NASA TECHNICAL NOTE

NASA TN D-8477 c.1

NASA TN D-8477

LOAN COPY: RETU[illegible]
AFWL TECHNICAL L[illegible]
KIRTLAND AFB, N[illegible]

TECH LIBRARY KAFB, NM

0134213

INTERIOR NOISE REDUCTION IN A LARGE CIVIL HELICOPTER

James T. Howlett, Sherman A. Clevenson, John A. Rupf, and William J. Snyder

Langley Research Center
Hampton, Va. 23665

[illegible] AUG 1977
Technical Library
AF Weapons
Laboratory

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JULY 1977

TECH LIBRARY KAFB, NM

0134213

1. Report No. NASA TN D-8477	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle INTERIOR NOISE REDUCTION IN A LARGE CIVIL HELICOPTER		5. Report Date July 1977
		6. Performing Organization Code
7. Author(s) James T. Howlett, Sherman A. Clevenson, John A. Rupf, and William J. Snyder		8. Performing Organization Report No. L-11349
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665		10. Work Unit No. 505-10-26-04
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Technical Note
		14. Sponsoring Agency Code

15. Supplementary Notes

James T. Howlett, Sherman A. Clevenson, and William J. Snyder: Langley Research Center.
John A. Rupf: JIAFS, The George Washington University.

16. Abstract

This paper presents the results of an evaluation of the effectiveness of current noise reduction technology in attaining acceptable levels of interior noise in a large (about 20 000 kg) passenger-carrying helicopter. The helicopter studied is a modified CH-53A with a specially designed, acoustically treated passenger cabin. The acoustic treatment reduced the average A-weighted interior noise levels from 115 dB to 87 dB. The study suggests selected improvements in the acoustic treatment which could result in additional reduction in cabin noise levels. The resulting levels would be only slightly greater than the interior noise levels of current narrow-body jet transports.

17. Key Words (Suggested by Author(s)) Interior noise; Helicopter interior noise; Aircraft interior noise; Aircraft acoustic treatment; Noise reduction	18. Distribution Statement Unclassified – Unlimited. Subject Category 71

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	41	$4.00

* For sale by the National Technical Information Service, Springfield, Virginia 22161

INTERIOR NOISE REDUCTION IN A LARGE CIVIL HELICOPTER

James T. Howlett, Sherman A. Clevenson, John A. Rupf,*
and William J. Snyder
Langley Research Center

SUMMARY

This paper presents the results of an evaluation of the effectiveness of current noise reduction technology to attain acceptable levels of interior noise in a large (about 20 000 kg) passenger-carrying helicopter. The helicopter used in the study is a modified CH-53A with a specially designed, acoustically treated passenger cabin. The results presented include a detailed comparison of the interior noise before and after installation of the passenger cabin. The acoustic treatment reduced the average A-weighted interior noise levels from 115 dB in the untreated vehicle to 87 dB inside the acoustically treated cabin. The study suggests that a reduction of acoustic leaks to 0.1 percent and an increase in the transmission loss of the rear cabin bulkhead could result in a significant reduction of cabin noise due to the main gear box. Specifically, a reduction of 12 dB from the first-stage planetary gear clash in the main gear box could result in an interior noise environment which is only slightly higher than that in current narrow-body jet transports.

INTRODUCTION

Helicopters which are much larger than those currently used for commercial operations are being considered for future passenger-carrying applications. (See refs. 1, 2, and 3.) The passenger acceptability of such a system must be considered in the evaluation of the concept. A major source of passenger complaint in current commercial operations has been the relatively high interior noise levels. (See ref. 3.) Thus, the ability to achieve acceptable cabin noise levels within practical constraints must be carefully evaluated.

Many studies of helicopter interior noise reduction have been reported in the literature. (See refs. 4 to 12.) The basic principles involved are stated, for example, in reference 4. Typical applications of these techniques to smaller helicopters (less than 10 000 kg) may be found in references 4 to 6. These applications have shown that acoustic

*Joint Institute for Advancement of Flight Sciences, The George Washington University, Hampton, Virginia.

treatment can reduce the interior noise levels, but the reduced levels are still high compared with most forms of commercial air transportation. References 7 to 12 discuss some aspects of the reduction of interior noise in large helicopters. However, there is no information in the literature to indicate whether noise reduction technology presently used in helicopters can reduce the noise levels in large, passenger-carrying helicopters to the levels of other aircraft in current use (for example, narrow-body jet transports).

The purpose of this paper is to evaluate the effectiveness of some of the current noise reduction technology in attaining acceptable levels of interior noise in a passenger-carrying, large helicopter. The helicopter used in this study, a modified CH-53A with a specially designed, acoustically treated passenger cabin, was developed as part of a research program to study a broad range of civil helicopter problems (ref. 7). The results presented herein include a detailed comparison of the interior noise before and after installation of the passenger cabin to show the effectiveness of the acoustic treatment. The effect of various flight conditions on interior noise is also discussed. The interior noise in this vehicle is compared with that in current passenger-carrying aircraft. The results of trend studies are presented which indicate the potential improvement in the interior noise environment of a large passenger-carrying helicopter.

ABBREVIATIONS

CHRA	civil helicopter research aircraft
L	overall sound pressure level, dB
L_A	A-weighted sound pressure level, dB
L_{PN}	perceived noise level, dB
L_{PNT}	tone-corrected perceived noise level, dB
PSIL	preferred speech interference level, dB
SPL	sound pressure level, dB
TL_{field}	field incidence transmission loss, dB
TL_{part}	partition transmission loss, dB

TEST APPARATUS

Test Aircraft

The civil helicopter research aircraft (CHRA) is a modified CH-53A military helicopter which is being used to investigate several aspects of civil helicopter operations. Figure 1(a) shows a photograph of the vehicle and table I presents the basic characteristics of the modified vehicle. The CHRA has uprated engines (nearly 3-MW power) and uprated transmissions to accept the higher power inputs. For comparison purposes, tests were conducted on this vehicle both before and after acoustic treatment. The untreated vehicle was completely void of acoustic treatment. After the initial tests, a 16-seat passenger cabin was installed in the forward part of the main cabin of the aircraft. This passenger cabin is 4.06 m long and has the appearance of a conventional commercial fixed-wing transport passenger cabin. (See fig. 1(b).)

Acoustic Treatment of CHRA

The potential sources of interior noise in a CH-53 helicopter and the associated mechanical frequencies are listed in table II. The geometric relationship between the primary sources of interior noise (the power train) and the acoustically treated passenger cabin is shown in figure 2. In contrast to commercial jet aircraft, all these noise sources are in the immediate vicinity of the passenger cabin; thus reduction of interior noise is particularly difficult. As figure 2 indicates, the main gear box is directly above the rear part of the passenger cabin. The engines are slightly above head level and are mounted directly against the sides of the cabins. The main drive shafts connecting the engines to the main gear box are located diagonally above the cabin. The space behind the cabin does not have acoustic treatment (except for some military-type fiberglass blankets) and, hence, is a path of noise which can be regarded as another source of noise which enters the treated cabin through the rear cabin bulkhead.

A sketch of the passenger cabin of the CHRA showing the acoustic treatment is presented in figure 3. The fuselage skin is covered with 0.5-mm-thick damping tape (see ref. 9 for details of damping tape) to reduce vibrations and, hence, noise radiating from the vibrating surface. This damping tape is also applied, where practical, to structural members such as main frames of the aircraft. The 8-cm-deep volume between the frames is filled with bags of fiberglass (16 kg/m^3 density). In the ceiling, two layers of lead separated with absorbent foam are installed (total thickness approximately 5 cm). The total density of the ceiling treatment is approximately 7.3 kg/m^2. One layer of lead and foam is installed in the cabin sidewalls. Interior trim panels on the cabin sidewalls and ceiling are mounted on vibration isolators. A raised plywood floor (2 cm thick) covered with carpet is installed over the metal cargo floor. The forward and aft ends of the passenger cabin are separated from the rest of the vehicle by 2-cm-thick plywood bulkheads (density approximately 9.8 kg/m^2) which are mounted to the airframe with vibration isolators. The rear face of the aft bulkhead was covered with a 1.3-mm-thick damping material which was held to the bulkhead by a series of 20-cm-long aluminum channels, 3 cm wide with 1.5-cm legs. The volume between the channels was filled with 2.5-cm-thick foam and the installation was covered with fabric for the sake of appearance. The bulkheads have a cork covering on the passenger side and acoustically sealed doors. Figures 4 to 8 show photographs of some of the acoustic treatment. In figure 7, note the ducting framework and air ducts in the four corners of the picture. This ducting protrudes through holes in the rear bulkhead. The size of the holes for the ducting framework can be seen in figure 8. The gaps between the bulkhead and the ducting framework are filled with absorbent foam to reduce the effects of acoustic leaks. There are two double-pane windows on each side of the cabin. The inner pane of these windows is attached to the acoustic treatment. The entire treatment has an average density of about 8 kg/m^2 and weighs about 180 kg. This acoustic treatment is a typical example of the application of available interior noise reduction technology for helicopters. (For examples, see refs. 4, 5, 6, and 11.) Additional details of the acoustic treatment may be found in reference 13.

INSTRUMENTATION AND TEST PROCEDURE

The acoustic data reported in this paper were obtained by using 1.27-cm condenser microphones. The voltage outputs of the microphones were recorded (after appropriate signal conditioning) on a tape recorder for subsequent analysis. Some of the data were digitized and a time series analysis computer program 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) sound pressure levels (SPL). However, most of the data were analyzed by using either analog equipment or a real-time analyzer to obtain the appropriate numerical and graphical results.

Data were obtained for a wide variety of flight conditions and microphone locations in both the untreated helicopter and the treated vehicle (CHRA). For all measurements, the microphones were positioned to correspond to ear level of a seated passenger (approximately 71 cm above the level of the seat cushion). A list of all flight conditions and the corresponding microphone locations is given in table III.

In the untreated aircraft, data were obtained for the flight conditions and microphone locations specified in table III(a). A frequency modulated (FM) flight tape recorder was used and 2 minutes of data were recorded simultaneously for each of the various flight conditions. These same flight conditions and microphone locations were repeated and the additional conditions and microphone locations listed in tables III(b) and III(c) were flown after installation of the acoustically treated cabin. In the acoustically treated vehicle, a carry-on, two-channel, amplitude modulated (AM) tape recorder was used in conjunction with type 1 (precision) sound level meters. With the use of this portable recorder, data from only two microphones could be recorded simultaneously so that the various flight conditions were repeated as often as necessary to obtain 1 to 2 minutes of data at several seat locations. This latter procedure required that at least three people be inside the acoustically treated cabin when the data were taken. Occasionally, two or three additional observers were present. In all cases, every effort was made to position those present so that there was no appreciable effect on the data being recorded. For example, no data were taken at a seat in which someone was sitting.

During a 1- to 2-minute data run in the treated vehicle, the sound level meters were observed to maintain a steady (average) A-weighted sound pressure level, ±1 dB, for most of the data recording period with an occasional deviation of ±3 dB. Similar deviations were observed when the same test conditions were repeated on different days. The noise levels reported in this paper correspond to the average levels observed for each flight condition and microphone location.

RESULTS AND DISCUSSION

Effect of Flight Conditions

In order to obtain thorough documentation of the interior noise environment inside the acoustically treated cabin of the CHRA, measurements were made for the variety of flight conditions and microphone locations listed in tables III(b) and III(c). These measurements include over 120 individual data points.

Figure 9 shows the interior noise in terms of L_A at each seat location in the acoustically treated cabin for two different cruise speeds and door configurations. The noise levels vary by approximately 10 dB throughout the cabin. For the 148 km/hr cruise (40 percent average engine torque) with the cabin doors closed, the arithmetic average of L_A in the cabin is 85 dB. The average L_A increases to 87 dB for the 278 km/hr cruise (50-percent average engine torque) with the cabin doors closed. For this vehicle, 278 km/hr is a typical cruising speed. With both cabin doors open (figs. 9(c) and 9(d)), the average L_A increases to 88 dB for the 148 km/hr cruise and to 92 dB for the 278 km/hr cruise. In all cases, the fourth row window seat on the left side of the vehicle has a higher noise level than the other seats. The higher level of noise at one seat location suggests an acoustic leak in the rear bulkhead since this seat is directly in front of one of the holes in the bulkhead described in the section on acoustic treatment. With both cabin doors closed, the average L_A decrease of 2 dB when the airspeed is reduced from 278 km/hr (fig. 9(b)) to 148 km/hr (fig. 9(a)) indicates that the normal cruise speed of 278 km/hr imposes a small penalty (2 dB on the average) on the A-weighted sound pressure levels.

The effect of a large variation of airspeed on L_A at two seat locations with both cabin doors closed is shown in figure 10. The maximum difference in L_A between these two particular seat locations is 2 dB. As the figure also shows, the general shape of the L_A curves corresponds to the power (torque) curve for the helicopter. The minimum noise levels occur in the intermediate speed range, higher levels occurring at 0 airspeed (hover in ground effect) and 278 km/hr cruise. A maximum 4-dB increase in L_A at the two seat locations indicated in the figure occurs when the cruise speed is increased from 93 km/hr to 278 km/hr. This result supports the statement that the normal cruise speed of 278 km/hr imposes a small penalty on the A-weighted sound pressure levels in the cabin. Although figure 10 presents noise levels for only the cabin-doors-closed configuration, the noise data for the three other door configurations (see table III(b)) yield similar results. The noise data for all these conditions are presented in table IV.

Figure 11 shows the effect of rate of climb on the interior noise with both cabin doors closed. The curve shows the average L_A for the two microphone locations and the forward speeds listed in table III(b). The average L_A increases slightly as the rate of climb is increased. This increase in L_A is consistent with the increase in the average engine torque also shown in the figure. For the flight condition investigated, the increase in L_A at the highest rate of climb is only 3 dB greater than that for the lowest rate of climb. Thus, rate of climb does not have a large effect on the average value of L_A for the flight conditions investigated.

The effect of rate of descent on the interior noise with both cabin doors closed is shown in figure 12. (See table III(b) for flight conditions and microphone locations.) As the figure indicates, the average values of L_A are essentially constant for the flight conditions investigated and the average torque decreases by 10 percent as the rate of descent is increased.

Noise Sources

The noise sources which are the primary contributors to the interior noise in the CH-53 helicopter are determined by comparing frequencies associated with peaks in the narrow band spectra of the interior noise with the frequencies of the potential sources. (See table II.) As shown in figure 13(a), there are three peaks above 100 dB in the spectrum of the untreated aircraft: tail rotor blade passage (nominally at 53 Hz), first-stage planetary gear clash (nominally at 1370 Hz) in the main gear box, and main bevel/tail take-off gear clash (nominally at 2710 Hz). Two of these peaks exceed 110 dB. Although the narrow band spectra are shown for only one flight condition (241 km/hr cruise) and one microphone location (second row aisle seat location, left side), narrow band spectra for all flight conditions and microphone locations (see table III) indicate that these three peaks consistently dominate the interior noise spectra.

Figure 13(b) shows a spectrum of noise in the acoustically treated vehicle (CHRA). Because of the lower noise floor in the acoustically treated cabin, peaks not evident in the noise spectrum for the untreated vehicle can easily be distinguished in the spectrum for the treated vehicle (for example, the engine sources at 227 Hz and 283 Hz), although these are not main peaks in the spectra in the acoustically treated cabin. The two higher frequency sources (first-stage planetary gear clash and main bevel/tail take-off gear clash) are still main sources of noise in the treated cabin, although their levels have been significantly reduced by the acoustic treatment. Note particularly that the narrow peak due to first-stage planetary gear clash extends almost 30 dB above the noise floor in the frequency range above 1000 Hz. This particular gear clash is the source which produces the most uncomfortable noise inside the treated cabin. (See refs. 1, 7, and 8.)

The sources of low-frequency noise (below 200 Hz) are indicated in figure 14. As shown in figure 14(a), tail rotor blade passage clearly dominates the low-frequency noise in the untreated aircraft. In the treated vehicle, as shown in figure 14(b), there is no single peak which dominates the low-frequency noise. Several peaks extend approximately 20 dB above the broadband noise. The two peaks caused by noise from the second-stage servo pump and the drive shafts are the highest in frequency and, therefore, noise from these sources is probably more uncomfortable than the others (that is, more sensitive to the human ear).

Effect of Acoustic Treatment

Noise reduction.- Data were taken on the untreated aircraft for the flight conditions and microphone locations listed in table III(a). These same flight conditions and microphone locations were repeated in the treated vehicle (both cabin doors closed) with the addition of a fourth microphone in the fourth row left side window seat location for a few of the flight conditions. The one-third-octave band data for all these measurements are shown by the envelopes in figure 15. The acoustic treatment reduced the one-third-octave band levels to the values indicated by the lower envelope in the figure. As the figure shows, there is less reduction in the levels for frequencies below 125 Hz than for those above 125 Hz. A 30-dB reduction of noise levels was obtained in some of the bands above 125 Hz. In particular, the figure shows the reduction obtained in the frequency ranges which contain the two main sources of high-frequency noise (1370 Hz and 2710 Hz).

The A-weighted sound pressure levels (L_A) were determined for the data shown in figure 15. The L_A in the untreated aircraft ranged from 108 dB to 122 dB with an average value of 115 dB for all flight conditions and microphone locations. The L_A in the treated cabin range from 82 dB to 90 dB with an average of 87 dB. The reduction of the average L_A values by 28 dB, from 115 dB in the untreated vehicle to 87 dB in the treated cabin, indicates a significant improvement in the cabin interior noise environment. This reduced level is 3 dB less than levels in a medium-sized helicopter currently being used for passenger transportation. (See ref. 3.)

In order to evaluate the reduction in interior noise attained by the acoustic treatment (i.e., insertion loss), the average values of the one-third-octave band levels after treatment were subtracted from the average values of the one-third-octave band levels before treatment. The resulting insertion loss is shown as the solid line in figure 16. As the figure shows, the insertion loss varies from 5 dB to over 30 dB. Of particular significance is the fact that the insertion loss has its highest values in the frequency range of 1300 Hz to 4000 Hz. This range includes the frequencies of the two primary sources of high-frequency noise on the untreated vehicle (1370 Hz and 2710 Hz). Hence, noise from these sources is reduced by approximately 30 dB. This reduction is largely responsible for the 28-dB decrease in L_A which was mentioned earlier.

Also shown for comparison purposes in figure 16 are theoretical curves for transmission loss. These curves represent predicted reductions in the interior noise due to insertion of a barrier wall between the noise sources and the microphone locations in a free field. The dotted and dashed curves in the mass-controlled region are the field incidence transmission loss curves for two materials with the densities indicated (ref. 14). As stated in the section entitled "Acoustic Treatment of the CHRA," the treatment installed has densities ranging from 7.3 kg/m^2 to 9.8 kg/m^2. Thus, in the mass-controlled region, the transmission loss would be approximately predicted by the dotted line. As the figure shows, this predicted transmission loss is about 6 dB greater than the experimental data. However, the dashed line suggests that the acoustic treatment in the vehicle is analogous to an acoustic barrier with a density of 4.9 kg/m^2 in the mass-controlled region.

Acoustic leaks.- Figure 17 shows one-third-octave band SPL in the fourth row, left side aisle seat location with the rear cabin door both open and closed. There is an increase of about 10 dB in most of the one-third-octave band sound pressure levels with the door open (approximately 25-percent open area in the rear bulkhead) except for noise in the frequency range of the drive shaft (near 100 Hz). The reason for this exception may be due to the low value of transmission loss at 100 Hz along with the path probably followed by noise from the drive shafts. Since the drive shafts are directly over the passenger cabin (see fig. 2), noise from these sources is probably radiated directly down into the cabin and, hence, is not affected by the rear cabin bulkhead. The difference between the two curves in figure 17 in the one-third-octave bands near 1370 Hz (first-stage planetary gear clash frequency) is approximately 10 dB.

The equation for evaluating the effects of acoustic leaks in the rear bulkhead on the transmission loss at a given frequency is (from ref. 14)

$$TL_{field} = 10 \log \frac{S_1 + S_2}{S_1 + S_2\tau} \tag{1}$$

where

TL_{field} field incidence transmission loss at a specific frequency

S_1 open area for acoustic leakage

S_2 area of partition

τ transmission coefficient of partition at a specific frequency (partition transmission loss equals $10 \log \frac{1}{\tau}$)

If the argument of the log in equation (1) is simplified, the result is

$$TL_{field} = 10 \log \frac{1}{c_1(1 - \tau) + \tau} \tag{2}$$

where

$$c_1 = \frac{\text{Percent open area}}{100}$$

Equation (2) is plotted in figure 18 for several values of c_1. The calculated partition transmission loss of the rear bulkhead (2-cm-thick plywood and the mass added by the damping material and the aluminum channels being neglected) is 20 dB at 1370 Hz (ref. 14). Hence, with the rear door open (25-percent leakage), the field incidence transmission loss at 1370 Hz is 6 dB, as indicated by the open triangle in the figure. As figure 17 has shown, the cabin noise decreases by 10 dB at 1370 Hz when the rear door is closed; thus, it is implied that the rear bulkhead has a TL_{field} of 16 dB at 1370 Hz.

If the difference between TL_{part} and TL_{field} is entirely due to acoustic leaks, then the rear bulkhead has at least a 2-percent leakage, as shown by the solid triangle in figure 18. This figure also shows that simply increasing the partition transmission loss (TL_{part}) will have very little effect (about 2 dB) on TL_{field}. In order to increase TL_{field} by 10 dB, the leakage must first be reduced to 0.1 percent. Then an increase in TL_{part} could result in a significant reduction of cabin noise due to first-stage planetary gear clash in the main gear box.

Passenger Acceptance

In order to assess the acceptability to passengers of the interior noise environment in the CHRA, several typical noise rating scales were compared with those for other helicopters and current narrow-body jet transports. The rating scales used in this paper are the following: overall sound pressure level (L), dB; A-weighted sound pressure level (L_A), dB; preferred speech interference level (PSIL), dB; perceived noise level (L_{PN}), dB; tone-corrected perceived noise level (L_{PNT}), dB. The PSIL is defined as the arithmetic average of the SPL in the three octave bands with center frequencies of 500 Hz, 1000 Hz, and 2000 Hz. The definitions of the other noise indicators may be found in reference 15.

In figure 19, the selected rating scales are compared for a current passenger-carrying (25 passenger) commercial helicopter, the CHRA, and a narrow-body jet transport. The data for the current commercial helicopter are based on the octave-band data presented in reference 3; the data for the narrow-body jet transport were obtained by a handheld sound level meter near the front of the tourist compartment during a normal commercial flight (the L_A value reported herein is in the range of levels reported in ref. 16), and the CHRA data are at the second row aisle seat location on the left side of the passenger cabin during a 241 km/hr cruise. (See table III(a).) As the figure shows, the noise levels in the CHRA are comparable with those in the current commercial helicopter on the basis of the chosen indicators and 5 dB to 7 dB higher than the levels in the jet transport.

Since the source which produces the most uncomfortable noise in the CHRA is due to first-stage planetary gear clash in the main gear box (refs. 1 and 8), an analytical study was conducted to determine the effect of reducing the noise from this one source. For the rating scales chosen, reduction of the noise from this particular source by more than 12 dB resulted in no further improvement. The results for a 12-dB reduction are shown in figure 19 by the dotted line in the bars for the CHRA. As the figure indicates, a reduction of 12 dB in the noise from this source would result in levels which are 1 dB to 4 dB greater than those in a current narrow-body jet transport for the rating scales which are compared.

CONCLUDING REMARKS

A study of interior noise in a large, passenger-carrying helicopter has been conducted. The results indicate that acoustic treatment typical of current noise reduction technology for helicopters provided a significant improvement of the interior noise environment in the passenger cabin. The average A-weighted sound pressure level of 115 dB for all flight conditions and microphone locations in the untreated helicopter was reduced to 87 dB inside the acoustically treated cabin. This reduced level is 3 dB less than the level in a medium-sized helicopter currently being used for passenger transportation. The noise reduction from acoustic treatment of the vehicle is analogous to that obtained from an acoustic barrier with a density of 4.9 kg/m^2.

The A-weighted interior noise levels were found to vary by 10 dB throughout the passenger cabin. At one seat location, the A-weighted noise levels are consistently greater than the levels at all other seats. This phenomenon suggests an acoustic leak in the rear bulkhead. Further analysis of the data indicated that reduction of acoustic leaks in the rear bulkhead to 0.1 percent, and an increase in the transmission loss of the rear bulkhead could result in a significant reduction of the interior noise levels in the cabin.

In the acoustically treated vehicle, one of the primary sources of interior noise is the main gear box, particularly first-stage planetary gear clash. A 12-dB reduction in the noise from this source could result in interior noise levels in a large helicopter which are only slightly greater than levels in a current narrow-body jet transport on the basis of several typically used noise rating scales.

Langley Research Center
National Aeronautics and Space Administration
Hampton, VA 23665
April 19, 1977

REFERENCES

1. Snyder, William J.; and Schoultz, Michael B.: Civil Helicopter Flight Research. AIAA paper 76-896, Sept. 1976.

2. Hinterkeuser, Ernest G.; and Sternfeld, Harry, Jr.: Civil Helicopter Noise Assessment Study – Boeing Vertol Model 347. NASA CR-132420, 1974.

3. Schlegel, Ronald G.; Stave, Allen M.; and Wolf, Alfred A.: Ride-Quality Criteria for Large Commercial Helicopters. Symposium on Vehicle Ride Quality, NASA TM X-2620, 1972, pp. 51-66.

4. Sternfeld, Harry, Jr.; Miller, Laymon N.; and Beranek, Leo L.: Acoustic Design for Transport Helicopters. J. American Helicopter Soc., vol. 2, no. 4, Oct. 1957, pp. 21-28.

5. Sternfeld, Harry, Jr.: New Techniques in Helicopter Noise Reduction. Paper presented at 4th International Aeronautical Congress About Rotating Wings and Vertical Flight (Paris, France), June 1959.

6. Cox, C. R.: Design Considerations for Acceptable Cabin Noise Levels in Light Helicopters. Joint Symposium on Environmental Effects on VTOL Designs (Arlington, Texas), American Helicopter Soc., Inc., Nov. 1970.

7. Snyder, William J.; and Schlegel, Ronald G.: Vehicle for Civil Helicopter Ride Quality Research. 1975 Ride Quality Symposium, NASA TM X-3295, DOT-TSC-OST-75-40, 1975, pp. 97-116.

8. Howlett, James T.; and Clevenson, Sherman A.: A Study of Helicopter Interior Noise Reduction. NASA TM X-72655, 1975.

9. Jones, David I. G.: Constrained Layer Treatments for Noise Control in a Helicopter. AFML-TR-73-305, U.S. Air Force, Mar. 1974. (Available from DDC as AD 783 234.)

10. Henderson, John P.; and Nashif, Ahid D.: Reduction of Interior Cabin Noise Levels in a Helicopter Through Additive Damping. Shock & Vib. Bull., Bull. 44, Pt. 5, U.S. Dep. Def., Aug. 1974, pp. 13-22.

11. Sternfeld, H.; Schairer, J.; and Spencer, R.: Investigation of Helicopter Transmission Noise Reduction by Vibration Absorbers and Damping. USAAMRDL Tech. Rep. 72-34, U.S. Army, Aug. 1972. (Available from DDC as AD 752 579.)

12. Hartman, R.; and Badgley, R.: Model 301 HLH/ATC Transmission Noise Reduction Program. USAAMRDL-TR-74-58, U.S. Army, May 1974. (Available From DDC as AD 784 132.)

13. Levine, Larry S.; and DeFelice, Jon J.: Civil Helicopter Research Aircraft Internal Noise Predictions. NASA CR-145146, 1977.

14. Beranek, Leo L., ed.: Noise and Vibration Control. McGraw-Hill Book Co., Inc., c.1971.

15. Edge, Philip M., Jr.; and Cawthorn, Jimmy M.: Selected Methods for Quantification of Community Exposure to Aircraft Noise. NASA TN D-7977, 1976.

16. Passenger Noise Environments of Enclosed Transportation Systems. Rep. No. EPA/550/9-75/025, U.S. Environ. Protect. Agency, June 1975. (Available from NTIS as PB-245-409.)

TABLE I. - CIVIL HELICOPTER RESEARCH AIRCRAFT CHARACTERISTICS

Mission gross weight, kg	16 586
Empty weight, kg	11 575
Alternate gross weight, kg	19 047
High-speed cruise, km/hr	304
Normal speed cruise, km/hr	278
Range, km	448
Length, m	17.2
Height, m	5.07
Width (blades folded), m	4.72
Main rotor diameter, m	21.9
Engine (2) power, MW	3
Number of passengers for –	
Proposed commercial design	44
Research configuration	16

TABLE II. - MECHANICAL FREQUENCIES AND THEIR SOURCES FOR CH-53 HELICOPTER

Frequency, Hz	Source	Frequency, Hz	Source
3.08	Main rotor rpm	705	Tail-box bevel gear clash
8.10	First-stage planetary rpm	1120	Accessory box gear clash
13.2	Tail rotor rpm	1370	First-stage planetary gear clash
15.9	Second-stage Sun gear rpm	1460	Intermediate box bevel gear clash
18.5	Main-rotor blade passage	2100	Noise-box input shaft gear clash Tachometer Oil pump Fuel control
27.3	First-stage Sun gear rpm	2710	Main-box bevel gear clash Tail take-off bevel gear clash
27.9	Main-box bevel gear rpm	4510	First-stage servo gear clash Second-stage servo gear clash Utility Hoist Lubrication pump Auxiliary propulsion package drive
38.3	Intermediate tail-rotor gear clash	5310	Accessory take-off bevel gear clash
41.6	Main-box oil pump rpm	5420	Main-rotor tachometer spur gear clash Tail-rotor drive shaft spur gear clash
46.8	Nose-box oil pump rpm	7020	Nose-box bevel gear clash
50.2	Tail-rotor drive shaft rpm		
52.8	Tail-rotor blade passage		
60.2	Fuel control rpm		
68.5	Utility pump rpm		
70.3	Tachometer drive rpm		
71.9	Hoist drive rpm		
75.7	Second-stage servo pump rpm		
86.3	Lubrication pump rpm		
100	Generator rpm Main-gear-box input shaft rpm Accessory drive shaft rpm		
118	Oil cooler rpm		
227	Free turbine rpm (100%)		
283	Gas turbine rpm (100%)		
417	Main-box oil pump spur gear clash		
527	Second-stage planetary gear clash		

TABLE III. - FLIGHT CONDITIONS

(a) Untreated and treated (CHRA) aircraft – three microphone locations (first row window seat, second row aisle seat, fourth row aisle seat, all on left side)

Hover in ground effect
Hover out of ground effect
Climb at 5.1 m/s; forward velocity 133 km/hr
Descent at 5.1 m/s; forward velocity 130 km/hr
Cruise at 148 km/hr
Cruise at 241 km/hr
30^{o} right bank
30^{o} left bank

(b) Treated (CHRA) aircraft – two microphone locations (first row window seat, fourth row aisle seat, both on left side)

Rate of climb, m/s	Door condition*						
10.0		✓		✓		✓	
7.6		✓		✓		✓	
5.1		✓		✓		✓	
0	✓✓	✓✓	✓✓		✓✓		✓✓
Rate of descent, m/s	**Door condition***						
2.5		✓		✓		✓	
5.1		✓		✓		✓	
7.6		✓		✓		✓	
Airspeed, km/hr . . .	0	93	148	167	222	241	278

*A single check (✓) indicates that cabin doors are closed; a double check (✓✓) indicates four cabin door configurations: (1) both closed, (2) both open, (3) front only open, and (4) rear only open.

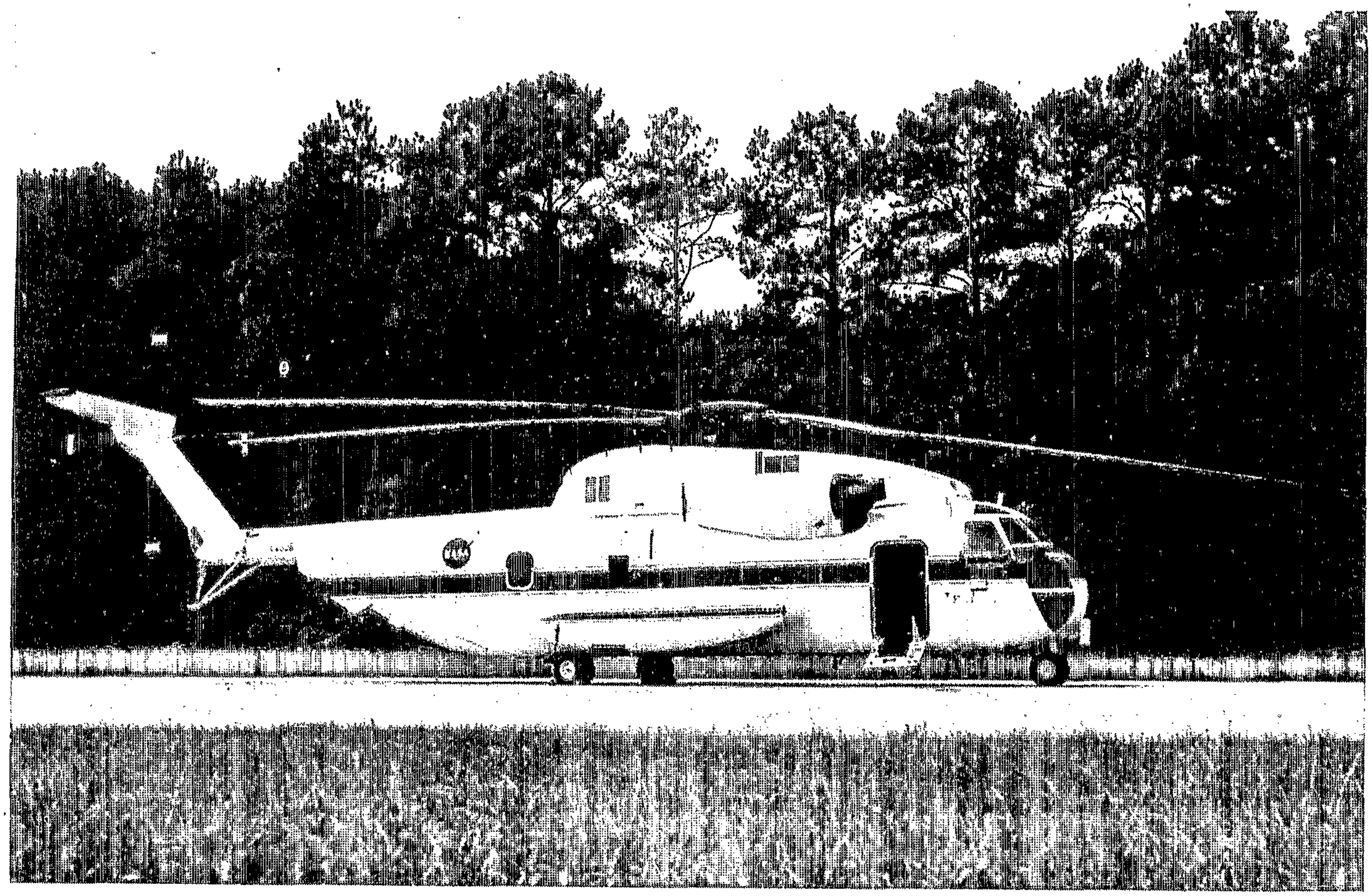
(c) Treated (CHRA) aircraft – 16 microphone locations (one at each seat location)

Cruise velocity, km/hr	Cabin doors
148	Both closed
148	Both open
278	Both closed
278	Both open

TABLE IV.- EFFECT OF AIRSPEED ON A-WEIGHTED INTERIOR NOISE LEVELS FOR TWO SEAT LOCATIONS

Door configuration	Microphone*	A-weighted interior noise levels at indicated airspeed of –				
		0 km/hr	93 km/hr	148 km/hr	222 km/hr	278 km/hr
Both closed	1	88	83	84	86	87
	2	89	85	84	87	87
Both open	1	88	91	88	91	93
	2	97	94	92	96	96
Front only open	1	88	86	86	87	90
	2	83	85	86	85	89
Rear only open	1	90	89	89	90	91
	2	96	93	93	96	97

*Microphone 1 at first row window seat; microphone 2 at fourth row aisle seat.



L-75-6936

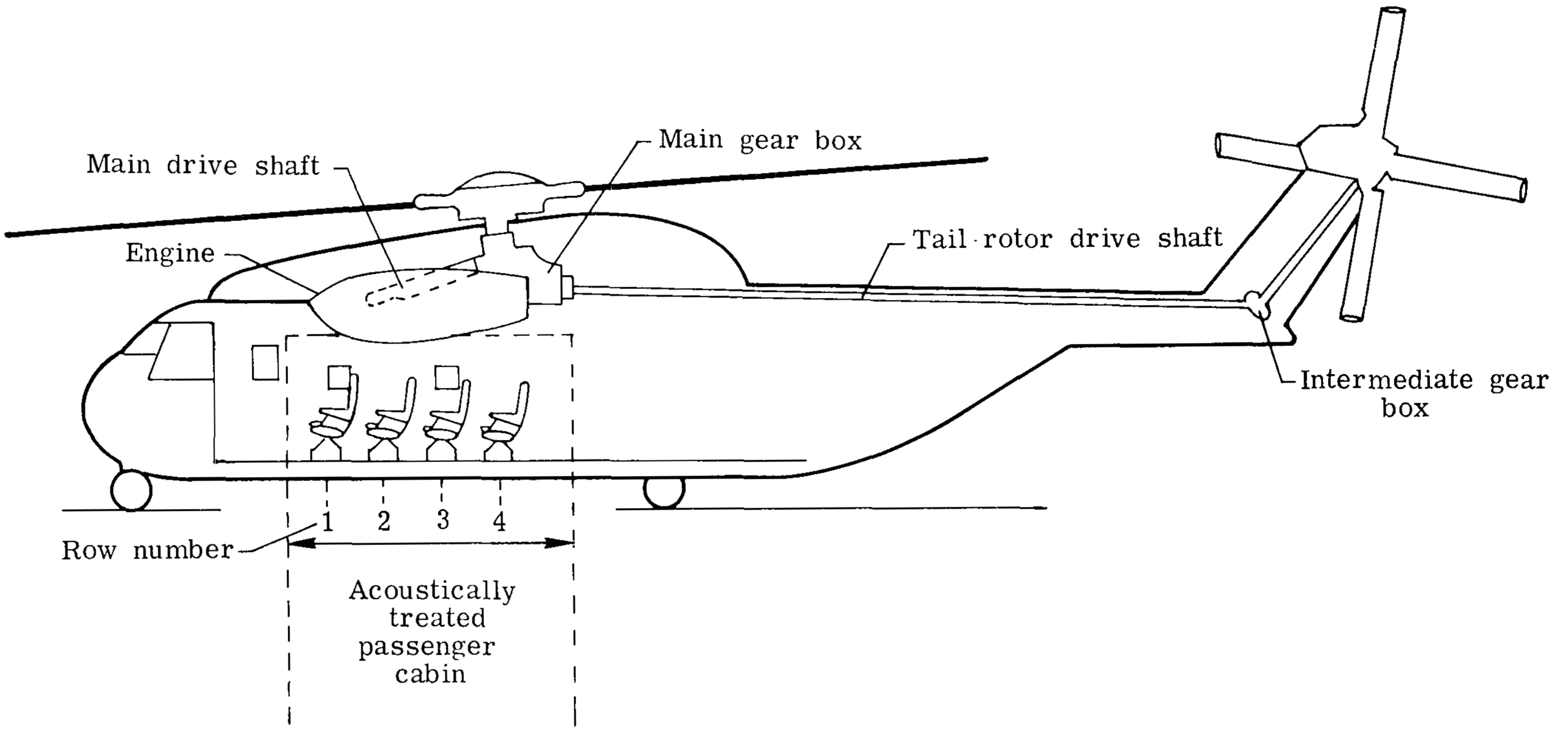
(a) Exterior view.

Figure 1.- Civil helicopter research aircraft (CHRA).

L-77-182

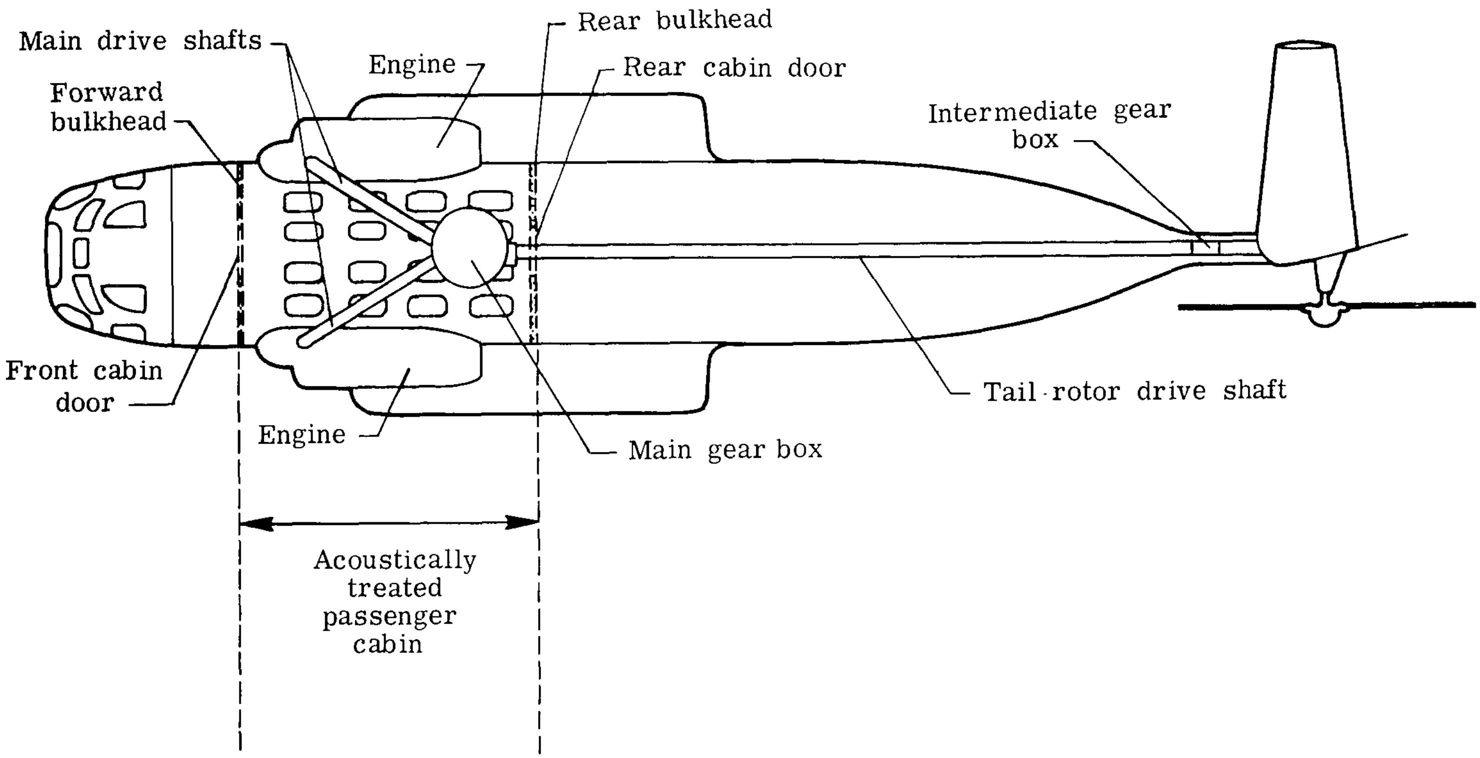
(b) Interior view.

Figure 1.- Concluded.



(a) Side view.

Figure 2. - Sketch of CHRA showing location of primary noise sources (power train) relative to passenger cabin.



(b) Top view.

Figure 2.- Concluded.

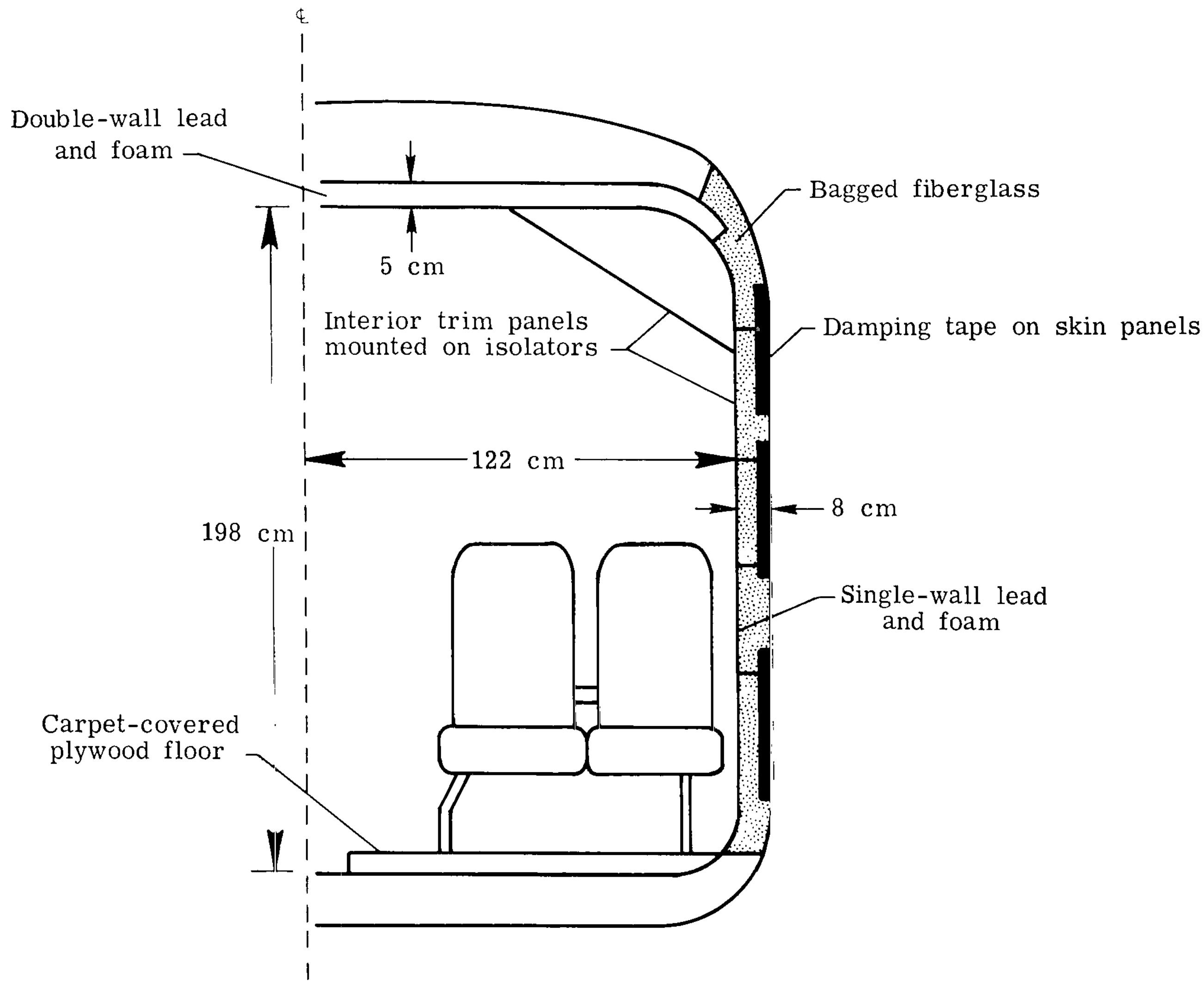
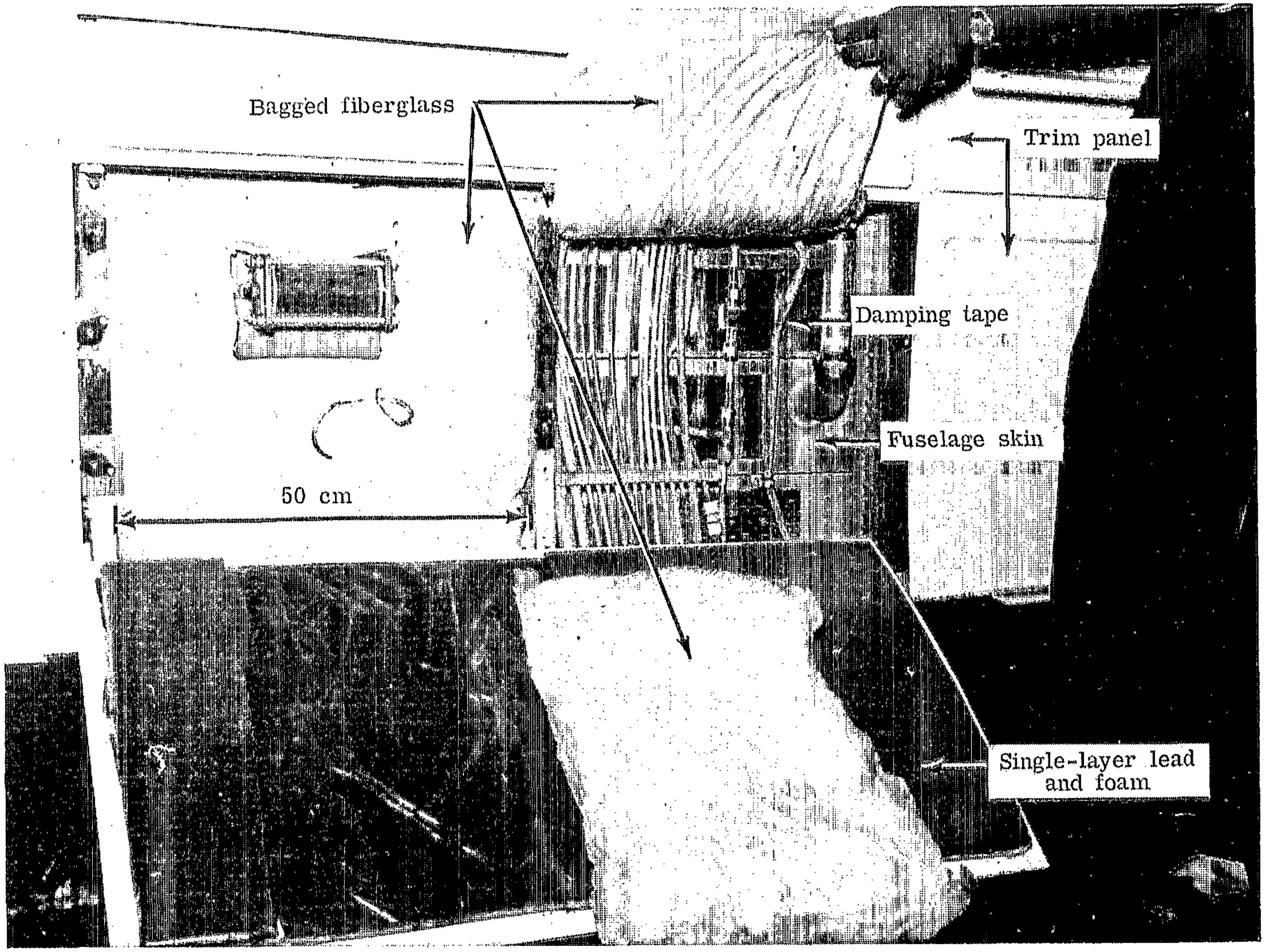
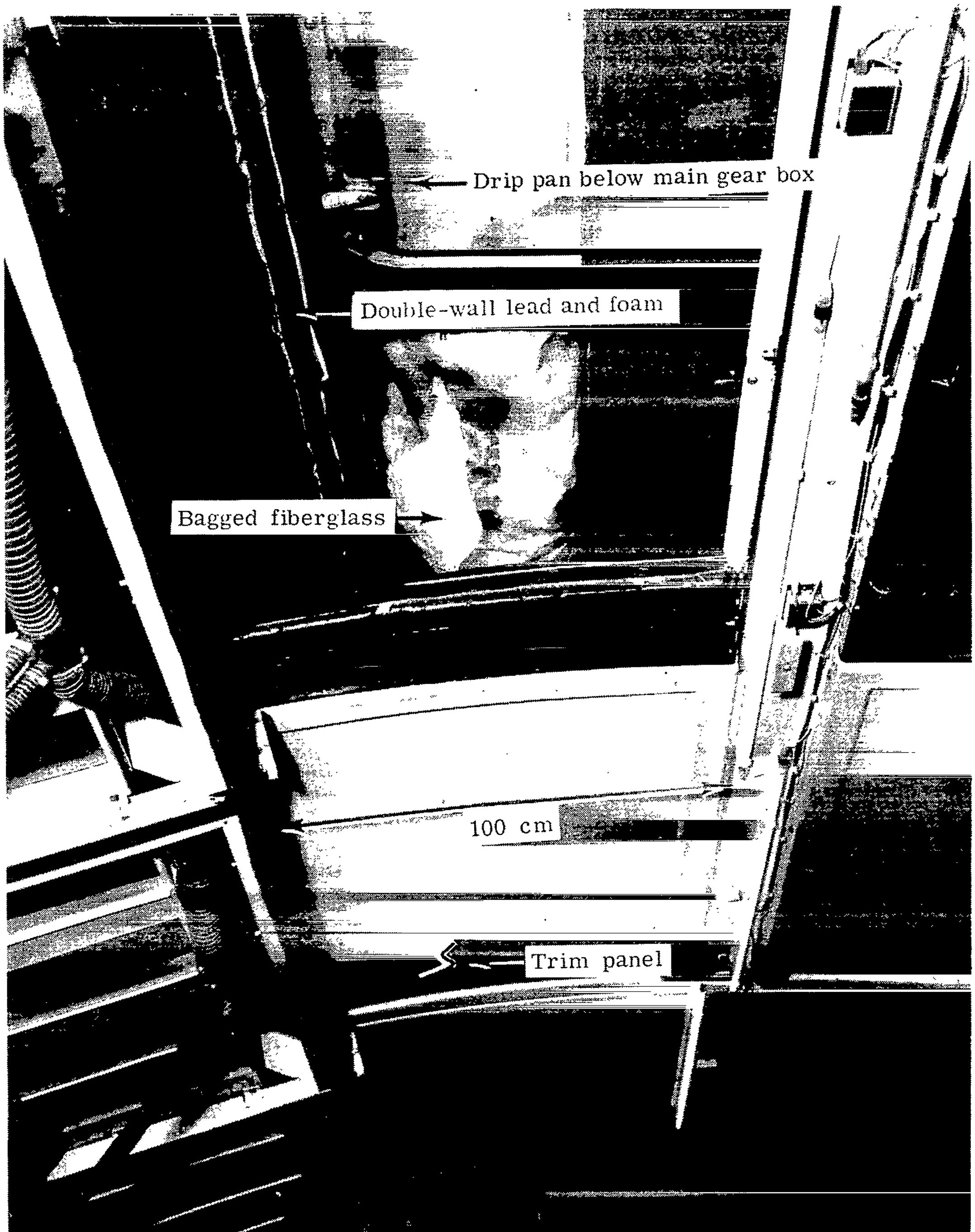


Figure 3.- Sketch of typical cabin section showing acoustic treatment.



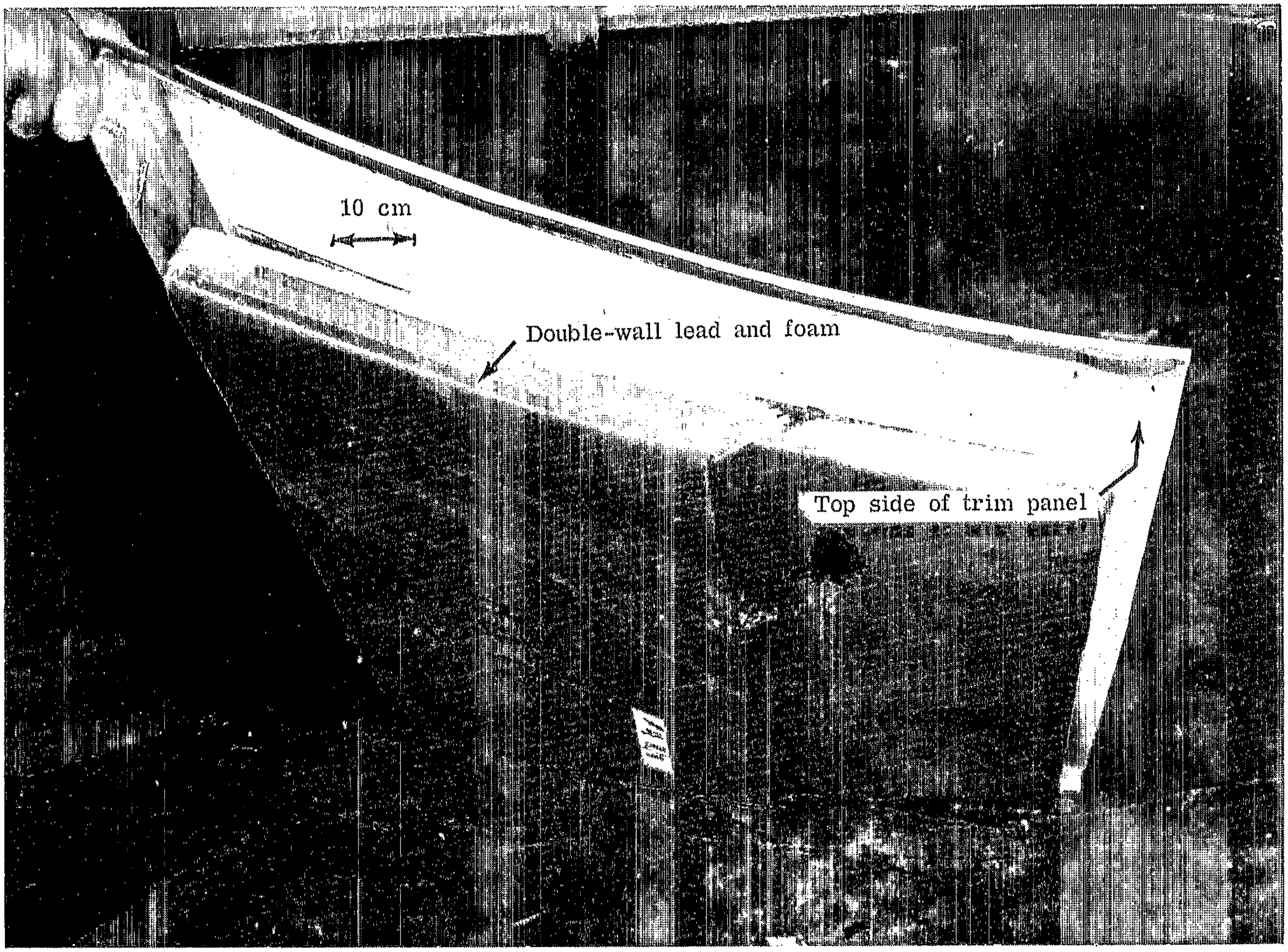
L-76-5860.1

Figure 4.- Typical acoustic treatment of passenger cabin sidewall.



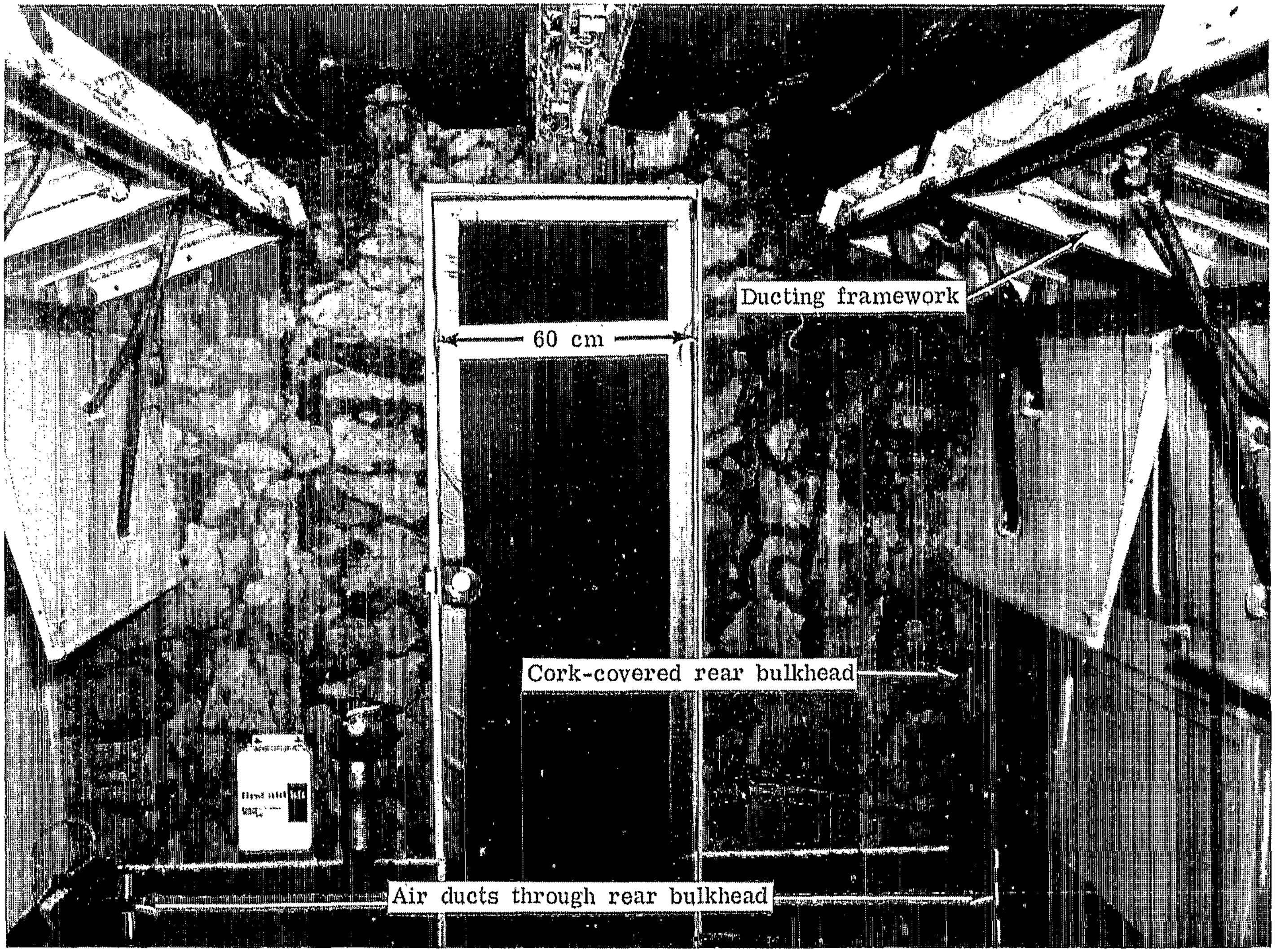
L-76-5857.1

Figure 5.- Area below main gear box with trim panel removed.



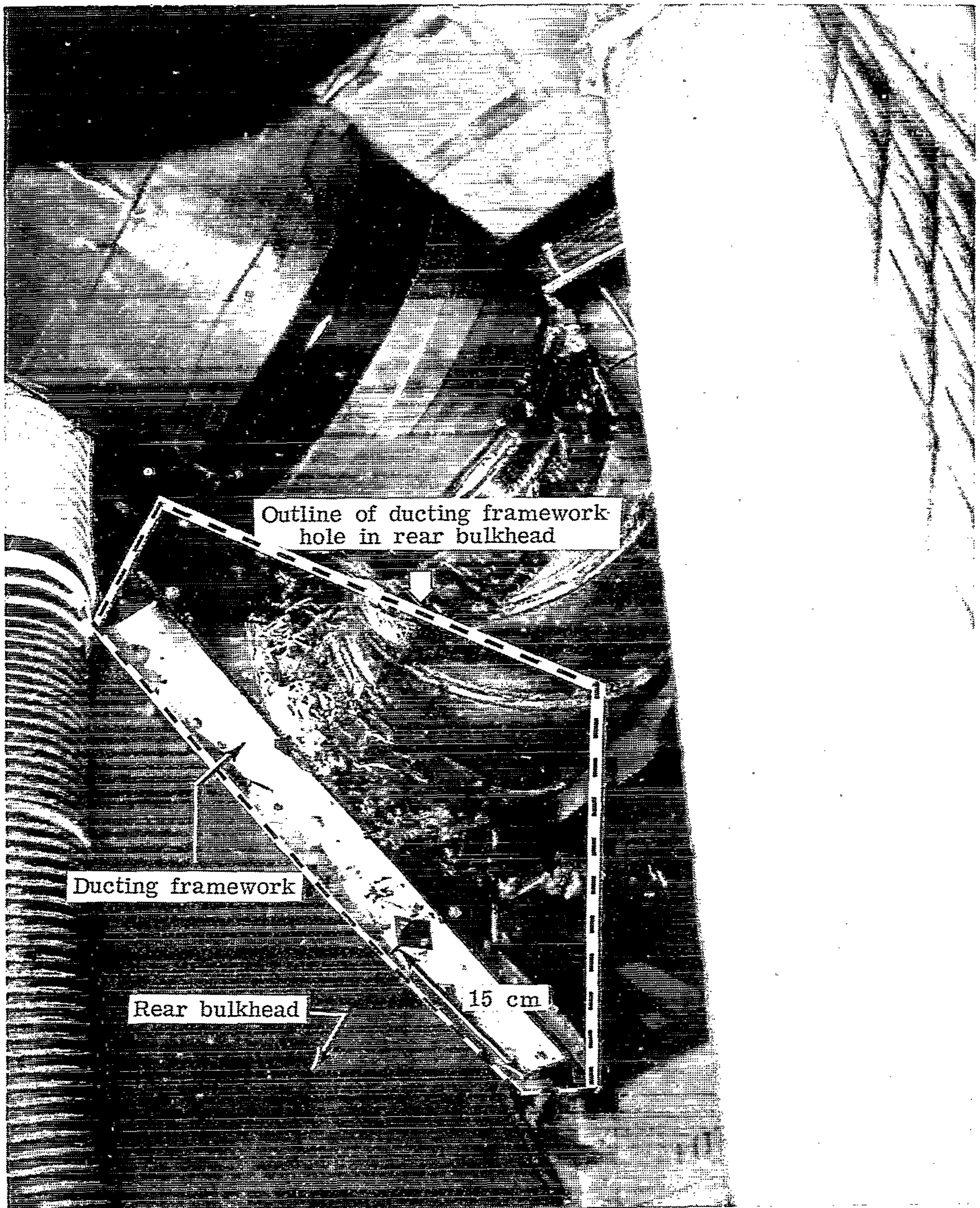
L-76-5856.1

Figure 6.- Acoustic treatment on trim panel below main gear box drip pan.



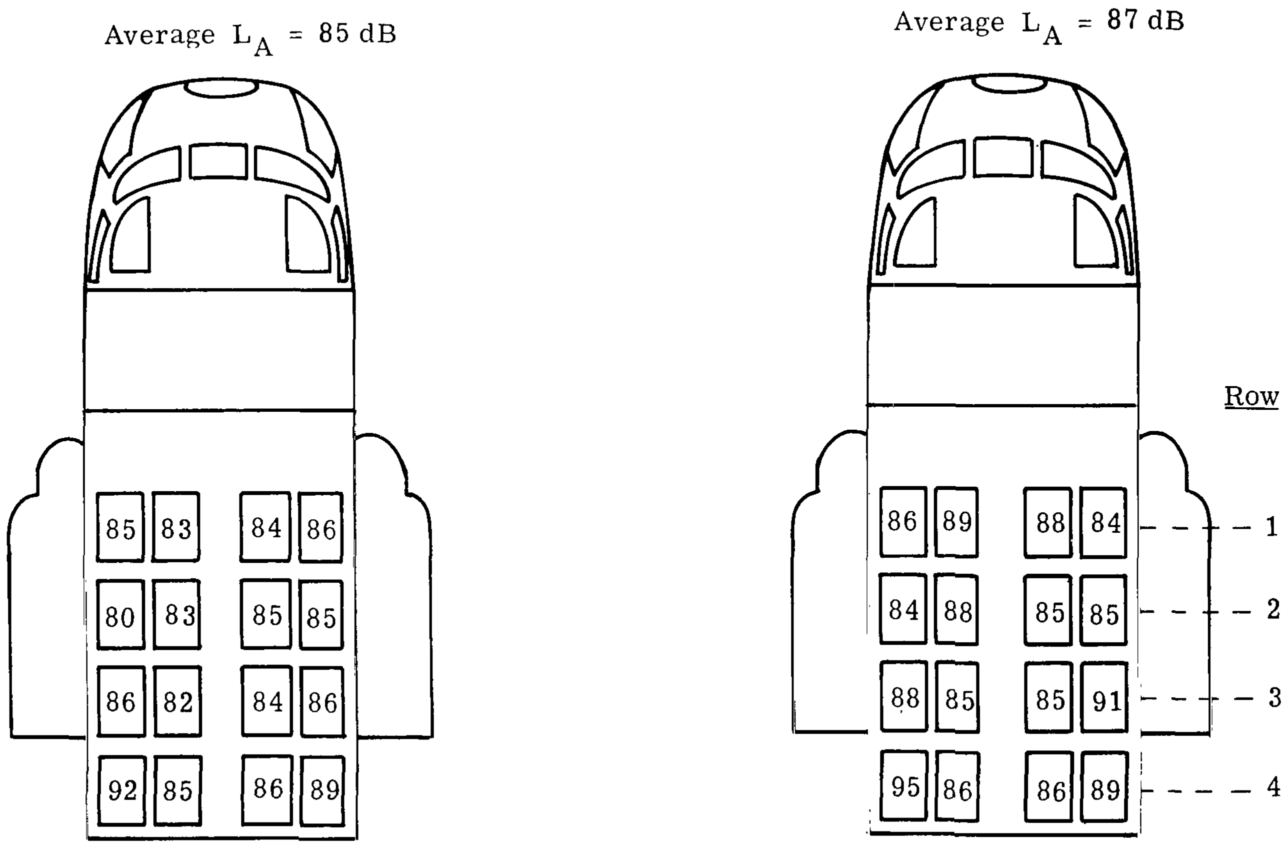
L-76-5862.1

Figure 7. - Cabin rear bulkhead.



L-76-5858.1

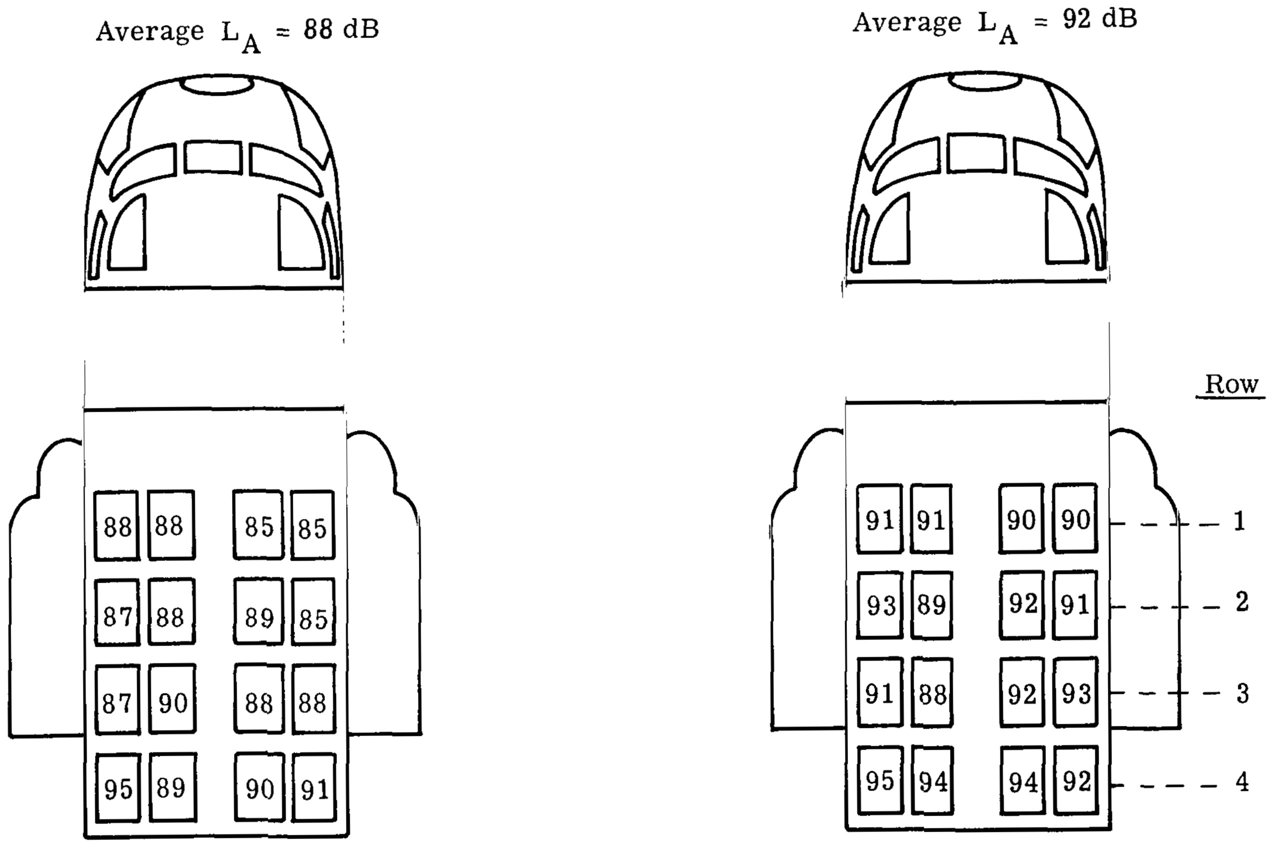
Figure 8.- Ducting framework through hole in rear bulkhead (outside passenger cabin).



(a) 148 km/hr cruise; both doors closed.

(b) 278 km/hr cruise; both doors closed.

Figure 9.- Variation of A-weighted interior noise with seat location.



(c) 148 km/hr cruise; both doors open.

(d) 278 km/hr cruise; both doors open.

Figure 9.- Concluded.

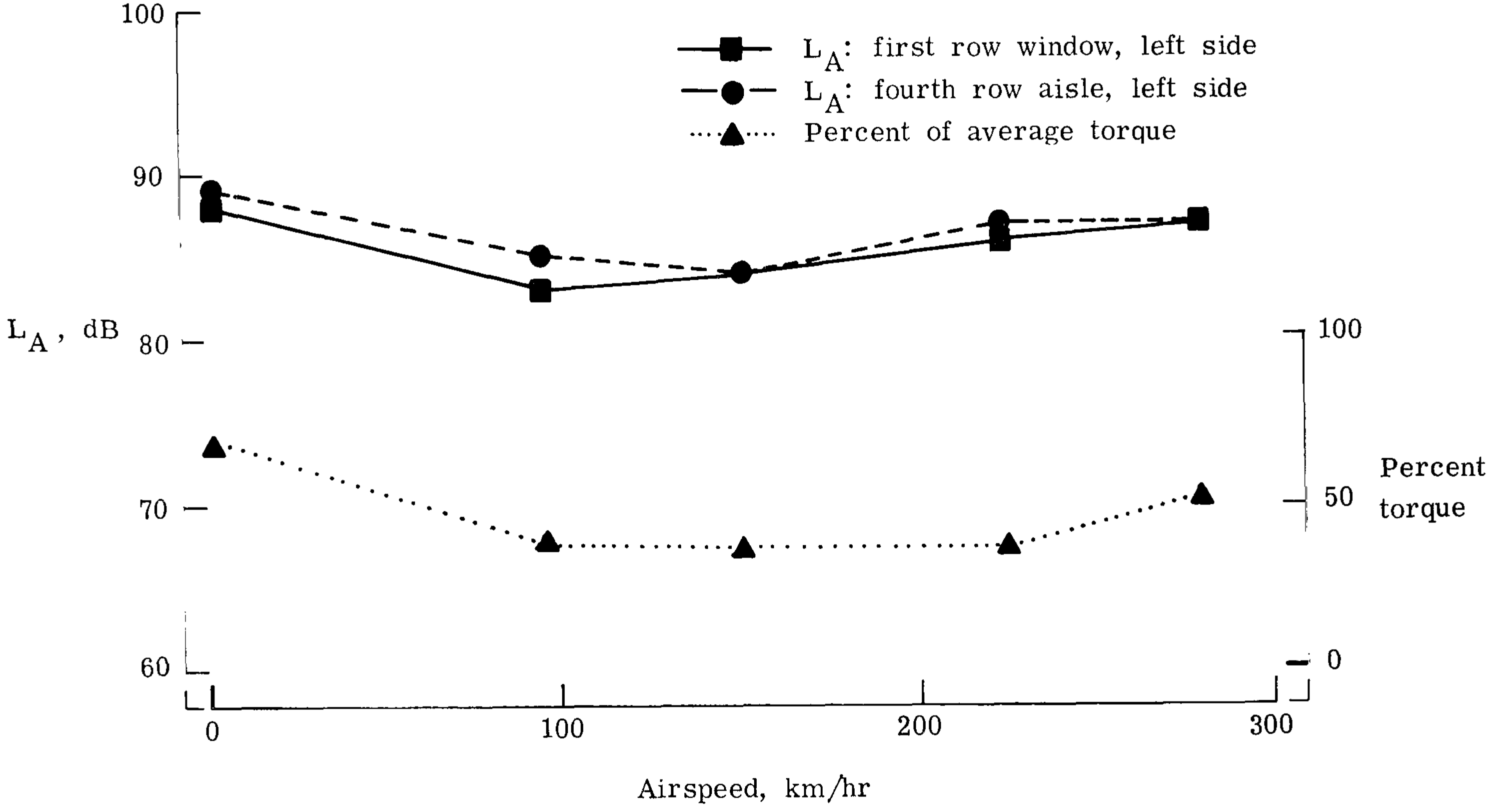


Figure 10.- Effect of airspeed on A-weighted interior noise level for two seat locations with both cabin doors closed.

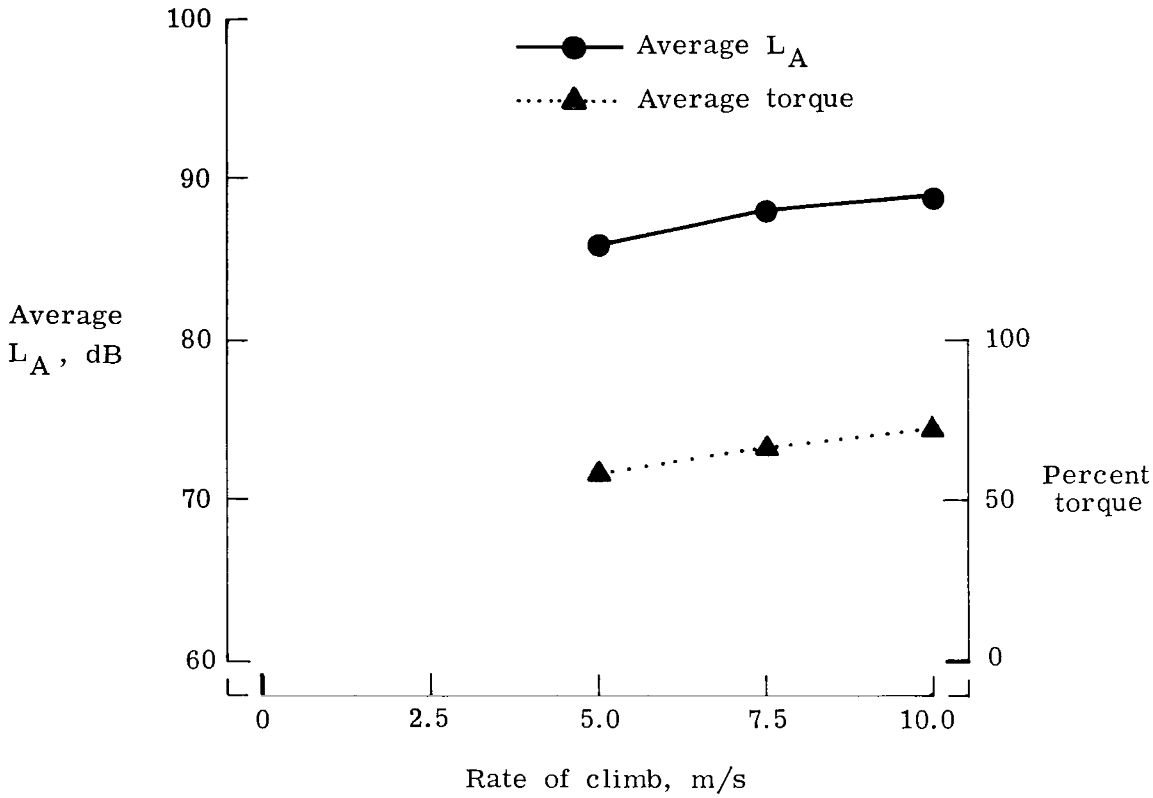


Figure 11.- Effect of rate of climb on average A-weighted interior noise level with both cabin doors closed.

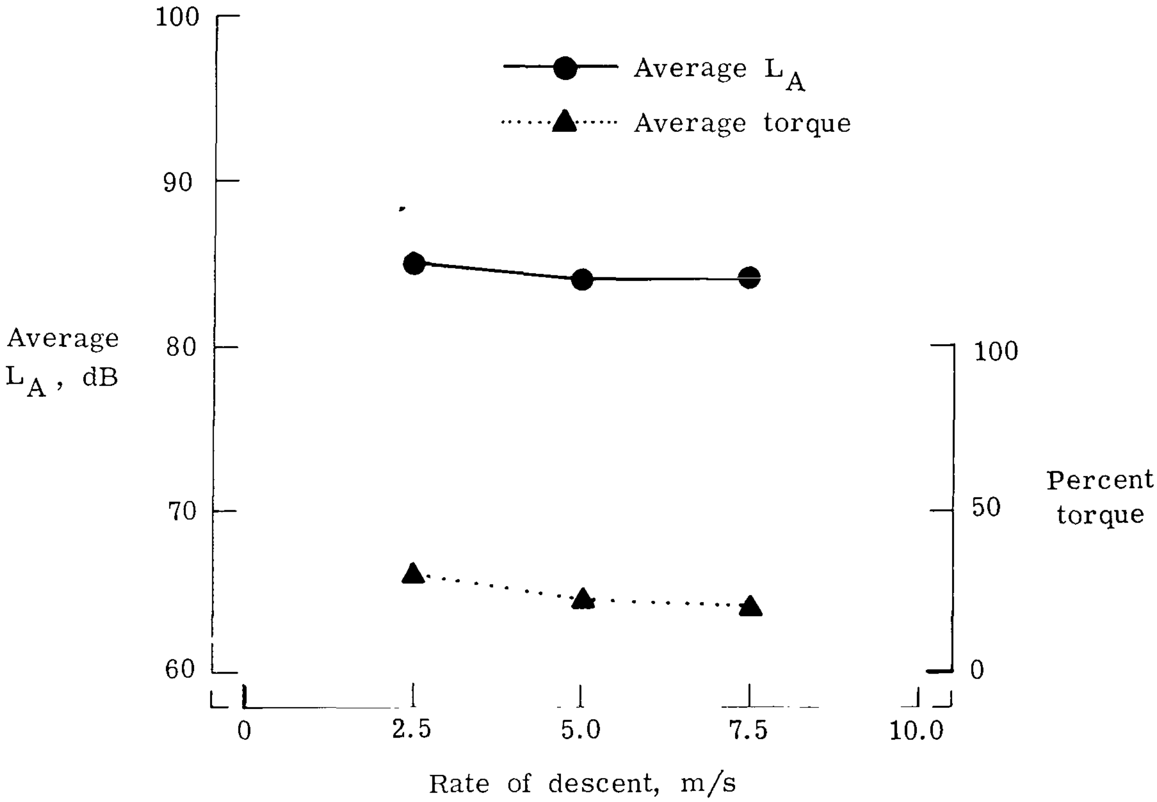
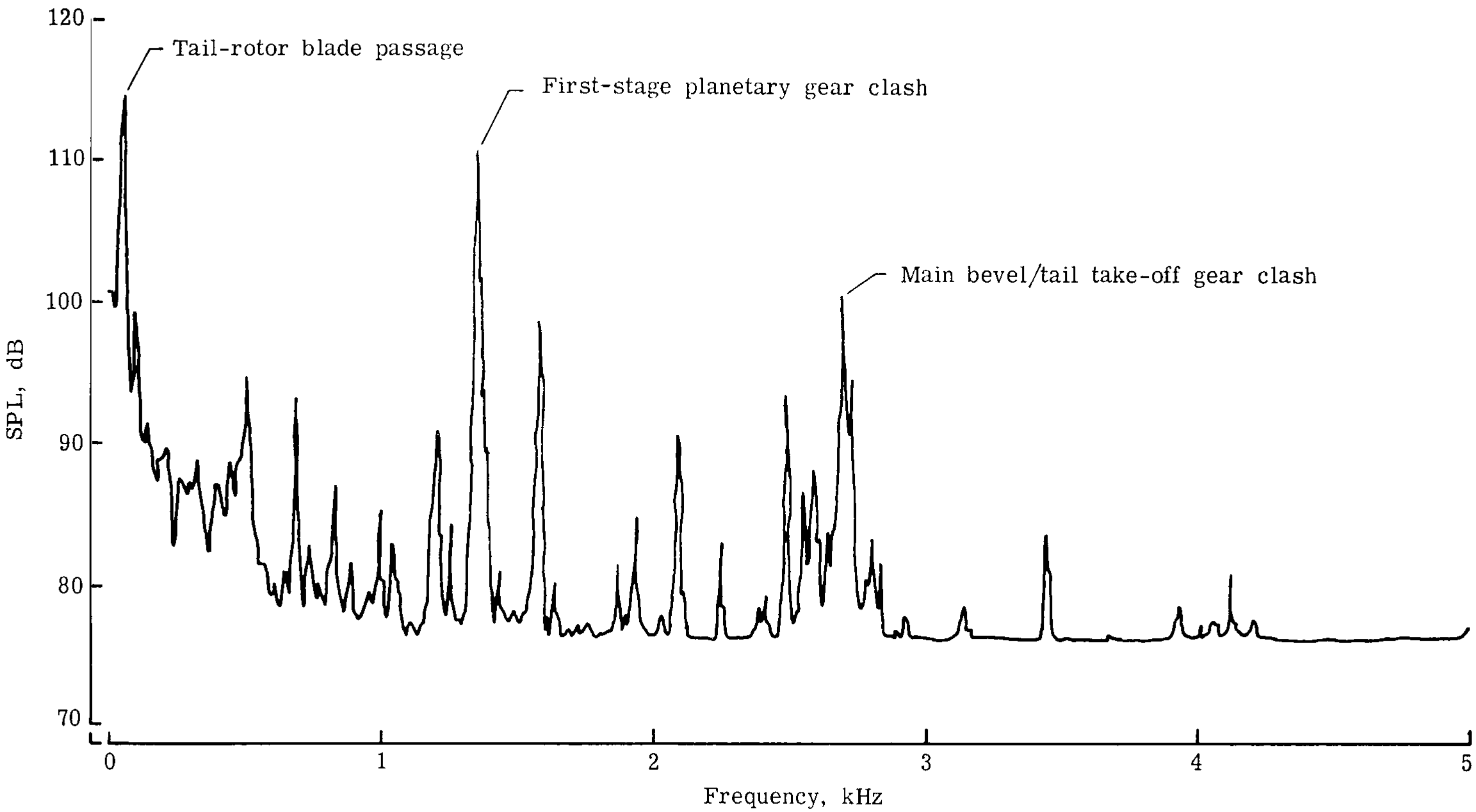
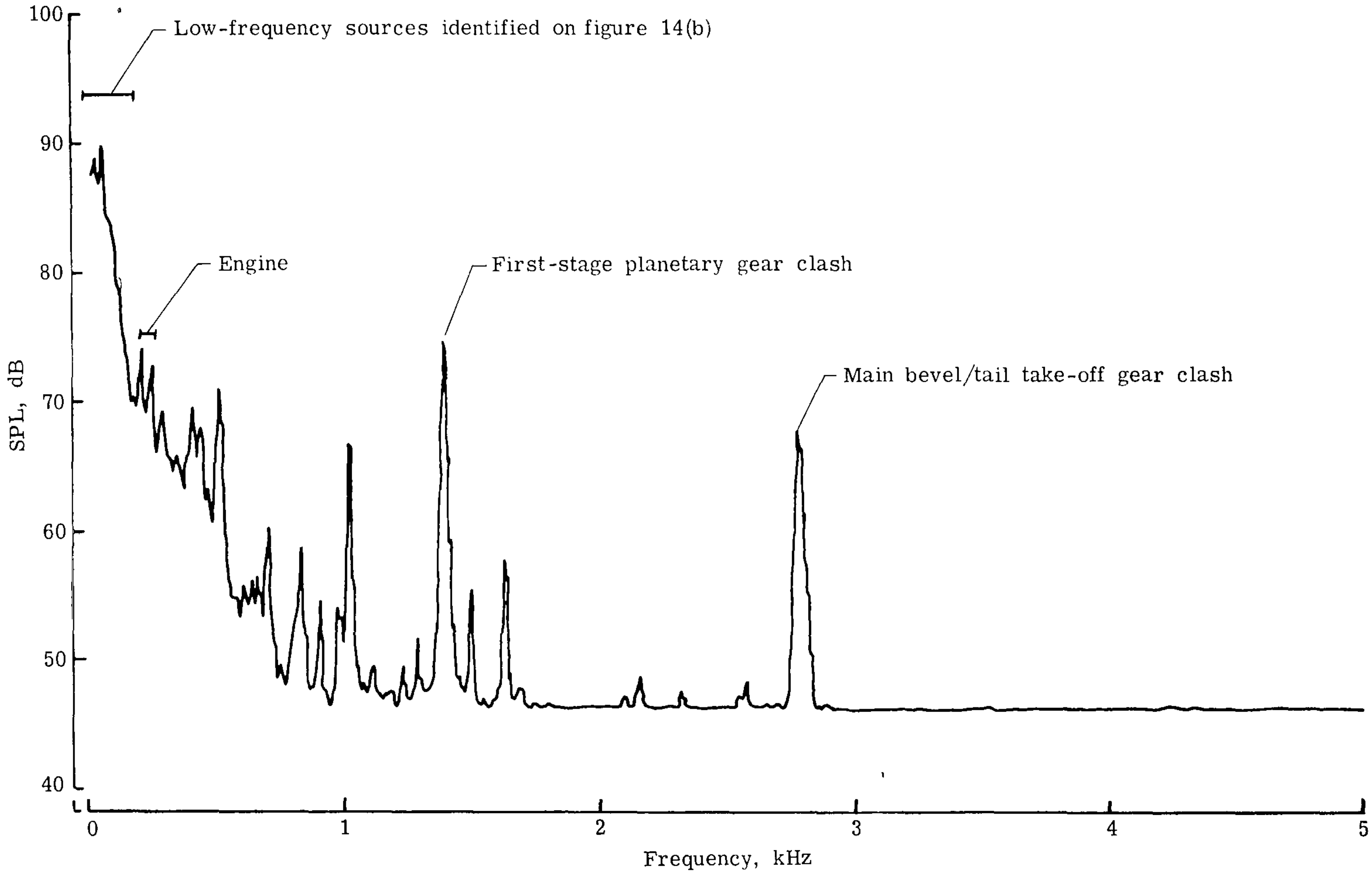


Figure 12.- Effect of rate of descent on average A-weighted interior noise level with both cabin doors closed.



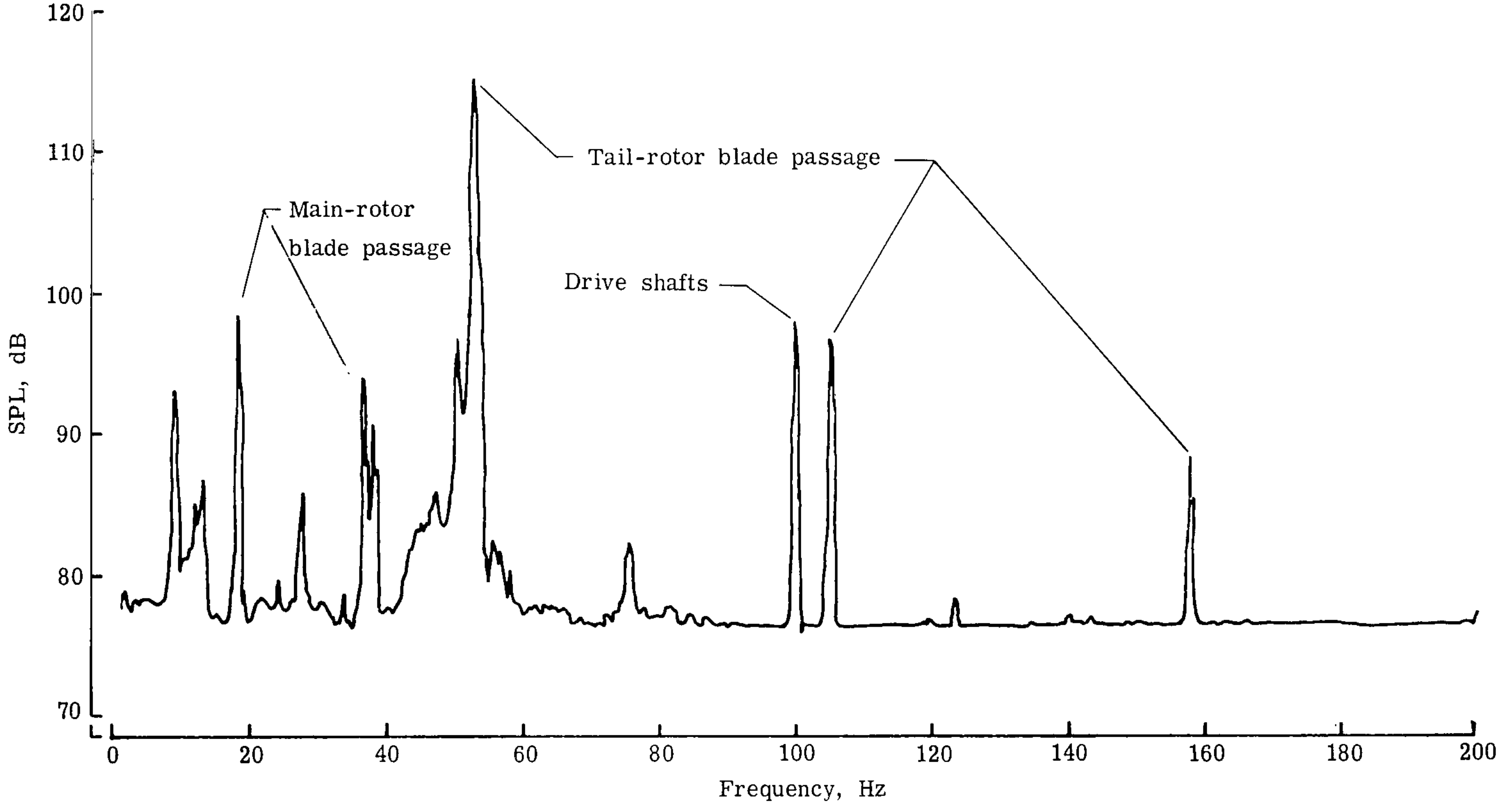
(a) Before acoustic treatment.

Figure 13.- Primary sources of interior noise in the CH-53 (241 km/hr cruise; second row aisle seat, left side). Bandwidth = 10 Hz.



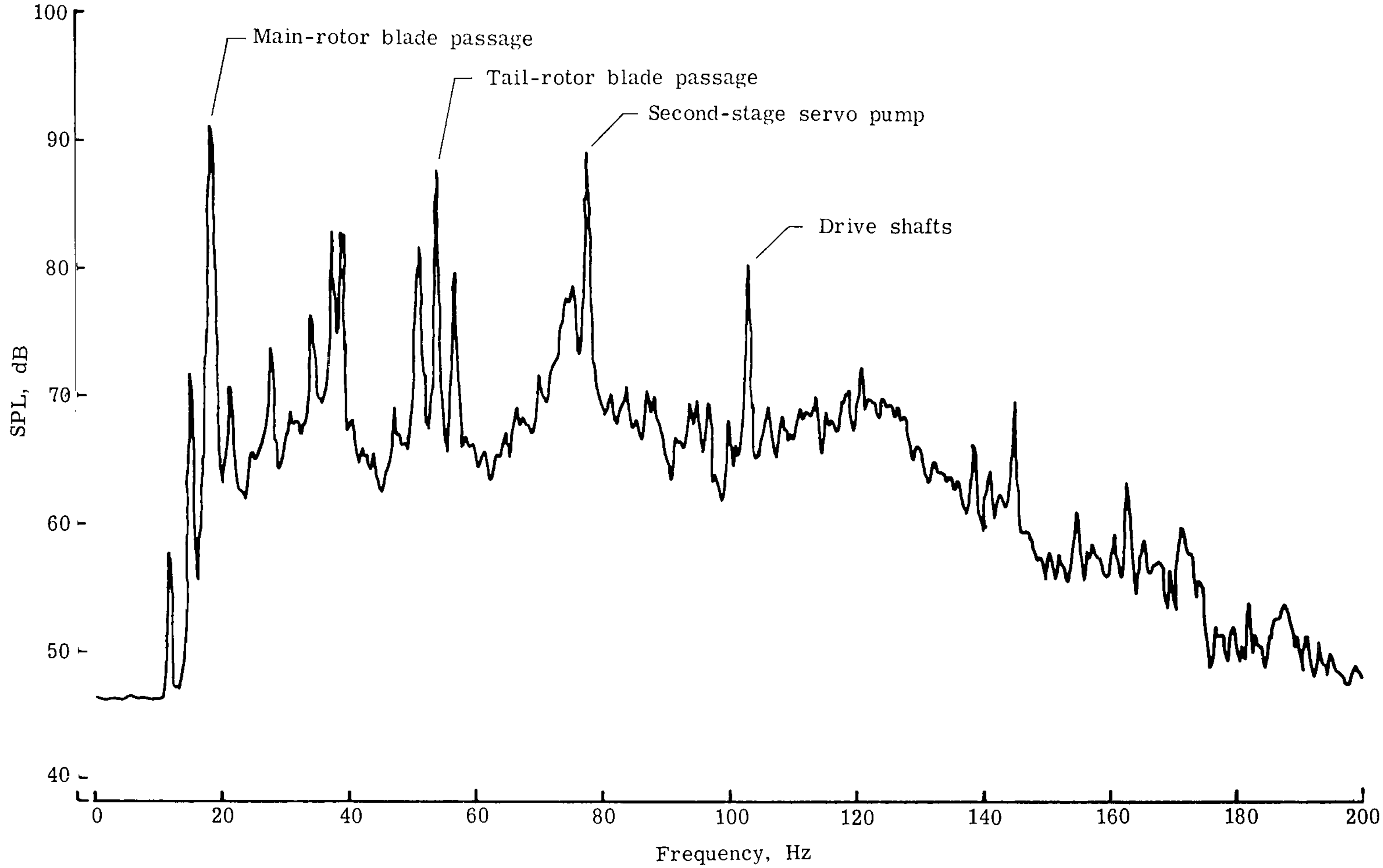
(b) After acoustic treatment (CHRA) with both cabin doors closed.

Figure 13. - Concluded.



(a) Before acoustic treatment.

Figure 14.- Sources of low-frequency interior noise in the CH-53 (241 km/hr cruise; second row aisle seat, left side). Bandwidth = 0.4 Hz.



(b) After acoustic treatment (CHRA) with both cabin doors closed.

Figure 14.- Concluded.

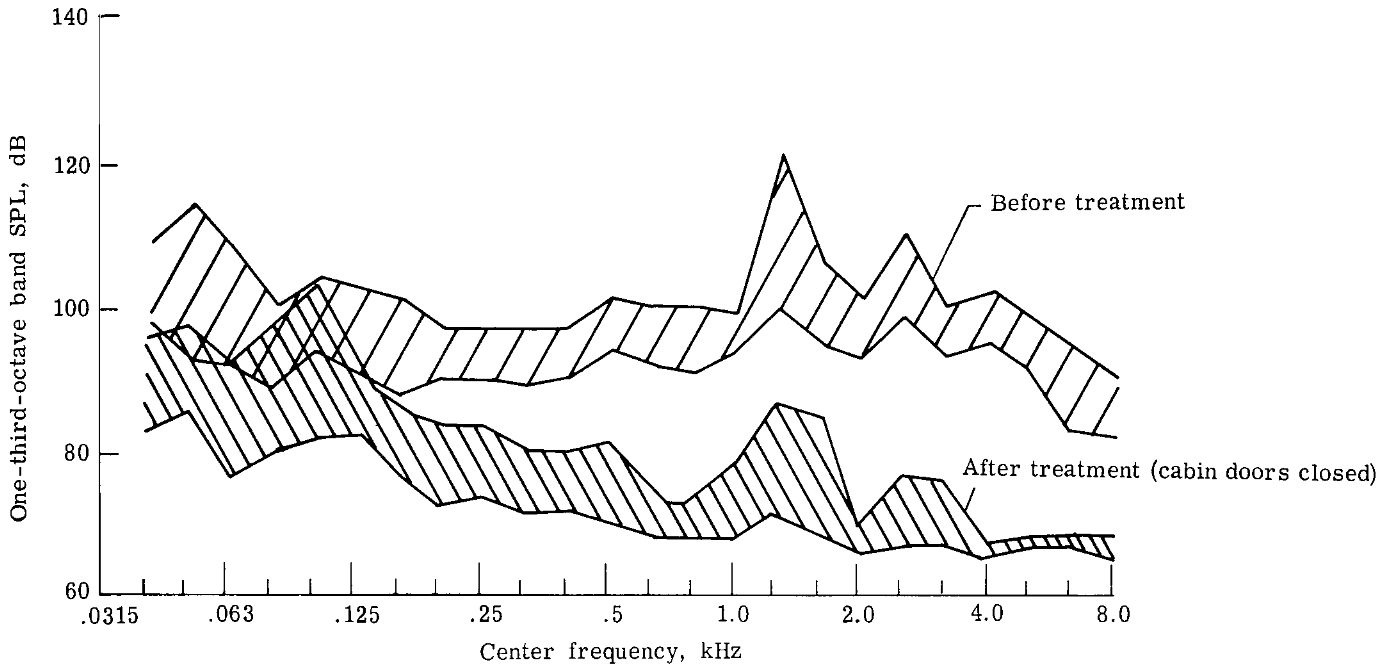


Figure 15.- Effects of acoustic treatment on interior noise in civil helicopter research aircraft for several flight conditions and microphone locations.

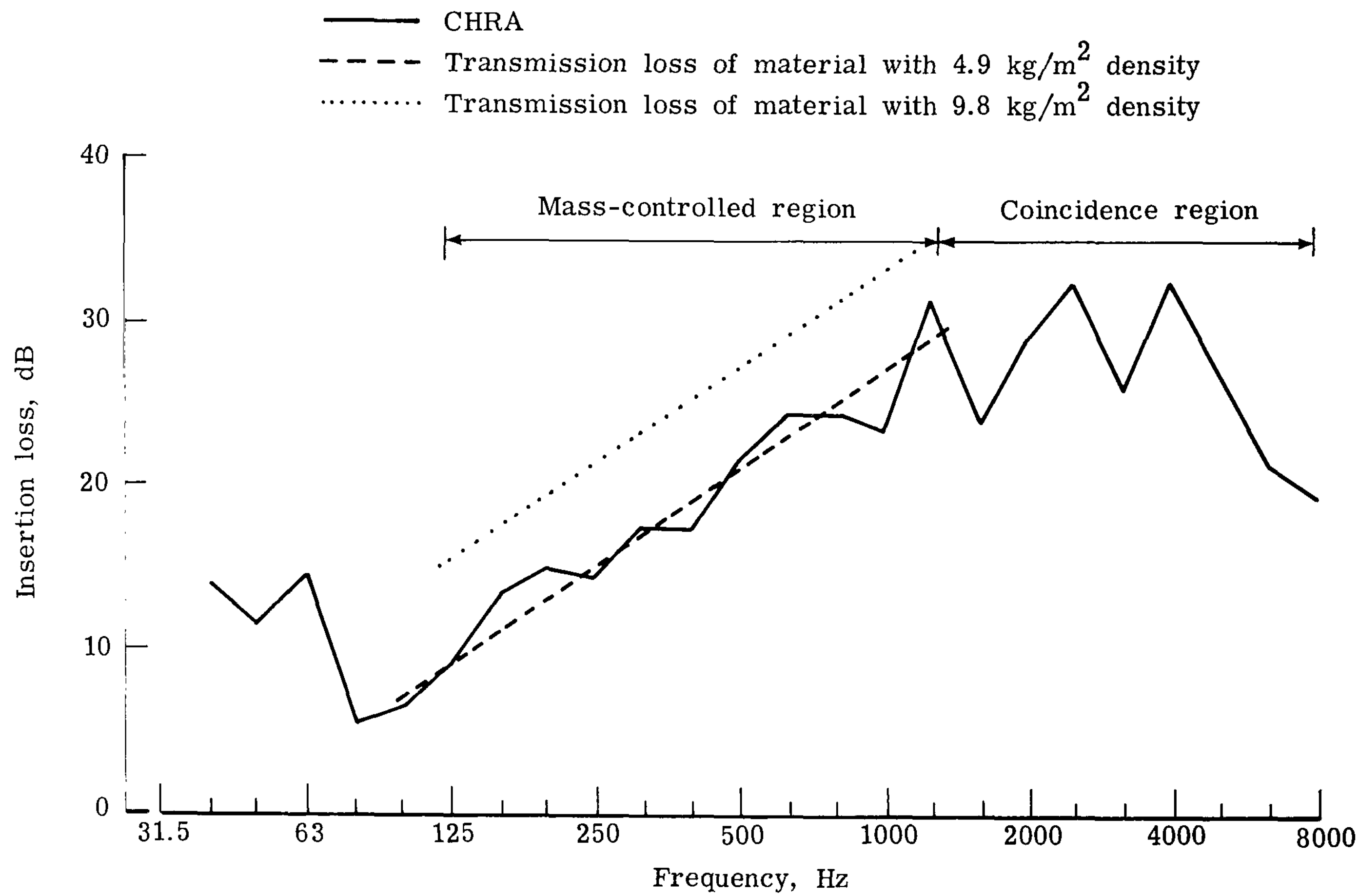


Figure 16. - Insertion loss of CHRA acoustic treatment compared with the transmission loss curves for two materials.

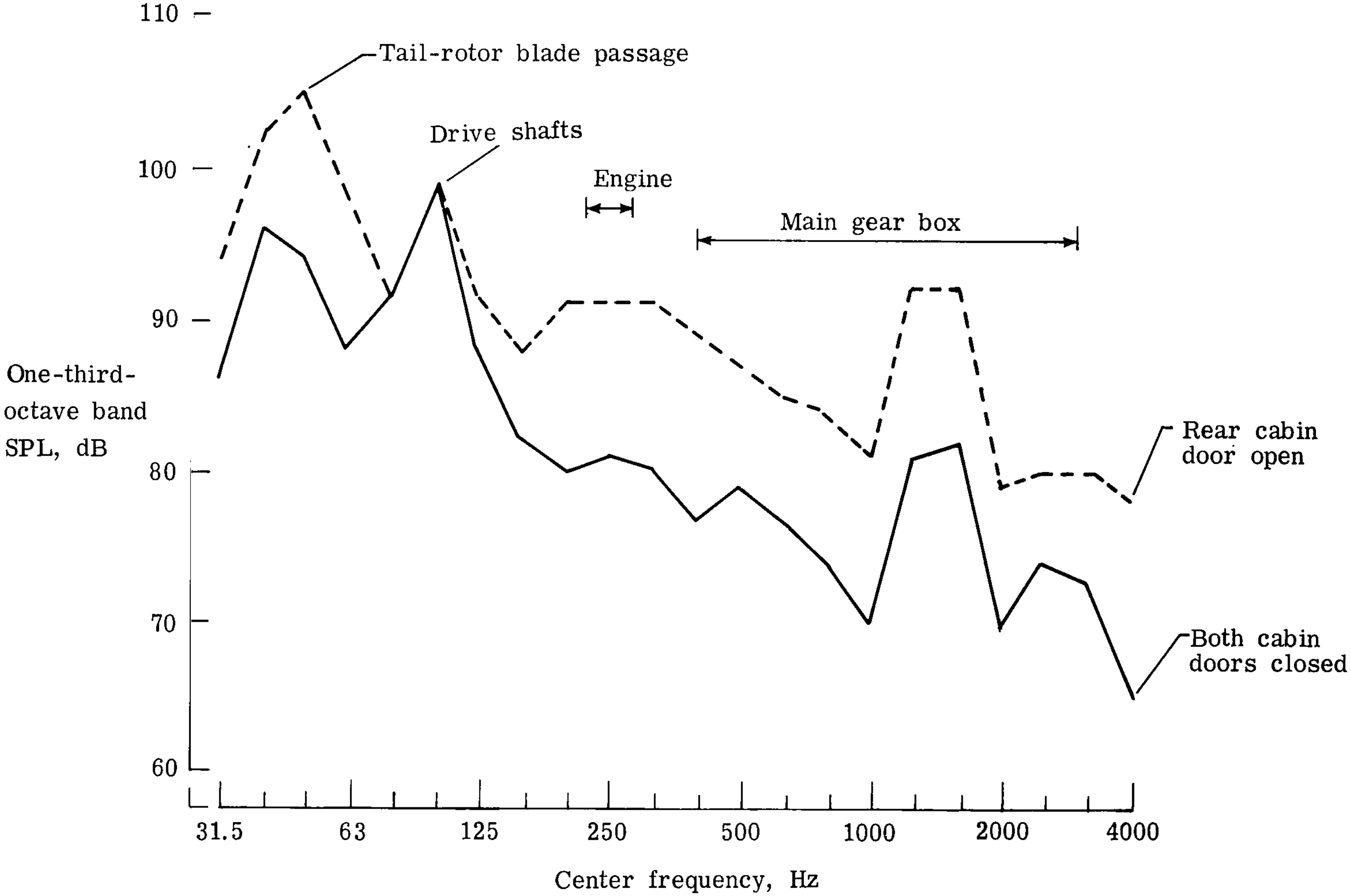


Figure 17.- Reduction of interior noise due to rear bulkhead (rear cabin door open; approximately 25-percent open area in the rear bulkhead).

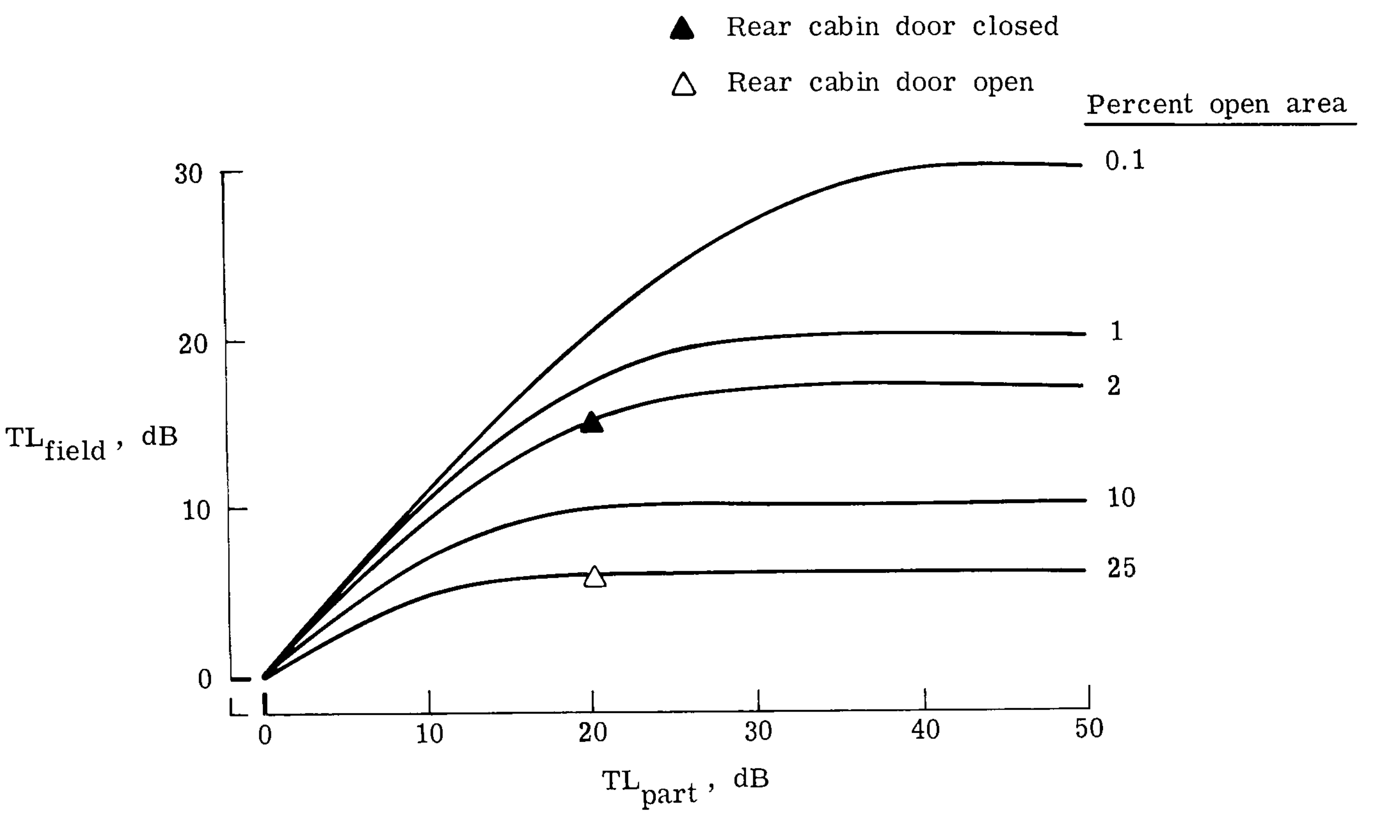


Figure 18.- Effect of acoustic leaks on transmission loss.

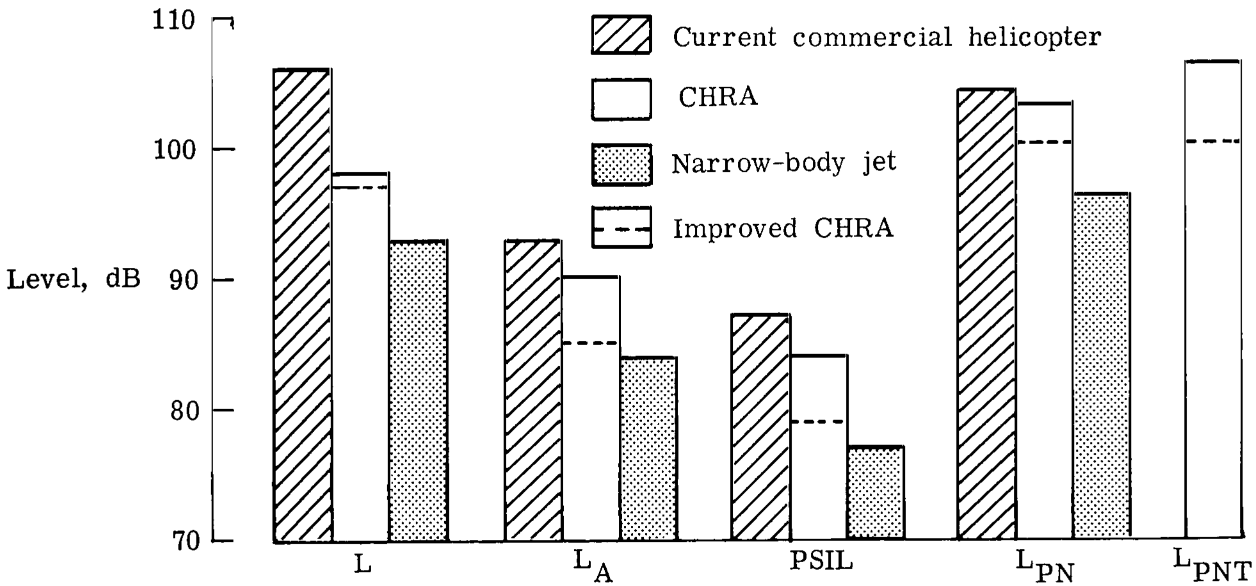


Figure 19.- Comparison of some typical noise rating scales for aircraft.

NASA-Langley, 1977 L-11349

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

SPECIAL FOURTH-CLASS RATE
BOOK

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
451

U.S.MAIL

448 C01 C1 U B 7706 S00903
DEPT OF THE AIR FORCE
AF WEAPONS LABORATORY
ATTN: TECHNICAL LIBRARY (SUL)
KIRTLAND AFB NM 87117

POSTMASTER: If Undeliverable (Section 158 Postal Manual) Do Not Return

"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