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NOISE MEASUREMENTS FOR VARIOUS
CONFIGURATIONS OF A MODEL
OF A MIXER NOZZLE - EXTERNALLY
BLOWN FLAP SYSTEM

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NOISE MEASUREMENTS FOR VARIOUS CONFIGURATIONS OF A MODEL OF A MIXER NOZZLE - EXTERNALLY BLOWN FLAP SYSTEM

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SUMMARY

Noise data were taken for variations to a large scale model of an externally blown flap lift augmentation system using a mixer type nozzle. The variations included two different mixer nozzles, two different wing models, and different lateral distances between the wing chord line and the nozzle centerline.

The mixer nozzles had either seven or eight flow passages with exit areas of 1255 and 1438 square centimeters, respectively. The lateral distance between the wing chord line and nozzle centerline, measured at the nozzle exit, was set at 48.9, 74.3, and 87 centimeters. This distance was varied in order to assess the effect of reducing the scrubbing action of the jet exhaust on the underside of the wing.

The trailing flap for both wing models was positioned at an angle of either 20° or 60° with respect to the wing chord line. The chord length of the two- and three-flap wing, with flaps retracted, was approximately the same at 2.08 meters. The section span of both models was 2.74 meters. The axial distance from the nozzle exit to the leading edge of the trailing flap was approximately the same for a given trailing flap deflection angle.

The results showed that the seven and eight lobe nozzles alone had approximately the same sound level at a given nozzle pressure ratio.

With the trailing flap in the 60° position the eight lobe nozzle with the wing was louder than the seven lobe nozzle both at a distance of 48.9 centimeters from the wing. Increasing the wing to nozzle distance to 74.3 centimeters had no effect on the sound level when the seven lobe nozzle was used. However, with the eight lobe nozzle, a 3-decibel reduction in sound level occurred. The two nozzles had about the same sound level when both were placed at 74.3 centimeters from the wing.

With the trailing flap in the 20° position an increase in wing to nozzle distance using either nozzle gave a decrease in sound level. However, the sound level using the eight lobe nozzle was greater than that for the seven lobe nozzle. A further increase in wing to nozzle distance from 74.3 to 87 centimeters using the eight lobe nozzle gave an additional decrease in sound level.

INTRODUCTION

For externally blown flap STOL aircraft to qualify for operation in densely populated areas some method must be found to decrease the additional noise caused by the high velocity jet impinging on the underside of the wing-flap system (ref. 1). Since the flap noise is proportional to the sixth power of the impingement velocity (refs. 2 and 3) an obvious method would be to decrease the impingement velocity while maintaining a high enough exhaust velocity for propulsion.

Velocity decay experiments were performed at Lewis (ref. 4 to 6) using mixer-type nozzles consisting of multielement flow passages rather than a single large nozzle with the same flow area. The results indicated that a rapid rate of velocity decrease could be obtained with the mixer nozzle. Noise tests were performed on a small scale EBF model using an orifice with multielement flow passages to obtain preliminary data on the concept (ref. 7). The results showed a 6-decibel decrease in the sound level below the wing with the trailing flap in the landing position (60°) compared to the sound level obtained with a standard single convergent nozzle. A large scale mixer-nozzle was then fabricated and tested at Lewis (ref. 3). The results of reference 3 showed a similar decrease in sound level below the wing with the trailing flap in the 60° position when compared to the results using a standard nozzle. However, with the trailing flap in the takeoff position (20°) little difference in sound level was obtained when either the mixer nozzle or the standard nozzle was used.

The experiments described in reference 3 used a constant distance from the nozzle centerline to the wing chord line. This distance was varied in the experiments of reference 7, and the results showed a decrease in sound level below the wing when this spacing was increased. In addition, the sound pressure level (SPL) spectrum under the wing was altered drastically (i. e., a decrease in SPL in the middle frequency region of the spectrum).

This report presents the experimental results obtained when the nozzle to wing distance was varied on the large scale EBF facility of reference 3. Results are presented for seven and eight lobe mixer nozzles. The wing-flap system was changed to a three-flap arrangement so that the axial distance from the nozzle exit to the impingement point on the trailing flap, measured along the nozzle axis, was the same as the two-flap system of reference 3. In addition, the trailing flap for the three-flap wing was at the same angle, relative to the wing chord line, as that for the two-flap wing.

APPARATUS AND PROCEDURE

Air flow system. - Figure 1 shows a schematic of the air flow system. Dry, cold air (280 to 300 K) was supplied to a 40.6-centimeter-diameter gate shutoff valve from

the air supply system (1.03×10^6 N/m² max.) by way of a 60.9-centimeter-diameter underground pipe line. A 25.4-centimeter-diameter butterfly valve was used to control the flow to the nozzles. The nozzle centerline was 3.91 meters above grade.

A muffler system installed in the line downstream of the flow control valve attenuated internal noise caused primarily by the flow control valve. Essentially, the muffler system consisted of perforated plates and dissipative type mufflers. The perforated plates were located immediately downstream of the flow control valve (40-percent open area) and at the entrance and exit of the first dissipative mufflers (20-percent open areas). Both dissipative mufflers were sections of pipe that housed crossed splitter plates oriented at right angles to one another so that the flow was divided into four channels. The internal surfaces of the muffler pipes and the surfaces of the splitter plates were covered with an acoustic absorbent material. The second dissipative muffler was located downstream of the last 45° elbow in the air flow line to take advantage of the reflections caused by turning the flow. In addition, the flow system was wrapped externally with fiber glass and leaded vinyl sheet to impede direct radiation of internal noise through the pipe wall.

Two screens were placed in the air line downstream of the last muffler to improve the flow distribution to the nozzle.

Wing-Flap Systems

Two-flap wing. - The two-flap wing that was used for the experiments described herein was the same as that used in references 1 and 3. The wing (fig. 2) had a chord length of 208 centimeters with the flaps retracted and a span of 274 centimeters. The flaps could be placed in one of three positions relative to the wing chord line: (1) leading flap, 30°; trailing flap, 60° (fig. 2(a)); (2) leading flap, 10°; trailing flap, 20° (fig. 2(b)); and (3) zero angle (flaps retracted). The distance from the nozzle centerline to the wing chord line, measured at the nozzle exit, was 48.9 centimeters with the flaps in the 30°-60° setting. With the flaps in the 10°-20° setting, two wing to nozzle distances were tested, 48.9 and 61.6 centimeters. The leading edge of the wing was 17.8 centimeters upstream of the nozzle exit. The distance from the nozzle exit to the impingement point on the 60° flap, measured along the nozzle axis, was 183 centimeters. With the flaps in the 10°-20° setting the distance from the nozzle exit to the trailing edge of the 20° flap was 243.1 centimeters (measured along the nozzle axis).

The wing was oriented so that there was a 5° angle of attack between the wing chord line and nozzle axis. The wing was mounted so that the spanwise direction was vertical. The nozzle axis was located at a spanwise position 1.64 meters from the bottom of the wing section and 1.31 meters from the top.

Three-flap wing. - The three-flap wing is shown in figure 3. The modification to the wing flap system was necessary in order to investigate the effect of increasing the distance from the fixed portion of the wing and the nozzle and maintain the same flow field at the trailing flap. Figure 3(a) shows the arrangement for the trailing flap in the 60° position and a nozzle to wing distance of 74.3 centimeters. An additional flap was needed to serve as a filler for the increased slot width behind the fixed wing when the original flaps were moved to the position shown. The angles shown for the first flap (3°) and second flap (50°) were necessary to prevent a severe discontinuity in the flow over the top surfaces of the flaps. Only one nozzle to wing distance was tested for the trailing flap in the 60° position.

Figure 3(b) shows the configuration of the three-flap wing with the trailing flap in the 20° position. The first flap was set at 13° from the wing chord line and the second flap was set at 15° . Three nozzle to wing distances were tested for this configuration: 87.0, 74.3, and 48.9 centimeters. With a wing to nozzle distance of 74.3 centimeters the lateral distance between the trailing flap and nozzle centerline for the three-flap wing was the same as that for the two-flap wing.

Mixer Nozzle

Figure 4 shows the configuration and dimensions of the mixer nozzle. The nozzle consisted of four straight lobes and four lobes that were canted 10° outward from the nozzle centerline. The canted lobes promoted the velocity decay (ref. 4). The exit area of the nozzle lobes was reduced by about 20 percent from the upstream portion of the lobe. The total exit area of the eight lobe nozzle was 1438 square centimeters. An elliptical centerbody was placed upstream of the lobes to improve the flow coefficient of the nozzle. A comparison of actual flow rate to ideal flow rate showed that the ratio was approximately 0.99. The conversion to a seven lobe nozzle was made by blocking off one of the canted lobes. The exit area for the seven lobe nozzle was 1255 square centimeters.

Figure 5 shows the position of the nozzle lobes relative to the wing. The seven lobe nozzle (fig. 5(a)) was positioned so that the blocked off lobe was closest to the underside of the wing. Figure 5(b) shows that the eight lobe nozzle was positioned so that a straight lobe was closest to the wing.

Figure 6 is a photograph of the facility with the three-flap wing in place and the trailing flap at the 60° setting.

Instrumentation

The noise data were measured by twenty 1.27-centimeter-diameter condenser microphones placed at various intervals on a 15.24 meters radius circle around the wing-nozzle setup. The center of the microphone circle was located on the nozzle centerline halfway between the nozzle exit and the intersection with the 60° flap. The microphone circle was in a horizontal plane 3.91 meters above an asphalt surface and perpendicular to the vertically mounted wing. Wind screens were placed on all microphones. A standard piston calibrator (124 dB ± 0.2 dB, 250 Hz tone) was used to calibrate the condenser microphones. The noise data were analyzed by a one-third octave band spectrum analyzer referenced to 2×10^{-5} newtons per square meter.

The air flow rate was measured by an orifice flowmeter located in a straight section of the underground air supply line upstream of the gate shutoff valve. Pressure drop across the orifice flowmeter and static pressure upstream of the flowmeter were measured by strain-gage pressure transducers. Strain-gage pressure transducers were also used to measure total and static pressure upstream of the nozzle. All pressures were recorded on strip-chart instruments. Temperatures were measured upstream of the flow orifice and test nozzle by thermocouples immersed in the flow stream.

Weather data were also monitored and/or recorded (barometer, temperature, humidity, wind speed, and direction).

Procedure

Far field noise data were taken for various pressure ratios across the test nozzle. The test procedure was to obtain a steady flow condition for a given total pressure upstream of the nozzle. Three noise data samples were taken at each microphone location. An atmospheric loss correction was applied to the average of the three samples to give lossless sound pressure level data at 15.24 meters. From these sound pressure level spectra the overall sound pressure levels were calculated at each microphone location.

All instrumentation was calibrated before each run and checked after the run. The overall sound data acquisition system was checked by flowing air through a reference orifice located near the center of the microphone circle, analyzing the emitted sound, and examining the data to see if the results obtained from the current run agreed with a previous run.

RESULTS AND DISCUSSION

Noise Measurements Using the Seven Lobe Mixer Nozzle

The noise data for the seven lobe mixer nozzle, used alone and with the three-flap wing, are shown in figure 7. The results are given for only one nozzle pressure ratio, but the results for other pressure ratios are similar. The distance from the wing to the nozzle centerline for this case was 74.3 centimeters. Using this wing to nozzle distance the trailing flap for the three-flap wing is subjected to the same flow field (velocity, and velocity distribution) as the trailing flap of the two-flap wing reported in reference 3. Figure 7(a) shows the overall sound pressure level (OASPL) directivity at a radius of 15.24 meters. The OASPL directivity for the nozzle alone is symmetrical about the nozzle centerline. The directivity with the wing in place is altered considerably and a substantial increase in noise level, over that produced by the nozzle alone, occurs from 0° to 100° from the engine inlet. In addition, the figure shows that when the trailing flap is in the 60° setting, the noise level forward and below the wing (0° to 90°) is considerably louder than when the flap is in the 20° setting. This is caused by the presence of a greater impingement area in the path of the jet exhaust when the trailing flap is in the 60° position, in addition to a redirection of nozzle alone noise. The sound pressure level (SPL) one-third octave spectra at 85° from the engine inlet are shown in figure 7(b). The spectra for the nozzle blowing on the flaps peak at about 400 hertz with the 60° flap configuration having higher levels over the entire frequency range.

A comparison of noise data for the seven lobe mixer nozzle with the two-flap wing reported in reference 3 and the nozzle with the three-flap wing is shown in figures 8 and 9. The distance from the wing to the nozzle centerline was 48.9 centimeters for the two-flap wing and 74.3 centimeters for the three-flap wing. Again, for these wing to nozzle distances, the trailing flaps are subjected to identical flow fields. Figure 8 shows the noise data for the wing flaps in the landing setting (trailing flap at 60°). Figure 8(a) shows that the OASPL for the two wings is very similar in directivity and level. The SPL spectra at 85° from the engine inlet (fig. 8(b)) again show approximately the same level. With the wing flaps in the landing setting, increasing the distance from the nozzle to the fixed wing from 48.9 to 74.3 centimeters has very little effect on the noise generating characteristics of the system.

Figure 9 shows the noise data for the two wing systems with the flaps in the takeoff position (trailing flap at 20°). The OASPL for the three-flap wing is only slightly lower than that for the two-flap wing for a nozzle pressure ratio of 1.7 (from 0° to 140° from the engine inlet). For the lower pressure ratio (1.3) the level is 2 to 3 decibels lower with the three-flap wing. The SPL spectra at 85° , figure 9(b), again show a greater

separation in level for the two-wing systems at the lower nozzle pressure ratio.

The variation of the peak OASPL with the seven lobe mixer nozzle exhaust velocity for the two- and three-flap wings is shown in figure 10. With the trailing flap in the 60° position, the peak OASPL for the three-flap wing occurs at 25° from the engine inlet and for the two-flap wing the peak OASPL occurs at 70° from the engine inlet. With the trailing flap in the 20° position, the peak OASPL for the three-flap wing occurs at 135° from the engine inlet and for the two-flap wing the peak OASPL occurs at 125° . The peak OASPL for the three-flap wing is shown to vary as the eighth power of the nozzle exhaust velocity whereas for the two-flap wing a seventh power relation is shown.

The peak OASPL as a function of flap impingement velocity is shown in figure 11 for the two wing systems. Free stream jet velocity measurements for the seven lobe mixer nozzle are reported in reference 3. The flap impingement velocities in figure 11 were taken as the peak free stream measurements at a distance of 183 centimeters downstream of the nozzle exit (this distance is the same as the distance from the nozzle exit to the impingement point on the 60° flap, measured along the nozzle axis, when the wing is in place). Figure 11 shows that the peak OASPL varies as the sixth power of the flap impingement velocity for all configurations. With the trailing flap at the 60° position both wing systems show the same peak OASPL for a given flap impingement velocity. With the trailing flap in the 20° position the peak OASPL for the three-flap wing is approximately 3 decibels less than that for the two-flap wing.

Comparison of Noise Data for Seven and Eight Lobe Nozzles

Nozzles alone. - The noise data for the seven and eight lobe nozzles alone are shown in figure 12. Figure 12(a) shows that both nozzles have approximately the same OASPL at the high nozzle pressure ratio (1.7). At a pressure ratio of 1.3 the eight lobe nozzle is approximately 1 decibel louder. The SPL spectra at 85° from the engine inlet (fig. 12(b)) again show that the two nozzles give approximately the same noise level. The data shown in the figure are not adjusted for scale effects. The difference in sound level for the two nozzles operating at the same exhaust velocity and temperature is proportional to the ratio of the areas (ref. 1). The ratio of the total areas of the eight lobe and seven lobe nozzles is 1.15. Therefore, the eight lobe nozzle would have a sound level approximately 0.6 decibel greater than that of the seven lobe nozzle. This small increment is within the accuracy of the instrumentation and is not large enough to justify correction. In addition, the frequency of the one-third octave spectrum can be scaled by using the Strouhal relation between frequency and nozzle diameter. If the equivalent diameters of the nozzles are used, their ratio (1.07) is small enough to make the correction trivial.

The variation of total sound power level with nozzle exhaust velocity for the two nozzles is shown in figure 13. The level varies as the eighth power of the nozzle exhaust velocity.

Nozzles with two-flap wing. - Figure 14 shows the noise data for the seven and eight lobe nozzles with the two-flap wing. The trailing flap was in the 60° position and the nozzle to wing distance was 48.9 centimeters. The distance from the nozzle exit to the impingement point on the trailing flap was the same for both configurations (183 cm). The OASPL (fig. 14(a)) shows that the eight lobe nozzle with the wing is louder than the seven lobe nozzle with the wing. This is a result of the difference in orientation of the nozzle lobes with respect to the wing (fig. 5). In effect, the eight lobe nozzle is closer to the wing causing more wing scrubbing. Figure 14(b) shows the SPL one-third octave spectra at 85° from the engine inlet. Again, the eight lobe nozzle with the wing has a greater sound level at a nozzle pressure ratio of 1.7. At a pressure ratio of 1.3 the eight lobe nozzle with the wing is louder up to a frequency of 1250 hertz. Above this frequency there is little difference in the level for the two configurations.

Nozzles with three-flap wing. - A comparison of the noise data for the seven and eight lobe nozzles with the three-flap wing is shown in figures 15 and 16. The nozzle to wing distance was 74.3 centimeters and the distance from the nozzle exit to the impingement point on the trailing flap was the same for both configurations. Figure 15 shows the data for the trailing flap in the 60° position. Very little difference is shown for either the OASPL (fig. 15(a)) or the SPL spectra (fig. 15(b)) for this flap setting. Figure 16 shows the results for the trailing flap in the 20° position. The OASPL (fig. 16(a)) shows that the wing with the seven lobe nozzle is quieter at all angles from the engine inlet. Again, the difference in noise level is attributed to the orientation of the nozzle lobes with respect to the wing (fig. 5). In effect, the flow from the eight lobe nozzle scrubs more surface area on the trailing flap than the flow from the seven lobe nozzle. The SPL spectra at 85° (fig. 16(b)) show that the greatest difference in sound level for the two configurations occurs at the low end of the frequency range (100 to 1000 Hz).

Eight lobe nozzle with three-flap wing for wing to nozzle distance of 74.3 cm. - Figure 17 shows a direct comparison of the results for the eight lobe nozzle with the three-flap wing. The results are shown for the trailing flap in the 60° and 20° settings and a wing to nozzle spacing of 74.3 centimeters (same data as shown in figs. 15 and 16). Also shown are the results for the nozzle alone. The results in figure 17 are for a nozzle pressure ratio of 1.7 and are typical of the results for other pressure ratios. Figure 17(a) shows that there is only a 1 or 2 decibels separation in the OASPL under the wing (0° to 100°) for either flap setting. The sound level with the wing in place is considerably higher than that for the nozzle alone (from 0° to 100°). The SPL spectra at 85° (fig. 17(b)) again show that the sound levels are approximately the same for either flap setting with a peak at about 400 hertz.

Eight lobe nozzle with three-flap wing with the trailing flap in the 20° setting and various wing to nozzle distances. - Figure 18 shows the results obtained when the wing to nozzle distance was varied using the eight lobe nozzle with the three-flap wing. The trailing flap was in the 20°, or takeoff, position and the nozzle pressure ratio was 1.7. Also shown in the figure are the noise data for the eight lobe nozzle alone. The wing to nozzle distance was set at 48.9, 74.3, and 87.0 centimeters. As the wing is moved away from the nozzle a larger portion of the jet exhaust misses the trailing flap, which deteriorates the lift characteristics of the air foil. The extent of the deterioration would have to be determined by aerodynamic tests. The OASPL (fig. 18(a)) shows that by increasing the wing-to-nozzle distance from 48.9 to 87.0 centimeters there is a decrease in the sound level under the wing (0° to 100°). The SPL spectra at 85° (fig. 18(b)) show a similar decrease in level in the low frequency range.

The perceived noise level (PNL) directivity pattern at 152.4 meters is shown in figure 19 for the previous configurations. From 0° to 100° from the engine inlet the PNL decreases as the wing to nozzle distance is increased.

Comparison of Noise Data for Eight Lobe Nozzle with Two-Flap and Three-Flap Wings

Figure 20 shows a comparison of the noise data for the two-flap and three-flap wings using the eight lobe mixer nozzle. The trailing flap was in the 60° position. The nozzle to wing distance for the two-flap wing was 48.9 centimeters and for the three-flap wing it was 74.3 centimeters. The distance from the nozzle exit to the impingement point on the trailing flap, measured along the nozzle axis, was the same for both configurations. The OASPL (fig. 20(a)) shows that the nozzle with the two-flap wing is louder at all angles from the engine inlet. The SPL spectra (fig. 20(b)) again show that the nozzle with the two-flap wing has a greater noise level.

The maximum wing to nozzle distance that was tested using the three-flap wing with the trailing flap in the 20° setting was 87 centimeters. Noise data were also taken using the two-flap wing with the 10°-20° flap setting for flow conditions, relative to the trailing flap, that duplicated those for the maximum wing to nozzle distance with the three-flap wing. In order to do this the wing to nozzle distance for the two-flap wing was set at 61.6 centimeters. Figure 21(a) shows that the OASPL is greater for the two-flap wing with a wing to nozzle distance of 61.6 centimeters. The SPL at 85° (fig. 21(b)) shows that the greatest difference in level between the two wing systems occurs in the 200 to 800 hertz frequency range.

A comparison of the PNL directivity patterns at 152.4 meters for the two- and three-flap wings using the eight lobe nozzle is shown in figures 22 and 23. Figure 22 shows the comparison of the PNL for the two wing systems with the trailing flap in the 60° position. The two-flap wing has a 2 to 3 PNdB greater level from 0° to 85° from the engine inlet for a nozzle pressure ratio of 1.7. At the lower nozzle pressure ratio (1.3) the difference is slightly less. Figure 23 shows the PNL comparison with the trailing flap in the 20° position. The difference in PNL at a nozzle pressure ratio of 1.7 is between 1.0 and 2 PNdB (0° to 145°). At a nozzle pressure ratio of 1.3 the difference in PNL is negligible.

CONCLUDING REMARKS

Two mixer-type nozzles, one with seven lobes and one with eight lobes, with a total exit area ratio of 1.15 were tested and found to give approximately the same sound levels at a given nozzle exhaust velocity.

When the seven lobe nozzle was used with the wing and with the trailing flap in the 60° setting, the results showed no change in noise level when the distance between the wing and nozzle was increased. However, when the eight lobe nozzle was used, the results showed a decrease in noise level when the distance between wing and nozzle was increased. The decrease in noise level is attributed to less scrubbing on the fixed wing as the eight lobe nozzle is moved away from the wing.

With the trailing flap in the 20° setting a decrease in noise level was obtained when the wing to nozzle distance was increased when either the seven lobe or eight lobe nozzle was used.

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National Aeronautics and Space Administration,
Cleveland, Ohio, February 13, 1973,
741-89.

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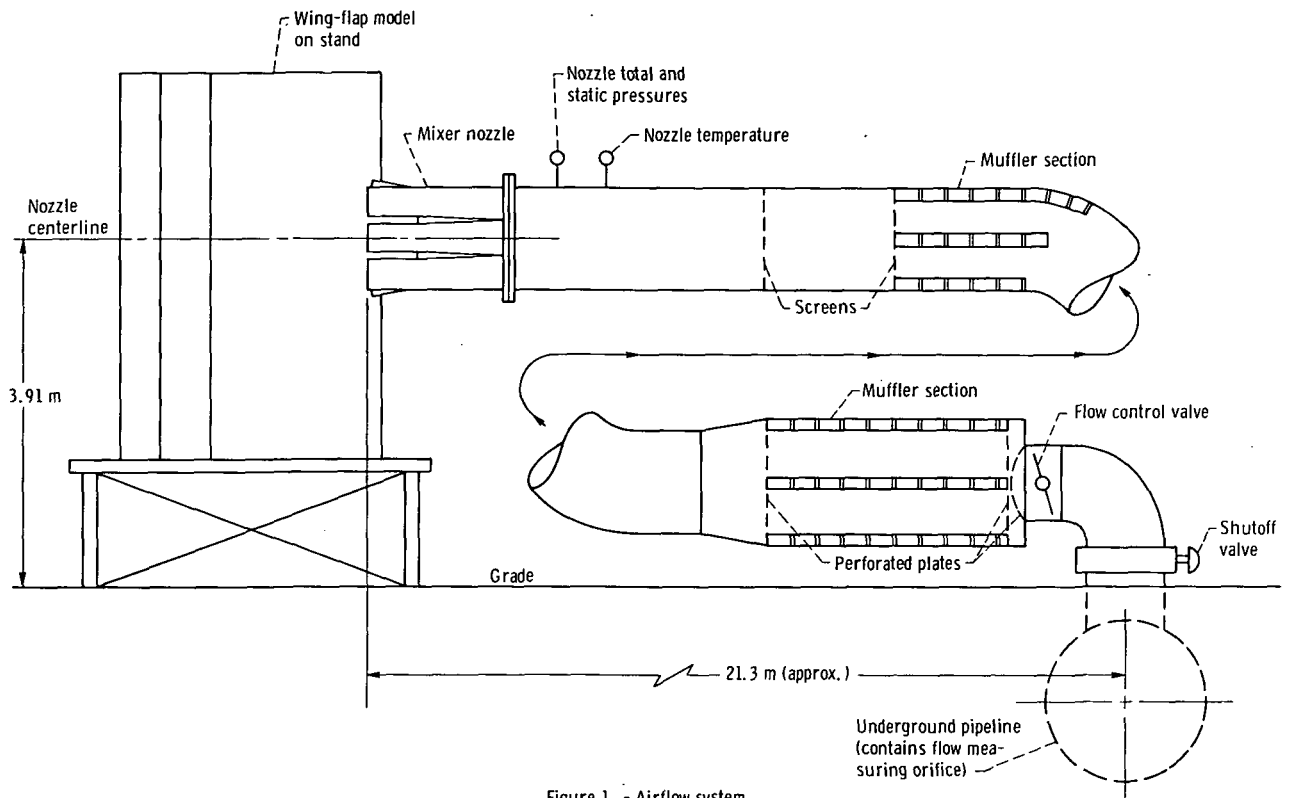
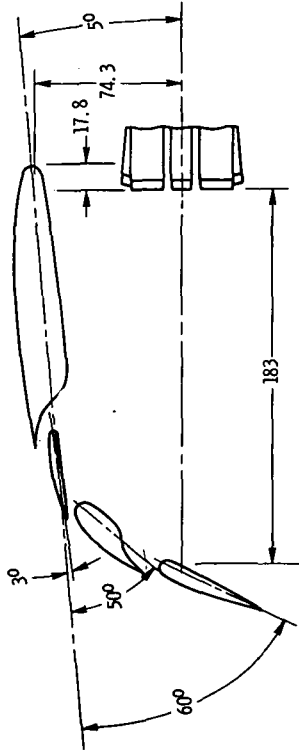
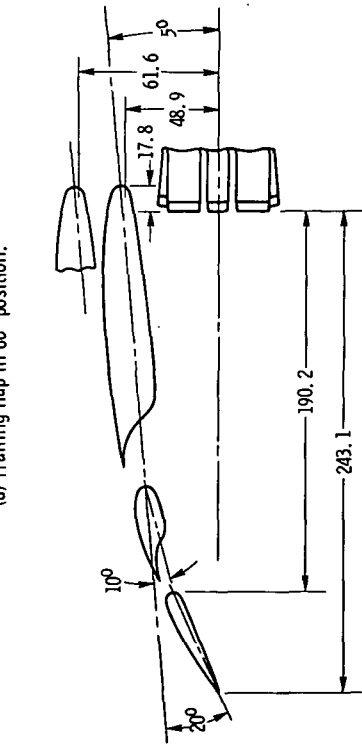


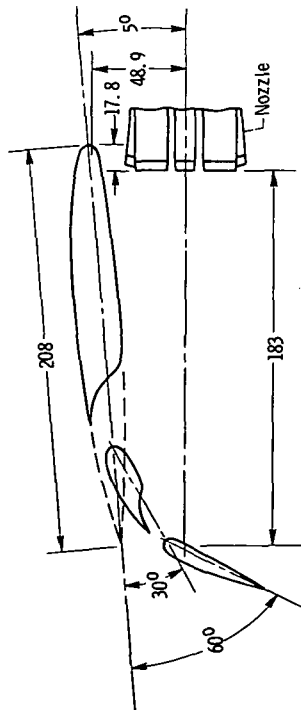
Figure 1. - Airflow system.



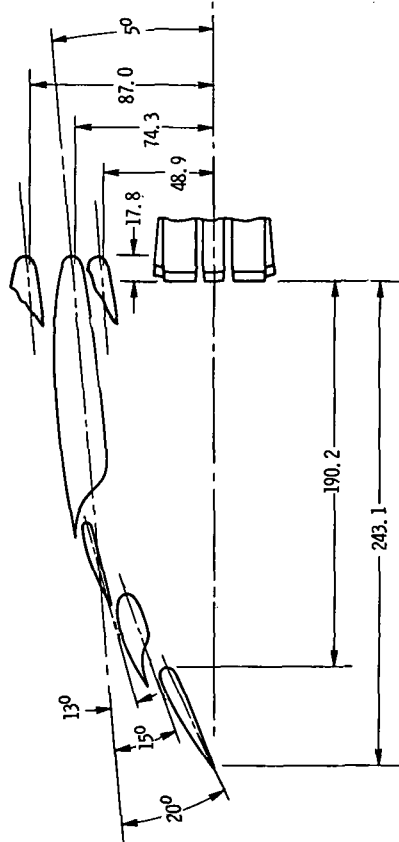
(a) Trailing flap in 60° position.



(a) Trailing flap in 20° position.



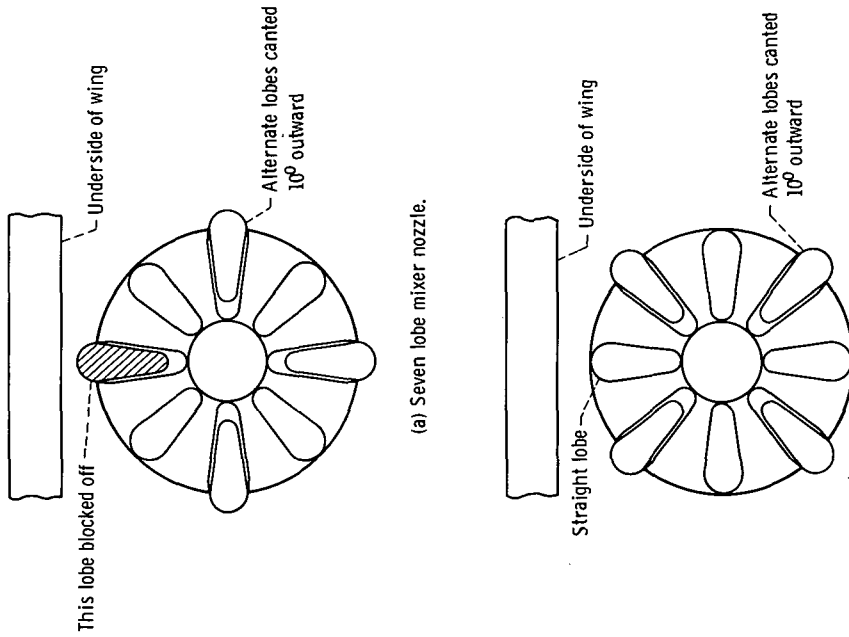
(b) Trailing flap in 60° position.



(b) Trailing flap in 20° position.

Figure 3. - Test configuration of externally blown flap model with three-flap system. (All dimensions are in centimeters.)

Figure 2. - Test configuration of externally blown flap model with two-flap system. (All dimensions are in centimeters.)



(a) Seven lobe mixer nozzle.
 (b) Eight lobe mixer nozzle.
 Figure 5. - Position of mixer nozzle relative to wing. View at exit plane of nozzle look upstream.

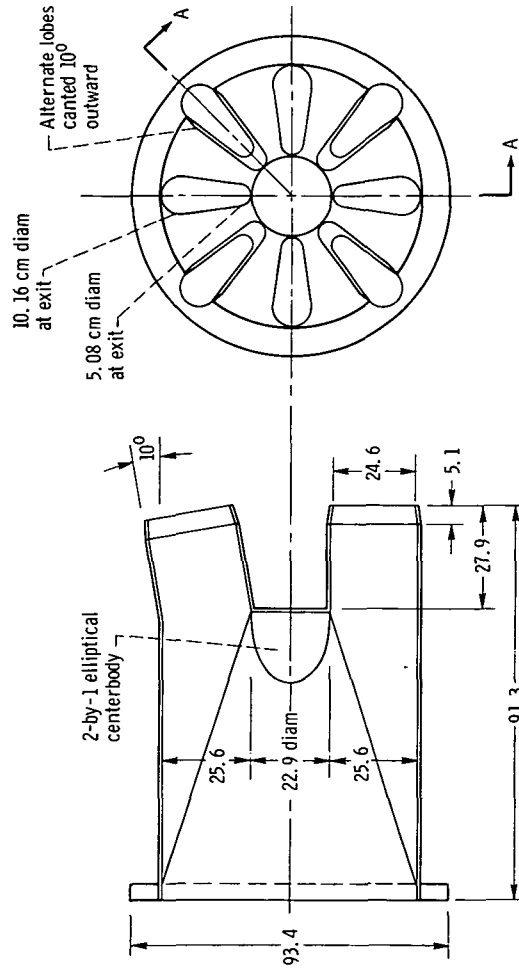


Figure 4. - Configuration and dimensions of mixer nozzle. (All dimensions in centimeters.)

View A-A

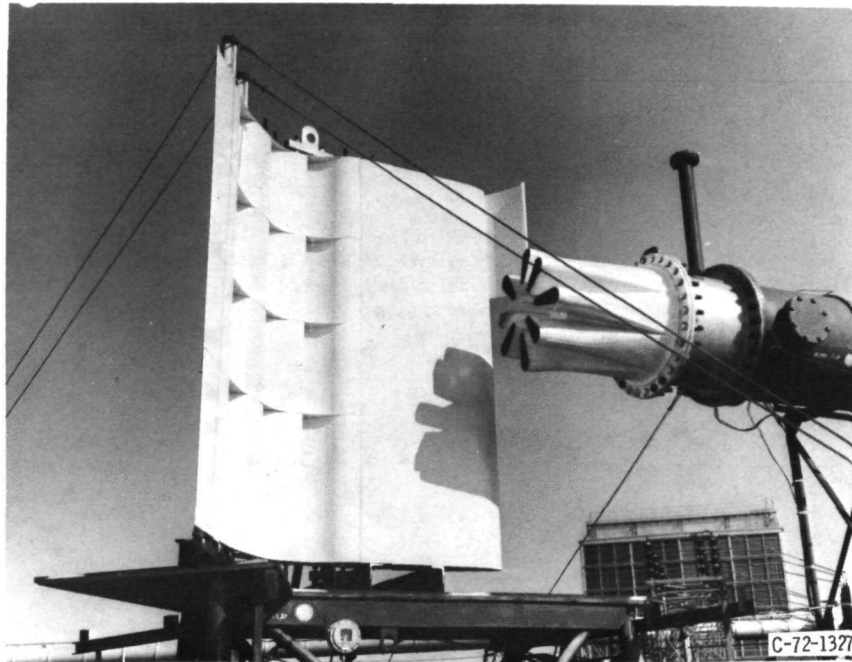
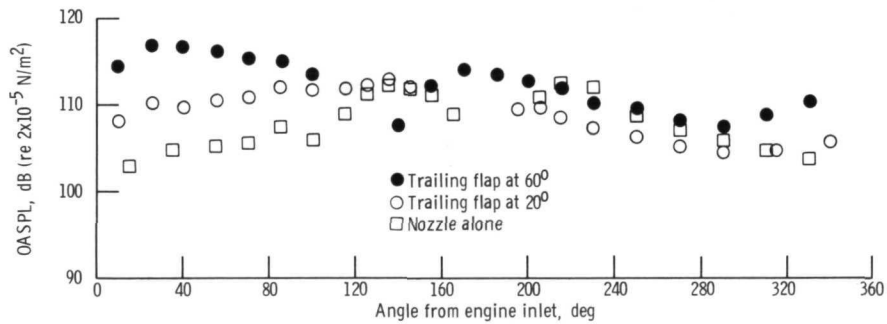
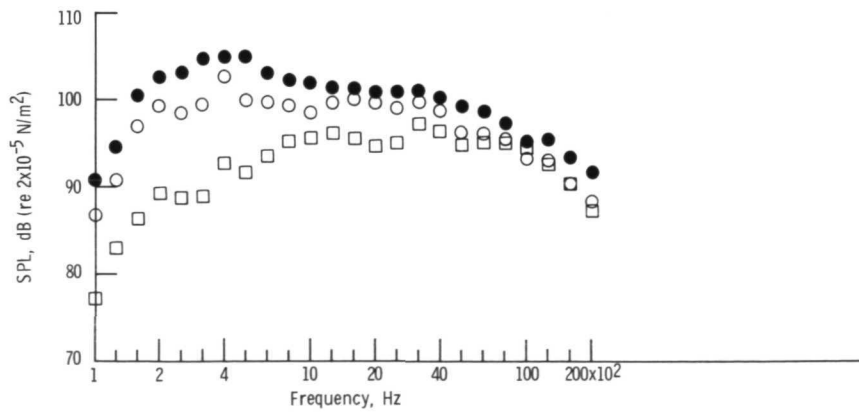


Figure 6. - Test installation.

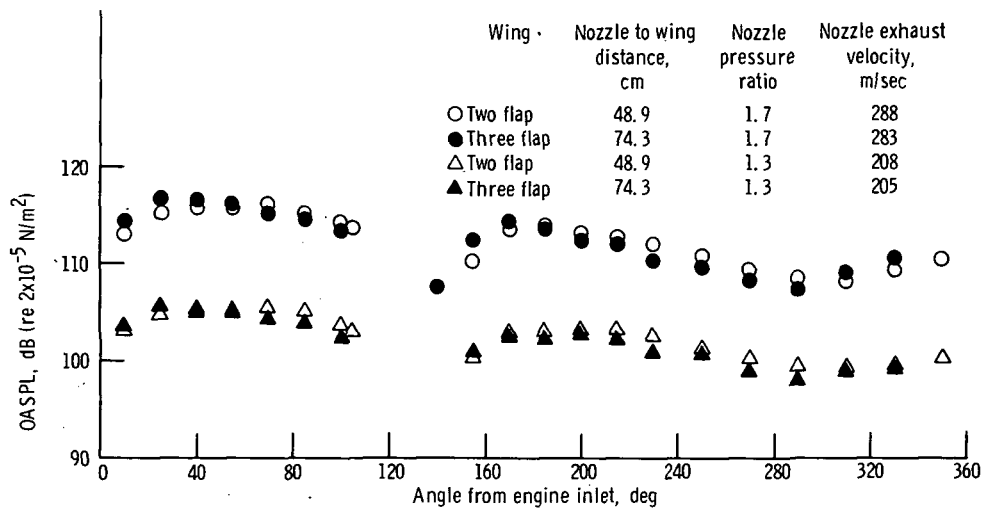


(a) Overall sound pressure level (OASPL) directivity.

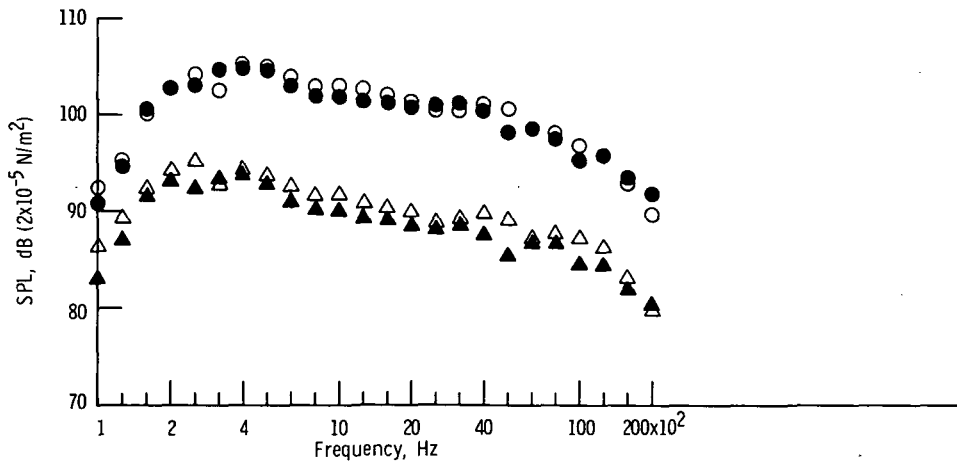


(b) Sound pressure level (SPL) one-third octave spectra at 85°.

Figure 7. - Comparison of noise data for seven lobe mixer nozzle alone and nozzle with three-flap wing. Nozzle to wing distance, 74.3 centimeters; nozzle pressure ratio, 1.7; nozzle exhaust velocity, 283 meters per second; microphone radius, 15.24 meters.

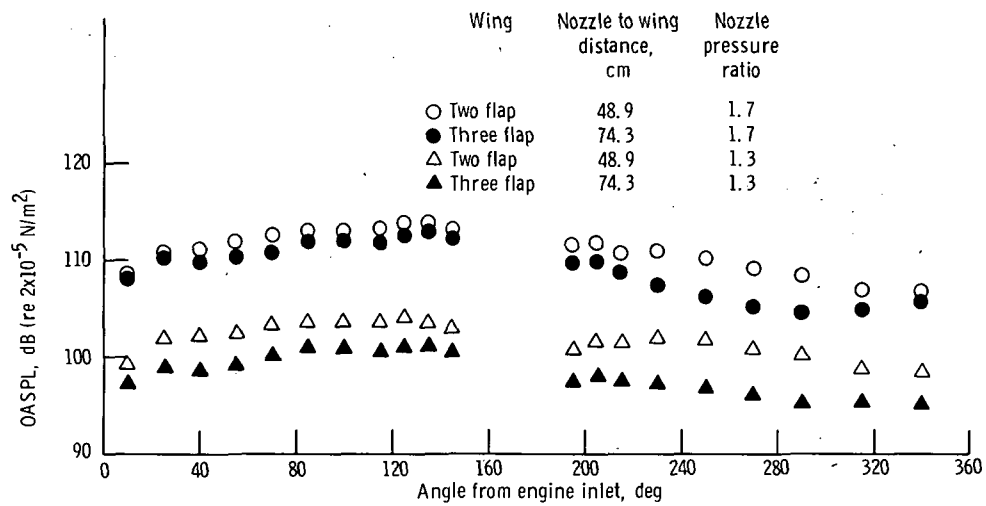


(a) Overall sound pressure level (OASPL) directivity.

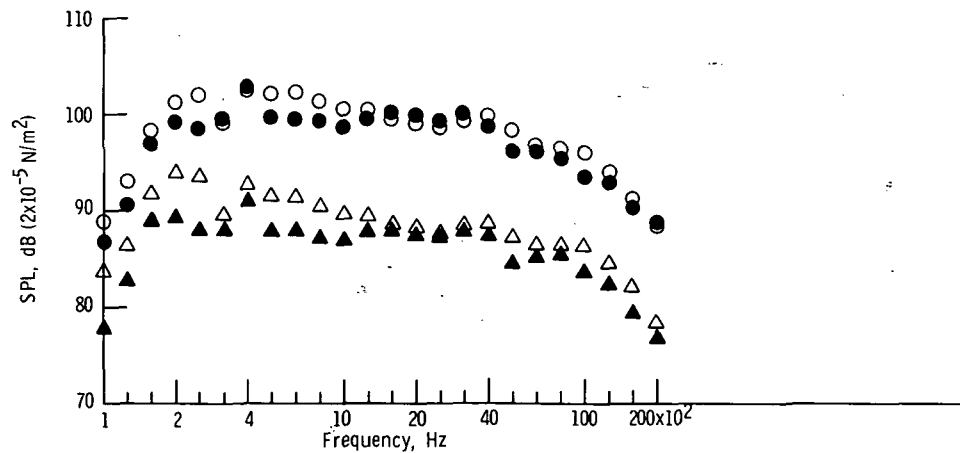


(b) Sound pressure level (SPL) one-third octave spectra at 85°.

Figure 8. - Comparison of noise data for seven lobe mixer nozzle with two- and three-flap wings. Trailing flap at 60° position; microphone radius, 15.24 meters.



(a) Overall sound pressure level (OASPL) directivity.



(b) Sound pressure level (SPL) one-third octave spectra at 85°.

Figure 9. - Comparison of noise data for seven lobe mixer nozzle with two- and three-flap wings. Trailing flap at 20° position; microphone radius, 15.24 meters.

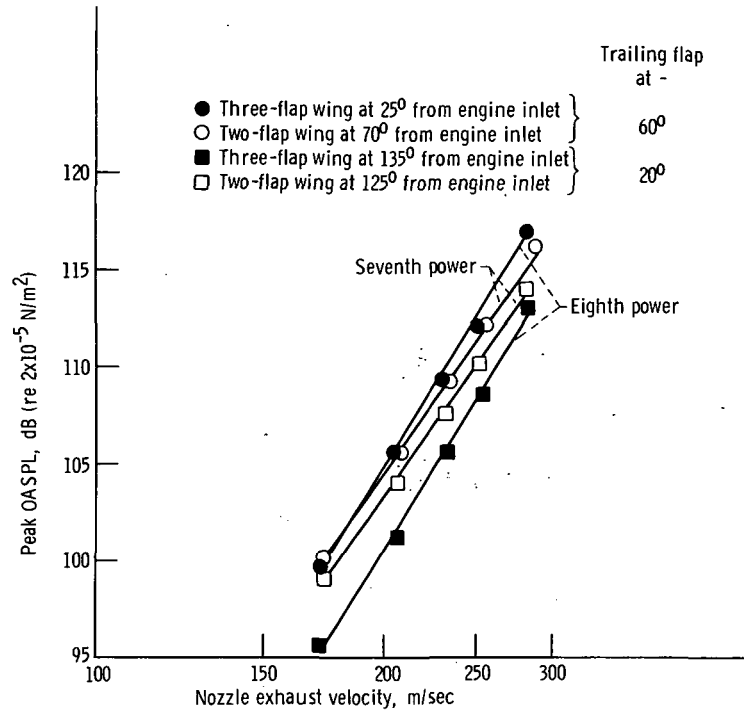


Figure 10. - Variation of peak overall sound pressure level (OASPL) with nozzle exhaust velocity for two- and three-flap wings. Seven lobe mixer nozzle; microphone radius, 15.24 meters.

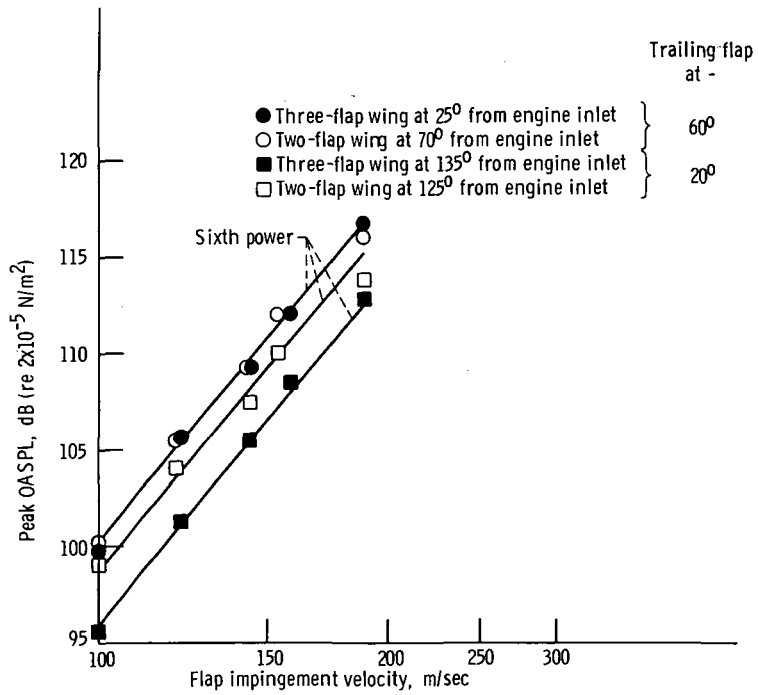


Figure 11. - Variation of peak overall sound pressure level (OASPL) with flap impingement velocity for two- and three-flap wings. Seven lobe mixer nozzle; microphone radius, 15.24 meters.

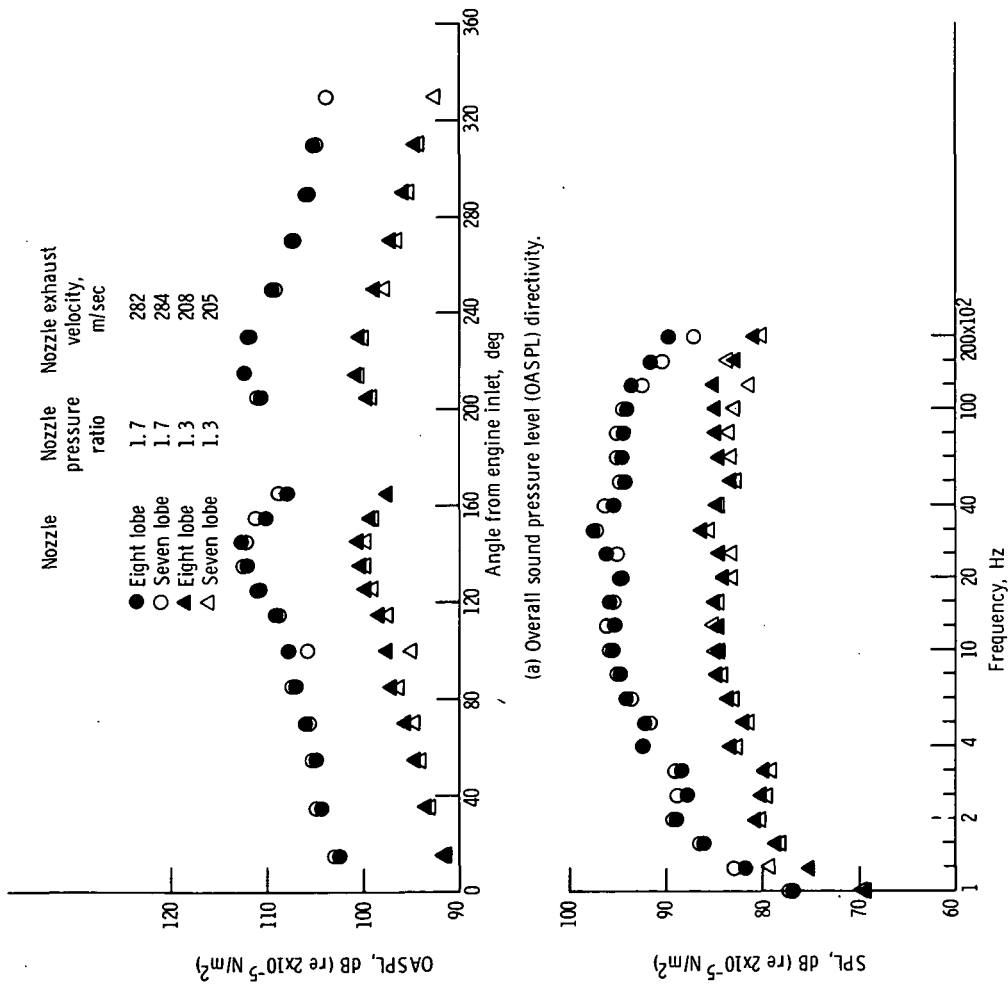


Figure 12. - Comparison of noise data for seven and eight lobe nozzles alone. Microphone radius, 15.24 meters.

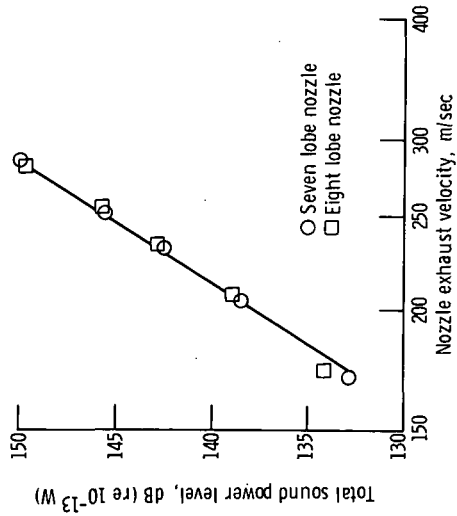
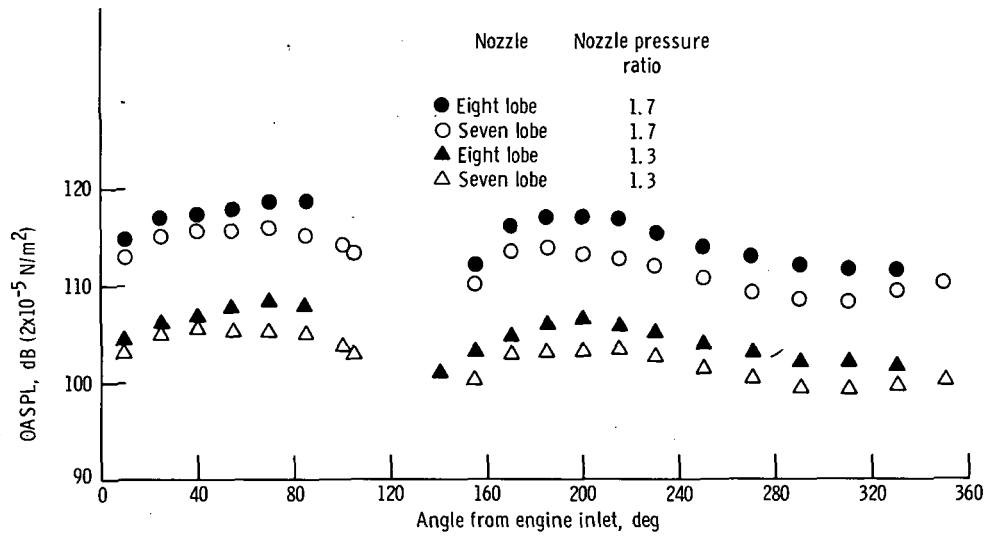
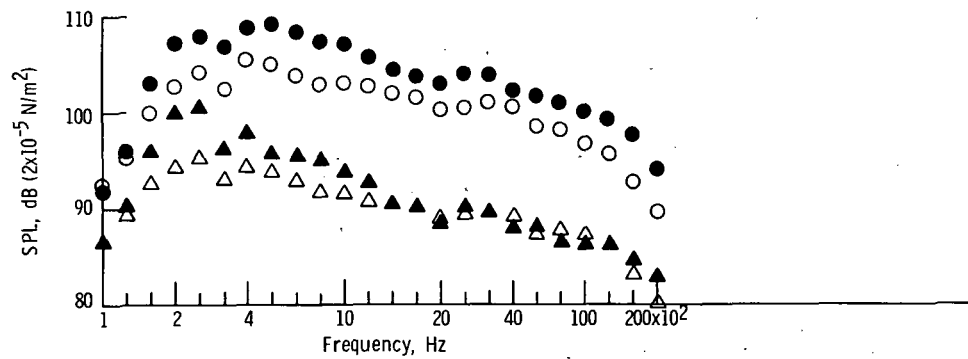


Figure 13. - Variation of total sound power level with nozzle exhaust velocity for seven and eight lobe nozzles.

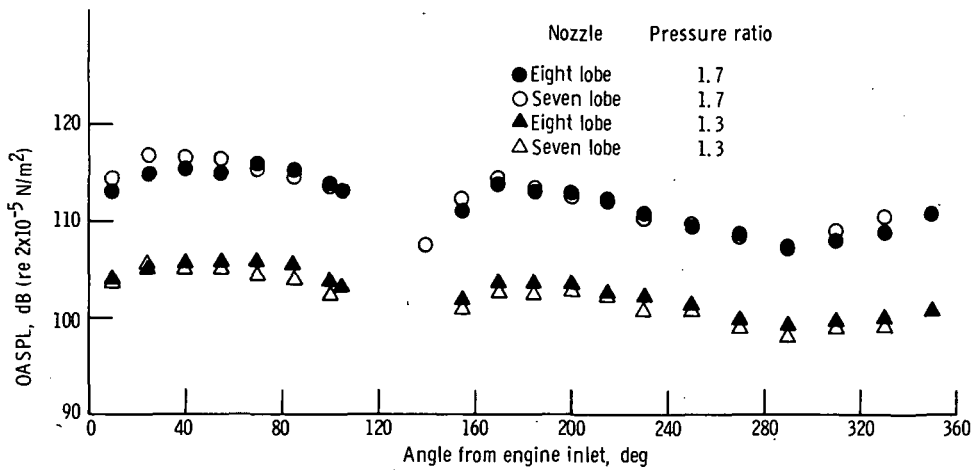


(a) Overall sound pressure level (OASPL) directivity.

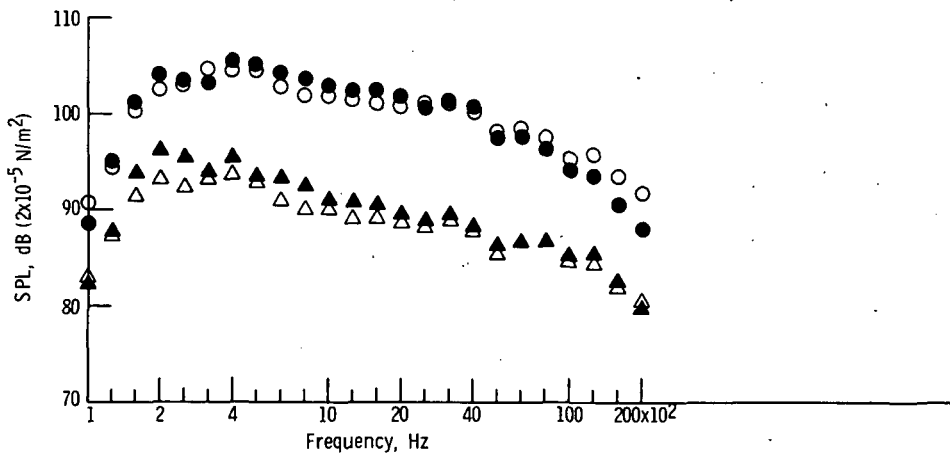


(b) Sound pressure level (SPL) one-third octave spectra at 85°.

Figure 14. - Comparison of noise data for seven and eight lobe nozzles with two-flap wing with trailing flap in 60° position. Nozzle to wing distance, 48.9 centimeters; microphone radius, 15.24 meters.

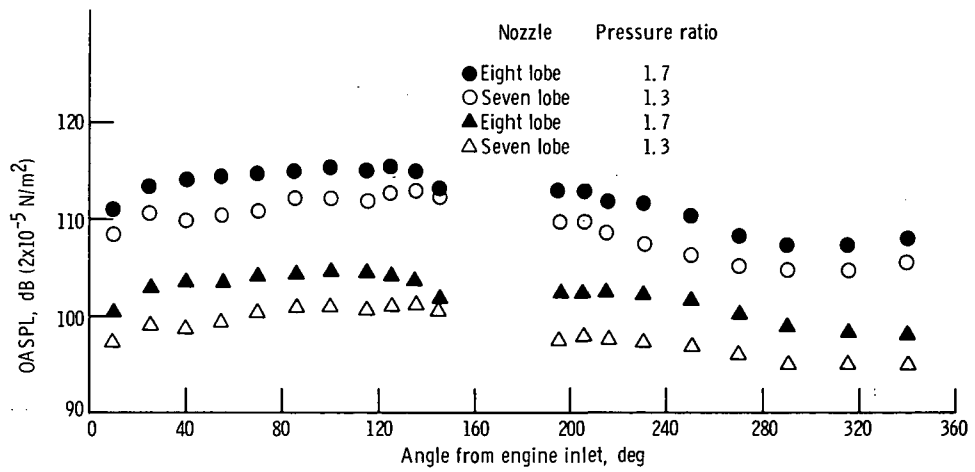


(a) Overall sound pressure level (OASPL) directivity.

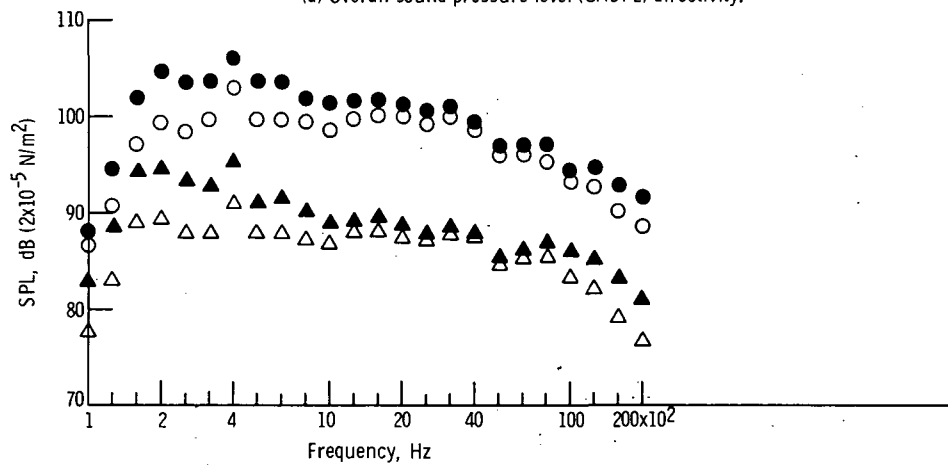


(b) Sound pressure level (SPL) one-third octave spectra at 85°.

Figure 15. - Comparison of noise data for seven and eight lobe nozzles with three-flap wing with trailing flap in 60° position. Nozzle to wing distance, 74.3 centimeters; microphone radius, 15.24 meters.

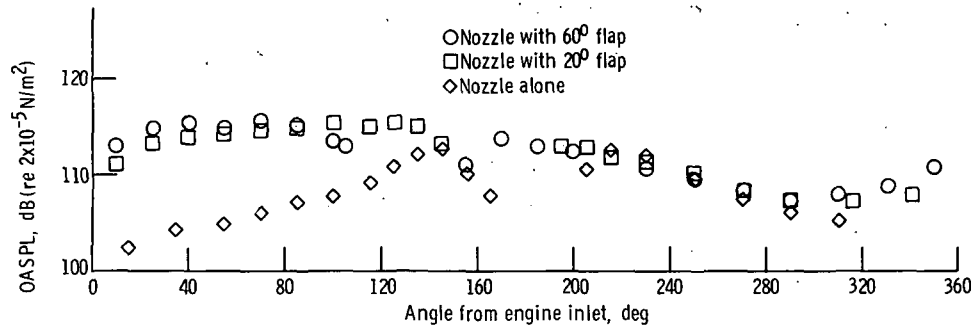


(a) Overall sound pressure level (OASPL) directivity.

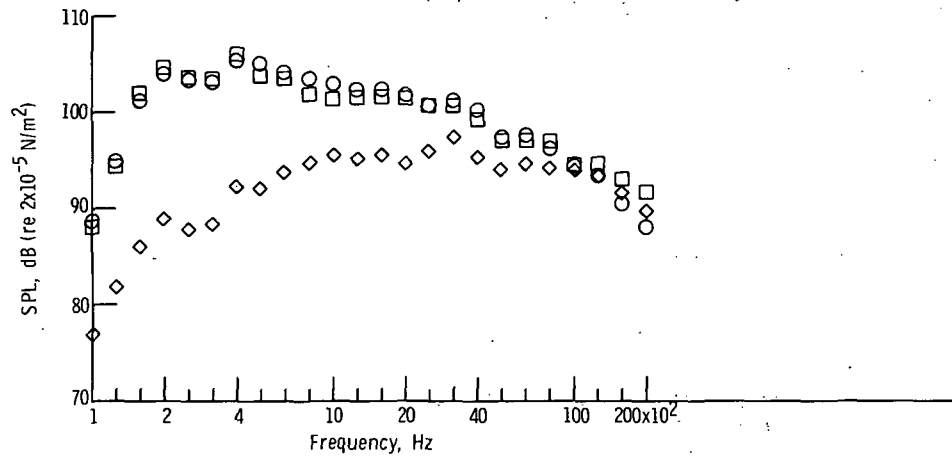


(b) Sound pressure level (SPL) one-third octave spectra at 85°.

Figure 16. - Comparison of noise data for seven and eight lobe nozzle with three-flap wing with trailing flap in 20° position. Nozzle to wing distance, 74.3 centimeters; microphone radius, 15.2 meters.

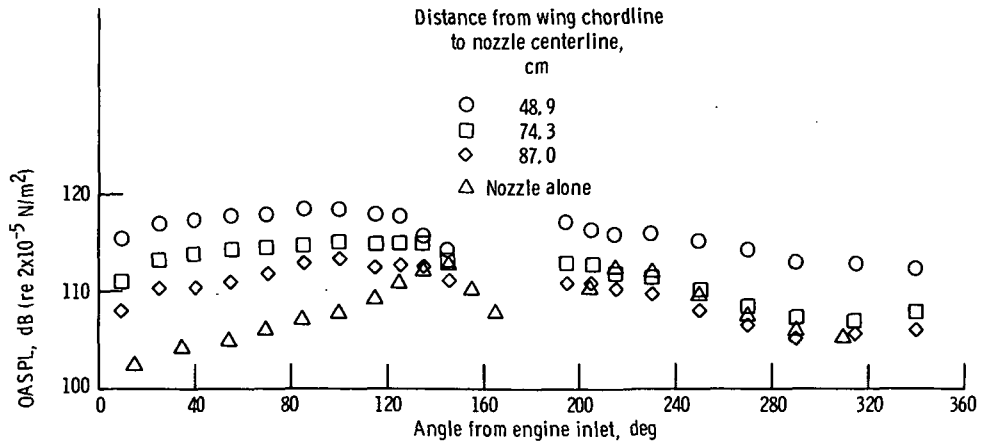


(a) Overall sound pressure level (OASPL) directivity.

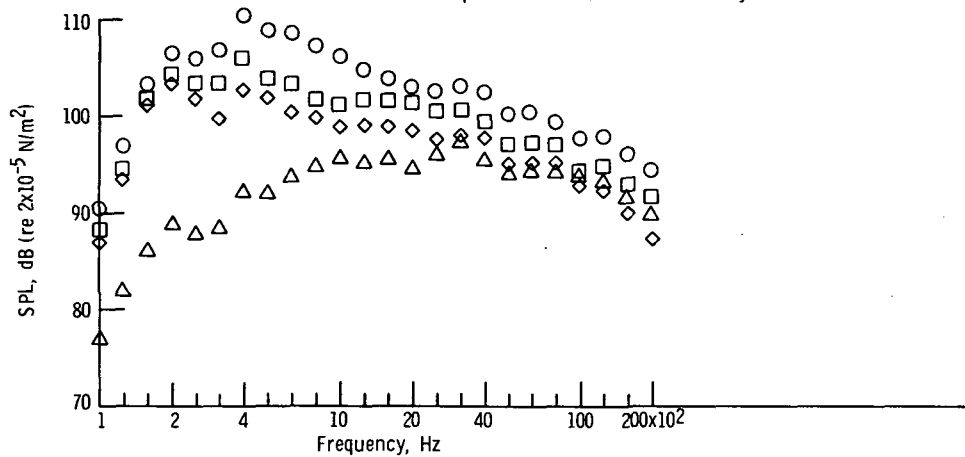


(b) Sound pressure level (SPL) one-third octave spectra at 85° .

Figure 17. - Comparison of noise data for eight lobe nozzle alone and nozzle with three-flap wing with trailing flap in 60° and 20° positions at a nozzle to wing spacing of 74.3 centimeters. Nozzle pressure ratio, 1.7; microphone radius, 15.24 meters.



(a) Overall sound pressure level (OASPL) directivity.



(b) Sound pressure level (SPL) one-third octave spectra at 85° .

Figure 18. - Comparison of noise data for eight lobe nozzle with three flap wing with trailing flap in the 20° setting at various wing to nozzle distances. Nozzle pressure ratio, 1.7; microphone radius, 15.24 meters.

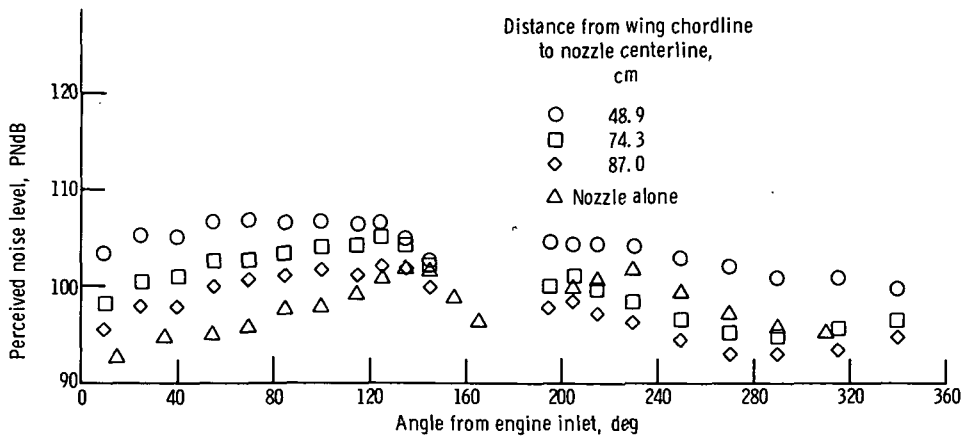
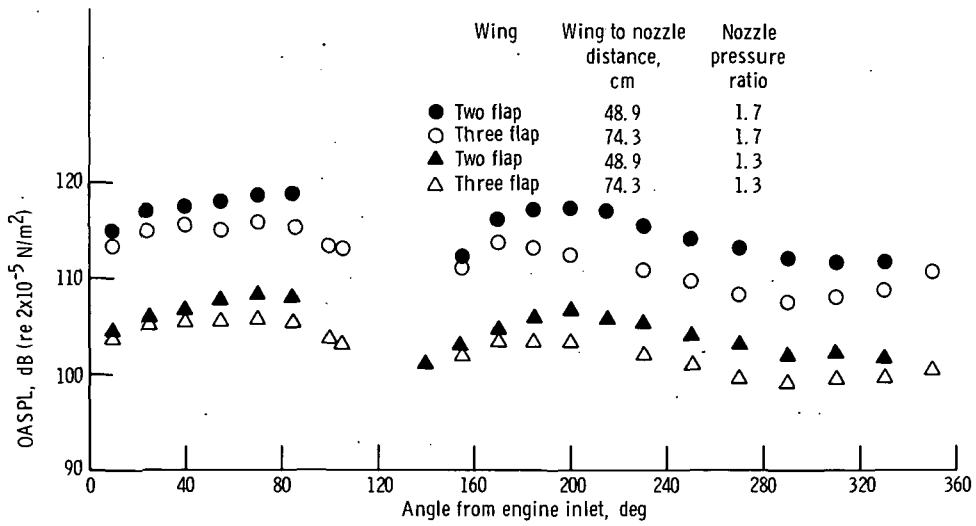
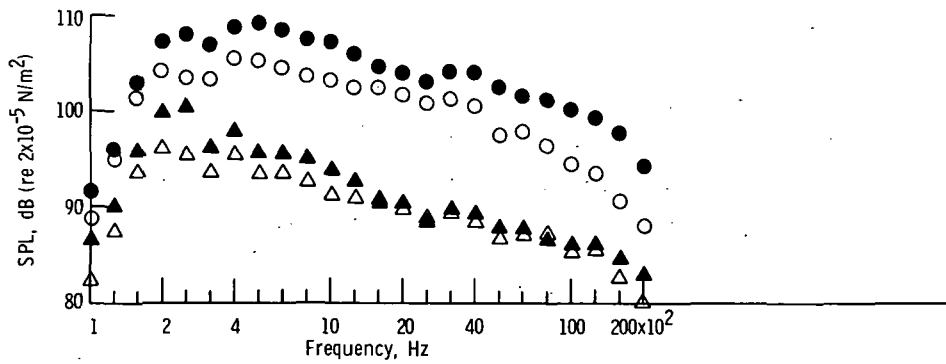


Figure 19. - Comparison of perceived noise level (PNL) directivity pattern at 152.4 meters for eight lobe nozzle with three-flap wing with trailing flap in the 20° setting and various wing to nozzle distances. Nozzle pressure ratio, 1.7.

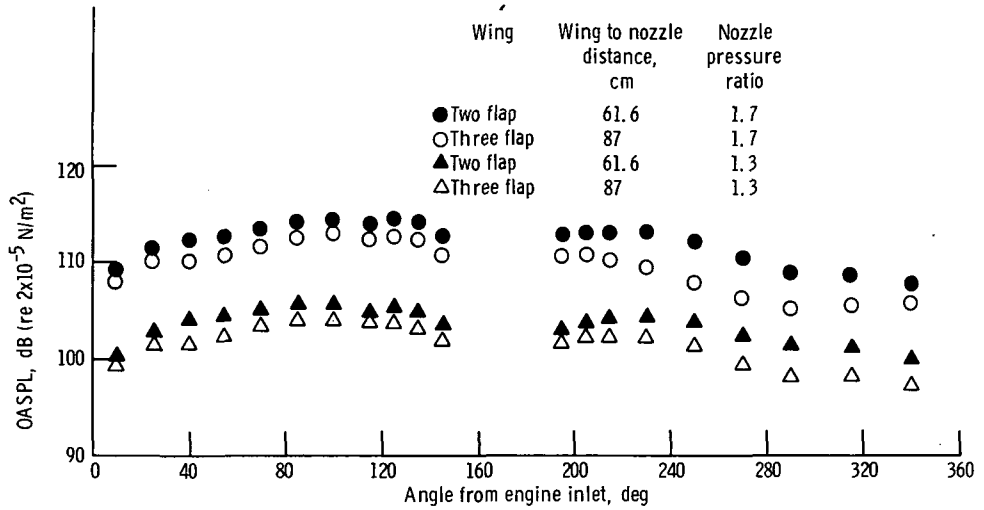


(a) Overall sound pressure level (OASPL) directivity.

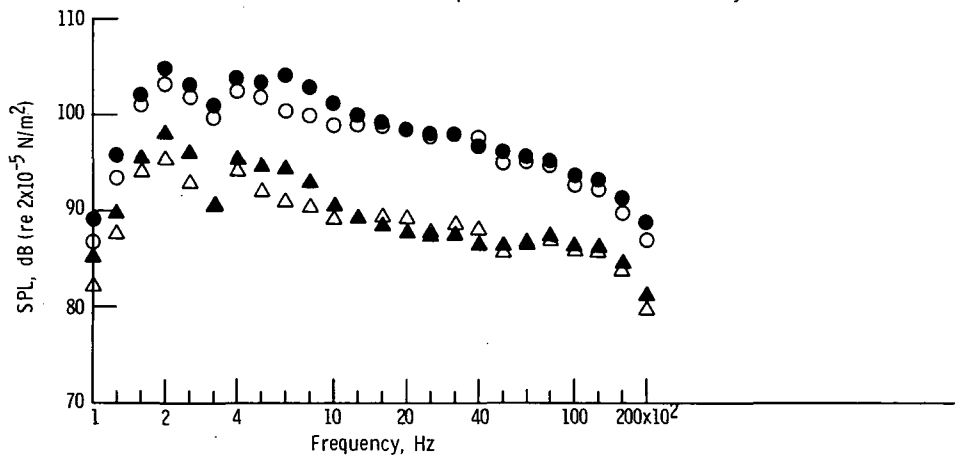


(b) Sound pressure level (SPL) one-third octave spectra at 85°.

Figure 20. - Comparison of noise data for eight lobe nozzle with two- and three-flap wing. Trailing flap at 60° setting; microphone radius, 15.24 meters.



(a) Overall sound pressure level (OASPL) directivity.



(b) Sound pressure level (SPL) one-third octave spectra at 85°.

Figure 21. - Comparison of noise data for eight lobe nozzle with two- and three-flap wing. Trailing flap at 20° setting; microphone radius, 15.24 meters.

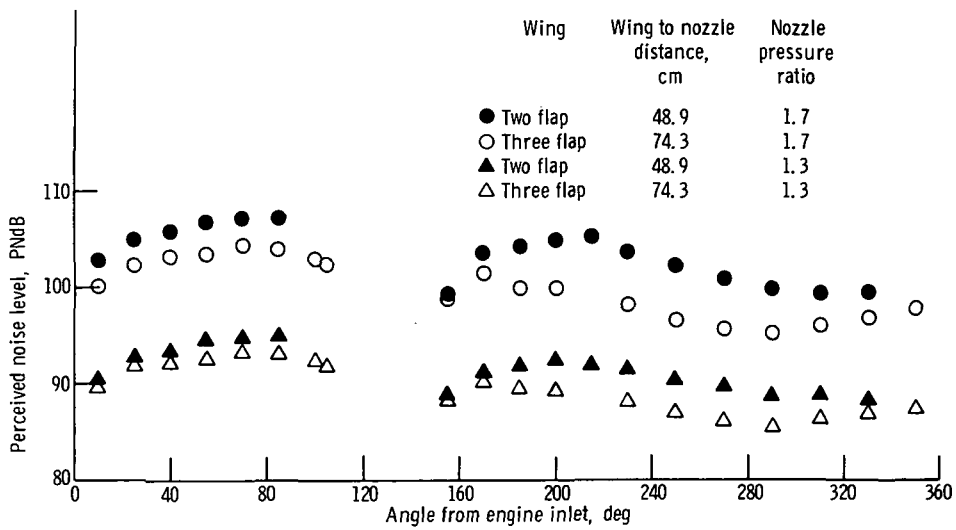


Figure 22. - Comparison of perceived noise level directivity pattern at 152.4 meters for eight lobe nozzle with two- and three-flap wing. Trailing flap at 60° setting.

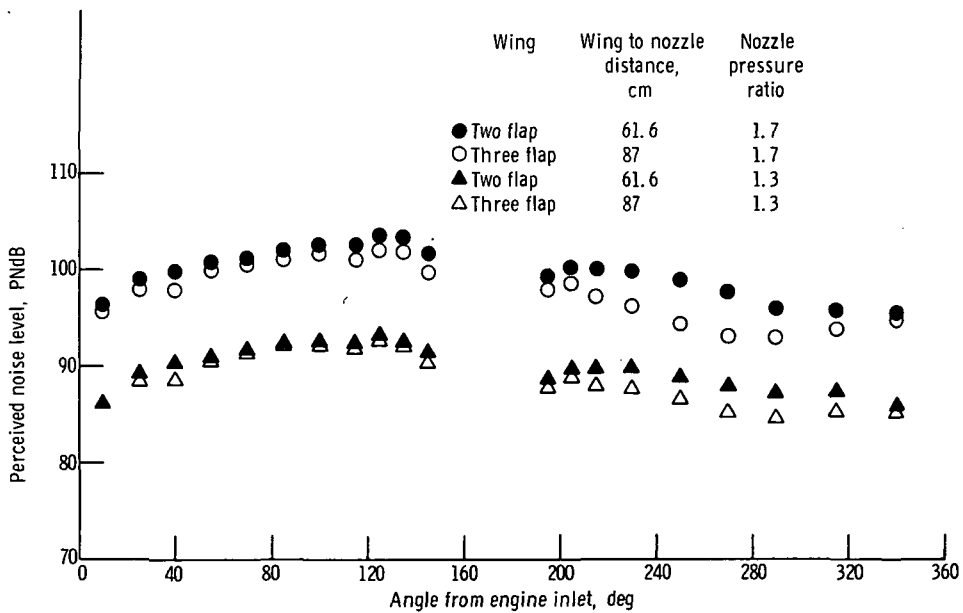


Figure 23. - Comparison of perceived noise level directivity pattern at 152.4 meters for the eight lobe nozzle with the two- and three-flap wing. Trailing flap at the 20° setting.



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