NASA TECHNICAL MEMORANDUM

NASA TM X-72655

NASA TM X-72655

A STUDY OF HELICOPTER INTERIOR NOISE REDUCTION

(NASA-TM-X-72655) A STUDY OF HELICOPTER INTERIOR NOISE REDUCTION (NASA) 8 p HC $3.25 CSCL 01C

N75-23556

Unclas
G3/05 21801

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May 1975

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER, HAMPTON, VIRGINIA 23665

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
TMX-72655		

4. Title and Subtitle	5. Report Date
A STUDY OF HELICOPTER INTERIOR NOISE REDUCTION	May 1975
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
James T. Howlett and Sherman A. Clevenson	
9. Performing Organization Name and Address	10. Work Unit No.
NASA-Langley Research Center Hampton, VA 23665	504-09-21-01
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Aeronautics and Space Administration Washington, DC 20546	Technical Memorandum
	14. Sponsoring Agency Code

15. Supplementary Notes

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17. Key Words (Suggested by Author(s)) (STAR category underlined)	18. Distribution Statement
Interior noise, helicopters Star Category 05	Unclassified Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	6	$3.25

*Available from { The National Technical Information Service, Springfield, Virginia 22151
STIF/NASA Scientific and Technical Information Facility, P.O. Box 33, College Park, MD 20740 }

A STUDY OF HELICOPTER INTERIOR NOISE REDUCTION

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Abstract

The interior noise levels of existing helicopters are discussed along with an ongoing experimental program directed toward reducing these levels. Results of several noise and vibration measurements on Langley Research Center's Civil Helicopter Research Aircraft are presented, including measurements taken before and after installation of an acoustically treated cabin. The predominant noise source in this helicopter is the first-stage planetary gear clash in the main gear box, both before and after installation of the acoustically treated cabin. Noise reductions of up to 20 dB in some octave bands may be required in order to obtain interior noise levels comparable to commercial jet transports.

Introduction

The interior noise levels in current civil helicopters are relatively high compared to the interior noise levels in many other forms of air and ground transportation. Reduction of helicopter noise levels may be required to achieve passenger acceptability and to avoid hearing damage risk associated with high noise levels (Ref. 1). This problem has become more important with the increased demand for helicopters in civil sector applications such as short-haul and off-shore drilling operations.

The NASA Langley Research Center is studying the potential for using large helicopters in civil helicopter applications. This study includes a series of tests to establish passenger acceptability of current civil helicopters and a research program to develop technology that can be used to provide helicopter interior noise levels comparable to those of conventional commercial air transportation (e.g., wide-body jet aircraft) without undue performance penalties.

The purposes of this paper are to describe the helicopter interior noise environment, including typical interior noise levels of civil helicopters, and to describe a test program currently underway to determine the sources and paths of helicopter interior noise. The description of the test program includes the long-range goals of the program and the latest results of several noise and vibration measurements on the Langley Research Center's Civil Helicopter Research Aircraft, CH-53, including measurements taken before and after installation of an acoustically treated cabin.

Presented at the 31st Annual National Forum of the American Helicopter Society, May 1975.

Assessment of Current Interior Noise Levels

Since the current fleet of civil helicopters consists primarily of modified versions of existing military configurations (Ref. 2), the interior noise reduction technology for civil helicopters has largely been directed toward reducing interior noise in existing helicopters as opposed to developing quiet interiors in the original design stage. Although some progress has been made in reducing the interior noise levels (Ref. 3), the current fleet of civil helicopters still appears to need significant reductions in interior noise levels to obtain wide acceptance of helicopter operations by passengers (Ref. 2).

As an indication of progress in reducing helicopter interior noise, Figure 1 presents octave-band sound pressure levels (SPL) for some typical aircraft. The envelope labeled "military helicopter" is for a military vehicle and the spread in the data is for different seat locations within that helicopter. Even though the envelope is for one helicopter, the envelope is representative of most military helicopters. According to the Occupational Safety and Health Act (OSHA), for example, this noise level is unacceptably high without ear protection.

The envelope labeled "commercial helicopter" is for a specific commercial helicopter. The variation in the data is also associated with different seat locations in the helicopter. As in the case of the military helicopter, this envelope is typical of most acoustically treated helicopters in commercial operation today. According to OSHA specification, the allowable exposure time without ear protection is 4 hours per day for the octave-band data shown for this commerical helicopter. However, the OSHA exposure time is related to possible hearing damage only. For long flight times, the ability to communicate face-to-face without difficulty is essential for widespread passenger acceptability. Hence, for the purpose of this paper, a wide-body jet aircraft during cruise has been chosen as an acceptable goal for interior noise. As the dashed curve on Figure 1 shows, the acoustically treated commercial helicopter must have the interior noise levels reduced by 10 dB to 30 dB, depending on the octave band, to become comparable to the wide-body jet aircraft. The fact that current noise reduction technology, when applied to an existing helicopter, does not reduce helicopter interior noise to levels comparable to the latest commercial jet-transport aircraft suggests that quiet interiors must be considered in the design stage if helicopters are to have acceptable interior noise levels. In order to design quiet interiors, improved technology is needed in the areas of noise source identification, noise path identification, and noise control techniques.

L-10076

Present Research

In order to achieve significant and economically feasible noise reductions for the existing fleet of civil helicopters, advanced noise control technology will be required. The Langley Research Center is presently involved in a research program using Langley's Civil Helicopter Research Aircraft. This program includes the evaluation of all aspects of civil helicopter flights, such as economic and energy considerations, passenger acceptability, and community acceptability of the exterior noise. The objective of the interior noise portion of this program is to characterize the interior noise levels, identify the noise sources and paths, develop improved methods for noise source/path identification, and reduce the interior noise levels. If these goals can be achieved, the results should lead to the development of optimum weight/cost noise reduction methods. In order to demonstrate that the results are generally applicable, the techniques developed for the research helicopter must be verified by application to several different helicopters.

The final proof that helicopter interior noise is sufficiently well understood is the capability to predict accurately, at the design stage, the interior noise levels in the finished product. This ultimately involves designing, constructing, and testing a "quiet" helicopter.

Initial Experiments and Test Apparatus

Test Vehicles

As previously discussed, Langley's Civil Helicopter Research Aircraft (Fig. 2) is being used for the initial studies. This helicopter, which is approximately 20 meters long, can carry over 40 passengers in a commercial configuration. At the cruise speed of 160 knots, its range is approximately 250 nautical miles. The untreated helicopter was a military configuration without acoustic treatment. All of the troop seats were removed except four which were required for the personnel conducting the test. For some of the results presented in this paper, a special acoustically treated passenger cabin with 16 seats was installed in the forward section of the cargo area. The forward and aft ends of this cabin were separated from the rest of the helicopter by acoustically treated bulkheads which were vibration isolated from the airframe. Typical acoustic treatment of the cabin walls is shown in Figure 3. A plywood floor covered with carpeting was installed over the metal cargo floor. The inside of the fuselage panels was treated with damping tape and both the panels and stringers were covered with bagged fiberglass. In the ceiling, two layers of lead-vinyl separated with foam was installed. The interior trim panels were mounted on vibration isolators, and gave the interior the appearance of a conventional commercial aircraft.

Instrumentation and Test Methods

The acoustic data were taken by four microphones suspended on 0.48 cm (3/16 in.) bungee cords at vertical locations corresponding to passenger ear levels (approximately 71 cm above the seat cushion) both in the untreated and treated aircraft (see Fig. 4). In order to assist in the identification of the noise paths, six accelerometers were bonded to various structures and panels above the level of the microphones (see Table 1 and Fig. 4 for locations). The voltage outputs from the accelerometers and three of the microphone transducers were recorded (after appropriate signal conditioning) on a 14-channel FM flight tape recorder. Sound pressure measurements were obtained on the fourth microphone using a type 1 (precision scientific) sound level meter whose output was recorded on a direct-record tape recorder. All data were subsequently digitized and a TSA (time series analysis) program (Ref. 4) was used to obtain both numerical and graphical outputs in terms of octave-band, one-third octave-band, and narrow-band (nominal 10 Hz bandwidth) analyses.

Recordings of the vibration and noise environments within the aircraft were obtained at discrete times during its entire flight (see Table 2 for the discrete flight segments). When a particular flight condition was established, tape recorders were activated to record 2 minutes of data. Voice annotation was also used on the tape recorders, but was difficult to interpret due to the ambient noise levels.

Results and Discussion

Narrow-band sound pressure spectrum and acceleration power spectral density (PSD) are shown in Figure 5 for the helicopter with no acoustic treatment during hover out-of-ground effect (OGE). The analyses for both noise levels and acceleration PSD's were performed using a nominal 10-Hz bandwidth. The data shown are for microphone number 2 and accelerometer number 2. Although the interior noise has many possible primary sources (rotors, gear boxes, engines, etc.) these data show the main source occurs at approximately 1370 Hz which corresponds to first-stage planetary gear clash in the main gear box. The peak amplitude at 1370 Hz is at least 10 dB above all other peaks in the spectrum, indicating that for this flight condition, the other sources of interior noise do not significantly contribute to the overall noise level.

Two other frequencies are emphasized in the figure. The tail rotor-blade passage frequency occurs at approximately 53 Hz; main bevel and tail take-off gear clash occurs at approximately 2700 Hz. For this particular flight condition, the peak amplitude at 2700 Hz is not high relative to the other two predominant peaks in the spectrum. However, for other flight conditions (e.g., Fig. 6) the amplitudes at this frequency are also a predominant source of interior noise. Therefore, for comparison purposes, the main bevel and tail take-off gear clash frequency is emphasized for hover OGE.

The acceleration PSD also has peak amplitudes in the spectrum at 1370 Hz and 2700 Hz, suggesting that some relationship exists between noise and structural vibration at these frequencies. However, at the tail rotor-blade passage frequency, nominally 53 Hz, the PSD does not have a high peak amplitude relative to the two frequencies previously discussed. Since most panels in the fuselage skin are similar to the panel on which accelerometer number 2 is mounted, the data of Figure 5 suggest an airborne path for the noise from the tail rotor-blade passage. Although only a small sample of the data obtained is presented in this paper, an examination of the data from the other noise and vibration transducers supports the above conclusions.

Data similar to that shown on Figure 5 are presented in Figure 6 for the same two transducers during a 130-kt cruise. The cruise condition, of course, is the flight condition which involves the longest exposure time for passengers during the short-haul missions being considered. Most of the comments made about Figure 5 also apply directly to Figure 6. One exception is that the SPL peak amplitude in the spectrum at 2700 Hz is comparable to the noise levels at 53 Hz and 1370 Hz during this flight condition. Although the tail rotor-blade passage produces the highest peak amplitude in the SPL spectrum during the 130-kt cruise condition, the frequency is quite low, 53 Hz, and will be heard greatly attenuated from the level shown because the human ear is not as sensitive to lower frequencies as to the frequencies around 1000 Hz. As during hover, this figure shows the first-stage planetary gear clash to be a main contributor to the interior noise. The same relationship between peak amplitudes in the SPL spectrum and the PSD spectrum exists during the 130-kt cruise as during hover OGE. Thus Figure 6 supports the results stated in the discussion of Figure 5. Since the nature of the relationship between noise and structural vibration (i.e., source/path identification) is not well understood, further research is needed in methods for noise source/path determination.

Some preliminary data have been obtained for this helicopter with the acoustically treated cabin installed. The measurements were taken at microphone location number 3 (fourth row, isle seat). The results, in terms of SPL octave bands, are shown in Figure 7. The shaded area at the top of the figure is the octave-band data for all microphones and all flight conditions for the helicopter with no acoustic treatment. Except for three octave bands containing the main sources of interior noise (center frequencies of 63 Hz, 1000 Hz, and 2000 Hz), the data have less than a 10-dB spread. The solid curve is the octave-band data for microphone number 3 during hover IGE with no acoustic treatment. The effect of the acoustic treatment is indicated by the dotted curve. These data were taken inside the acoustically treated cabin at approximately the same location as microphone number 3 during hover IGE. As the figure indicates, up to 30 dB of noise reduction was obtained in some octave bands. This is a significant improvement in the interior noise levels compared to those of the untreated helicopter. Although not directly shown by the octave-band data, the first-stage planetary gear clash (1370 Hz) still dominates the high-frequency interior noise in the acoustically treated cabin. Since pure tones are subjectively more annoying to people than broad-band noise, the first-stage planetary gear clash is the most bothersome source of interior noise in the acoustically treated cabin.

Also shown on Figure 7 for comparison purposes are the octave-band data representative of a wide-body jet aircraft during cruise. Although a significant reduction in interior noise levels has been achieved by the acoustic treatment, 20 dB additional noise reduction is required in some octave bands to make the helicopter interior noise levels comparable to those of a wide-body jet aircraft during cruise.

Concluding Remarks

This paper has presented data on the interior noise levels in typical military and civilian helicopters. In particular, some detailed information on the noise and vibration levels was given for the Langley Research Center's Civil Helicopter Research Aircraft. Inside the acoustically treated cabin of this helicopter, a pure tone at approximately 1370 Hz, corresponding to the first-stage planetary gear clash frequency in the main gear box, dominates the interior noise. Comparison of interior noise levels in this helicopter before and after installation of the acoustically treated cabin shows reduction in interior noise levels up to 30 dB in some octave bands. However, an additional reduction of 20 dB is required in some octave bands to make the interior noise levels in this helicopter comparable to the levels in a wide-body jet aircraft during cruise.

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Table 1. Characteristics of Instrumentation and Locations of Transducers.

TRANSDUCER	AMPLITUDE RANGE	FREQUENCY RANGE (Limited by tape recorder)	MEASURING LOCATIONS (All on port side)
Accelerometer			
1	1 - 100 g_{rms}	1 - 5000 Hz	Frame at rear engine mount
2	↕	↕	Centered on panel
3			On stringer near main gear box frame
4			Main gear box supporting frame
5			Centered on panel
6			Centered on panel
Microphone			
1	50 - 100 dB	2 - 500 Hz	First row, window seat
2	↕	↕	Second row, isle seat
3			Fourth row, isle seat
4		100 - 10000 Hz	Center line below main gear box drip pan

Table 2. Flight Conditions for Which Noise and Vibration Measurements Were Obtained.

Lift-off
Hover in-ground-effect (IGE)
Hover out-of-ground-effect (OGE)
Climb at 1000 ft/min, forward velocity 72 kts
Cruise at 80 kts
Cruise at 130 kts
30° bank to the right
30° band to the left
Descent at 1000 ft/min, forward velocity 70 kts
Landing

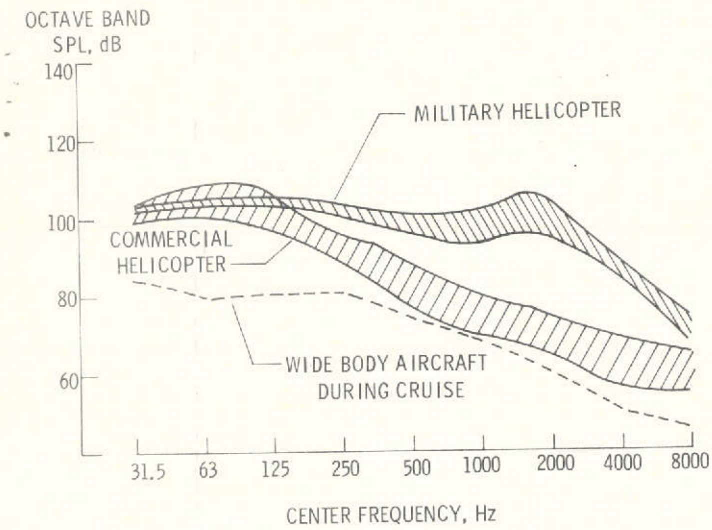


Figure 1. Typical octave-band sound pressure levels (SPL) for aircraft.

Figure 2. Langley Research Center's Civil Helicopter Research Aircraft.

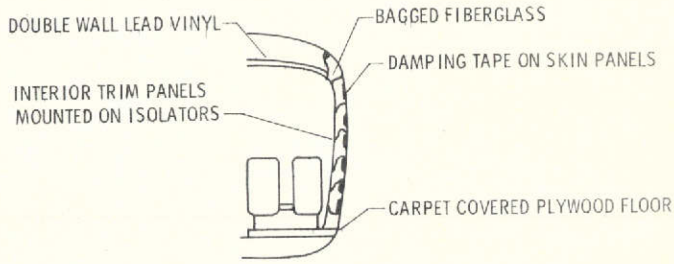
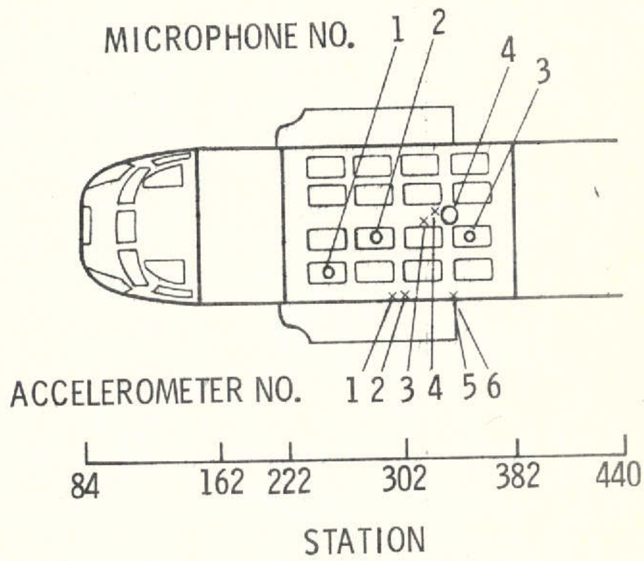
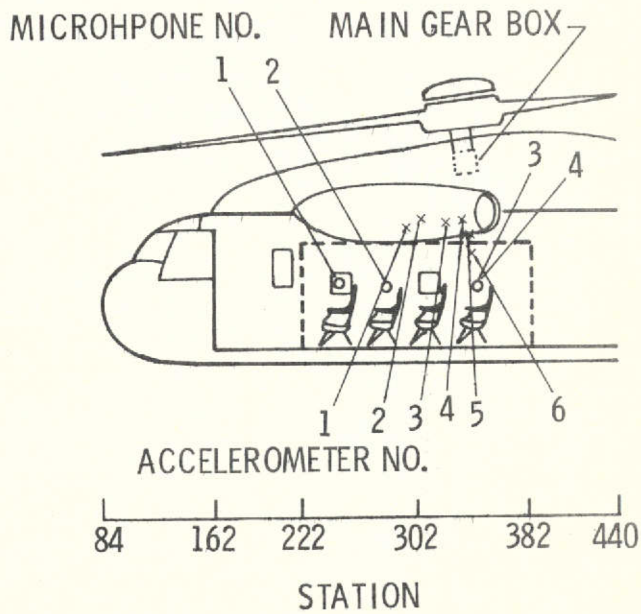


Figure 3. Sketch of typical cabin section showing acoustic treatment.



(b) Top view.

Figure 4. Sketch of cabin showing transducer locations.



(a) Side view.

Figure 4. Concluded.

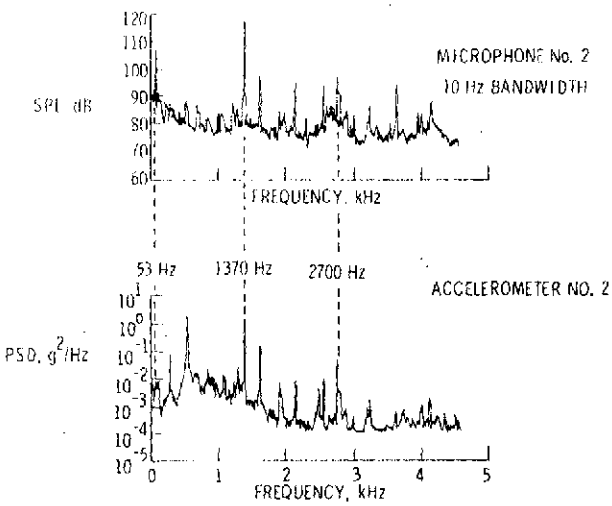


Figure 5. Narrow-band sound pressure level (SPL) and acceleration power spectral density (PSD) for untreated helicopter during hover OGE.

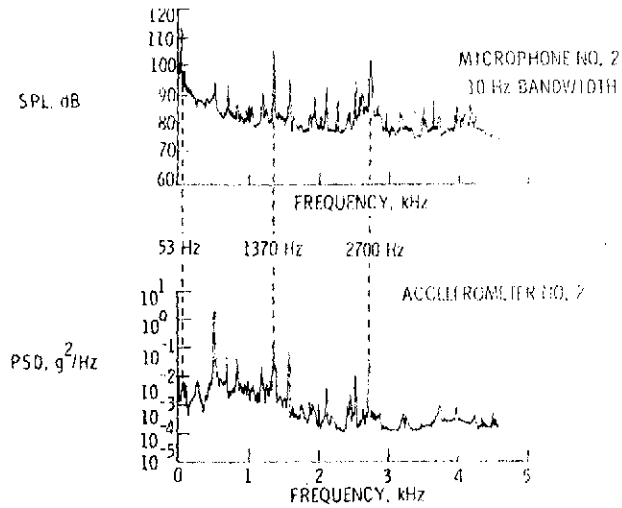


Figure 6. Narrow-band sound pressure level (SPL) and acceleration power spectral density (PSD) for untreated helicopter during 130 knot cruise.

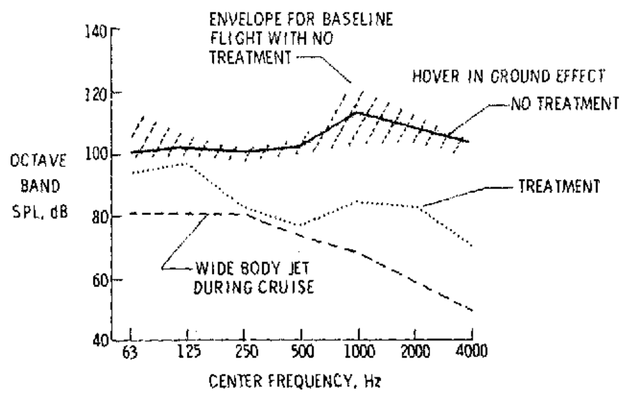


Figure 7. Effect of acoustic treatment on interior noise levels of LRC Civil Helicopter Research Aircraft.