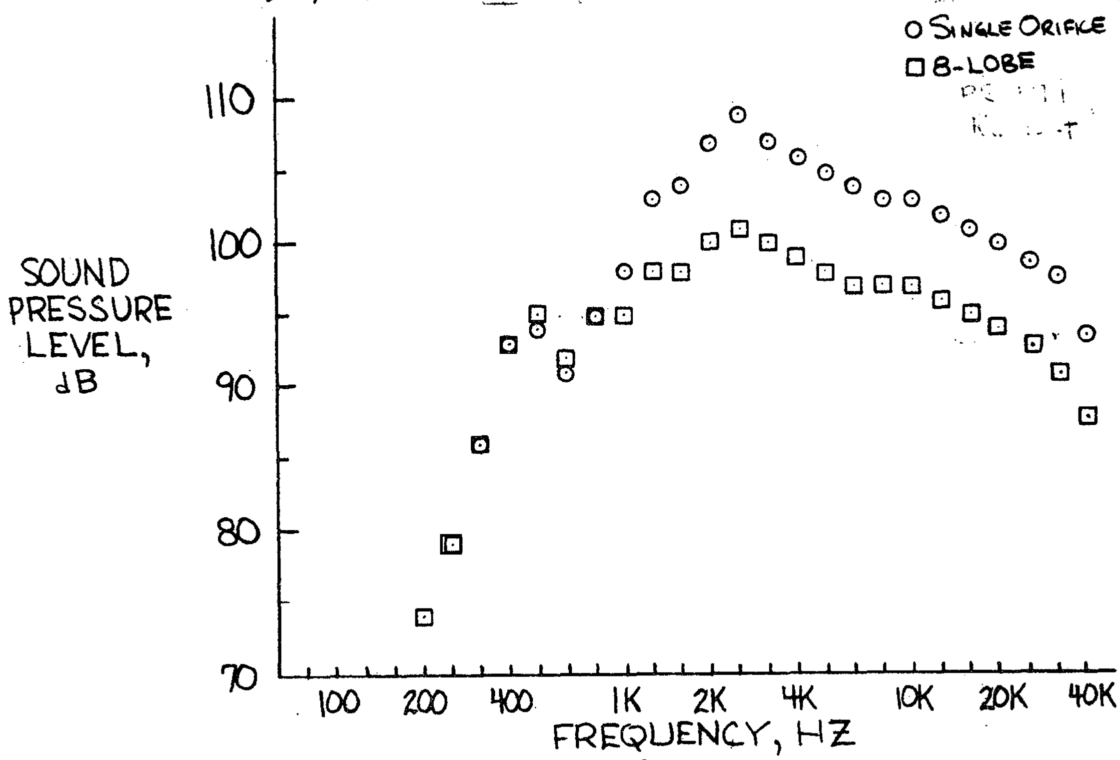

(b) SPL 1/3-octave spectra below wing at 80° microphone.

**Figure 5.** Cont.




(a) Overall sound pressure level directivity pattern.

Figure 6. Comparison of noise data for single orifice and 8-lobe orifices with 30-60° flaps. Orifice pressure ratio, 1.74; orifice exhaust velocity, 296 m/sec.




(b) SPL 1/3-octave spectra at 80° microphone.

Figure 6. Cont.