NASA TECHNICAL MEMORANDUM

NASA TM X-2942

NASA TM X-2942

NOISE TESTS ON AN EXTERNALLY BLOWN FLAP WITH THE ENGINE IN FRONT OF THE WING

by Allen M. Karchmer and Robert Friedman

Lewis Research Center

Cleveland, Ohio 44135

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • DECEMBER 1973

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM X-2942		

4. Title and Subtitle	5. Report Date
NOISE TESTS ON AN EXTERNALLY BLOWN FLAP WITH THE ENGINE IN FRONT OF THE WING	December 1973
	6. Performing Organization Code
7. Author(s) by Allen M. Karchmer and Robert Friedman	8. Performing Organization Report No. E-7564
	10. Work Unit No. 501-24
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135	11. Contract or Grant No.
	13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Noise tests were conducted with a nozzle exhausting over a small scale model of an externally blown flap (EBF) lift-augmentation system, with exhaust impingement on the wing leading edge. Two series of tests were conducted: with wing leading edge inside the nozzle; and with leading edge set back from the nozzle exit plane 1 diameter on the jet axis. The results indicated no significant differences in spectral shape, level, or directivity pattern. Static lift and thrust tests were conducted on the same model indicated considerable flow attachment on both configurations, with slightly greater attachment and turning for the wing outside the nozzle. Finally, a comparison with engine-above- and engine-below-the-wing EBF's tested by previous investigators shows the acoustic performance of the configurations tested for this report to lie between the other two.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Jet aircraft noise; Lift augmentation; Short takeoff aircraft; Blown flaps; Aerodynamic noise; Aerodynamic acoustics	Unclassified - unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	15	Domestic, $2.75 Foreign, $5.25

* For sale by the National Technical Information Service, Springfield, Virginia 22151

NOISE TESTS ON AN EXTERNALLY BLOWN FLAP WITH THE ENGINE IN FRONT OF THE WING

by Allen M. Karchmer and Robert Friedman

Lewis Research Center

SUMMARY

Noise tests were conducted with a nozzle exhausting over a small scale model of an externally blown flap life-augmentation system. Two series of tests were conducted: with the leading edge of the wing inside a 10.2-centimeter-diameter pipe; and with the leading edge of the wing set back a distance of 1 pipe diameter from the exit plane of a 10.2-centimeter-pipe. In the latter case, the wing was supported by a 5.1-centimeter-diameter cylindrical strut which also served as an axisymmetric plug to form a nozzle. The open flow area in both cases was 61.9 square centimeters, equivalent to an 8.8-centimeter-diameter circular nozzle. Noise tests were made for pressure ratios of 1.35 and 1.15, corresponding to jet exhaust velocities of 220 and 156 meters per second, respectively. The flap positions for each pressure ratio were 30°-60° (landing) and 10°-20° (takeoff).

The results indicated no significant differences in spectral shape, level, or directivity pattern for the two configurations. Static lift and thrust tests conducted on the same model indicated considerable flow attachment on both configurations, with slightly greater attachment and turning for the wing leading edge outside the nozzle. Finally, a comparison of externally blown flaps with the engine above and below the wing tested by previous investigators showed the acoustic performance of the configuration tested for this report to lie between the other two.

INTRODUCTION

Short takeoff and landing (STOL) aircraft are intended to use airports located in or near highly populated urban areas. The practicality of such aircraft will depend in large measure on whether or not their noise levels are acceptable to the local communities. One technique to enable such aircraft to accomplish its short takeoff and landing is the use of a lift-augmentation device consisting of an externally blown flap (EBF). Such a device, however, can result in a considerable redirection and generation of noise (refs. 1 to 4).

The location of the engine relative to the wing can be an important consideration in the design of such aircraft for several reasons: much of the resulting noise arises from the interaction of the jet exhaust on the wing and blown flap surfaces; and the physically large engines used present possible structural and aerodynamic constraints. Previous investigators have reported acoustic data on an engine-below-the-wing configuration (refs. 1 to 4) and an engine-above-the-wing configuration (refs. 5 to 7).

With the high bypass, low pressure ratio engines currently being proposed for STOL aircraft, consideration must be given to an engine with its exhaust at least partially impinging on the wing leading edge. For this third alternative the wing leading edge can be either outside or inside the exhaust nozzle. In the latter scheme, the wing leading edge would be exposed to a low impingement velocity, and noise generated near the leading edge might be reduced. Further, the nozzle might serve to shield what noise is generated at or near the leading edge.

This report presents acoustic data obtained from two series of tests conducted on a model engine-in-front-of-the-wing configuration. The tests were conducted with wing leading edge protruding inside the nozzle and outside the nozzle 1 nozzle diameter downstream of the exit plane for two flap settings: 10° - 20° (takeoff) and 30° - 60° (landing). Tests of each of these configurations were conducted at pressure ratios of 1.35 and 1.15 corresponding to nozzle exit velocities V_j of 220 and 156 meters per second.

APPARATUS AND PROCEDURE

Air Flow Facility

The outdoor acoustic facility is shown schematically in figure 1. Dry pressurized air was supplied at ambient temperature from a laboratory compressor system. The flow system consisted of a flow-measuring orifice, a control valve, a perforated plate used to reduce the valve noise, a four-chamber baffled muffler, and a 5-meter length of 10.2-centimeter-inside-diameter (nominal 4-in.) piping.

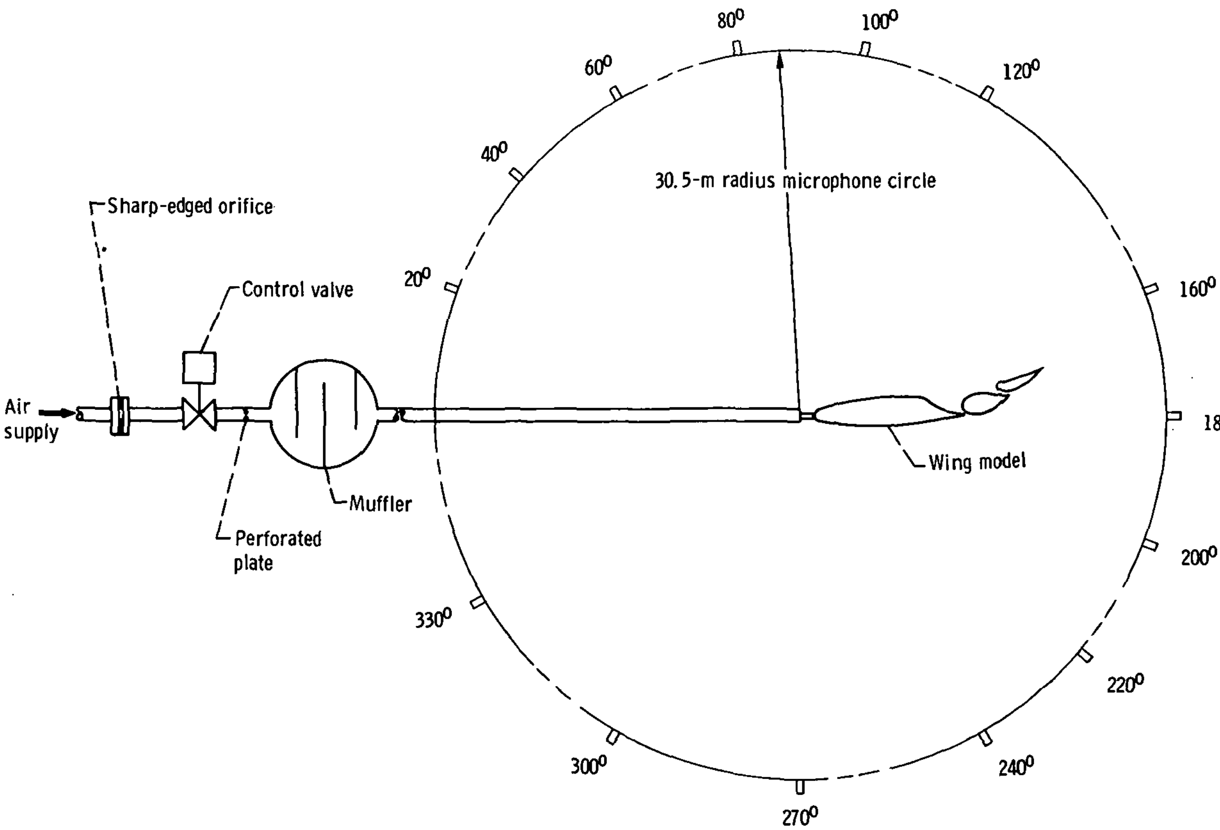
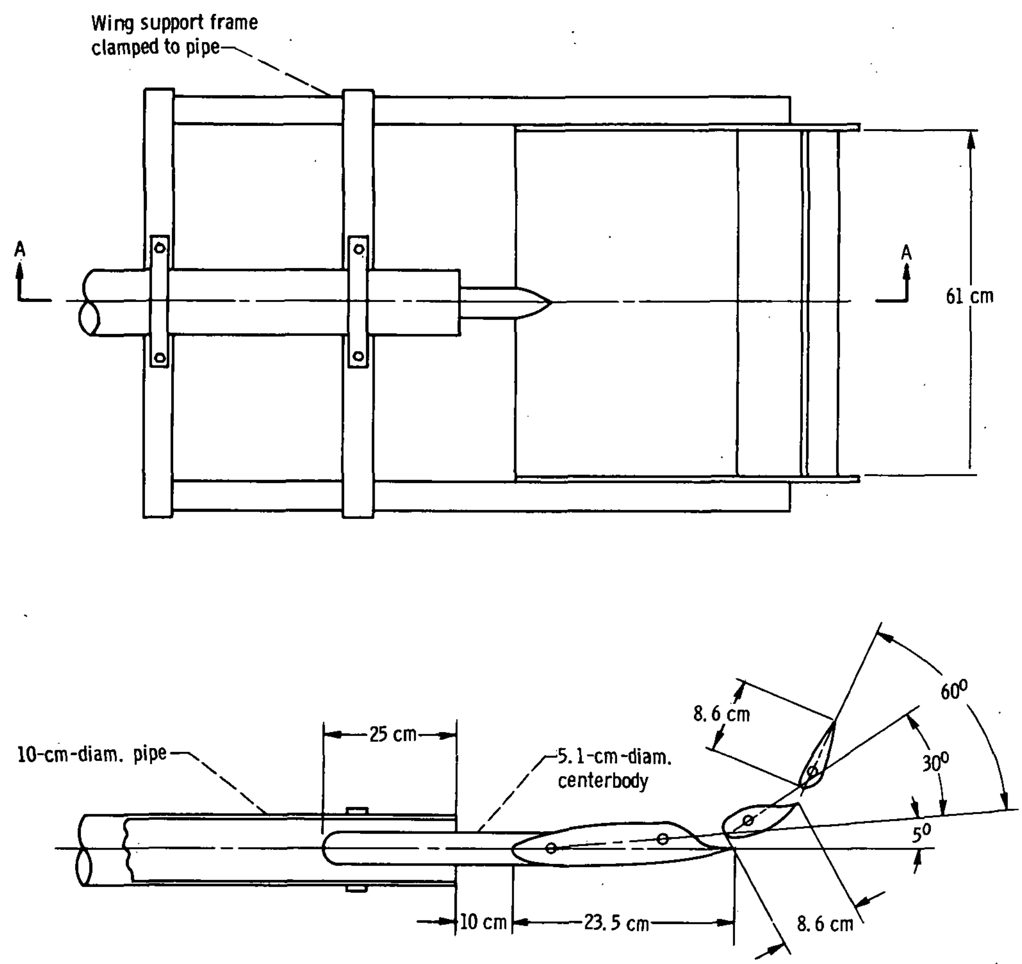


Figure 1. - Schematic of test installation, plan view.

Test Models

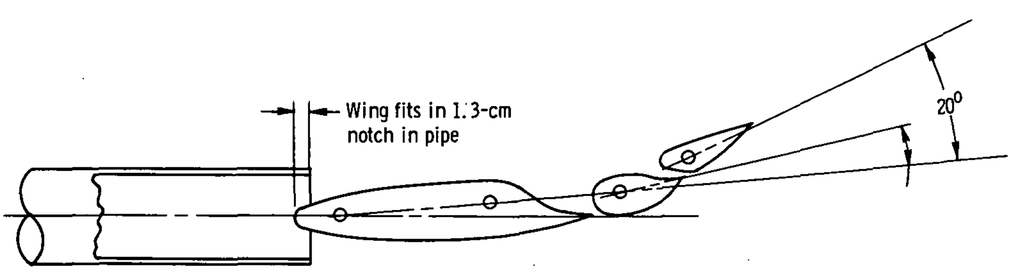
The acoustic experiments were conducted with configurations which had the common feature of exit airflow from the 10-centimeter pipe flowing over a scale model wing. Two models were used as shown in figure 2. In configuration 1 (fig. 2(a)) the wing was mounted outside the exit plane of the nozzle in a frame that was clamped to the piping. The leading edge of the wing was 1 pipe diameter downstream from the pipe exit. A 5.1-centimeter cylindrical centerbody with hemispherical leading edge extended into the pipe. The centerbody formed an annular nozzle at the pipe exit with an area of 61.9 square centimeters (contraction ratio of 1.33). The centerbody was attached to the wing only, and there were no supports or struts in the pipe.

In configuration 2 (fig. 2(b)), no centerbody was used and the wing was centrally mounted in a slot in the pipe (with the same frame as was used in configuration 1) to such a depth as to provide 61.9 square centimeters flow area in the exit plane of the nozzle. The exit flow area was equally divided above and below the wing. The clearance around the slot was sealed with clay.



Section A-A (frame not shown)

(a) Configuration 1: wing outside nozzle (30°-60° flaps shown).



(b) Configuration 2: wing inside nozzle (10°-20° flaps shown). (Frame not shown.)

Figure 2. - Wing and nozzle models for engine-in-front-of-the-wing tests.

The wing used in configurations 1 and 2 had two adjustable flap elements. Noise measurements were made at flap settings corresponding to takeoff (10^{o}-20^{o}) and landing (30^{o}-60^{o}). These angles were measured from the mean chord line of the wing (which was at an angle of 5^{o} to the pipe centerline) as shown in figure 2. In all cases the slots between the flaps were open as shown. Details of this wing model are found in references 1, 4, and 7 where, with minor modifications, it was used for blown-flap and above-the-wing EBF noise research.

Instrumentation and Procedure

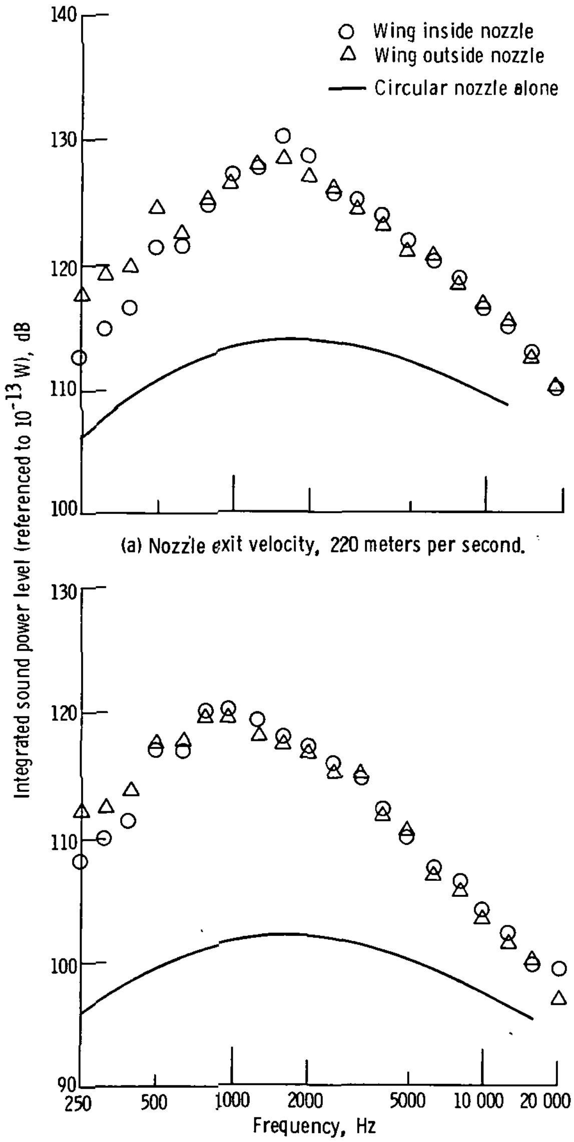
Acoustic data were measured as shown in figure 1 by fourteen 1.27-centimeter condenser microphones located on stands at the horizontal plane of the piping (1.56 m above a smooth asphalt surface) on a 3.05-meter-radius circle. The microphone in line with the jet was omitted, either at 140^{o} as shown for 30^{o}-60^{o} flaps or at 160^{o} for 10^{o}-20^{o} flaps. For both configurations the wing was oriented vertically, hence the microphone array represented a flyover simulation. Sound data were analyzed by a 1/3-octave band sprectrum analyzer. The analyzer determined sound pressure level (SPL) spectra referenced to $2x10^{-5}$ newton per square meter (0.0002-μm bar). Overall sound pressure levels (OASPL) and integrated sound power levels (PWL) referenced to 10^{-13} watts were computed from the SPL data. Background noise and cancellations and reinforcements due to ground reflection were appreciable only below 240 hertz, well below the frequency of peak experimental noise, and no corrections were made for these effects.

A total pressure probe was located just upstream of the nozzle exit. Pressure and temperature were read remotely. Exit velocity was calculated by a one-dimensional isentropic equation using the measured temperature and total to ambient pressure ratio. Data were taken at nominal velocities of 156 and 220 meters per second.

RESULTS AND DISCUSSION

Acoustic Results

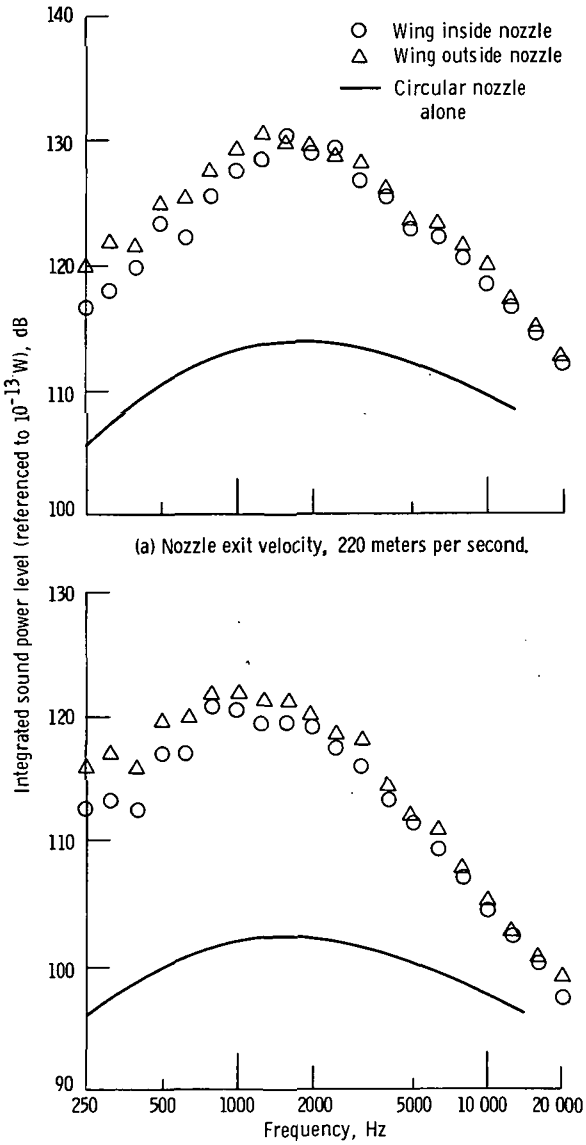
Figures 3 and 4 are 1/3-octave-power spectral plots for each of the exhaust velocities tested and for flap angles of 10^{o}-20^{o} and 30^{o}-60^{o}. The plots show the results for the nozzle plus blown-flap configuration for the case of the wing leading edge inside the nozzle and for the case where the leading edge is set back from the nozzle exit plane a distance of 1 pipe diameter. The power spectra for a circular nozzle alone are shown



(a) Nozzle exit velocity, 220 meters per second.

(b) Nozzle exit velocity, 156 meters per second.

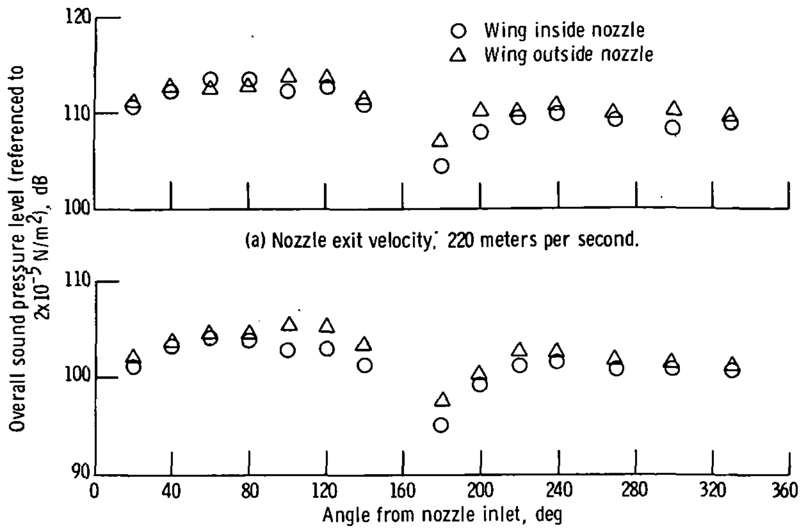
Figure 3. - Sound power level plotted against 1/3-octave center band frequency for wing leading edge inside and outside nozzle and for circular nozzle alone. Flap angle, 10^0-20^0.



(a) Nozzle exit velocity, 220 meters per second.

(b) Nozzle exit velocity, 156 meters per second.

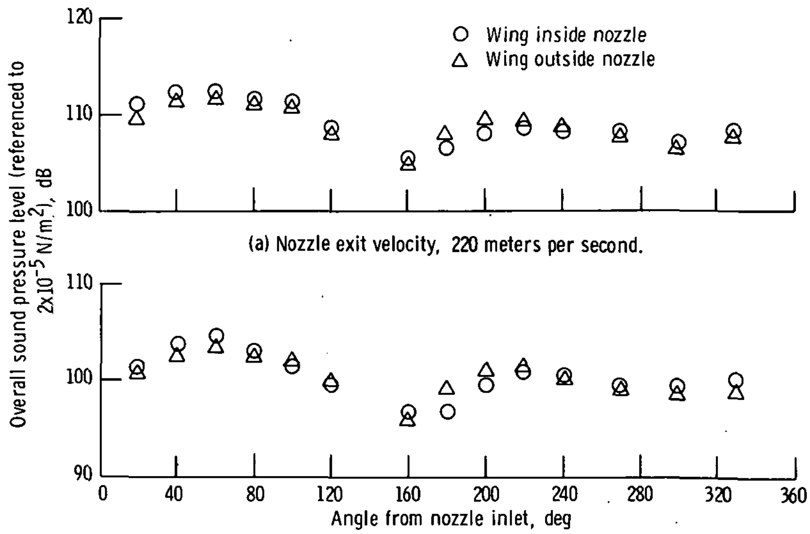
Figure 4. - Sound power level plotted against 1/3-octave center band frequency for wing leading edge inside and outside nozzle and for circular nozzle alone. Flap angle, 30^0-60^0.



(a) Nozzle exit velocity, 220 meters per second.

(b) Nozzle exit velocity, 156 meters per second.

Figure 5. - Comparison of overall noise levels for leading edge inside and outside nozzle. Flap angle, 10°-20°.



(a) Nozzle exit velocity, 220 meters per second.

(b) Nozzle exit velocity, 156 meters per second.

Figure 6. - Comparison of overall noise levels for leading edge inside and outside nozzle. Flap angle, 30°-60°.

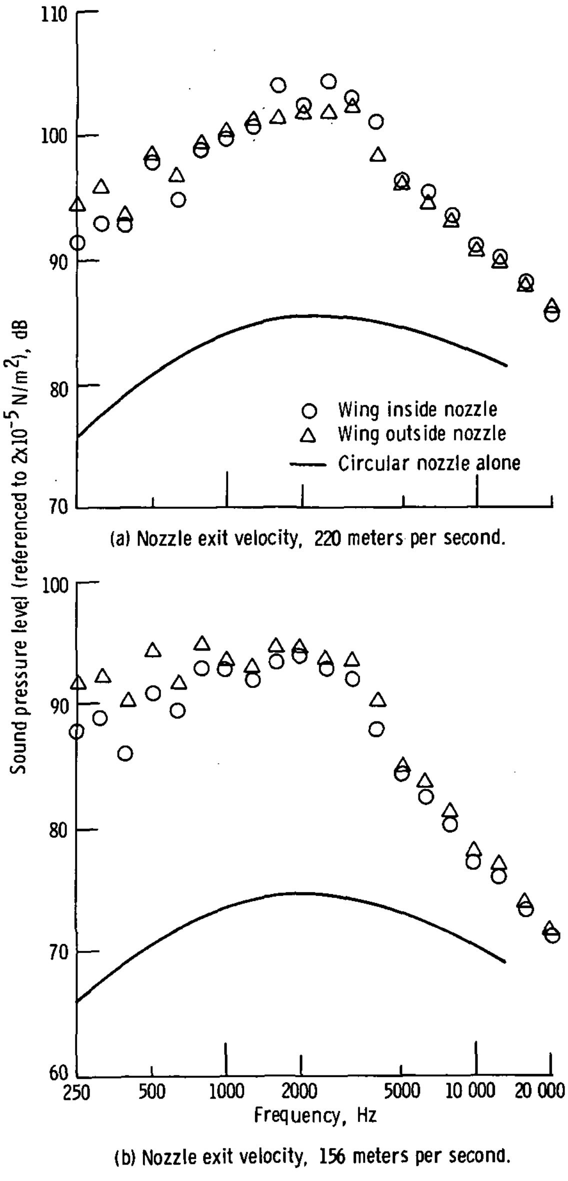


Figure 7. - Sound pressure level plotted against 1/3-octave center band frequency for wing leading edge inside and outside nozzle and for circular nozzle alone. Microphone angle, 100°; flap angle, 10°-20°.

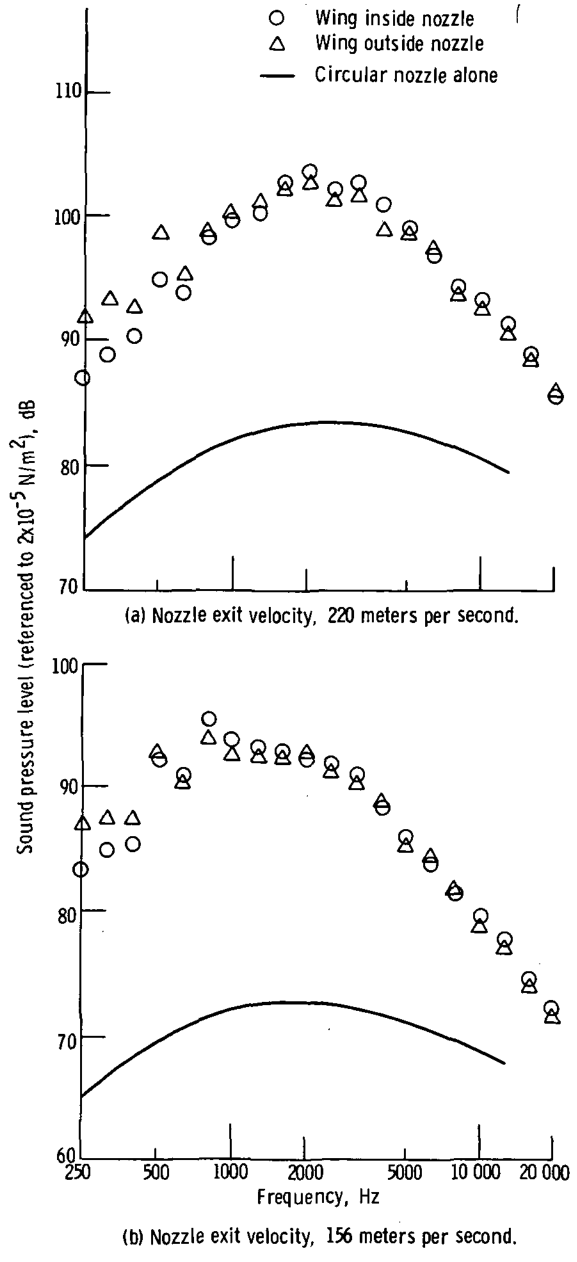


Figure 8. - Sound pressure level plotted against 1/3-octave center band frequency for wing leading edge inside and outside nozzle and for circular nozzle alone. Microphone angle, 80°; flap angle, 30°-60°.

on these figures for comparison purposes. The circular nozzle spectra were scaled to the 8.8-centimeter equivalent diameter and to the appropriate velocity (by V_j^8) from unpublished data collected in tests conducted for reference 8. The nozzle diameter used in reference 8 was 5.26-centimeters.

The presence of the wing-flap system, as would be expected, adds significantly to the power levels over the entire spectral range, the greatest addition occurring at frequencies near the peak of the nozzle alone spectrum with less addition at frequencies above and below the peak. A comparison of the power spectra for each of the two EFW configurations in figures 3 and 4 shows no significant differences. That is, moving the wing leading edge from a position outside the nozzle to the inside of the nozzle produces no significant changes in the power spectral shape or level.

Similar trends are observed in the OASPL directivity pattern (figs. 5 and 6). Here again, the level and, in this case, the directivity pattern are essentially the same for the leading edge either inside or outside the nozzle. For both configurations the directivity patterns are relatively uniform, with the exception of the usual "shadow" zone in line with the jet exhaust.

Figures 7 and 8 are spectral plots of the SPL as a function of 1/3-octave center band frequencies for the two EFW configurations. The SPL spectra for the nozzle alone are also shown. The data in figure 7 are for a microphone angle of 100^{o} from the nozzle inlet and in figure 8 for 80^{o}. These angles correspond to positions beneath the aircraft during takeoff (fig. 7) and landing (fig. 8), respectively. There is little significant difference in the noise levels and, in this case, the spectral shape, between either of the EFW configurations. Again, however, the presence of the wing-flap system adds significantly to the nozzle-alone noise.

Comparison with Other EBF Configurations

Previous investigators have reported acoustic data for other blown flap configurations using the same wing-flap model: engine below the wing (refs. 1 and 4) and engine above the wing (refs. 5, 7, and 9). A direct, rigorous quantitative comparison between those results and the data reported here is not possible because of differences in nozzle size, which makes scaling difficult. However, some preliminary qualitative conclusions can be made.

Figure 9 shows the power spectra for engine-in-front-of, engine-below, engine-above-the-wing configurations for a jet velocity of 220 meters per second and flap angle 30^{o}-60^{o} (landing). The below-the-wing spectrum was obtained from unpublished data collected in tests conducted for reference 4. The data were taken with a circular nozzle of 7.8-centimeter diameter. Although this nozzle and its orientation relative to the wing-flap system was atypical of most of the data in reference 4, it was chosen because the nozzle diameter was closest to the equivalent diameter used in the tests conducted for this report. The data were for a jet velocity of 200 meters per second. The data for the above-the-wing spectrum were obtained from reference 5. The configuration included a circular nozzle with deflector and fully covered flap slots. This configuration was chosen because of the attached flow and resulting lift augmentation, which are necessary for STOL applications. The nozzle used in reference 5 had a diameter of 5.1 centimeters and a jet exit velocity of 225 meters per second. In both cases the levels were velocity scaled to 220 meters per second by V_j^6 and area scaled to 61.9 square centimeters. The frequencies were scaled linearly with velocity and equivalent nozzle diameter.

The velocity scaling is straightforward, since most data for flow over a surface have indicated a velocity to the 6th power relation for the level and a simple linear velocity scaling for frequency. The geometric scaling used to account for size differences is considerably less reliable. A level scaling by area and frequency scaling by diameter (or square root of area) implies that the entire configuration grows linearly by the same amount. In the three cases compared, however, the wing-flap systems were all the same size, with only the nozzle diameters being different. Since the nozzle diameters used in the below and above-the-wing cases were both scaled upward, the data in figure 9 are somewhat high for these two configurations, and the true levels would actually be less, with overscaling being more significant for the over-the-wing case because of its considerably smaller nozzle diameter. Hence caution should be exercised in arriving at any rigorous conclusions from these data. Nevertheless, some qualitative conclusions may be made. Based on the assumed scaling laws and qualifications mentioned previously,

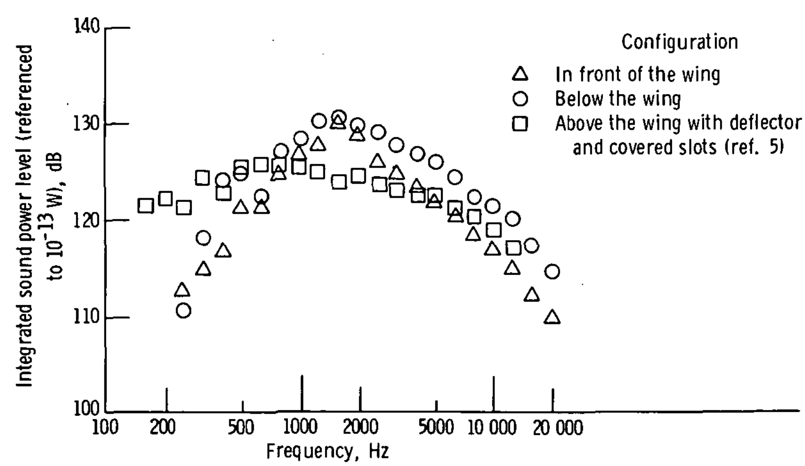


Figure 9. - Comparison of power spectra for engine-in-front-of-, engine-below-, and engine-above-the-wing schemes. Nozzle exit velocity, 220 meters per second; flap angle, 30°-60°.

figure 9 indicates that the engine-in-front-of and engine-below-the-wing configurations are comparable in peak power and frequency with the EFW configuration showing a more rapid rolloff at frequencies greater than the peak frequency. The above-the-wing case, though, generates less acoustic power at the peak frequency than the other two, but rolls off somewhat slower than the other two. The integrated sound powers for all three configurations are approximately the same.

Figure 10 shows the more important SPL spectra at a representative position beneath the wing (microphone angle, 80°). The source of the data for the below-the-wing

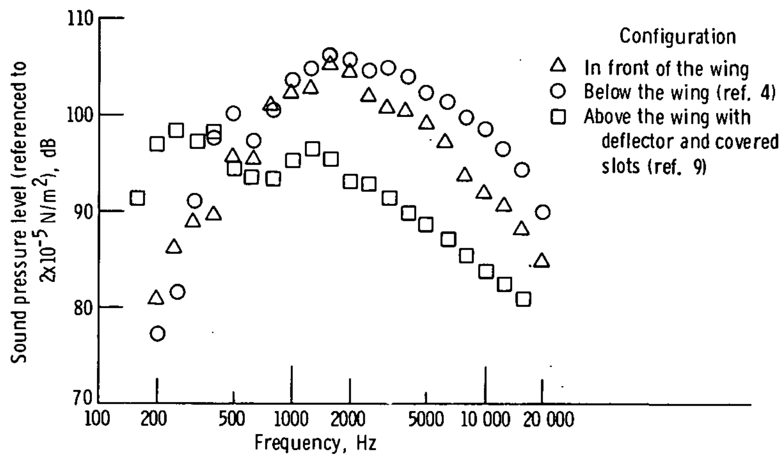


Figure 10. - Comparison of sound pressure level spectra for engine-in-front-of-, engine-below-, and engine-above-the-wing schemes. Nozzle exit velocity, 220 meters per second; flap angle, 30°-60°; microphone angle, 80°.

case is the same as for figure 9, and the source for the above-the-wing case is reference 9. These data are also for a flap angle of 30°-60° and V_j = 220 meters per second. The same scaling as that used for figure 9 was used for this figure, and the same comments concerning the geometric scaling uncertainties apply to this figure as well. Once again, for the below- and in-front-of-the-wing configurations, the peaks occur at the same frequencies, but the spectrum for the EFW case rolls off more rapidly The above-the-wing case, though, appears to be considerably quieter, not only at the peak frequency but also over a relatively wide band about the peak. Similar results hold for the takeoff position of the flaps (but they are not shown here).

Flow Attachment

Since the primary purpose of an externally blown flap is to provide lift augmentation, it is vitally important that the exhaust flow has good attachment to the wing-flap system.

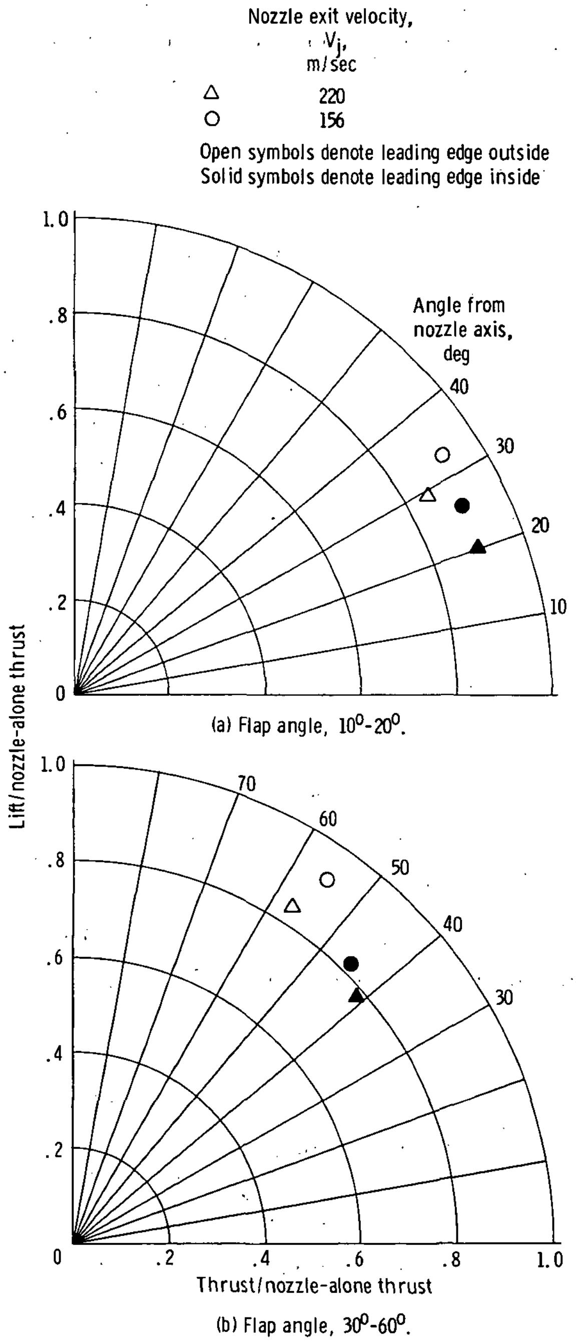


Figure 11. - Turning effectiveness of engine-in-front-of-the-wing (EFW) configurations.

Static lift and thrust data provide a measure of the degree of flow attachment to the upper and lower surfaces of the flaps and a measure of the turning efficiency of the wing-flap system. Figures 11(a) and 11(b) are polar plots of the static turning effectiveness for the flap settings in the takeoff and landing positions, respectively. The data are shown for both jet exit velocities considered and for the leading edge of the wing inside and outside the nozzle. The points were computed from measured values of static life and thrust, and normalized by the static thrust of the nozzle alone. Details of the lift and thrust measuring facility can be found in reference 7.

For the case where the leading edge was outside the nozzle (open symbols), good attachment and lift augmentation was achieved in both landing and takeoff flap positions, with turning of approximately 56° and 30°, respectively, at both jet velocities compared to a geometric chord angle of 65° and 25°. The efficiencies in both cases are between 80 and 90 percent. Although the efficiency of the system with the wing leading edge inside the nozzle is the same or only slightly less, the flow attachment for this case is not nearly as good, 20°-25° of turning for the takeoff position but only 40°-45° for the landing position.

It would appear from these preliminary static tests, then, that since the acoustic performance of both configurations was the same, the configuration with the wing outside the nozzle would be preferred on the basis of its performance as a lift-augmentation device.

SUMMARY OF RESULTS

From the tests conducted and comparisons made with published and unpublished data, the following conclusions can be made (within the limits of the scaling relation used):

1. For the engine in front of the wing, there is no significant difference in spectral shape and level or noise directivity with the wing leading edge inside the nozzle or with it set back from the nozzle exit plane 1 nozzle diameter.

2. The total power generated for the two configurations tested is approximately equal to that of engine-under- and engine-over-the-wing configurations tested by previous investigators, but the power spectrum for the EFW rolls off from the peak, more rapidly than the other two.

3. The sound pressure level spectrum at positions beneath the wing for the engine in front of the wing generally lies between those of the engine-below- and engine-above-the wing schemes, being less than the below-the-wing scheme but more comparable to the below-the-wing configuration than the above-the-wing scheme.

4. For both landing and takeoff flap positions, the static-lift-augmentation performance for the configuration with the wing leading edge outside the nozzle is somewhat better than the case with the leading edge inside the nozzle. The latter produced only partial turning of the exhaust flow.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, August 9, 1973,
501-24.

REFERENCES

1. Dorsch, R. G.; Krejsa, E. A.; and Olsen, W. A.: Blown Flap Noise Research. Paper 71-745, AIAA, June, 1971.
2. Dorsch, R. G.; Kreim, W. J.; and Olsen, W. A.: Externally-Blown-Flap Noise. Paper 72-129, AIAA, Jan. 1972.
3. Goodykoontz, Jack H.; Dorsch, Robert G.; and Groesbeck, Donald E.: Mixer Nozzle-Externally Blown Flap Noise Tests. NASA TM X-68021, 1972.
4. Olsen, William A.; Dorsch, Robert G.; and Miles, Jeffrey H.: Nose Produced by a Small-Scale, Externally Blown Flap. NASA TN D-6636, 1972.
5. Reshotko, Meyer; Olsen, William A.: and Dorsch, Robert G.: Preliminary Noise Tests of the Engine-Over-the-Wing Concept. I: 30^{o}-60^{o} Flap Position. NASA TM X-68032, 1972.
6. Reshotko, Meyer; Olsen, William A.; and Dorsch, Robert G.: Preliminary Noise Tests of the Engine-Over-the-Wing Concept. II: 10^{o}-20^{o} Flap Position. NASA TM X-68104, 1972.
7. Dorsch, R. G.; Reshotko, M.; and Olsen, W. A.: Flap Noise Measurements for STOL Configurations Using External Upper Surface Blowing. Paper 72-1203, AIAA, Nov. 1972.
8. Olsen, W. A.; Gutierrez, O. A.; and Dorsch, R. G.: The Effect of Nozzle Inlet Shape, Lip Thickness, and Exit Shape and Size on Subsonic Jet Noise. Paper 73-187, AIAA, Jan. 1973.
9. von Glahn, U.; Reshotko, M.; and Dorsch, R. G.: Acoustic Results Obtained with Upper-Surface-Blowing Lift-Augmentation Systems. NASA TM X-68159, 1972.

NASA-Langley, 1973 —— 1 E-7564

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons. Also includes conference proceedings with either limited or unlimited distribution.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include final reports of major projects, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546