# Investigation of Interior Noise in a Twin-Engine Light Aircraft

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**This paper describes experimental studies of interior noise in a twin-engine, propeller-driven, light aircraft. An analytical model for this type of aircraft is also discussed. Results indicate that interior noise levels in this aircraft due to propeller noise can be reduced by reducing engine rpm at constant airspeed (about 3 dB), and by synchrophasing the twin engines/propellers (perhaps up to 12 dB). Ground tests show that the exterior noise pressure imposed on the fuselage consists of a complex combination of narrow-band harmonics due to propeller and engine exhaust sources. This noise is reduced by about 20-40 dB (depending on the frequency) by transmission through the sidewall to the cabin interior. The analytical model described uses modal methods and incorporates the flat-sided geometrical and skin-stringer structural features of this light aircraft.**

## Introduction

PREVIOUS studies have indicated that excessive interior noise in light aircraft arises from sources primarily associated with the propellers, the engines, and the engine exhaust, and that the noise is transmitted to the interior through airborne and/or structureborne paths. Improved methods of controlling the interior noise associated with these sources and paths are required, especially for new aircraft with improved performance, in order to provide reduced noise levels with minimum effect on aircraft performance and weight. The problem of noise control is complicated by the variety of sources and transmission paths, all of which must be considered, because any single source-path combination may cause an unsatisfactory interior noise environment for a particular configuration and because the reduction of noise from one source-path may bring another into dominance. The design of the cabin interior is also important because the characteristics of the space and its acoustic treatment have an important effect on the noise level in the cabin.

Some information on the factors influencing aircraft interior noise and its control is available in the literature. Interior noise levels and their relation to aircraft operating conditions such as engine rpm have been described for single-engine light aircraft.[1-3] A review of cabin noise levels and control measures from a consumer's point of view is given in Ref. 4. This information suggests that reduced interior noise levels might be obtained by operational procedures involving the choice of engine rpm or the synchrophasing of twin engines. Effort toward understanding and reducing propeller source noise[5-11] has been directed principally to far-field community noise applications. This work can be used as a general guide; however, it appears that the information required for interior noise control studies is not available. Theoretical and experimental investigations related to fuselage sidewall noise transmission have been carried out for simple panels with rectangular enclosures,[12] multiple cavities,[13,14] closed cylinders,[15] and representative large-aircraft structures.[16] The effects of fuselage curvature, air flow, and cabin pressurization have been studied analytically.[17,18] Recent research includes an experimental study of noise transmission through a variety of flat stiffened panels into a rectangular absorbing enclosure;[19] an experimental study of the influence of added stiffness due to stringers, composites, and honeycomb constructions on panel transmission loss;[20] an analytical study of the optimization of cylindrical fuselage weight while retaining structural strength[21]; and a study of modal frequency tuning and stringer damping effects on the transmission loss of stringer-stiffened flat panels.[22] In order to develop lightweight noise-resistant fuselage sidewalls, an analytical model developed specifically for the light aircraft under consideration is required. These references provide basic information useful in the development of such a model.

The work described in this paper was carried out to provide some of the needed information on the characteristics of interior noise, exterior noise, and transmission characteristics of an actual light aircraft. Some early results from the work reported herein are discussed in Refs. 25 and 26.

## Aircraft Noise Measurements

The aircraft used in these studies is shown in Fig. 1. Nominally this aircraft has a takeoff gross weight of 3175 kg, a useful load of 1200 kg, and cruises at an airspeed of 80 m/s at 3050-m alt with each engine running at 70% power. The range at the most economical cruise speed is 2575 km. Each engine has six cylinders, is rated at 320 hp, and drives a 236-cm diam three-bladed propeller through a gearing system that turns the propeller at about 64% of the engine rpm. The propeller plane intersects the fuselage at approximately the middle of the passenger cabin, and the propeller tip clearance from the sidewall is approximately 13 cm. The engine exhaust ports are located near the aft end of the nacelle, near the baggage compartment as indicated in Fig. 1. There are four ports, one on each side of each nacelle, with three cylinders exhausting through each port. The cabin interior was finished in standard trim for this aircraft and provided seats for pilot, copilot, and four passengers. The carpet in the passenger section was removed, leaving the floor of bare aluminum. The fuselage structure consists of frame and stringer members (Fig. 2) with skin panels of approximately 0.06-0.1-cm thickness.

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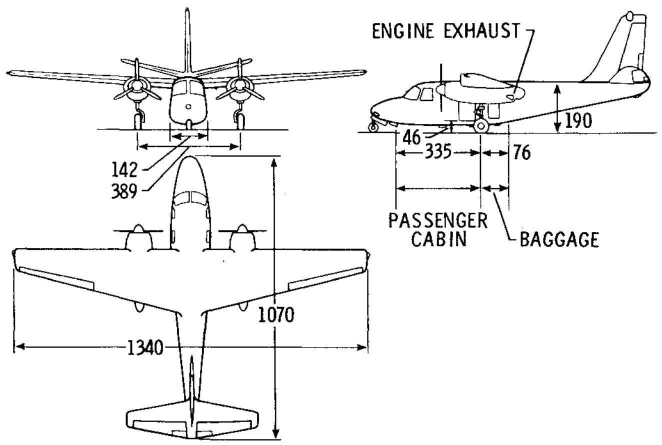


Fig. 1 Sketch of twin-engine light aircraft used in interior noise studies (dimensions in cm).

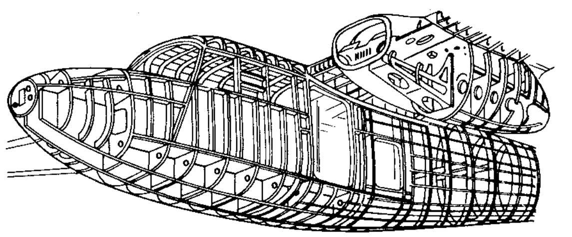

Fig. 2 Structural features of a twin-engine light aircraft.

Flight tests were run at constant altitude (the cabin was not pressurized) with both engines running at equal power output. Noise measurements were made at constant flight speed while varying engine rpm (utilizing the variable blade pitch feature of the propellers), and surveys of the noise at various positions within the cabin were made at constant rpm. The noise measurements were made primarily at the ear level of a seated passenger. Ground tests included engine runups to measure internal and external noise, and noise transmission tests with the engines shut down and using a speaker for a noise source. The data presented in this paper were obtained using four instrumentation systems. The in-flight data were taken using two precision sound level meters, and recordings were made on a portable four-channel FM tape recorder having a signal-to-noise ratio of 42 dB and a frequency response of 0-10 kHz. The data for the static tests were taken using ten precision condenser microphones of 0.6-cm diam mounted flush on the fuselage sidewall, two precision condenser microphones of 0.6-cm diam for the interior noise measurements, and six microaccelerometers. Two of the accelerometers were mounted to sidewall panels, two to sidewall frames, one to a window, and one to a major structural member in the wing. The data were recorded 12 transducers at a time on a 14-channel FM tape recorder which was remotely located. The data presented showing forward speed effects (and a small portion of the static data) were taken using selected transducers described above and recorded on a four-channel FM tape recorder. In each of the setups described above, the overall frequency response was from below 4 Hz to over 10 kHz. The noise transmission data were taken on-line using two sound level meters, a loudspeaker with amplifier and servocontrolled sweep oscillator, and a level recorder.

The overall levels during flight were determined by tracing out the level history from the tape recorders using a log converter and a time sweeping X-Y recorder. The A-weighted levels were determined the same way except with an A-weighting filter between the tape recorder and the log converter. The spectral content was obtained using a hard-wired 500-line spectrum analyzer/averager. All spectra presented

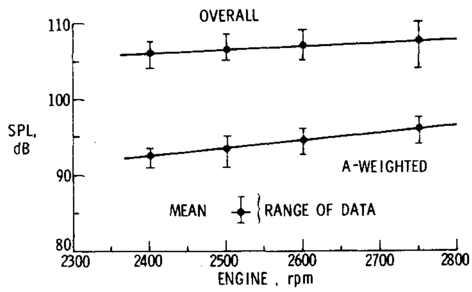


Fig. 3 Variation of interior noise with engine rpm in a twin-engine light aircraft: 80 m/s airspeed, 1920-m altitude.

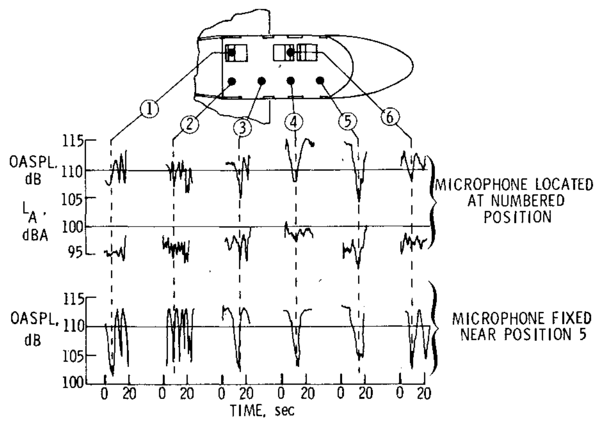


Fig. 4 Variation of interior noise with time and position in a twin-engine light aircraft: passenger ear level, 75% power, 80 m/s airspeed, 2160-m altitude, engine rpm 2750.

were analyzed from 0 Hz to 1 kHz, with a nominal bandwidth of 3.2 Hz. The number of averages was 16, 32, or 64, depending on the length of data sample available.

## Interior Noise In Flight

A series of tests were performed to determine whether interior noise could be reduced by varying engine operating conditions while maintaining constant altitude and airspeed. The results are shown in Fig. 3. The microphone was located at ear level in the propeller plane, between pilot and copilot seats (position M shown in Fig. 6). The manifold pressure was adjusted to obtain a constant airspeed for a range of engine rpm values; propeller blade pitch also varied, but engine power remained in the order of 80%.

Figure 3 shows the variation of overall and A-weighted sound levels with rpm (and implicitly with engine power and blade pitch angle). The range of data indicated in Fig. 3 at each rpm results from variations of level that occur with time during flight due to interference of noise originating in the two engine/propellers. This variation is explained more fully below. The variation is about 1.5 dB (linear) and about 3.5 dB (A-weighted) over the rpm range shown. This result suggests that for this aircraft a noticeable (although small) reduction of interior noise can be obtained without an airspeed performance penalty. Variation of engine rpm (and the attendant variations of engine power and blade pitch) are expected to change both the levels and frequency of the exterior noise. Both effects should contribute to the variations of interior noise shown in Fig. 3, however, this test did not distinguish whether level or frequency was the primary cause. In addition, some unpublished test data on another twin-engine light aircraft indicate that fuel consumption as well as noise is reduced at lower rpm values (with varying power and blade pitch but constant altitude and airspeed). Thus, lower interior noise levels and improved performance (lower fuel consumption) may both result from operation at engine conditions featuring low rpm. Use of such operating conditions to reduce noise may require verification of satisfactory engine operation and longevity.

The variation of interior noise level with both position and time is shown in Fig. 4 for constant-airspeed constant-altitude flight. These data were obtained using two microphones, one held fixed and a second moved in turn to the locations shown in the sketch at the top of the figure. A brief time history was recorded from both microphones simultaneously on a tape recorder as the moving microphone was held in each of the numbered positions. The moving microphone was held at seated ear level and the fixed microphone was held about 15-cm lower at position 5. Figure 4 shows that the noise level at a given position varies substantially with time; the overall level at the fixed microphone varied by about 12 dB, while the overall level at the other positions varies by 5-7 dB. The rapidity of the variation with time is different at different times, as can be seen by comparing the time history plots for the fixed microphone corresponding to positions 1 and 2 with those associated with microphones 3, 4, and 5. (See also Fig. 5.) This variation of level with time is due to interference of the noise originating in the two engines and to slight random differences in rpm. When a single engine was run up (on the ground), it was observed that the variation was only about ± 1 dB. Comparisons of the noise level at the fixed reference position with those at the other positions shows that the noise level moves up and down uniformly in space. For example, the time history at position four shows that the overall sound pressure level (OASPL) at that location is highest when the OASPL at the reference position is highest, and that the OASPL at position 4 reaches a minimum at the same time that the reference position OASPL reaches its minimum. (For each numbered microphone position, the OASPL, $L_A$, and OASPL of the fixed microphone are time correlated.) The A-weighted level follows this trend but with less variation of level. This result suggests that interior noise levels in this aircraft could be reduced if the engines could be controlled so as to obtain the lowest levels shown in Fig. 4. Engine control that synchronizes the rpm and phases the blade positions ("synchrophasing") is expected to contribute to interior noise reductions. In addition, Fig. 4 shows that the control setting that minimizes the noise at one location would also minimize the noise, both OASPL and A-weighted, at all other locations in this aircraft.

To investigate the contributions of propeller noise sources and engine noise sources to the fluctuations of OASPL shown in Fig. 4, a narrowband analysis of the noise measured by the microphone fixed near position 5 was performed. For this aircraft, the engines have six cylinders and a four-stroke cycle, so the fundamental engine firing frequency is three times the shaft rpm. The fundamental blade passage frequency of the three-bladed propeller is about 64% of the fundamental

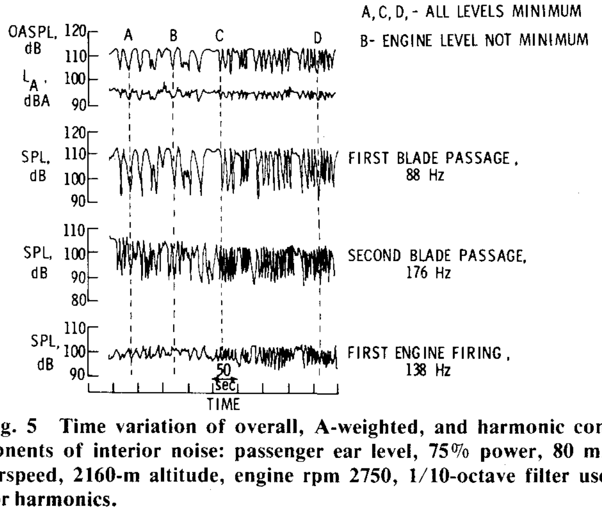


**Fig. 5 Time variation of overall, A-weighted, and harmonic components of interior noise: passenger ear level, 75% power, 80 m/s airspeed, 2160-m altitude, engine rpm 2750, 1/10-octave filter used for harmonics.**

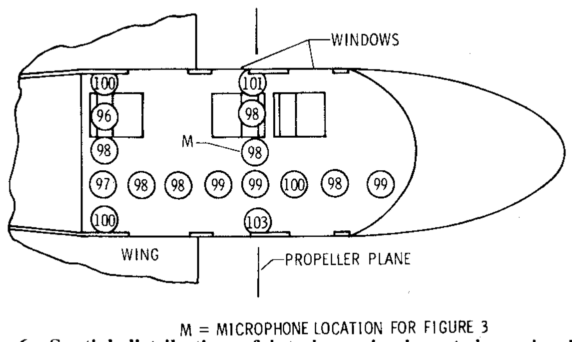


**Fig. 6 Spatial distribution of interior noise in a twin-engine light aircraft: A-weighted SPL, 75% power, 2160-m altitude.**

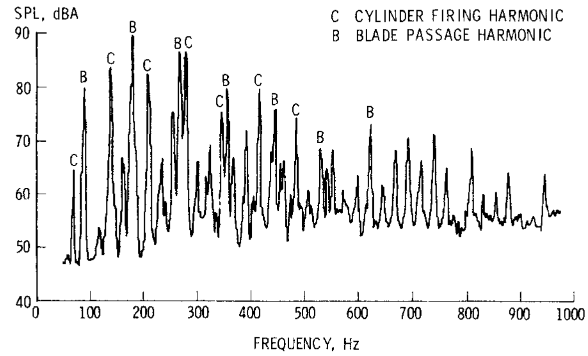


**Fig. 7 Spectrum of interior noise in a twin-engine light aircraft: 2750 rpm; 80 m/s airspeed, 2160-m altitude, 79% power, measured at ear level in the propeller plane.**

engine frequency, so the propeller harmonics are separated in frequency from the engine harmonics. To obtain the narrowband data, the noise signal measured in flight was fed through a 1/10-octave band pass filter (approximately 7% bandwidth) and through a log converter to transform the filtered signal into sound pressure level in dB. The 1/10-octave filter was centered on the propeller or engine harmonic of interest. (See spectra in Figs. 7 and 8.) The results are shown in Fig. 5. Figure 5 shows that the overall SPL and A-weighted SPL follow closely the fluctuations in the level of the first blade passage harmonic at 88 Hz. Significant variations are shown to occur for both harmonics of the blade passage frequency and for the engine firing frequency, 138 Hzg however, the level of the engine harmonic varies less than the levels of the prop harmonics. As indicated by the dotted lines, there are times when all three harmonics, as well as the overall, reach a minimum value (time A, C, D); however, there are other times when the propeller harmonics are minimized but the engine harmonic is not (time B). This result suggests that maximum benefit will be obtained from synchronization (and/or synchrophasing) when engine noise is taken into account along with propeller noise in the design and operation of the synchronization device.

The variation of A-weighted sound level with position is shown in Fig. 6 for flight at constant altitude, rpm, and airspeed. Each level shown in Fig. 6 is the maximum value reached at the location as the level fluctuated in time. Figure 6 shows that the A-weighted noise level varies with position by about 4 dB at the locations in the interior (away from the sidewalls), and that the highest levels occur in the propeller plane and ahead of it. Higher levels are measured 5 cm from the sidewalls as indicated by the partly circled values. For the small cabin and low frequencies (propeller first-blade-passage frequency of 88 Hz) of this aircraft, the significance of these higher levels is not clear. Figure 6 indicates that passenger positions near the rear of the cabin have the lowest levels.

An A-weighted spectrum of the interior noise measured in flight is shown in Fig. 7. Spectral averages were taken over long times, so the data of Fig. 7 represent levels near the maximums of the time-varying levels shown in Figs. 4 and 5. Figure 7 shows that the interior noise consists of narrow bands of noise at harmonics of the propeller blade passage frequency and of the cylinder firing frequency. Broadband noise that might be associated with aerodynamic sources, such as boundary layer or separated flow, is shown to be well below the level of the narrowband harmonics. The occurrence of high-level (A-weighted) blade harmonics suggests that propeller noise transmitted through the fuselage sidewall is an important source of interior noise. High-level harmonics associated with the cylinder firing frequency indicate that the engine exhaust is also an important source of cabin noise. Figure 7 shows that the highest A-weighted noise levels occur in the range of 70-600 Hz, and that the levels are lower at higher frequencies. Reduction of the cabin noise for passenger comfort, as measured by both A-weighted sound level and preferred speech interference level (PSIL), requires attention to the behavior of the noise sources and transmission paths in the frequency range from about 70 to about 600 Hz.

## Fuselage Exterior Noise

Spectra of the noise measured under static conditions by microphones mounted flush with the fuselage skin surface are shown in Fig. 8. The spectrum measured in the propeller plane shows that the noise at that location consists almost entirely of propeller blade passage harmonics; the cylinder harmonics are lower than adjacent propeller harmonics by 10 dB or more except at 312 Hz. The propeller harmonics drop off in magnitude at the rate of about 3 dB per blade harmonic. The spectrum measured near the exhaust port at the aft end of the nacelle shows that cylinder firing harmonics dominate. Furthermore, every third harmonic (those occurring at multiples of three times the cylinder firing frequency) is higher than the intervening two. This characteristic suggests that the exhaust port on the side of the nacelle nearest the fuselage is dominating the noise field, and that only one exhaust port per engine would need to be muffled to reduce the interior noise. Reference to Fig. 7 suggests that the exhaust noise reaching the interior also consists primarily of the third multiples of cylinder firing frequency. Comparing the two spectra shown in Fig. 8 indicates that propeller and engine exhaust noise are of approximately equal magnitude.

To illustrate the distribution of the propeller and exhaust noise over the fuselage sidewall, one harmonic has been chosen from each spectrum as indicated by the circles in Fig. 8, and its magnitude determined for the array of flush-mounted microphones shown in Fig. 9. The variation of noise with the horizontal coordinate $X/D$ shows that the first engine harmonic is highest at aft locations and drops off at forward locations, while the first propeller blade harmonic is highest at forward locations and drops off at aft locations. These two noise sources add up to produce an overall noise level that does not vary much with fore and aft position. The variation of noise with vertical coordinate $Y/D$ shows that the propeller and overall noise levels are highest at $Y/D=0$ and drop off with increasing distance from that point. The point $Y/D=0$ is the point of closest approach of the propeller tip to the fuselage.

The noise level calculated for the first blade harmonic using the method of Ref. 10 is indicated by the dotted line in Fig. 9. Comparison of the calculated and measured values shows that the calculation produced about the same trend of noise with position, and that the calculated magnitudes either agree closely or are a few dB higher than the measured values, depending on position. The agreement shown suggests that noise levels (at least for the first harmonic) calculated from Ref. 10 could be used as inputs to fuselage response analyses for trend studies.

The effect of forward speed on the fuselage sidewall noise for ground conditions was determined from taxi tests. The aircraft power and rpm were established with the aircraft held stationary by the brakes; then the tape recorder was turned on and left running as the brakes were released and the aircraft allowed to accelerate to the desired speed, which was held constant by braking. Segments of the taped noise recorded with the aircraft stationary and with the aircraft taxiing at constant speed were analyzed to obtain the overall and spectral component noise levels shown in Fig. 10. It can be seen that the change of overall noise level is, at most, a slight decrease with increasing forward speed. However, a close examination of noise levels associated with different harmonics indicates that forward speed has only negligible effect on the first blade harmonic at all locations on the fuselage and on the second blade harmonic at $X/D=0$. Higher-frequency blade harmonics are decreased substantially in magnitude with increasing forward speed. The variation of the levels of the engine firing harmonics with forward speed was not systematic (some increased, some decreased), and the changes at 20.5 m/s were less than 3 dB.

## Sidewall Noise Transmission

To investigate the aircraft sidewall noise transmission characteristics, interior and exterior noise time histories were tape recorded simultaneously with one engine running. Each noise signal was analyzed to obtain spectra such as those shown in Figs. 7 and 8. At the frequency corresponding to each harmonic of the propeller blade passage frequency, the interior noise level (SPL) was subtracted from the exterior noise level (SPL) to obtain noise reduction values. Figure 11 shows that the sidewall reduces the blade passage noise pressures by about 30 dB, over the frequency range of about 80-750 Hz. Noise reduction values existing in flight may be different from values shown in Fig. 11 due to forward speed effects, different exterior noise distributions, and ground plane effects. A suitable analysis was not available for calculation of sidewall noise reduction to provide insight into

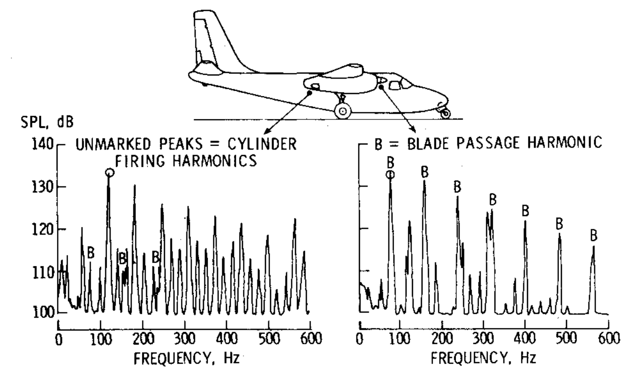


**Fig. 8 Spectra of the exterior noise on the fuselage of a twin-engine light aircraft. Ground static test: 2600 rpm, 40% power.**

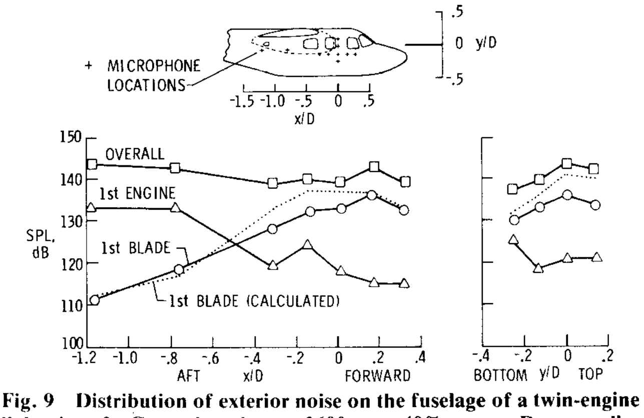


**Fig. 9 Distribution of exterior noise on the fuselage of a twin-engine light aircraft. Ground static test: 2600 rpm, 40% power, D = propeller diameter.**

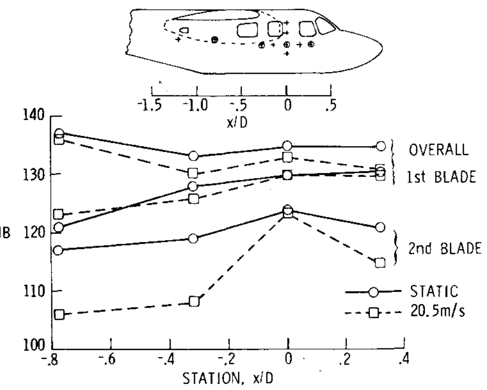


**Fig. 10 Effect of forward speed on the exterior noise on a twin-engine light aircraft. Ground static and taxi tests: 2600 rpm, 40% power.**

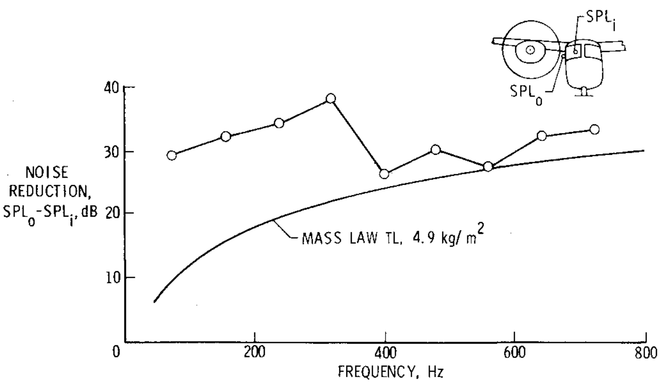


**Fig. 11 Noise reduction of a light aircraft sidewall at the propeller blade-passage harmonics. Ground test: 2600 rpm, 40% power.**

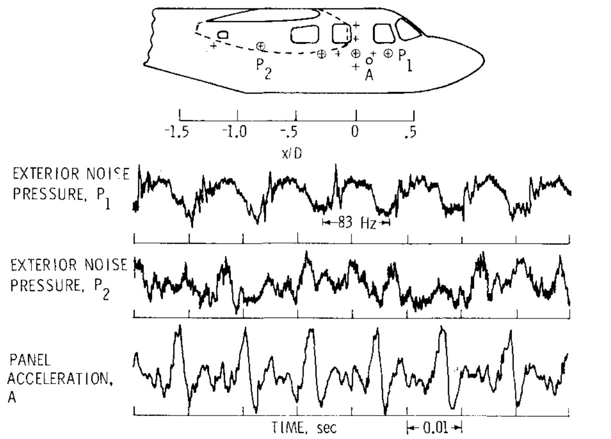


**Fig. 12 Time histories of exterior noise and panel acceleration during engine operation on a twin-engine light aircraft. Ground test: 2600 rpm, 40% power.**

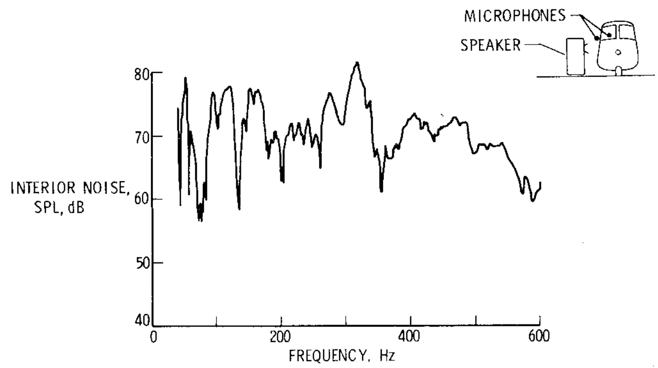


**Fig. 13 Noise transmission characteristics of a twin-engine light aircraft sidewall: 100 dB input, sine wave.**

the mechanisms governing noise transmission. Therefore, as a first step toward understanding of the data shown in Fig. 11, a calculated transmission loss (TL) curve based on mass law transmission for the overall approximate average surface density of this aircraft sidewall (4.9 $kg/m^2$) is shown. Mass law is often used in acoustics as a "par value" for evaluation of TL, and large structural panels tested under laboratory conditions often exhibit mass law transmission loss in some frequency ranges. At frequencies above about 400 Hz, the measured noise reduction and the calculated TL have about the same value; the differences might be attributed to inaccuracy of the estimated surface density, to varying TL of the different sidewall components, or to differences between noise reduction (which includes acoustic properties of the cabin interior) and TL. At frequencies below 400 Hz, the measured noise reduction is substantially greater than the calculated TL. The differences are thought to be due to the effects of sidewall stiffness, resonance, and propeller type input, and indicate that additional experimental and analytical studies are required to obtain the understanding needed to improve control of fuselage noise transmission.

An example of fuselage response is presented in Fig. 12. The accelerometer was located on the center of a panel indicated in the figure by the letter "A." The exterior noise pressure near the propeller, *P1*, has a regular, almost periodic appearance dominated by the first blade passage tone at about 83 Hz. The exterior pressure at the aft location, *P2*, has a much less regular appearance; however, pulses with a period of 0.015 s (associated with the dominant third harmonic of cylinder firing) appear in the trace. The panel acceleration *A* has a very regular appearance, with a large component at the blade passage frequency, 83 Hz, but also, quite clearly, large components at higher frequencies. As might be expected, the acceleration trace shows large differences from the pressure traces due to resonances in the structure, acceleration responses to frequency components that do not appear large in the pressure traces, and response to other driving forces.

To investigate the effects of different noise inputs on the noise reduction of the test aircraft, sinusoidal speaker tests were performed and the results are shown in Fig. 13. A 100-dB noise was applied normal to the exterior of the fuselage, an exterior microphone was used for closed-loop control of the level, and interior noise was measured while the frequency was varied over the range shown. The variation of interior noise with frequency shows many peaks and valleys suggestive of modal response. The interior noise levels shown, when compared with the 100-dB exterior noise, indicate noise reduction values ranging from 20-40 dB depending on the frequency. It does not appear to be a straightforward matter to deduce the "actual" noise transmission characteristics of the fuselage shown in Fig. 12 from the sinusoidal data shown in Fig. 13. Methods to allow such deductions are needed to take advantage of the lower cost and reduced complication of speaker/sinusoidal testing while providing accurate information on transmission loss in service.

## Interior Noise Analysis

The experimental work described so far has indicated a need for analytical methods of interior noise calculation. The purpose of the following discussion is to give a brief overview description of the steps that have been taken so far to develop and validate an analysis for the aircraft studied in this paper.

Figures 1 and 2 illustrate some of the features typical of the construction of a light aircraft fuselage that are important when formulating a mathematical model of fuselage noise transmission. The sidewalls of the cabin consist of comparatively heavy-gage stiffener members (Fig. 2) with little curvature (Fig. 1) supporting thin skin panels. A model

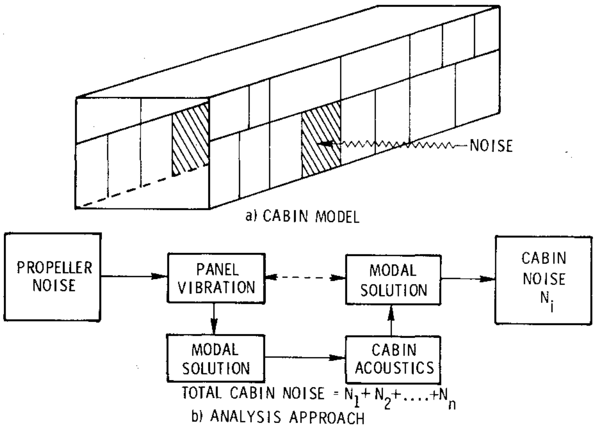


**Fig. 14 Analytical model for interior noise of a twin-engine light aircraft.**

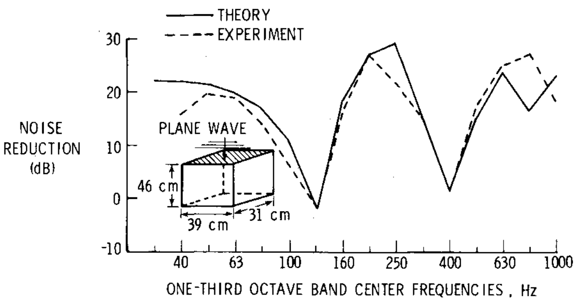


**Fig. 15 Noise reduction of a 0.16-cm aluminum panel: random plane input, 1% damping.**

consisting of flat plates supported by straight rigid beams appears to be an appropriate first approximation for analysis of such sidewalls. Figure 2 suggests that the floor members are of heavier and curved construction, which together with the greater distance from the propeller tips (Fig. 1) suggests that the floor transmits a relatively small amount of noise and may be considered rigid. Because of its greater distance from the propeller and its curvature (and for simplicity), the ceiling is also considered rigid. The nearly flat floor, sidewalls, and ceiling suggest that the cabin interior may be treated as a rectangular enclosure.

The analytic model formulated on the basis of these observations for the aircraft studied in this paper is shown in Fig. 14. According to the analytical model shown, at a location of interest, interior noise due to motion of one panel or a unit of several panels is calculated using the steps in sequence indicated by the block diagram at the bottom of the figure. To obtain the total noise at the location of interest, the contributions of all the vibrating panels are added. The modal method of solution was chosen for this analysis because of its improved ability to resolve details of the noise transmission phenomena in the low-frequency range, as compared to empirical or statistical energy methods. The rectangular shape has also been chosen to allow simple representations of the modes of the structural and acoustic elements rather than the more unwieldly (but perhaps more rigorous) finite-element representations. The development of the equations based on the model illustrated in Fig. 15 is described in detail in Refs. 23 and 24. Comparisons of interior noise calculated by these analyses with measured interior noise are presented in Refs. 23-26.

To illustrate the validity of the analysis, quantitative comparison of interior noise, measured and calculated, is shown in Fig. 15 for a simple box structure. The data in Fig. 15 were obtained by applying a random white-noise 100-dB acoustic wave on a thin aluminum panel mounted in a specially constructed box that allowed noise transmission into the box only through the flexible panel. The speaker was arranged to apply the noise as close to normal as possible. Modal behavior of the system is indicated by the decreased noise reduction at frequencies of 120 and 400 Hz. The agreement between theory and experiment is reasonably good. In Ref. 25, reasonably good agreement between theory and experiment is also shown for a similar box structure subjected to a sinusoidal acoustic wave having frequencies over the 0-1000 Hz range. These results indicate that modal analysis is an appropriate method of solution.

## Concluding Remarks

Experimental studies of the interior noise of a twin-engine light aircraft are described in this paper. The propeller plane of the aircraft studied intersects the fuselage near the middle of the passenger cabin, which itself is about 3.4-m long.

Flight measurements show that the aircraft can be operated over a range of engine rpm for a constant airspeed, and that the lowest interior noise level (by 3.5 dB) occurred at the lowest rpm tested. The flight measurements also show the occurrence of fluctuations of the interior noise level with time due to interaction of the noise from the two engines/propellers. Fluctuations of up to 12 dB overall (7 dB, A-weighted) were observed, with fluctuations of both the propeller and engine tones contributing to the fluctuations of the overall level. Comparisons of the fluctuations at various positions in the cabin indicate that when the noise reaches a minimum at one position, it is also minimum at all other positions. These results suggest that reductions of interior noise level may be sought by appropriate operational procedures or by addition of devices for engine synchrophasing.

Measurements of the exterior noise on the fuselage sidewall using flush-mounted microphones show that the noise field imposed on the fuselage consists of a complex combination of narrowband harmonics associated with engine exhaust and propeller sources, with complicated distributions over the sidewall, all of which are affected to a different degree by forward speed. The propeller noise harmonic levels are shown to be 26-36 dB lower in the cabin interior than on the exterior of the propeller plane.

A brief description is given of the development of an interior noise prediction method that is structured to account for the particular kind of noise input and structural features found in twin-engine light aircraft. Comparison of initial results from this method with experimental data for noise transmission through a flat panel into a rectangular box are encouragingly good.

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