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PRELIMINARY NOISE TESTS OF THE ENGINE-OVER-THE-WING CONCEPT

I. 30° - 60° FLAP POSITION

by M. Reshotko, W. A. Olsen, and R. G. Dorsch

Lewis Research Center
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Meyer Reshotko, William A. Olsen
and Robert G. Dorsch

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio

INTRODUCTION

STOL aircraft will be using airports located close to large population centers. The noise generated by these airplanes must therefore be kept down to acceptable levels within the nearby community. This is a difficult engineering task because the employment of lift augmentation devices may generate and/or redirect noise. For example, the use of externally blown flaps for lift augmentation results in considerable flap interaction noise (ref. 1).

A possible solution to the STOL noise problem is to locate the engine above the wing. In addition to the noise created by the jet exhaust, there are other noises created at various locations in the engine which are carried out the exhaust and sometimes predominate. By placing the engine above the wing, the wing shielding can reduce the exhaust noise during flyover. However, in order to obtain lift augmentation it is necessary that the engine exhaust flow be attached to the wing and flaps. This

requires either a specially shaped exhaust nozzle or the use of exhaust deflectors when a conventional nozzle is employed.

This report summarizes the results of preliminary acoustic tests of the engine over the wing concept. The tests were conducted at the NASA Lewis Research Center with a small wing section model (32 cm chord) having two flaps set at the landing position, which is 30° and 60° respectively. The engine exhaust was simulated by an air jet from a convergent nozzle having a nominal diameter of 5.1 centimeters. Factors investigated for their effect on noise include nozzle location, wing shielding, flap leakage, nozzle shape, exhaust deflectors, and internally generated exhaust noise.

APPARATUS

Typical test configurations with both a slot and a circular nozzle in place over the wing are shown in figure 1. All tests were conducted with the wing at a 5° angle of attack with respect to the nozzle centerline and with the flaps at the 30°-60° position. Details of the wing and flap system are given in reference 1. The wing was moved to various positions under the nozzle and the relative nozzle locations with respect to the wing are shown in figure 2(a). Two nozzles were used in the test series, a circular nozzle with a nominal 5.1 centimeter diameter and a slot nozzle with an aspect ratio of 5, both having the same cross-sectional area (27.1 cm^2). In order to be able to vary the chordwise location of the flow exit plane the circular nozzle had an extended 26 centimeter long lip (fig. 1(b)). Each nozzle

was supplied by pressurized air at a temperature of about 278 K. Data were obtained at nominal jet velocities within a range of 175 to 280 m/sec (nominal pressure ratios of 1.25 to 1.7, respectively). The air supply system contained a series of mufflers which removed sufficient valve noise to assume that it was not included in the measured noise. In order to evaluate the noise leakage through the slots between the flaps, the flap slots were covered during some runs with a cloth tape that could be easily removed. The exhaust deflector plates used to attach the flow to the wing and flaps are shown in figures 2(b) and 2(c) for the round and slot nozzles respectively. Sideplates 3 centimeters high, forming a 12.7 centimeter flow channel extending from the wing leading edge to the trailing edge of the last flap were also used in some runs to obtain flow attachment.

Sound data were taken by microphones placed on a 3.05 meter radius centered at the nozzle exit. The microphone horizontal plane and jet centerline were located 1.5 meters above the ground. The sound data were analyzed by a 1/3 octave band spectrum analyzer. The analyzer determined sound pressure level spectra referenced to 2×10^{-5} N/m^2 (0.0002 microbar). Overall sound pressure levels were computed from the SPL data. A typical setup for noise measurement is illustrated in figure 3 where the microphones are appropriately placed on the circle.

In some runs an orifice plate was used to create a dominant internal noise in the nozzle exhaust flow, which exceeded all the aerodynamic noises of the experiment. The orifice plate contained four 1.1 centimeter diameter holes and was located 2.04 meters upstream of the nozzle exhaust plane.

RESULTS

In order to evaluate possible acoustic benefits associated with the engine-over-the-wing concept, the measured noise data presented herein are compared to the noise of the nozzle alone. The data are separated into two main categories; namely, that without internal noise and that with a dominant internal noise source present in the nozzle. Each of these main categories are additionally separated into those configurations in which the flow was not (or only partially) attached to the wing-flap surfaces and those in which substantially complete flow attachment to the surfaces was achieved.

WITHOUT INTERNAL NOISE

Unattached Flow

Nozzle alone. - A typical nozzle noise radiation pattern is shown in figure 4(a) where the OASPL for the slot nozzle is plotted as a function of the angle measured from the nozzle inlet. The data shown are for pressure ratios of 1.22, 1.39, and 1.67. Also shown in figure 4(b) are the sound pressure level spectra for the slot nozzle at an angle of 80° for the three pressure ratios. The 80° position was chosen because it is located directly under the wing when the airplane is in the landing attitude and therefore of special interest in these STOL noise experiments. The circular nozzle data is similarly shown in figures 4(c) and 4(d).

Wing shielding. - The noise data taken with each nozzle in position c_1 over the wing-flap system are shown in figure 5 in terms of OASPL as a

function of the angle from the inlet for a nozzle pressure ratio of 1.22.
At this low pressure ratio the presence of the wing causes the jet from the
circular nozzle to scrub along a portion of the wing surface resulting in
an increase in OASPL of up to 8 dB below the wing. Because the slot jet is
farther away from the wing surface than the circular jet (although the
nozzle centerlines are identical), the scrubbing effect is considerably
less.

Covering the flap slots with tape caused up to a 5 dB reduction in
scrubbing noise (under the wing) for the circular nozzle and a 3 dB maximum
reduction for the slot nozzle at a pressure ratio of 1.22 as shown in
figure 6. However, it is not clear whether this is due to the elimination
of noise leaking through the slots or to the fairing of the surface to a
smooth contour by the tape or to a combination of the two.

At higher pressure ratios there is some shielding of the jet noise
between an angle of 0° to 90° (fig. 7). The shielding effect becomes most
apparent at the highest pressure ratio (1.68) because the OASPL due to the
jet noise increases with the eighth power of the velocity while the scrub-
bing noise tends to increase the OASPL only as the sixth power of the
velocity. This indicates that the scrubbing noise predominates at the
lower pressure ratios.

Nozzle location. - The height and fore and aft location of the nozzle
exit plane relative to the wing surface can be critical. When the slot
nozzle was moved closer to the wing, from the c_1 location to the c_2
location, the noise level increased significantly by up to 12 dB under the

wing as shown in figure 8(a). This increase in noise level is caused by the increased jet scrubbing of the wing surface (partial attachment to the flaps), and the flap slots.

Moving the circular nozzle forward to location a_1 from the c_1 location caused only a small noise increase (2 dB) as seen in figure 8(b). By raising the nozzle from the a_1 to the a_2 location the maximum scrubbing noise reduction was about 3 dB.

Attached Flow

As pointed out in the Apparatus section two methods for attaching the flow to the flap surfaces were studied. The first consisted of using a deflector plate at the exit of the nozzles while the second consisted of placing the slot nozzle close to the wing surface and using sideplates to maintain flow attachment on the flaps.

Nozzle only with deflector. - In figure 9 the effect on noise level of the flow deflector for both circular and slot nozzles are shown together with the levels for the nozzles without deflectors. The use of a deflector on the circular nozzle caused a large overall increase in nozzle-only noise, about 14 dB maximum. For the slot nozzle the noise increase was somewhat less, about 7 dB.

Nozzle with deflector and wing. - When the jet flow was attached to the wing-flap system by use of a deflector plate, the noise level increased significantly compared with that without a deflector (flow not attached) at all three pressure ratios for the circular nozzle (fig. 10). The increase

in noise level was reasonably independent of the nozzle shape at comparable

pressure ratios as can be seen by comparing the data of figure 10 with the

slot nozzle case shown in figure 11.

Slot nozzle with sideplates and wing. - With the slot nozzle close to

the wing surface (c_2 position) and with sideplates, the noise level was

greater than that obtained without sideplates (flow detached) as shown in

figure 12. The overall noise level for this condition was substantially

the same as the previous case where the slot nozzle with a deflector was

located just above the wing.

WITH INTERNAL NOISE

Unattached Flow

The noise increase caused by the internal noise source (an orifice

plate) inserted upstream of the nozzle exit plane is shown in figure 13(a)

for the nozzle-alone case. In general, the presence of this dominant inter-

nal noise source caused an overall increase of 30 dB in the nozzle-alone

noise level. Also shown in figure 13(b) are the sound pressure level

spectra at an angle of 80° with and without an internal noise source. The

internal noise source caused a large increase in SPL and shifted the center

frequency to a higher frequency than that for the case without internal

noise.

Since the level of the dominant internal noise source was arbitrary,

only changes in noise level will be shown hereinafter.

Wing shielding. - The data in figure 14 show that the wing is an effective shield for the exhaust jet noise in which internal noise dominates. Under the wing, a large noise attenuation of up to 12 dB was obtained with the nozzles at the c_1 location and the flap slots open. In general, the slot nozzle data are slightly higher (1 or 2 dB) than that for the circular nozzle. Covering the flap slots caused an additional attenuation of about 2 dB.

Nozzle location. - With a large internal noise source present the effect of nozzle height and fore and aft location on noise level are small.

Moving the circular nozzle forward to the a_1 and a_2 location from the c_1 location, caused an approximate 2 dB noise increase in the lower forward quadrant (fig. 15). Lowering the slot nozzle to the c_2 location causes a very negligible noise change from the c_1 location.

Attached Flow

Nozzle only with deflector. - With a dominant internal noise source the use of a deflector did not appreciably affect the power level of the nozzle. However, as shown in figure 16 a redirection of the radiation pattern is evident in the lower front quadrant.

Nozzle with deflector and wing. - A comparison of noise data with and without a flow deflector for the engine-over-the-wing configuration is shown in figure 17. The increase in noise level caused by the deflector with the wing in place is about the same as for the previous case of nozzle alone.

CONCLUDING REMARKS

Data from this experiment show that in the absence of internal noise, wing shielding of jet noise is sensitive to nozzle pressure ratio. There was no noticeable benefit from shielding at the lowest pressure ratio (1.23) because of the presence of relatively high scrubbing noise. However, at the higher pressure ratios of 1.39 and 1.68 some shielding effects are evident.

The use of a flow deflector with the nozzles resulted in good flow attachment to the flaps. However, the resultant scrubbing action caused a large increase in noise compared to the unattached case.

The noise level with attached flow (deflector) is about the same as for an externally blown flap with the mixer nozzle of reference 2.

The jet exhaust flow from the slot nozzle partially attached itself to the wing and flaps when the nozzle was very close to the wing. However, the large increase in noise level due to scrubbing appears to outweigh any advantage in partial flow attachment.

When a dominant internal noise is present considerable shielding takes place and there is a large noise level attenuation under the wing. However, factors such as nozzle shape, nozzle height above the wing, and leakage through the flaps were found to have only a negligible effect on the noise level under the wing when the dominant internal noise was present.

REFERENCES

1. Dorsch, R. G.; Krejsa, E. A.; and Olsen, W. A.: Blown Flap Noise Research. AIAA Paper No. 71-745. Paper presented at the AIAA/SAE 7th Propulsion Joint Specialist Conference (Salt Lake City, Utah), June 1971.

2. Goodykoontz, J. H.; Olsen, W. A.; and Dorsch, R. G.: Preliminary Tests of the Mixer Nozzle Concept for Reducing Blown Flap Noise. NASA TMX-67938.
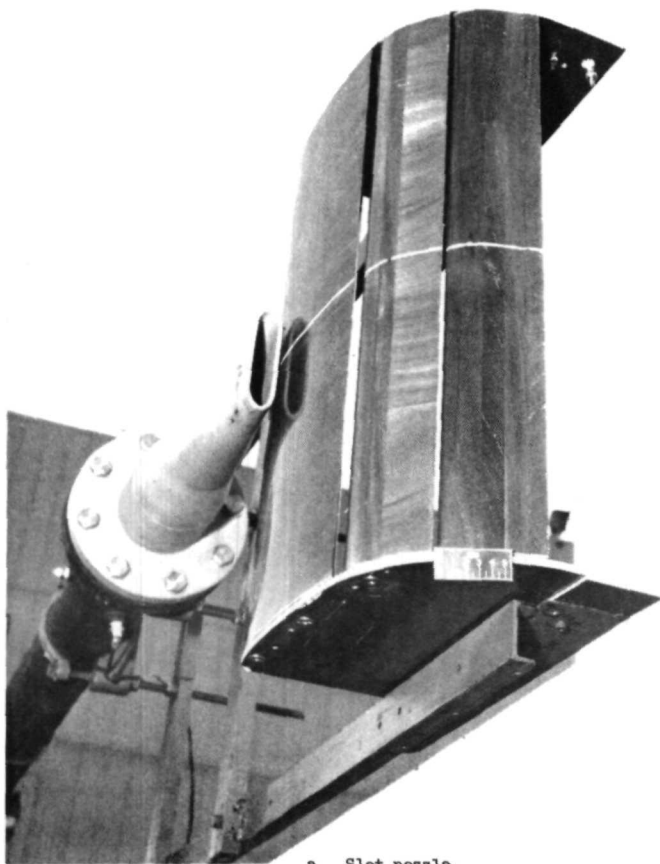
a. Slot nozzle.
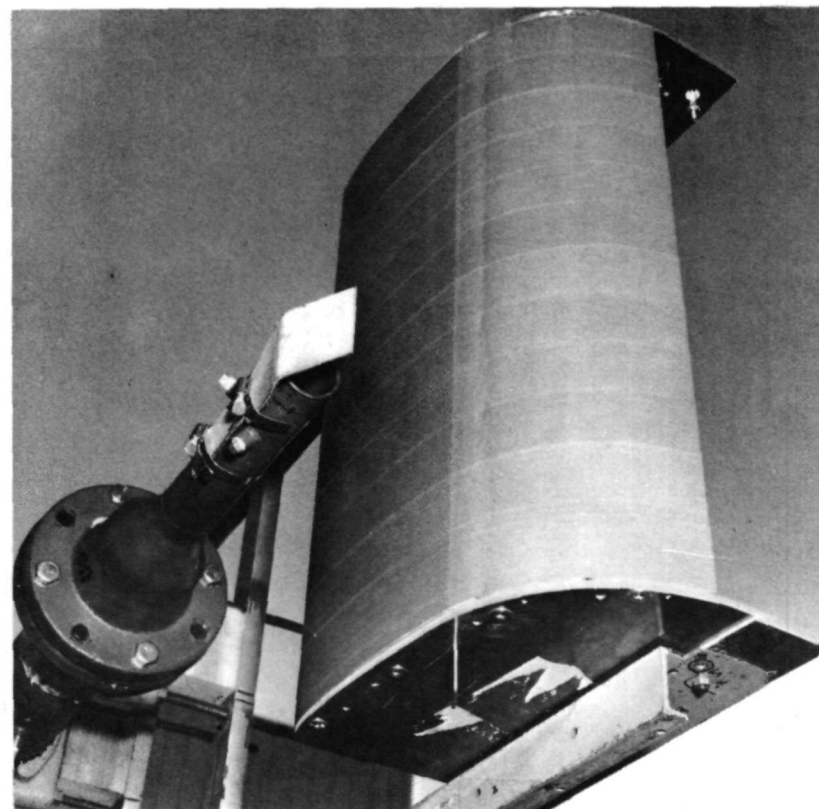
b. Circular nozzle with covered slots and deflector plate.

Figure 1. Typical test configurations of the engine-over-the-wing model with the flaps in a 30°-60° position.
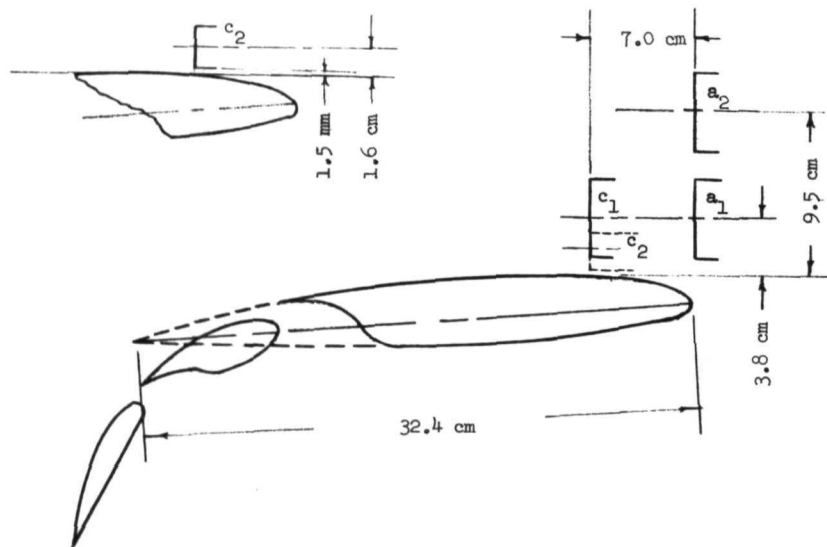
a. Nozzle locations with respect to the wing.
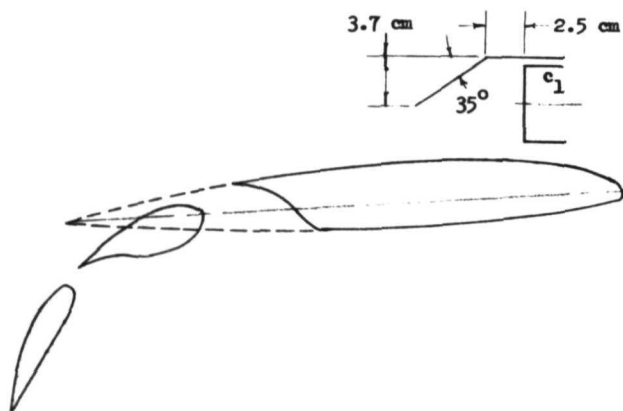
b. Circular nozzle with a 7.6 cm wide deflector.
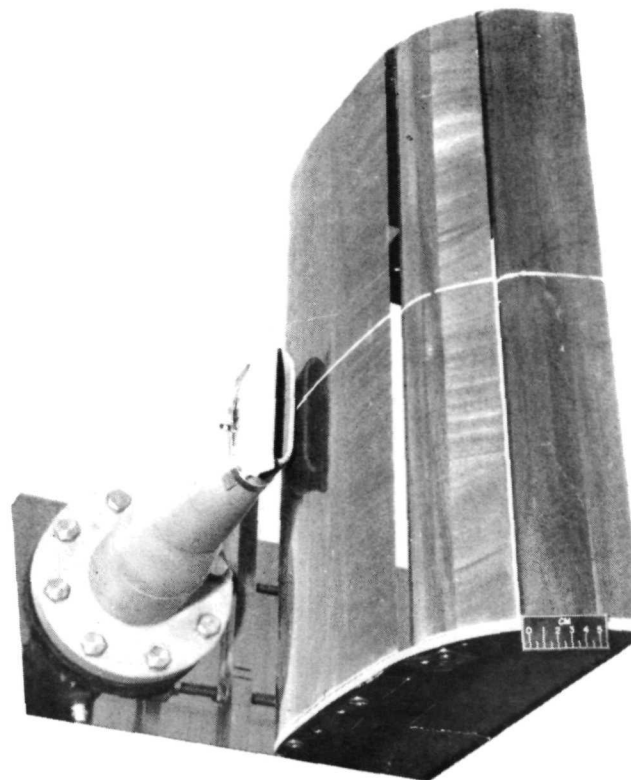
c. Slot nozzle with a 15.2 cm wide deflector.

Figure 2. Engine-over-the-wing test configurations.
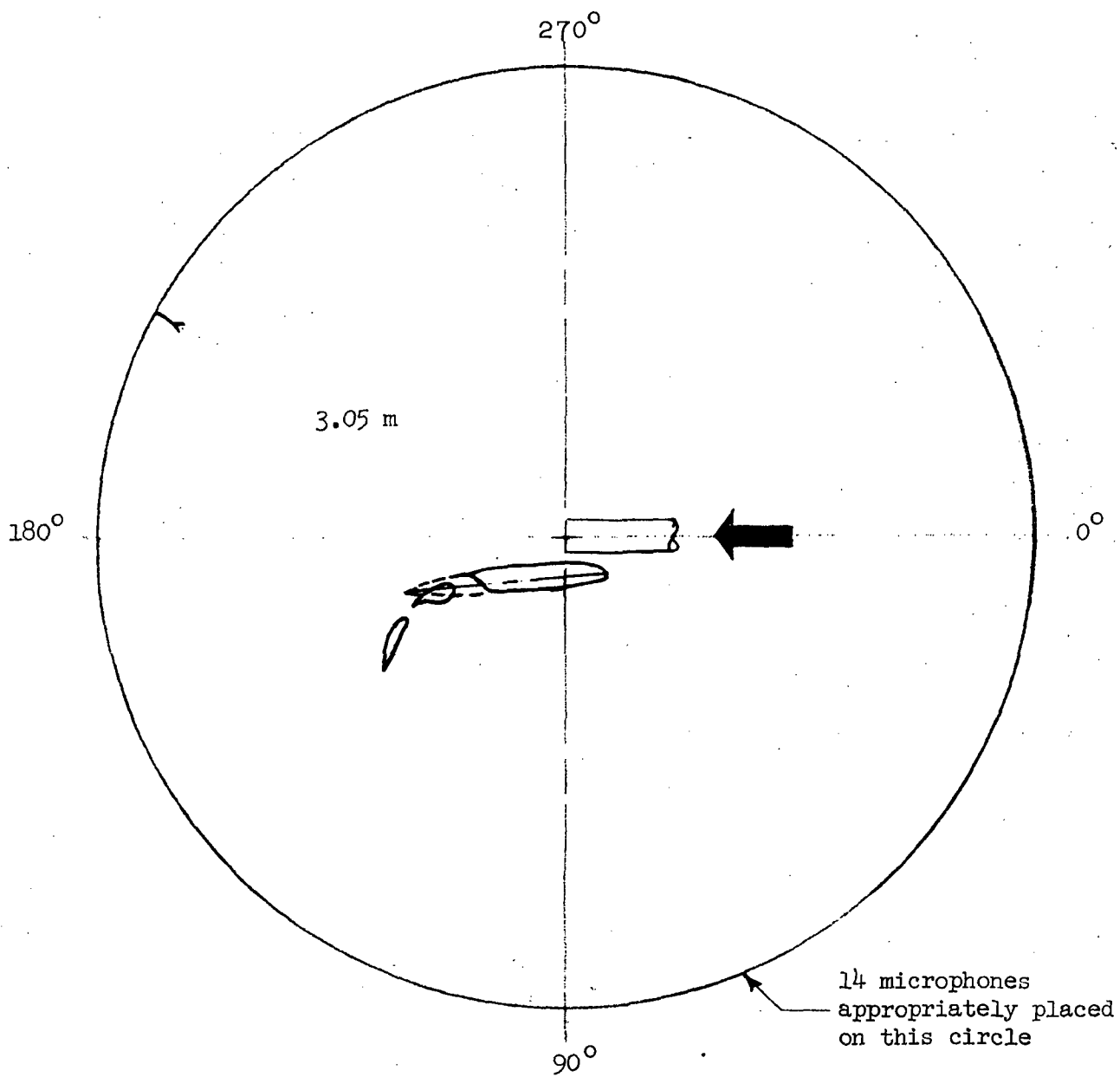
Figure 3. Microphone circle for small scale engine-over-the-wing model.
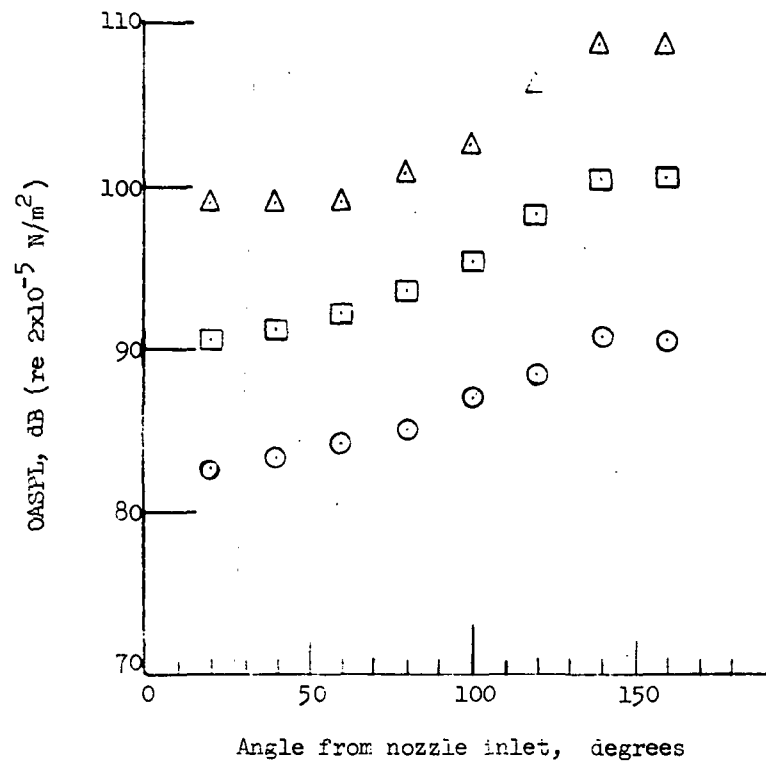
a. Noise radiation pattern for the slot nozzle alone.
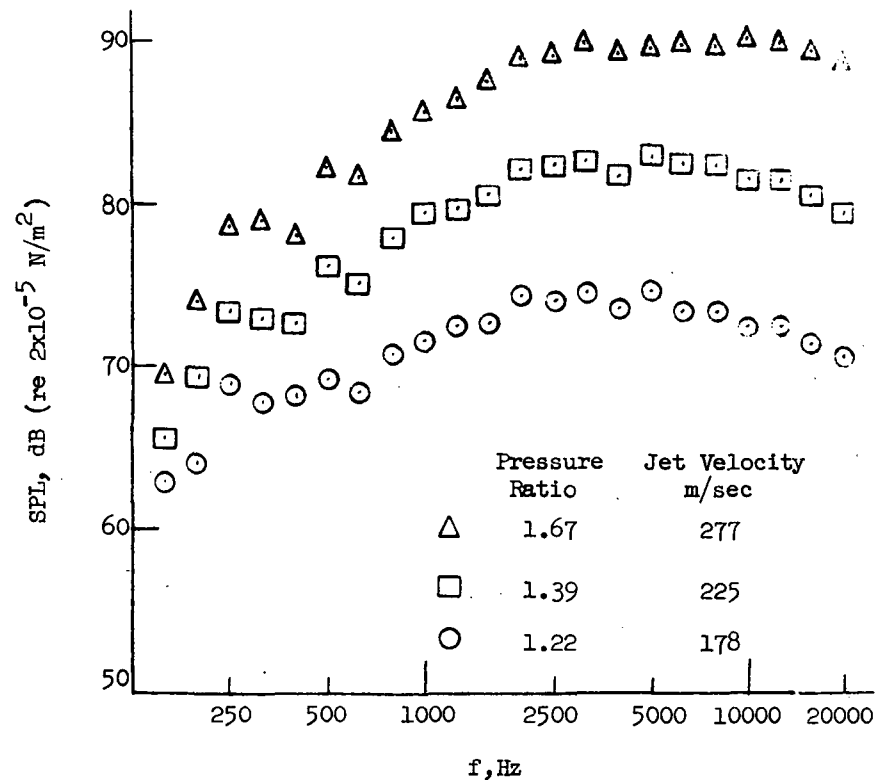
b. 1/3 octave sound pressure level spectrum at 80° for the slot nozzle alone.

Figure 4. Comparison of noise data at various jet velocities and pressure ratios for the nozzle-alone case.
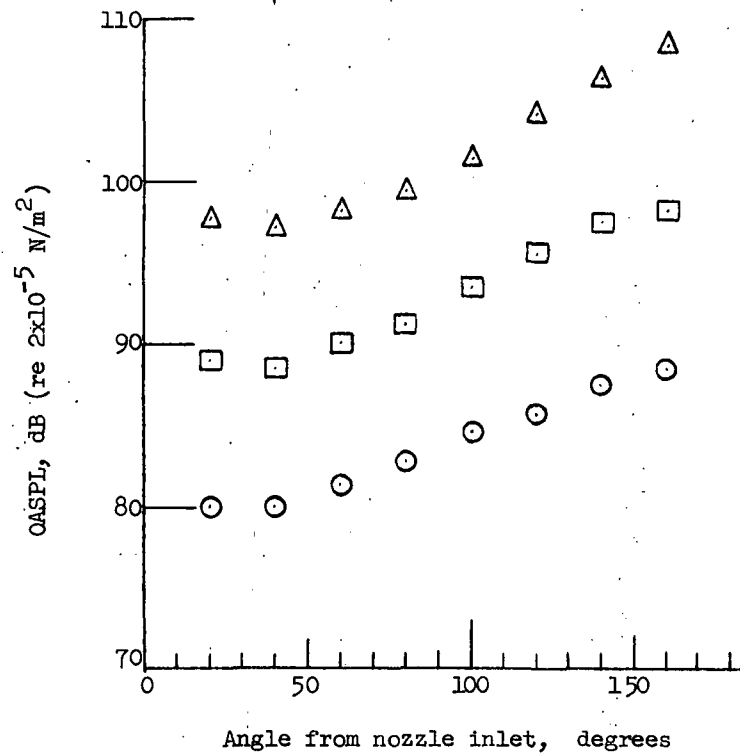
c. Noise radiation pattern for the circular nozzle alone.
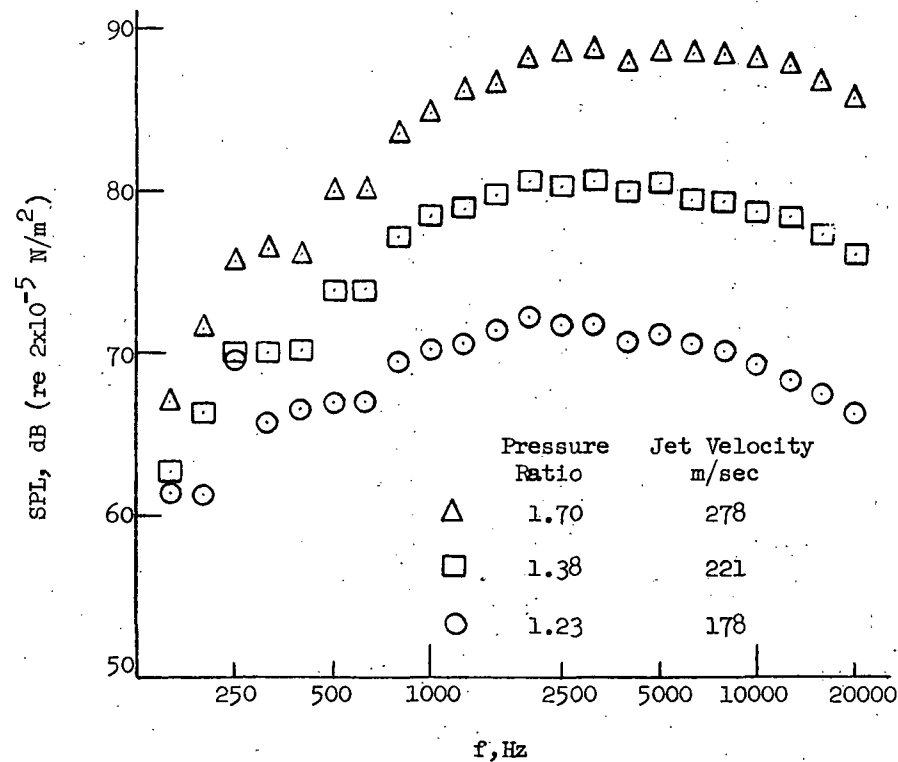
d. 1/3 octave sound pressure level spectrum at 80° for the circular nozzle alone.

Figure 4. Concluded.

a. Circular nozzle.
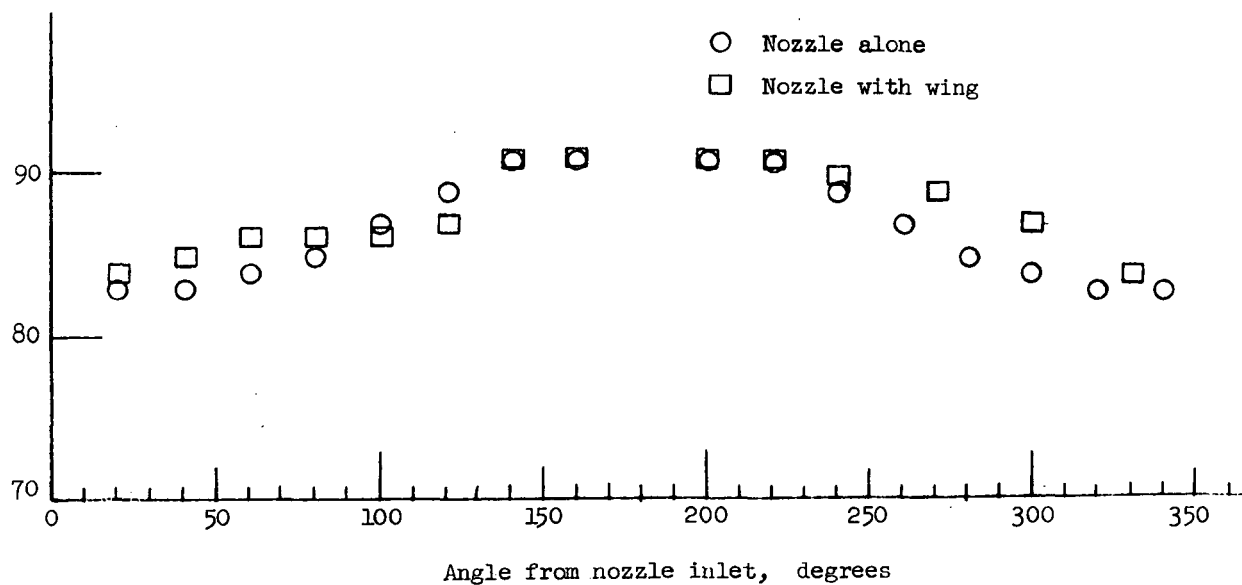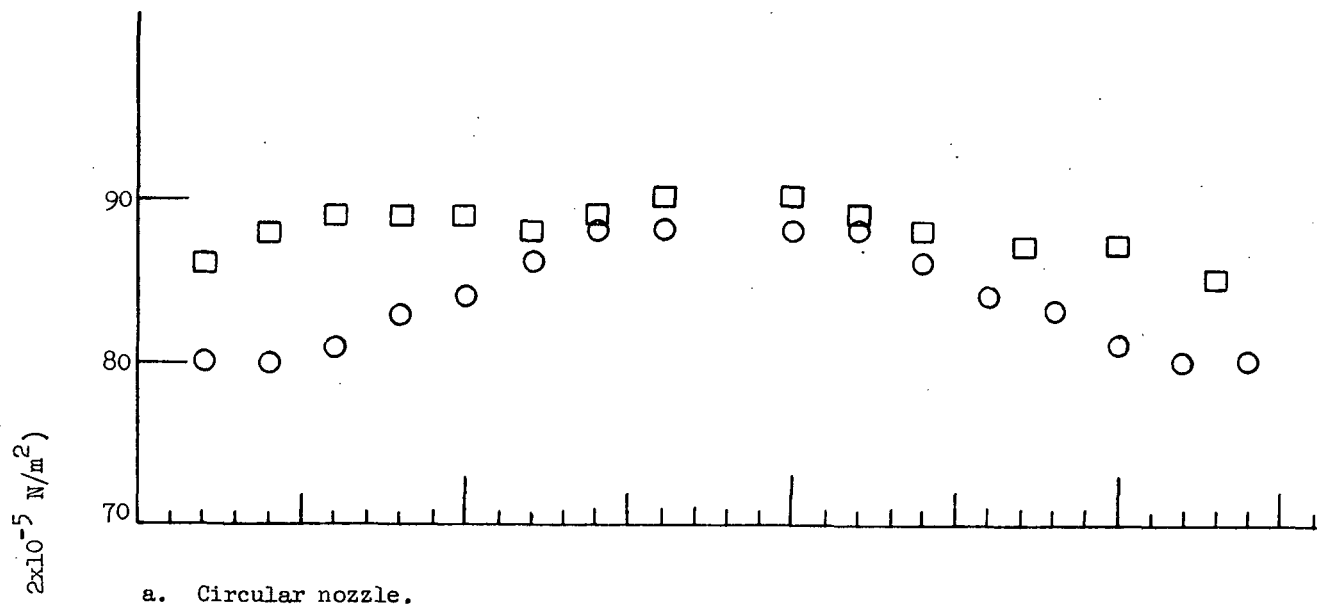
b. Slot nozzle.

Figure 5. Effect of wing shielding on the exhaust jet noise radiation pattern. Pressure ratio, 1.22; jet velocity, 178 m/sec; nozzle location, c_1.

a. Circular nozzle.

O   Nozzle alone
□   Nozzle with wing
△   Nozzle with wing and taped slots

Angle from nozzle inlet,   degrees
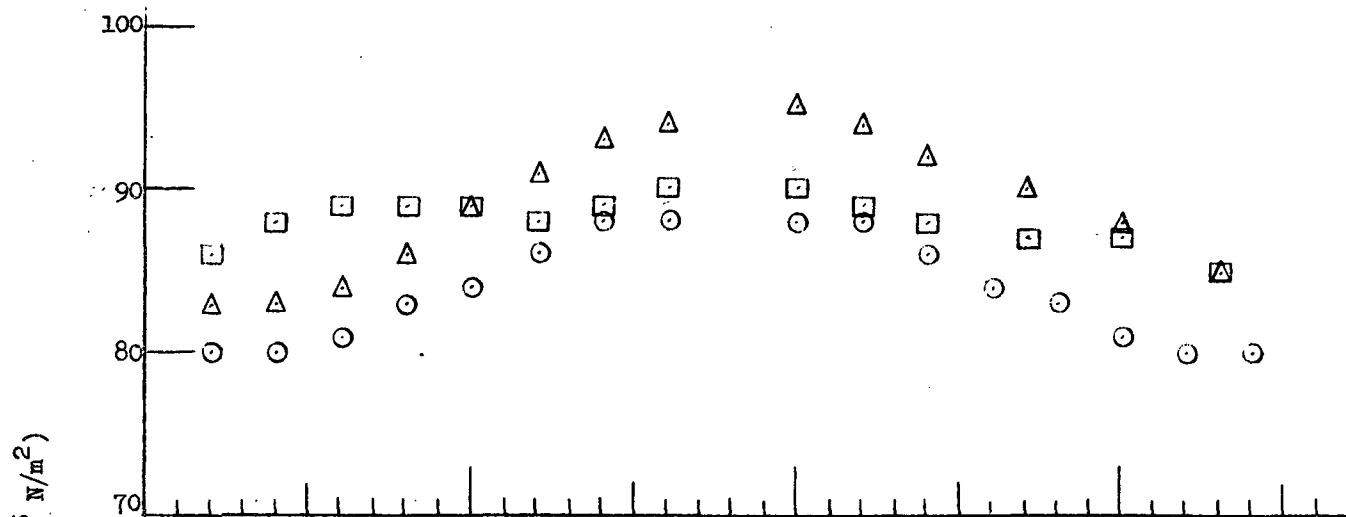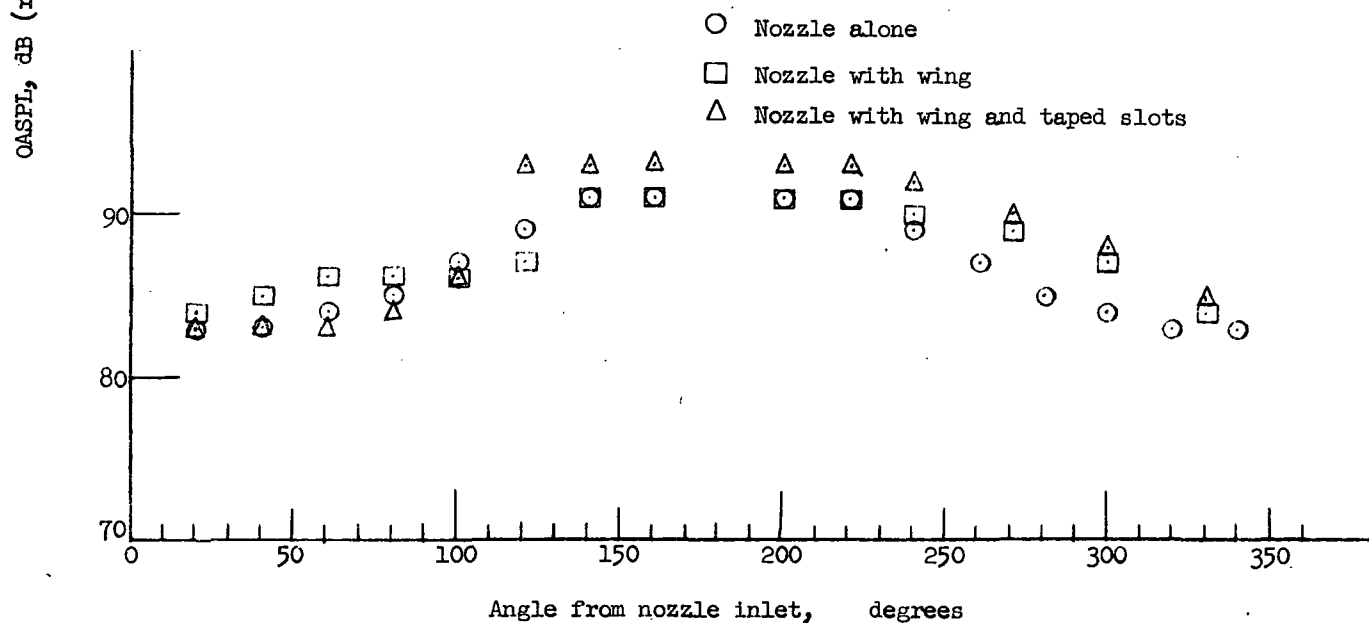
b. Slot nozzle.

Figure 6. Effect of wing shielding and flap slot leakage on the exhaust jet noise radiation pattern. Pressure ratio, 1.22; jet velocity, 178 m/sec; nozzle location, c_1.

a. Pressure ratio, 1.23; jet velocity, 178 m/sec.
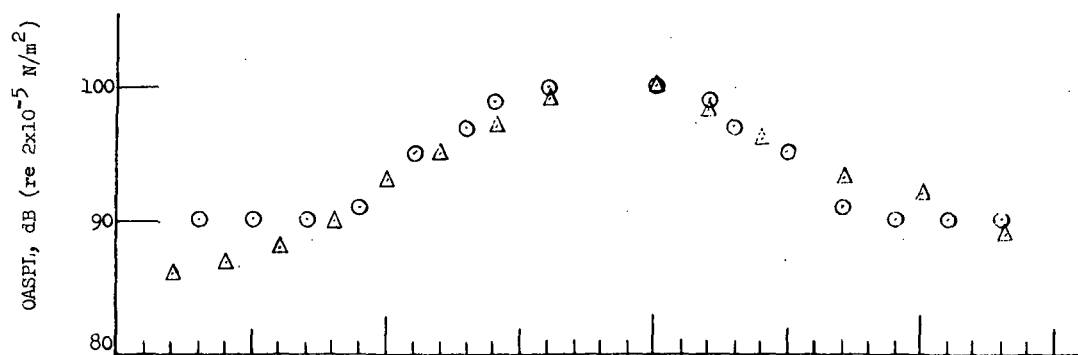
b. Pressure ratio, 1.39; jet velocity, 225 m/sec.

O   Nozzle alone

△   Nozzle with wing and taped slots

Angle from nozzle inlet,   degrees
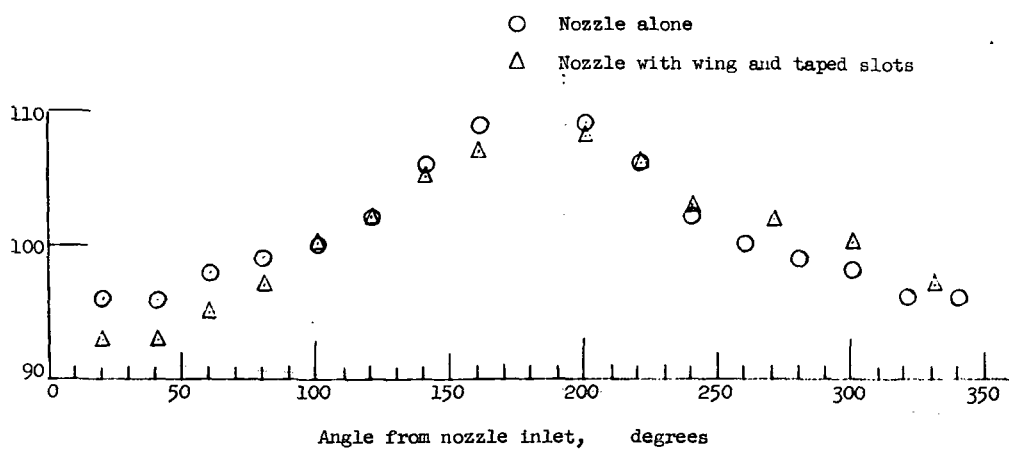
c. Pressure ratio, 1.68; jet velocity, 277 m/sec.

Figure 7.   The effect of nozzle pressure ratio on the shielding of the exhaust jet
noise.   Circular nozzle; nozzle location; c_1.
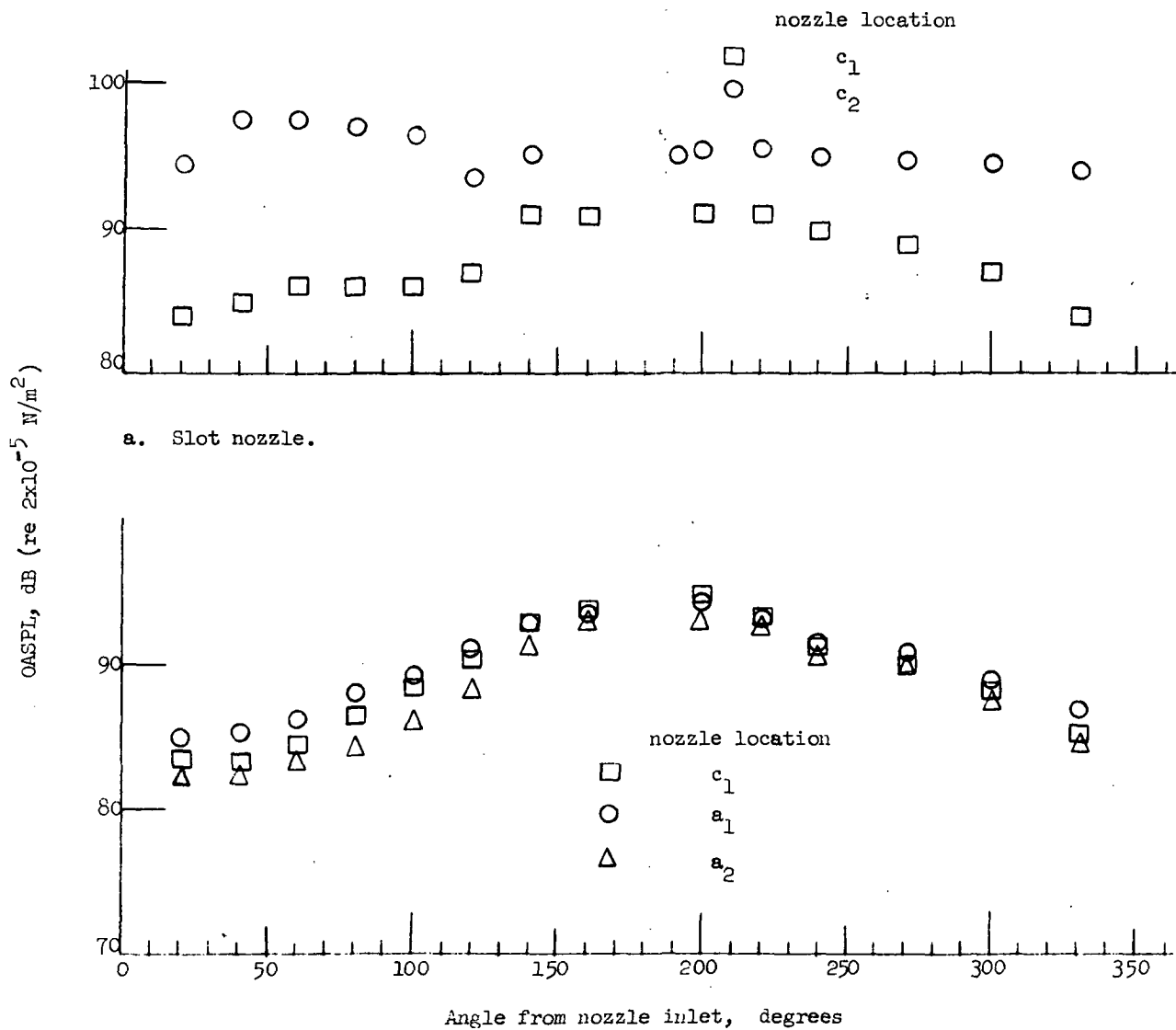
a. Slot nozzle.

b. Circular nozzle.

Figure 8. The effect of nozzle height and fore and aft location with respect to the wing on the noise radiation pattern. Pressure ratio, 1.23; jet velocity, 179 m/sec.

a. Circular nozzle.
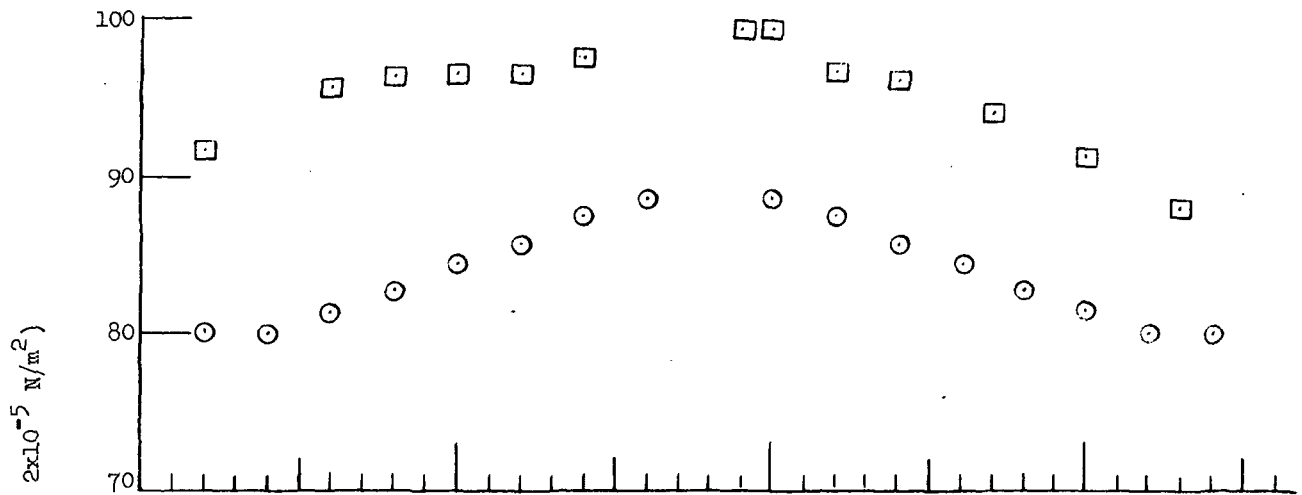
☐ With deflector

O Without deflector
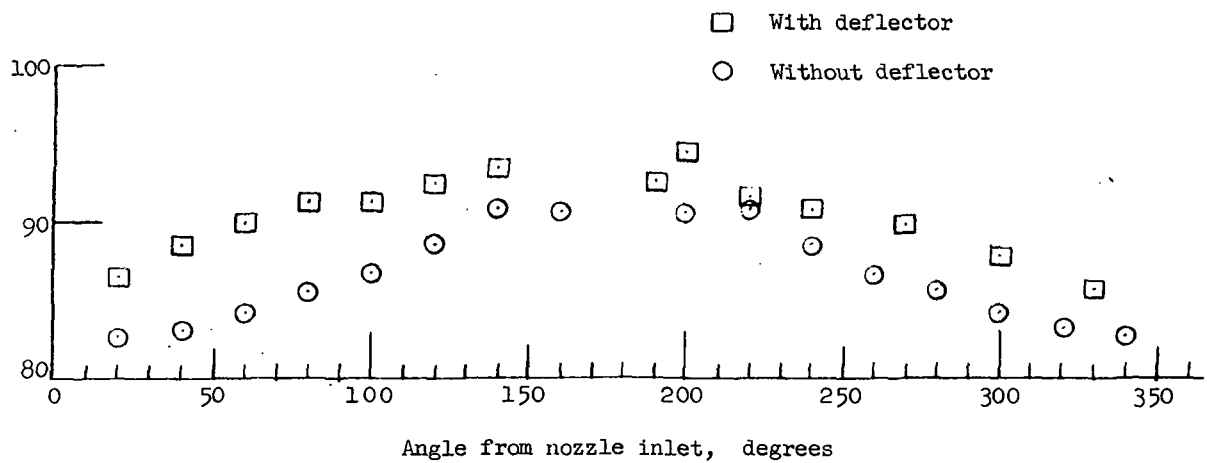
b. Slot nozzle.

Figure 9. Comparison of noise data with and without a flow deflector for the nozzle alone. Pressure ratio, 1.23; jet velocity, 180 m/sec.
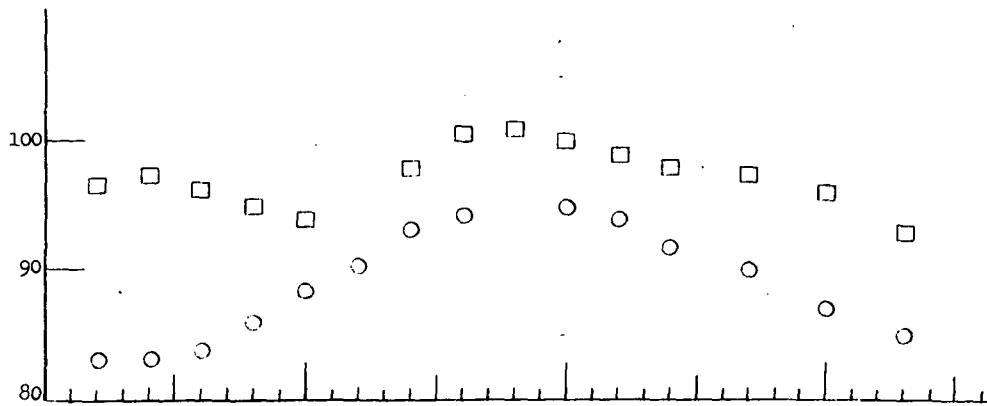
a. Pressure ratio, 1.23; jet velocity, 178 m/sec.
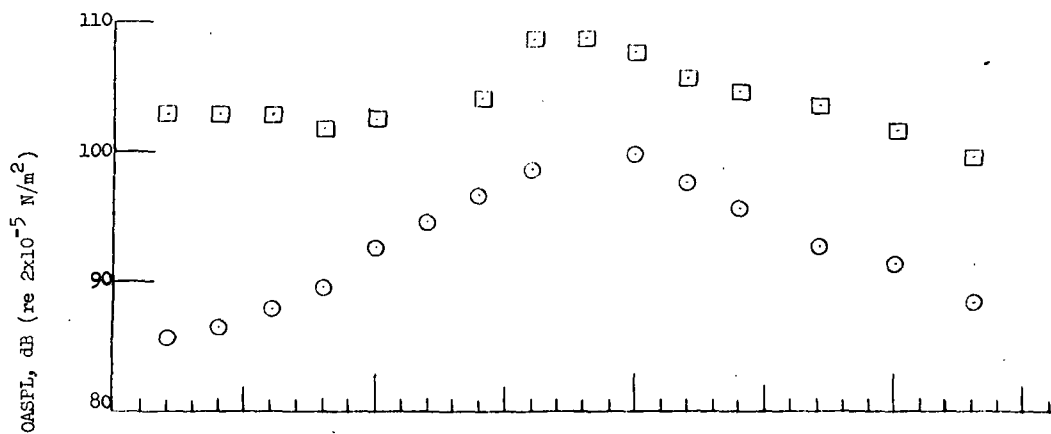
b. Pressure ratio, 1.39; jet velocity, 225 m/sec.

□   With deflector

O   Without deflector

Angle from nozzle inlet,   degrees
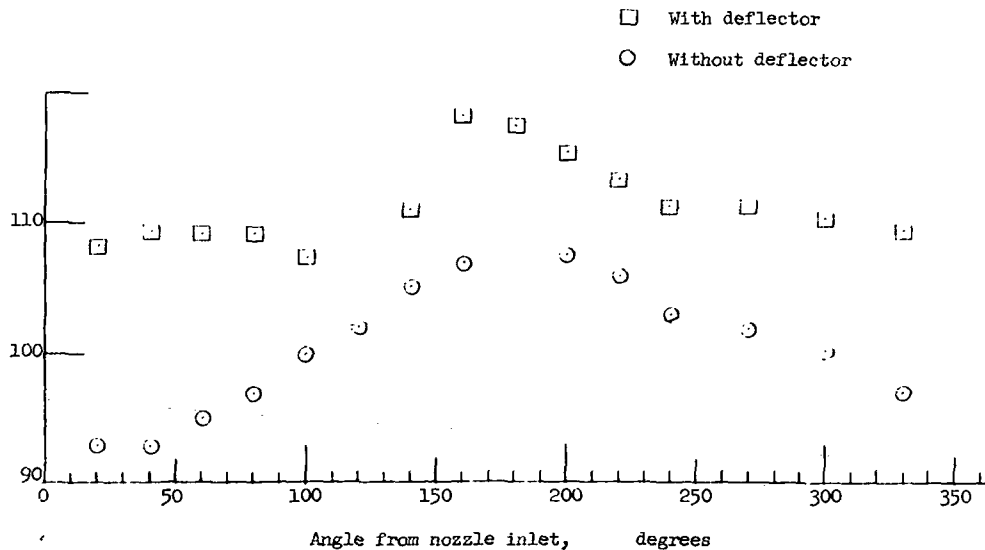
c. Pressure ratio, 1.68; jet velocity, 277 m/sec.

Figure 10.   The effect of a flow deflector attached to the nozzle on the noise radiation
pattern of the engine-over-the-wing model at various pressure ratios.
Circular nozzle; covered slots; nozzle location, c_1.
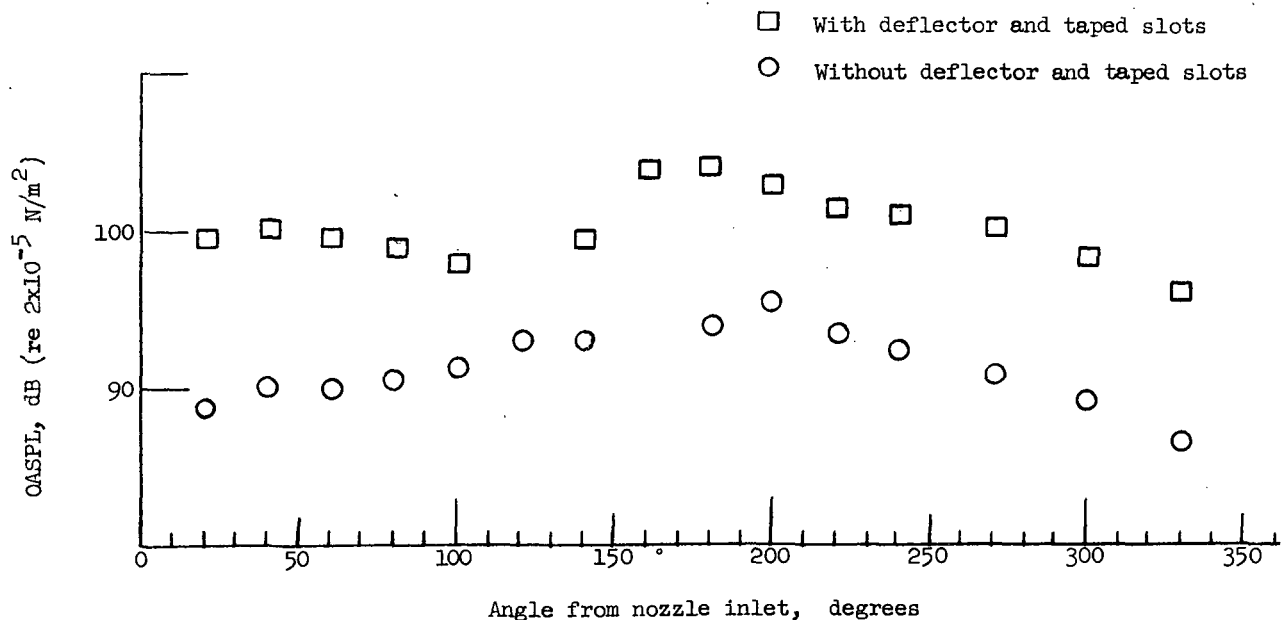
Figure 11. The effect of a flow deflector attached to the slot nozzle on the noise radiation pattern of the engine-over-the-wing model. Pressure ratio, 1.23; jet velocity, 178 m/sec; nozzle location, c_2.
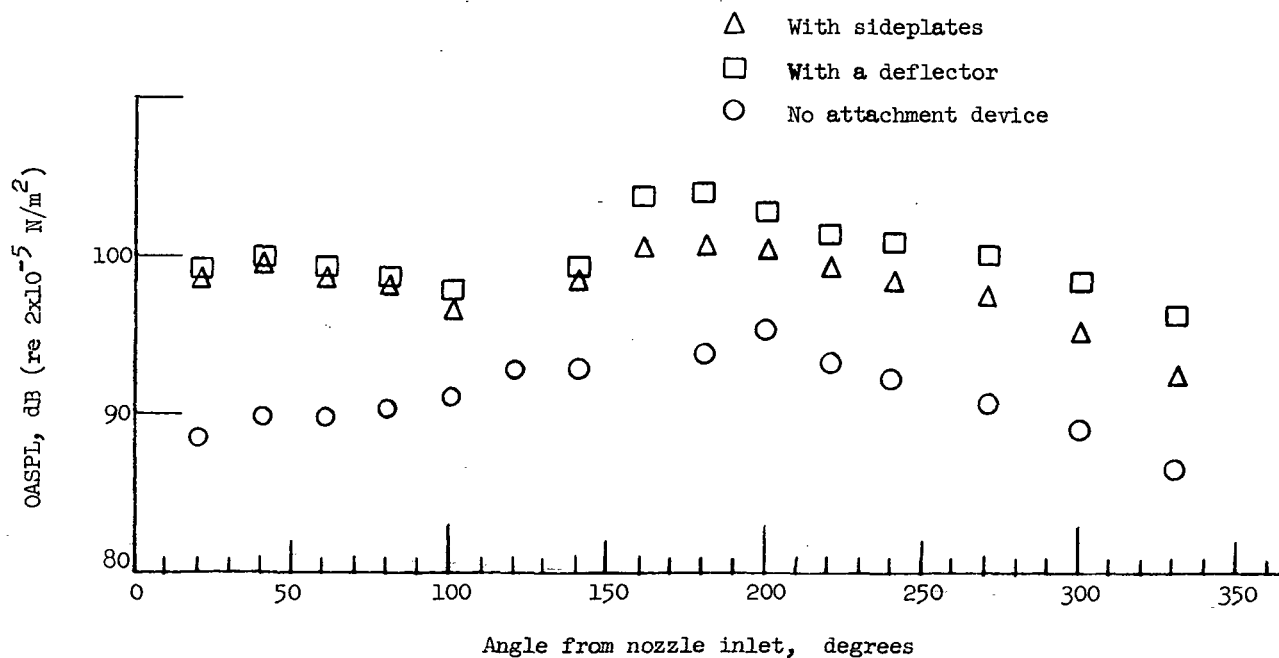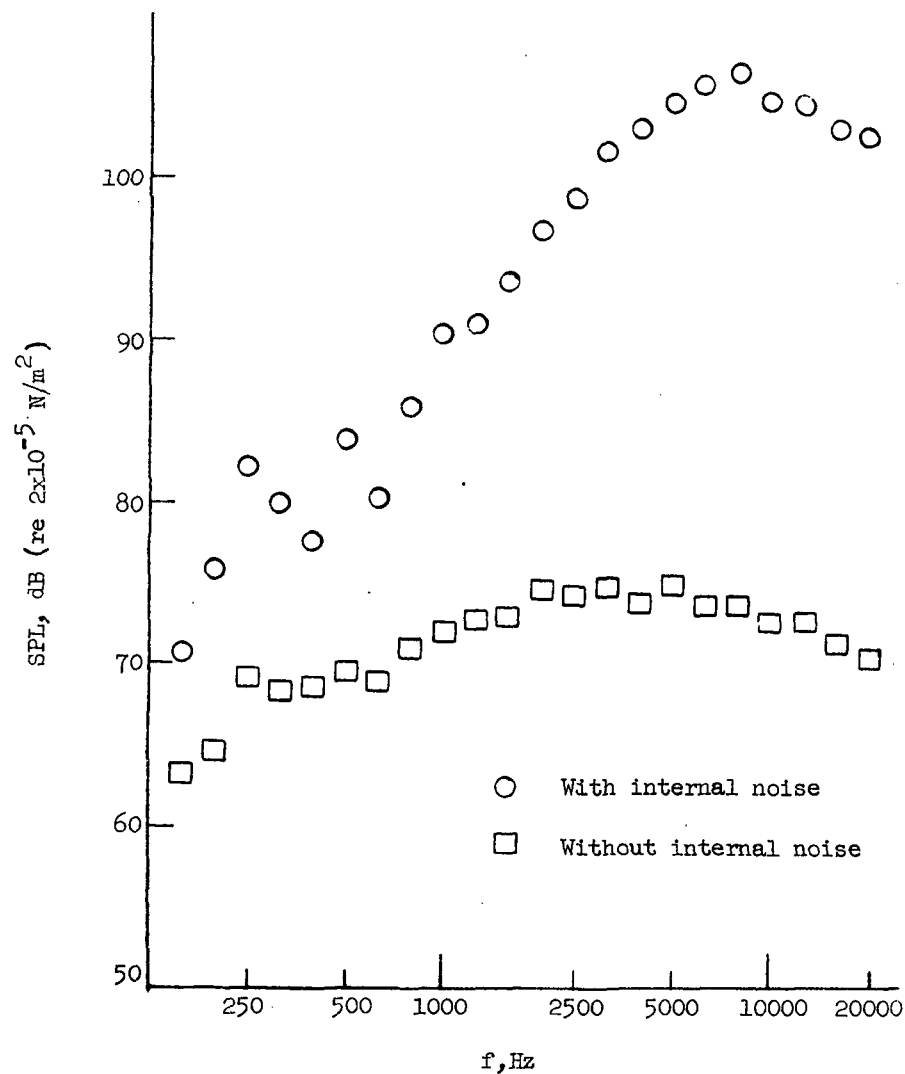

Figure 12. The effect of various flow attachment schemes on the jet noise radiation pattern. Slot nozzle; nozzle location, c_2; covered slots; pressure ratio, 1.23; jet velocity, 178 m/sec.
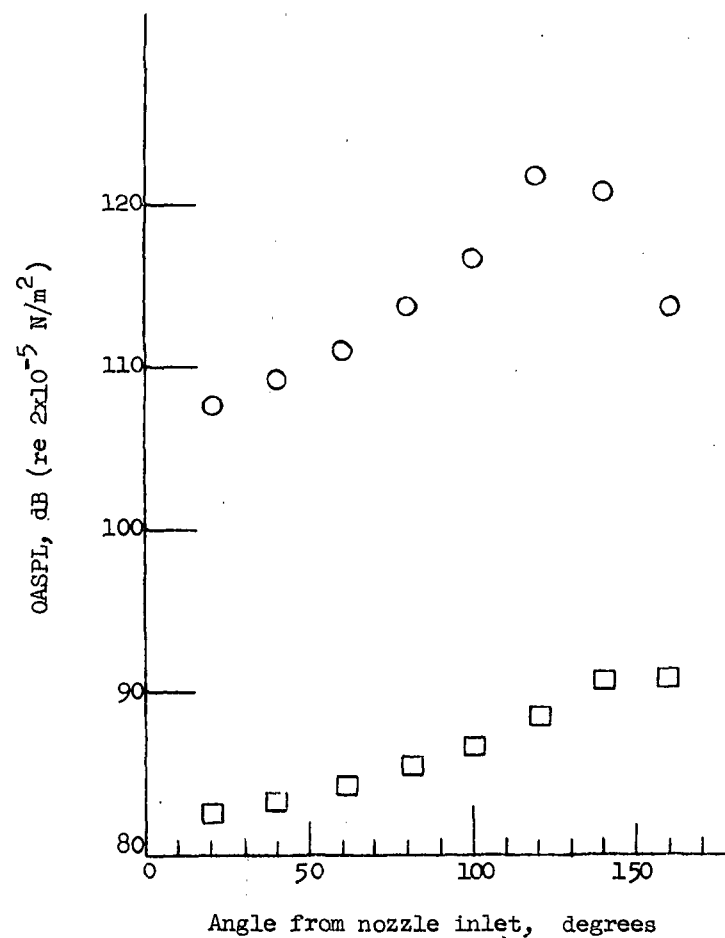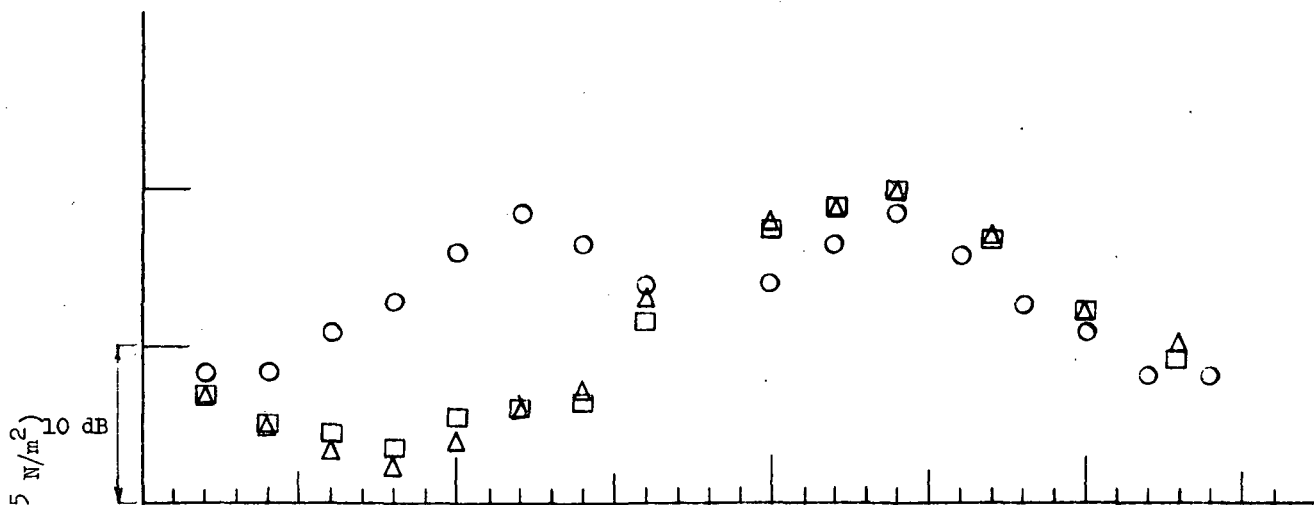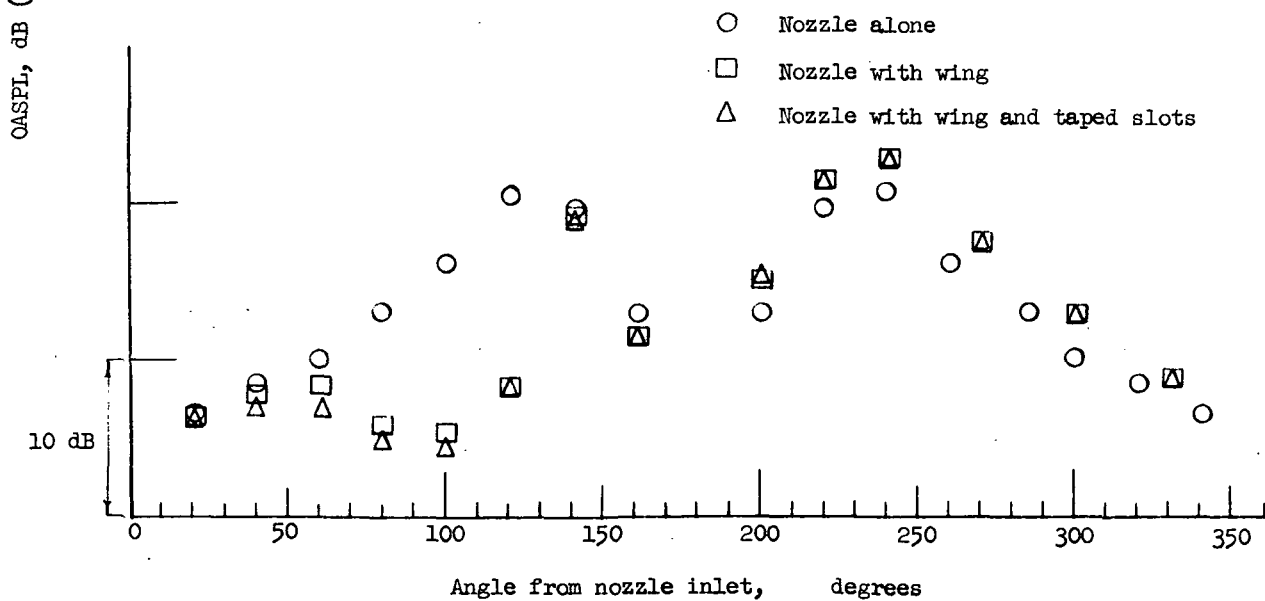
a. Noise radiation pattern.

b. 1/3 octave sound pressure level spectrum at 80°.

Figure 13.   Illustration of the internal noise source with a slot nozzle alone.   Pressure ratio, 1.22; jet velocity,
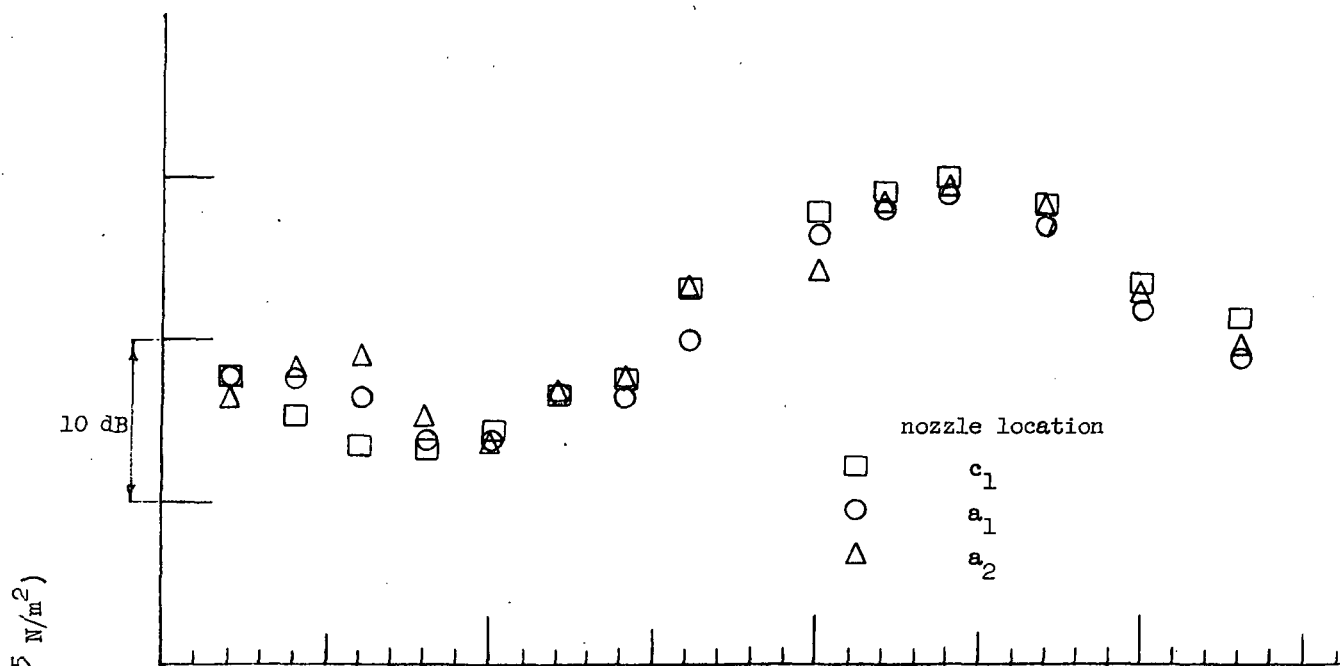179 m/sec.

a. Circular nozzle.

○   Nozzle alone

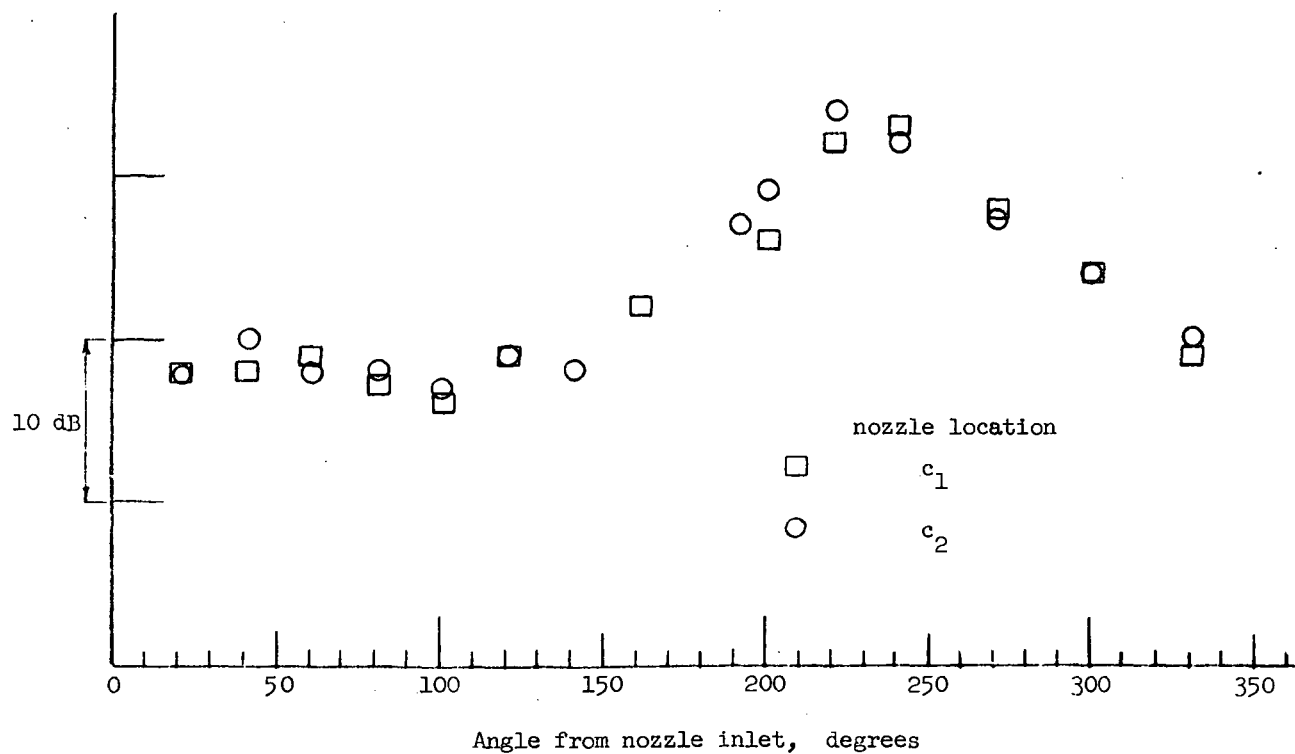□   Nozzle with wing

△   Nozzle with wing and taped slots

b. Slot nozzle.

Figure 14.   Effect of wing shielding and flap slot leakage on the noise radiation pattern with a dominant internal noise source. Pressure ratio, 1.23; jet velocity, 178 m/sec; nozzle location, c_1.

a. Circular nozzle.

b. Slot nozzle.

Figure 15. The effect of nozzle height and fore and aft location with respect to the wing on the noise radiation pattern with an internal noise source. Pressure ratio, 1.22; jet velocity, 178 m/sec.
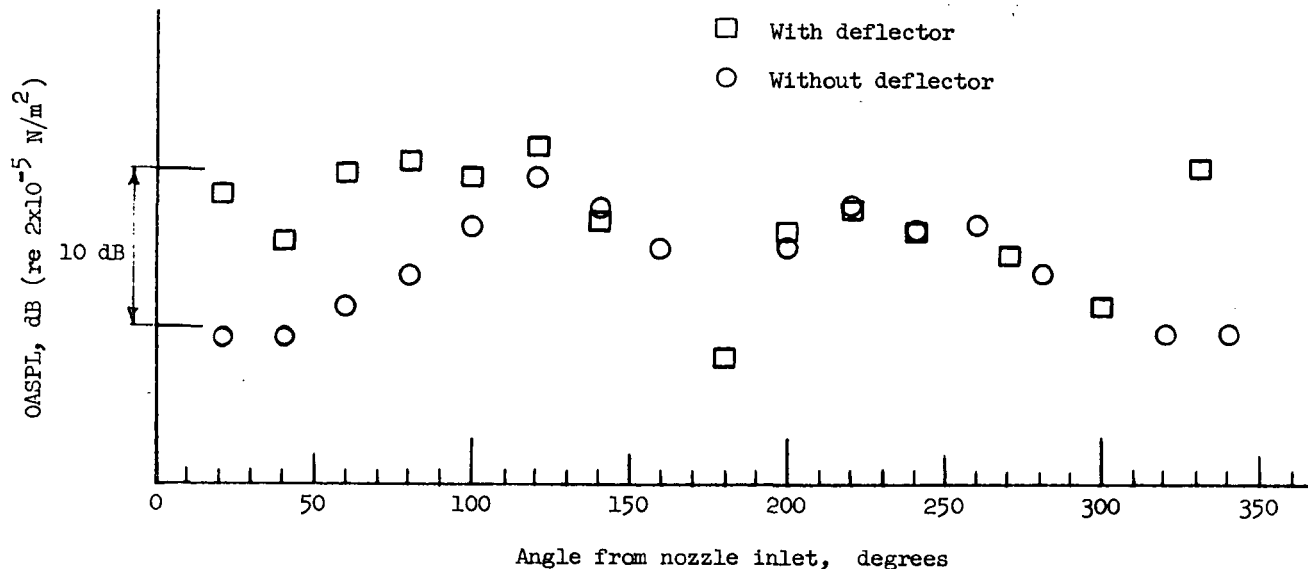
Figure 16. Comparison of noise data with and without a flow deflector for the circular nozzle alone with an internal noise source. Pressure ratio, 1.23; jet velocity, 180 m/sec.
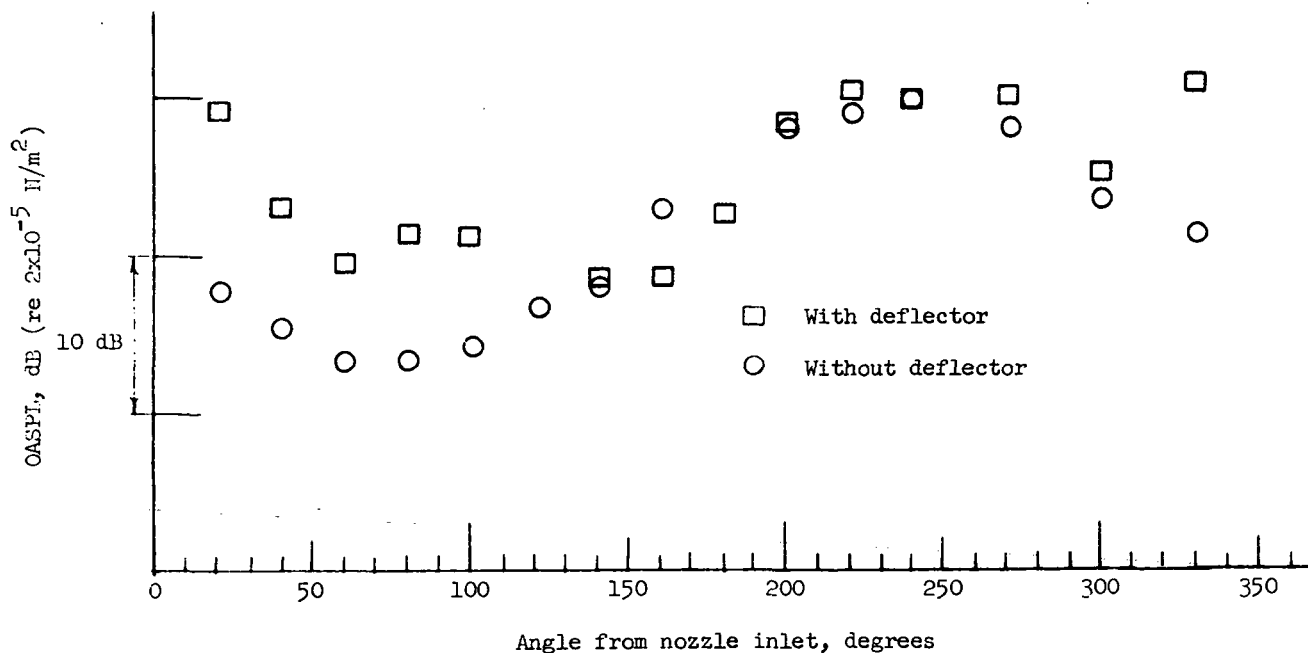

Figure 17. The effect of a flow deflector attached to the circular nozzle on the noise radiation pattern of the engine-over-the-wing model with an internal noise source. Pressure ratio, 1.23; jet velocity, 180 m/sec; nozzle location, c_1.