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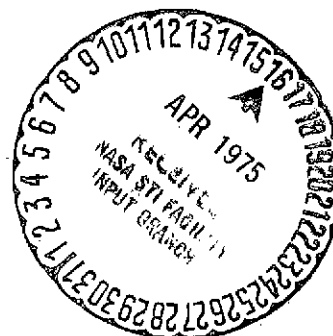
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**INTERIOR NOISE CONSIDERATIONS FOR
POWERED-LIFT STOL AIRCRAFT**

By

C. Kearney Barton

April 1975



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16. Abstract <p>Powered-lift configurations which are currently under development for future use on STOL aircraft involve impingement of the jet engine exhaust onto wing and flap surfaces. Previous studies have suggested that the impinging jet produces higher noise levels at lower frequencies than does the jet alone. These higher levels, together with the close proximity of the engine and flap noise sources to the fuselage sidewall, suggest that the noise levels in these aircraft may be high enough to interfere with passenger comfort. To investigate this possibility, interior noise levels were estimated for both an upper surface blown (USB) and an externally blown flap (EBF) configuration.</p> <p>This paper describes the procedure used to estimate the interior noise levels and compares these levels with levels on existing jet aircraft and on ground transportation vehicles. These estimates indicate high levels in the STOL aircraft; therefore, areas of possible improvements in technology for control of STOL interior noise are also discussed.</p>			
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INTRODUCTION

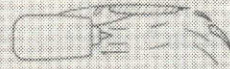
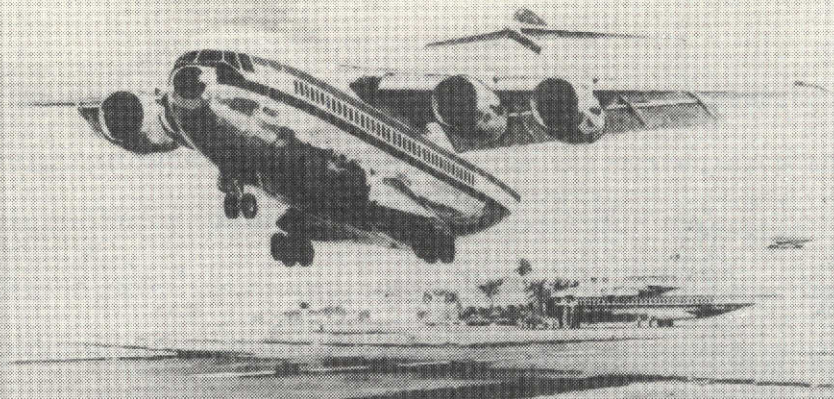
Powered-lift configurations which are currently under development for future use on STOL aircraft involve impingement of the jet engine exhaust onto wing and flap surfaces. Previous studies have suggested that the impinging jet produces higher noise levels at lower frequencies than does the jet alone (ref. 1). These higher levels, together with the close proximity of the engine and flap noise sources to the fuselage sidewall, suggest that the noise levels in these aircraft may be high enough to interfere with passenger comfort. To investigate this possibility, interior noise levels were estimated for both an upper surface blown (USB) and an externally blown flap (EBF) configuration.

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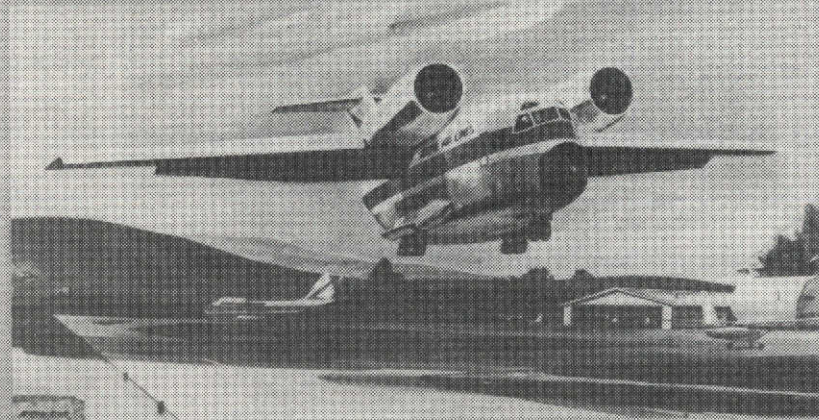
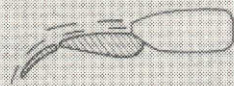
ARTIST'S CONCEPTS OF COMMERCIAL STOL TRANSPORTS USING POWERED-LIFT SYSTEMS
(Figure 1)

Figure 1 shows artist's concepts of commercial versions of aircraft employing externally blown flap and upper surface blowing powered-lift systems. These commercial versions were derived from two STOL aircraft configurations currently under development for the United States Air Force. Figure 1 illustrates the two features of these aircraft that are of interest with respect to interior noise, namely, the forward and inboard location of the engines that brings the noise sources close to the passengers, and the impingement of the engine jet on wing and flap surfaces that generates new noise sources.

Cross sections of the wing-flap systems for each concept illustrate the nature of the engine exhaust impingement on each wing-flap system. These sketches indicate the position of the flaps in the powered-lift configuration and show that the engine exhaust impinges directly on the wing and flaps for both powered-lift concepts. The sketches also indicate that during cruise, when the flaps are retracted, the USB engine exhaust is still located very close to the wing, while the EBF engine exhausts under the wing, much as conventional jets do. The interior noise for these two aircraft configurations was estimated.



EXTERNALLY BLOWN FLAP CONFIGURATION



UPPER SURFACE BLOWING CONFIGURATION

Figure 1.- Artist's concepts of commercial STOL transports using powered-lift systems.

STOL INTERIOR NOISE ESTIMATION PROCEDURE
(Figure 2)

The procedure used to estimate interior noise levels is outlined in figure 2. The essential steps are (1) establish the values of aircraft parameters that influence noise, (2) determine the sound levels on the outside of the fuselage ($SPL_{outside}$), (3) determine the reduction of noise level (NR) associated with noise transmission through the fuselage and with absorption of noise within the cabin, and (4) subtract NR from $SPL_{outside}$, to obtain the estimated interior level. The aircraft properties listed indicate that a large size aircraft is being considered. The aircraft properties are about the same as those of the United States Air Force aircraft now under development. Geometric properties of these aircraft presented in reference 2 were used. The only forcing input considered was that due to the engine exhaust and its impingement on the wing and flaps. For landing and takeoff, this source is thought to dominate the interior noise. However, during cruise, the design forward speed is high enough that an additional contribution from boundary layer inputs is to be expected. The forcing inputs were estimated from data on free jets and from recent measurements of surface pressures on the flaps of powered-lift systems. These sources were used because no data on fluctuating pressures on fuselage surfaces due to powered lift were available in the published literature. Values of sidewall noise reduction were obtained based on measured data that are available in the literature for narrow-body jet aircraft. These data were corrected for the larger values of wall thickness and surface density associated with the aircraft considered in this study. Further details of the forcing input and noise reduction are presented in figure 3.

AIRCRAFT

- 2 ENGINE USB, 4 ENGINE EBF
- FUSELAGE DIAMETER 216 in.
- GROSS WEIGHT \approx 150 000 lb

FORCING INPUT ($SPL_{OUTSIDE}$)

- EBF
CRUISE - FROM FREE JET
TAKEOFF/LANDING - FROM FLAP MEASUREMENTS
- USB
CRUISE/TAKEOFF/LANDING - FROM FLAP MEASUREMENTS
- ENGINE EXHAUST AND IMPINGEMENT ONLY (NO BOUNDARY LAYER)
- FORWARD SPEED EFFECTS NEGLECTED
- FREQUENCY RANGE 31.5 - 8000 Hz (OCTAVE BANDS)

SIDEWALL NOISE REDUCTION (NR)

- EMPIRICAL DATA FOR NARROW BODY JETS
CORRECTED FOR THICKNESS (INCREASED TO 6" THICK)
CORRECTED FOR MASS (INCREASED TO 6 lb/ft²)

INTERIOR NOISE

- $SPL_{INSIDE} = SPL_{OUTSIDE} - NR$

Figure 2.- STOL interior noise estimation procedure.

STOL FORCING INPUT AND SIDEWALL NOISE REDUCTION
(Figure 3)

The values of the external noise spectra ($SPL_{outside}$) and the fuselage noise reduction (NR) used in this study are shown in figure 3.

The external noise spectra were obtained for the worst location on the fuselage as follows. During cruise of the EBF configuration, the engine exhaust does not impinge on the structure. Therefore, the only noise sources considered are those of the jet alone. The method of ref. 3 was used to obtain the values shown, using an exhaust velocity of 500 ft/sec, an exhaust nozzle diameter of 52 in. and a distance of 98 in. from the engine centerline to the fuselage sidewall. Noise level distributions along the fuselage length were obtained from ref. 3 for two engines. Fuselage external noise spectra for the EBF takeoff and the USB takeoff configurations were obtained from surface pressure measurements made on the flaps of models and reported in references 4 and 5. These references reported overall fluctuating pressure levels and spectra at flap spanwise locations where fuselage sidewall would be located. The USB cruise levels were obtained by correcting the takeoff levels for the changes in air density (ρ) with altitude.

For the EBF takeoff and for the USB takeoff and cruise, figure 3 shows the noise levels are highest in the 63 Hz octave band, in comparison with EBF cruise which is highest in the 250 and 500 Hz bands. These high levels at the lower frequencies result from exhaust impingement on wing and flap surfaces. The noise levels for the EBF cruise are relatively lower at the low frequencies, mainly because the EBF engine does not impinge on the flap surfaces during cruise. Shown on the right of the figure is the sidewall noise reduction, which was based on the narrow-body data reported in ref. 5. The sidewall noise reduction was estimated by correcting the narrow-body data to a sidewall having a surface density of about 6 pounds per square foot and a thickness of about 6 inches using the method of ref. 6. As expected, the noise reduction is the lowest at the lower frequencies. Comparing the external noise spectra with the sidewall noise reduction shows that the STOL powered-lift configurations have their highest energy at frequencies where the sidewall noise reduction is low. Noise reduction values shown in figure 3 are considered to be high and obtainable only with careful application of the best current technology. The interior noise levels obtained by subtracting the noise reduction from the exterior noise spectra are shown in figure 4.

EXTERNAL NOISE SPECTRA

SIDEWALL NOISE REDUCTION

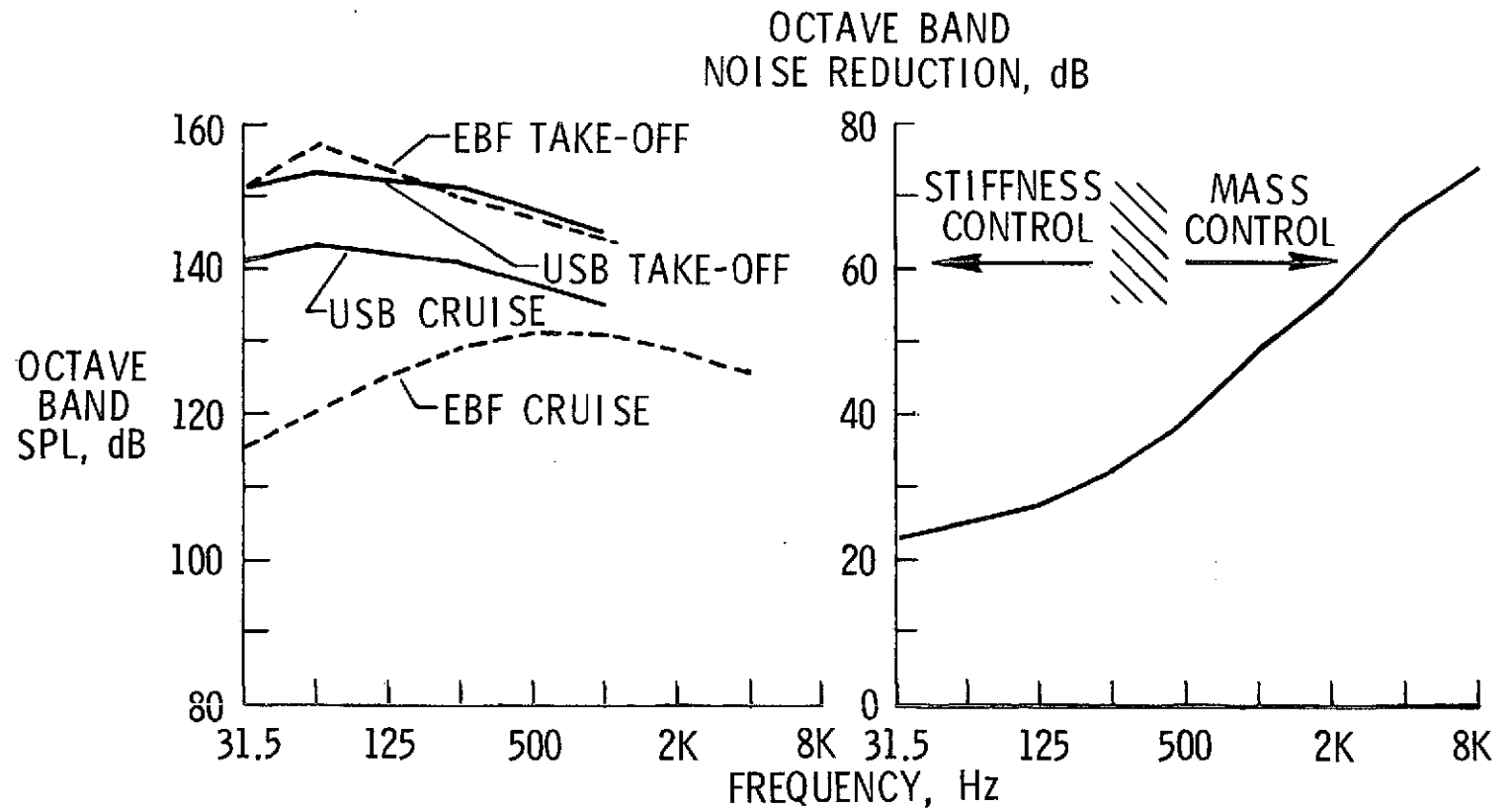


Figure 3.- STOL forcing input and sidewall noise reduction.

STOL INTERIOR NOISE SPECTRA
(Figure 4)

Interior noise spectra for takeoff and cruise conditions are shown in figure 4 for the USB (left) and the EBF (right). These spectra are the estimates for the seats having the highest levels and are not averages. As a point of reference, measured noise spectra for conventional jet aircraft (refs. 5 and 7 to 9) are included. The figure shows that the noise levels for the USB takeoff and cruise conditions are much higher than for conventional jets, and the levels are higher at the lowest frequencies. Differences of 20 to 30 dB are indicated in the 125 Hz octave band. For the EBF aircraft, the takeoff levels are very high, with levels 30 dB higher than CTOL jets at the lower frequencies. The cruise spectrum for the EBF configuration is only slightly higher than the spectra found on CTOL jets.

The A-weighted sound levels were calculated from these spectra for the cruise condition and the results are shown in figure 5.

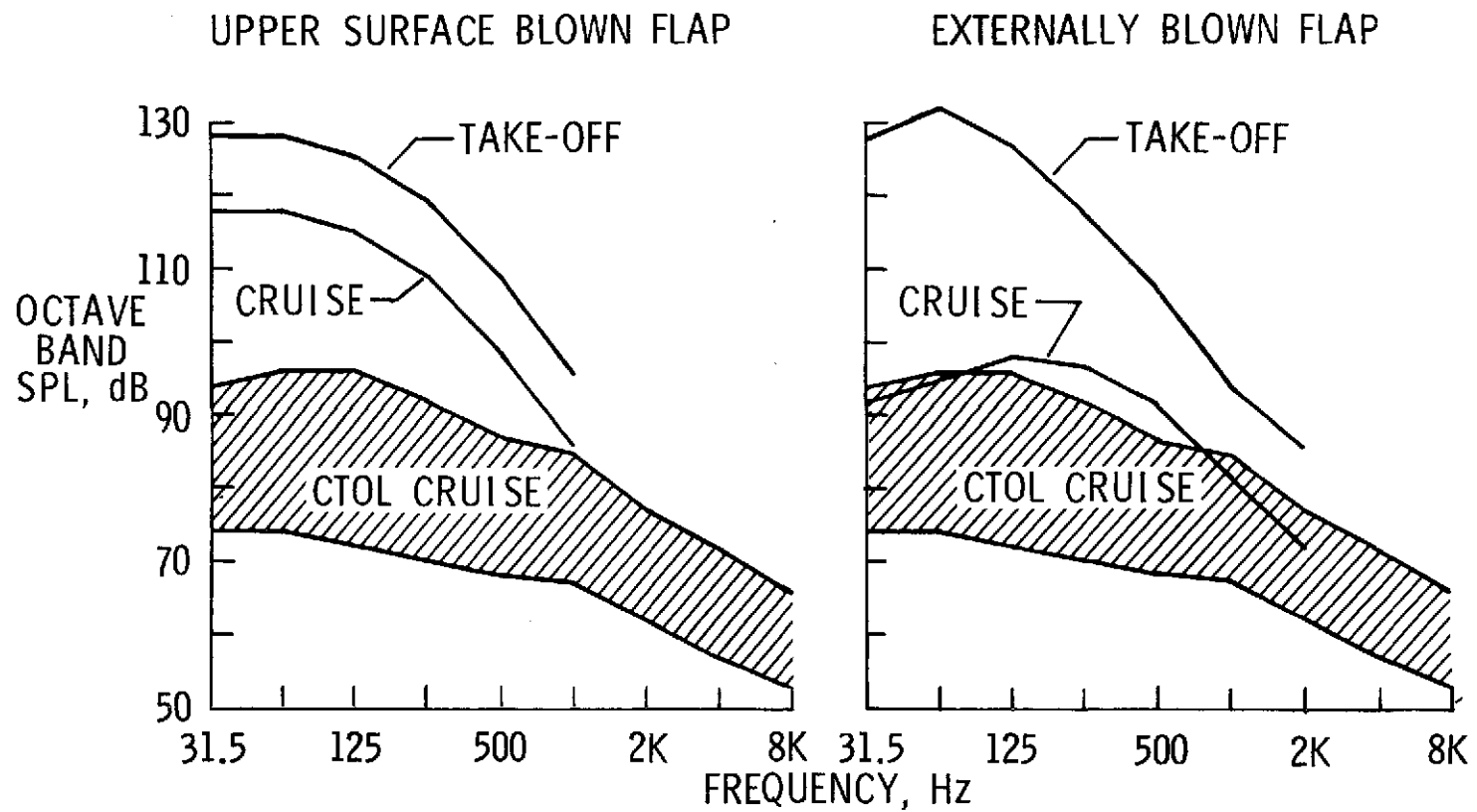


Figure 4.- STOL interior noise spectra.
(estimated)

COMPARISON OF INTERIOR NOISE LEVELS
(Figure 5)

Figure 5 shows that the A-weighted interior noise levels for both STOL configurations are high compared to ground transportation systems as well as compared to the OSHA 8 hour limit of 90 dBA. The measured data shown in figure 5 were obtained from refs. 7 to 14. The 15 dBA range shown for the STOL corresponds to the variation in noise level throughout the fuselage (refs. 13 and 15), with the noisiest seat shown at the top (calculated from the spectra in figure 4), and the quietest seat shown at the bottom. The levels for the USB aircraft are higher than those of the EBF aircraft during cruise (flaps retracted) since exhaust impingement occurs only for the USB configuration. That is, during cruise, when the flaps are retracted, the EBF configuration functions much as a conventional jet. The diamond marker represents a level estimated to be average for about half of the seats for the STOL and a similar value for a CTOL jet transport. The three levels marked with diamonds are shown in figure 6, along with A-weighted sound levels for takeoff and landing.

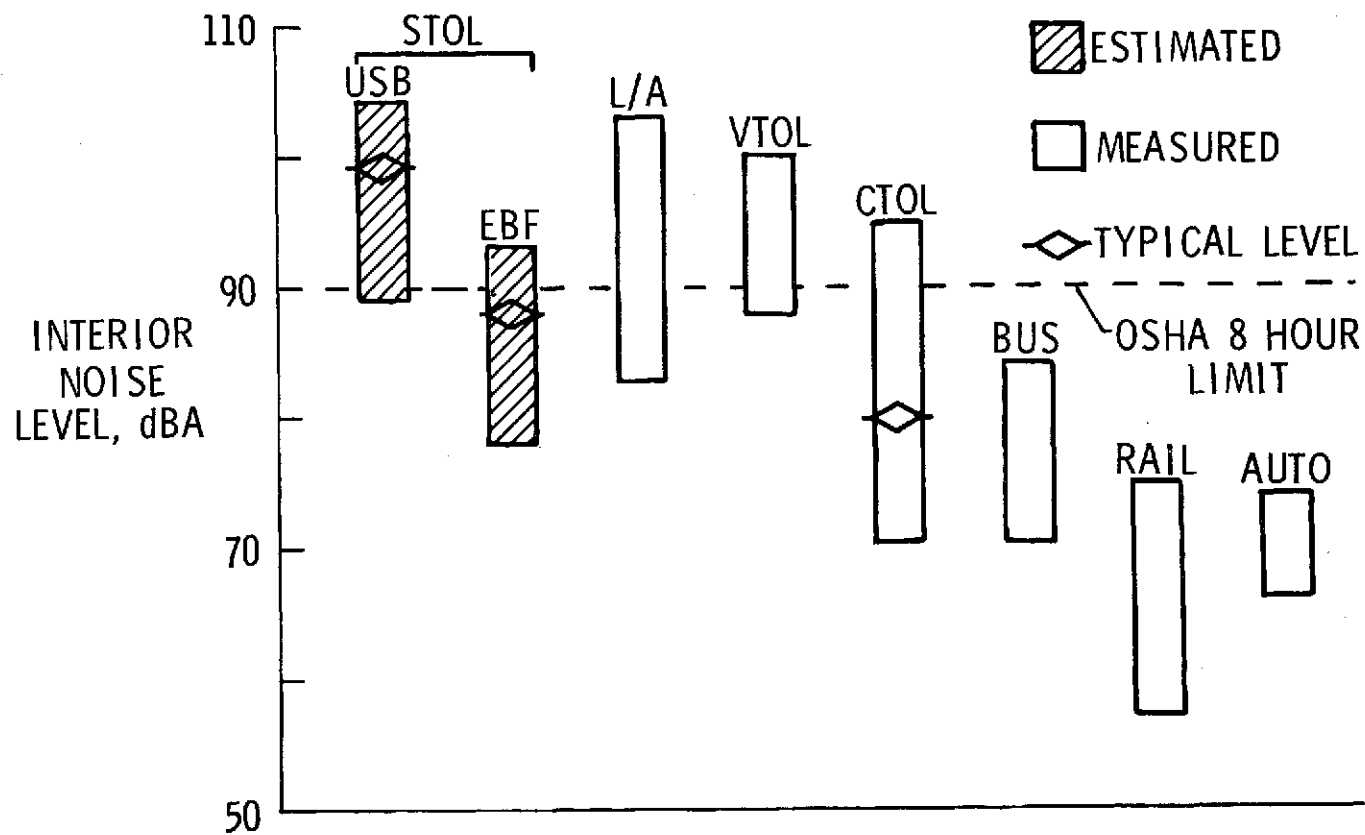


Figure 5.- Comparison of interior noise level.
(cruise conditions)

VARIATION OF INTERIOR NOISE WITH FLIGHT TIME
(Figure 6)

Figure 6 shows the variation of interior noise levels with flight time during takeoff, climbout, cruise, descent, and landing. The CTOL levels shown are included as a point of reference and represent the average interior noise for a typical narrow body jet aircraft. The STOL noise levels are higher than those of CTOL not only for cruise conditions, but are much higher (by about 30 dBA) during powered-lift operations. Also included for reference is the highest interior noise level typically found during thrust reversal on a CTOL jet. The main conclusions to be drawn from this figure are that the STOL interior noise levels are significantly higher during all flight conditions than for CTOL jets, and that the STOL levels are particularly high during powered-lift operations. Because of the nature of flight operations of STOL aircraft, the takeoff/climbout and descent/landing phases of flight are expected to last for significant time durations (of the order of tens of minutes compared to seconds duration for thrust reversal on CTOL aircraft). These time durations combined with high levels such as those shown in figure 6 can be expected to have a marked detrimental effect on passenger comfort.

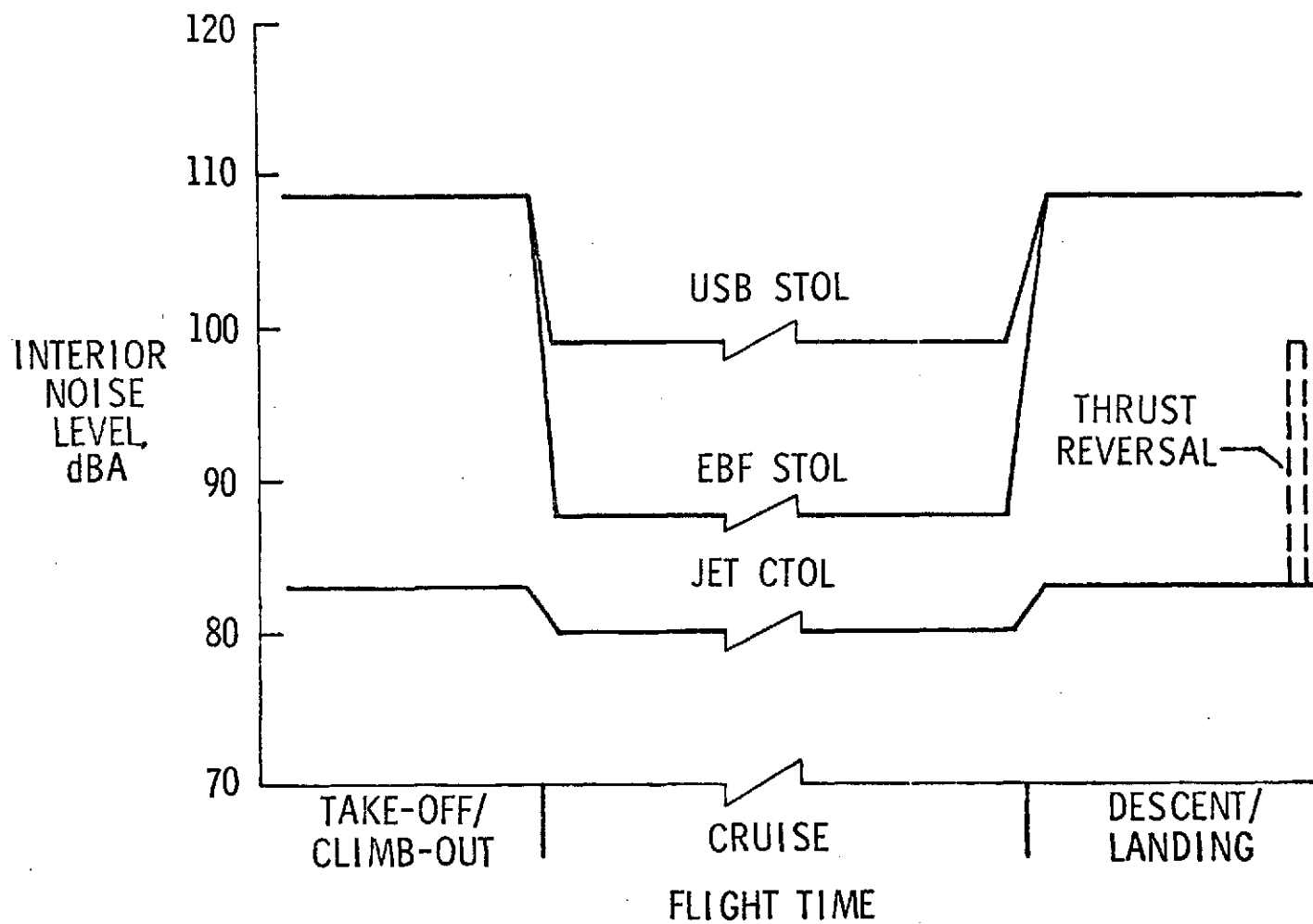


Figure 6.- Variation of STOL interior noise with flight time.

SUMMARY: STOL INTERIOR NOISE
(Figure 7)

Interior noise estimates show that the levels in powered-lift aircraft will be high, and that the major problem occurs at low frequencies. It can be concluded that the noise reduction of the best current technology sidewall (used in making these estimates) is not adequate to control the low frequency noise generated by impingement of jet engine exhaust on wing and flap surfaces.

The definition of acoustic loads on STOL fuselages must be improved so that more precise estimates of interior noise can be obtained and so that control techniques based on the actual external noise characteristics can be explored. (NASA-Langley has expanded its STOL wing and flap acoustic loads program to include loads on the fuselage sidewall.) The basic understanding of low frequency noise reduction must also be improved and requires investigations of low frequency noise reduction of panels ranging from simple panels to complex, aircraft type structures. Finally, new structural concepts must be developed to improve low frequency noise reduction for use on STOL type vehicles.

SUMMARY OF FINDINGS

- HIGH INTERIOR NOISE LEVELS ESTIMATED FOR EBF AND USB STOL CONFIGURATIONS
- LOW FREQUENCY NOISE PREDOMINATES
- CURRENT TECHNOLOGY SIDEWALL IS NOT ADEQUATE TO CONTROL LOW FREQUENCY STOL NOISE

RECOMMENDATIONS

- IMPROVE DEFINITION OF ACOUSTIC LOADS ON STOL FUSELAGE
- IMPROVE BASIC UNDERSTANDING OF LOW FREQUENCY NOISE TRANSMISSION
- DEVELOP NEW STRUCTURAL CONCEPTS TO CONTROL LOW FREQUENCY NOISE

Figure 7.- Summary STOL interior noise.

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