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CABIN NOISE REDUCTION - USE OF ISOLATED INNER CABINS

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1. INTRODUCTION

The introduction of civil helicopters and the increased use of military helicopters for troop transportation and submarine detection, etc. has led to a greater awareness of internal (cabin) noise. Whereas fixed wing civil aircraft internal noise levels have tended to decrease or remain constant over the years, helicopter cabin noise levels have increased. Typical soundproofed cabin noise levels are shown in Figure 1 and compared with measured data in commercial airliners. Standard helicopter soundproofing schemes of fibreglass bags give noise attenuations varying from 0dB at low frequencies to 15-20dB at high frequencies. With such treatments, however, the noise levels still lead to communication problems, masking of audio sonar information and crew fatigue and in some cases the levels exceed the Damage Risk Criteria. Figure 2 compares the helicopter noise levels with the 8 hr. per day 5 day per week DRC levels and the RAE specification for good face-to-face communication in passenger areas. The 8 hr. DRC levels refer to an exposure time related to a 5 day week but it is usual to apply the same values to any individual exposure time such as a single helicopter flight. The RAE specification has been taken from Ref. 1 which proposes maximum allowable noise levels for British military aircraft for consideration by the Joint Airworthiness Committee. The levels are based on Damage Risk Criteria and the need for acceptable intelligibility of speech. It is clear from Figures 1 and 2 that further reductions of 15-20dB throughout the spectrum are required to meet the good communication specification and be comparable with fixed wing civil aircraft.

This paper examines some of the methods used to soundproof helicopter cabins and in particular describes the 'isolated inner cabin' concept of soundproofing employed by WHL on the VIP Commando.

2. MILITARY SOUNDPROOFING SCHEMES

The soundproofing treatments on earlier helicopters consisted basically of fitting fibreglass bags or blankets between stringers and over frames in the roof and sidewalls. These were generally held in place by materials such as Velcro and hard trim panels. Control ducts, servicing points, doors and windows were not covered, however, thus reducing the soundproofing effectiveness. Later schemes considered a combination of transmission barriers and absorption materials, but with the new helicopters generating higher gearbox noise levels, the noise reductions required are well in excess of those obtained by conventional treatments.

3. NOISE SOURCES AND TRANSMISSION PATHS

The cabin noise is typically dominated by gearbox noise in the 300Hz-4kHz mid frequency range as shown in Figure 3 with the discrete frequency peaks at the gear meshing frequencies and harmonics and associated sidebands. Examples of these are the input bevel gears and the epicyclic gears with sidebands at intermediate frequencies. The low frequency noise (0-200Hz) is controlled by rotational noise from the main rotor and tail rotor at the blade passing frequencies and their harmonics while certain helicopters show high frequency engine noise discretes at 5kHz and above. Transmission barriers and absorption materials reduce the mid and high frequency noise but have very little effect at the lower frequencies for which vibration isolation techniques must be considered.

The noise reaching the cabin from the gearbox is a combination of the direct acoustic transmission of airborne sound through the structure and the noise radiated by the vibrating cabin surfaces. Recent airframe shake test measurements (Ref. 2) and flight tests have indicated that the major part of the noise is a result of high levels of structural radiation. In the shake tests a Lynx airframe (see Figure 4) was subjected to both single frequency and swept frequency inputs via a vibrator attached to one of the gearbox feet. The resulting airframe response was measured at a number of accelerometer positions on the airframe and microphones were positioned inside the cabin to monitor the noise environment. The excitation frequencies were chosen to be compatible with typical Lynx gearbox meshing frequencies in the range of 450Hz to 5kHz. As shown in Figure 5 high levels of vibration were measured on the airframe and at a number of accelerometer positions the vibration levels were of the same order as the input vibration levels at the gearbox feet. Also the shape of the vibration response curves of the airframe was similar to the shape of the noise response curves measured inside the cabin.

Since structural radiation contributes significantly to the cabin noise, future research on noise reduction is likely to be based on the use of honeycomb materials and constrained/unconstrained layer treatments in the airframe structure. Honeycomb materials have the advantages of high strength-to-weight ratio and are formed of lightweight honeycomb cores to which are bonded surface sheets of aluminium or fibreglass. With simple panel constructions the presence of acoustic bending waves give rise to a reduction in transmission loss at high frequencies but in sandwich constructions the waves are propagated at higher velocities and therefore have less effect on the transmission loss. Damping materials reduce noise by converting vibrational energy into heat and the constrained layer treatments are constructed of viscoelastic materials which absorb energy by shear motion. Simple damping factor measurements have recently been conducted on small samples of bonded constrained layer materials and some of these materials are under active consideration for future helicopters. There are, however, production problems involved with such schemes, e.g. the necessity to preform the constrained layer material and the method of fixing it to the airframe, and consideration must be given to the stress requirements and the effect of temperature variations. In the meantime the problem of reducing both acoustic transmission and structural radiation has been overcome to a certain extent by the use of an isolated inner cabin. From the multi role aspect and other considerations, this approach may prove to be the most cost effective solution.

4. VIP SOUNDPROOFING TREATMENT

An inner cabin concept has been installed on the VIP Commando helicopter (a Sea King variant) and consists essentially of a vibrationally isolated transmission barrier of high mass lined with absorption material. A diagrammatic representation is given in Figure 6. For servicing purposes there was a requirement that the soundproofing treatment should be easily and quickly detachable and thus individual soundproofing panels of approximate size 40 in. x 40 in. were designed. Each panel consisted of 22 gauge aluminium sheet coated on its outside surface with 1/16" thick Lord Corporation LD400 damping material and on its inside surface with 2" thick Dunlop DP103 acoustic foam and a perforated hard trim of 0.06" thick Fromoplas. The Fromoplas was perforated by 15 to 20% and covered with a woven fibreglass cloth backed by ¼" light foam to facilitate quilting. The transmission barrier reduces the noise passing through the structure while the foam on the inside prevents the build up of reverberant sound inside the cabin. Ideally the foam should not be covered but since a hard trim surface was required the Fromoplas was perforated for the most effective use of the foam absorbing properties.

The panels were attached to a metal frame by quick release fasteners and the frame was vibrationally isolated from a flange attached to the aircraft skin (see Figure 7). The frame and flange ran the full length of the VIP compartment with rubber isolation mounts attached at intervals of about 40 in. There was also a similar frame structure across the cabin at intervals of about 40 in. to join each roof panel to the next. The method of mounting was very important as it was essential to ensure that the high vibration levels on the airframe were not transmitted to the inner cabin. In this respect the Lord Corporation damping material was added to reduce local panel vibration as well as to increase the mass of the transmission barrier. The space between the panels and the aircraft skin was filled with fibreglass bags. Each panel had a total surface density of about 1.3lb/ft^2 and a weight of 20 lb.

Similar soundproofing panels were attached to the sidewalls while the single glazed windows were surrounded by a fibreglass moulding with foam backing. The VIP compartment was enclosed by soundproofed forward and rear bulkheads to give an interior layout as shown in Figure 8. Since the bulkheads (particularly the forward one) were required to give similar noise attenuations to the roof and side panels, they were constructed of 3/8" thick mallite board filled with a balsa core of density 6lb/ft^3 and lined with the LD400 damping material and padded leather. Particular attention was paid to sealing the roof and sidewall soundproofing panels to the bulkheads. Figures 9 and 10 show the mounting arrangement and roof panels respectively being installed in the aircraft.

Tests were required on the foam to determine its fire resistance, water absorption and oil contamination properties. This was necessary since acoustic foams had not previously been used in helicopters. No fire resistance tests were conducted by WHL but according to the manufacturers the Dunlop DP103 foam is fire retardent and meets the CAA8 flame resistance specification. Tests by the WHL Materials Laboratory showed that the plain (untreated) foam absorbed large amounts of water in very high humidity conditions (up to 3 times its own weight), but when the foams were treated with a 0.005" PVC coating, they absorbed only a small amount of water (20% increase in weight). In fact the existing fibreglass bag soundproofing treatment absorbed more water than the painted foams. The treated foams, however, took longer to recover to their normal weight when returned to a normal room temperature environment. Both the plain foams and the painted foams were found to be porous to hydraulic oil, engine and transmission oil and AVTUR fuel. Since the treated foams showed improvements in water absorption properties and fire resistance and since it was not clear at the time whether non treated foams would be permitted in helicopters from the toxic fumes point of view, it was decided to spray all the surfaces with the PVC coating. Providing that the correct thickness of the coating was not exceeded the acoustic properties of the foams were not changed to any great extent.

The air conditioning system consisted of a controllable air supply entering the VIP compartment through ducting in the lounge roof with adjustable outlets above each seating position. The air was extracted from the lounge through ducts on the port and starboard side of the cabin at floor level. It was necessary to ensure that the air conditioning system did not contribute to the cabin noise levels and thus noise checks were made on the air conditioning pack, mounted under floor level in the forward stewards bay, and associated ducting. Resulting treatment consisted of fitting a silencer to the pack outlet pipe and lining the ducts with foam.

It was necessary to support the air conditioning system and lighting arrangement from the soundproofing scheme as shown in Figure 7. Unfortunately this meant that the top quarter soundproofing panel was effectively enclosed on two sides by aluminium sheet and the 2" layer of foam was replaced by $1\frac{1}{2}$" of foam inside the soundproofing panel and $\frac{1}{2}$" of foam on the other side of the air conditioning duct, thus reducing the effectiveness of the foam in this area.

In addition to the soundproofing panels, the absorption properties of the cabin were increased by the carpet, seats and curtain materials. A photograph of the finished scheme is shown in Figure 11. The VIP compartment dimensions were approximately 13 ft, long x 7 ft. wide x 5 ft. high with a volume of 570ft^3 and an effective surface area (roof, sidewalls, forward and rear bulkheads) of about 300ft^2. The total weight of soundproofing was about 500 lb. but this included the support structures and the soundproofing in the forward and rear stewards bays as well.

5. SOUNDPROOFING ATTENUATIONS

A WHL survey of soundproofing schemes (Ref. 3) has shown that conventional treatments of fibreglass bags and blankets give similar attenuations for all helicopters. The attenuation increases with increasing frequency varying from 0dB at the low frequencies to 15-20dB at high frequencies. Amplification of the noise often occurs in the 31.5Hz-125Hz octave bands and at the high frequency end there is usually a fall off in attenuation which is thought to be associated with flanking transmission losses of the soundproofing treatment and the fact that parts of the cabin are not treated at all.

The attenuations obtained with the VIP treatment are compared with those of conventional treatments on the Commando helicopter in Figure 12. It is clear that the VIP soundproofing scheme gives a considerable improvement in noise attenuation throughout the frequency range. The transmission barrier and absorption materials obviously play an important part in reducing the mid and high frequency noise but it is pleasing to find that the vibration isolation techniques have reduced the low frequency noise by 5-10dB. Apart from the 31.5Hz, 63Hz and 500Hz octave bands, the VIP treatment has given an additional 10dB reduction to produce a total attenuation varying from 5-10dB at low frequencies rising to 25-30dB at high frequencies. The subjective impressions of the noise environment were far superior to those of conventionally soundproofed Sea Kings and Commandos and benefits were also noticed in face-to-face communication and intercom system interference. These observations are supported by the measured noise levels since the additional attenuations obtained in the 2kHz-8kHz frequency bands will assist the improvement in communications.

The reductions obtained in the 500Hz and 1kHz octave bands, however, were not as great as expected. This was considered to be due to the main gearbox noise, at the harmonics of the meshing frequency of the epicyclic gears, being transmitted down the sides of the airframe (between the skin and transmission barrier) into the cabin via the gaps between the window area and the soundproofing. This was confirmed to some extent by the fact that the noise levels inside the cabin increased considerably as one moved towards the windows but remained approximately constant between the centre of the cabin and the roof. These results suggested that the soundproofing scheme was acting as an effective transmission barrier in the roof area but the window areas were acting as holes in the soundproofing and radiating noise into the cabin. The 2.5mm perspex windows represented about 7% of the total cabin surface area and thus on future VIP Commandos improvements could be made with double glazing with a suggested arrangement of 4mm perspex + 100mm air gap + 2mm perspex. The two panes of perspex would be of differing masses to eliminate coincidence effects and a good seal would be required where the soundproofing meets the window frame. This would be complicated by the requirement that the cabin windows should also be escape hatches with both panes of the double glazing joined together at the window edges so that they open together.

6. CONCLUDING REMARKS

The window arrangement was just one of a number of weak points in the soundproofing scheme caused by compromises at the design/engineering stages to allow for weight restrictions, cabin size requirements, etc. Other weak points in the soundproofing schemes occurred where the individual soundproofing panels were fixed to the metal frames (see Figure 7). Between the edges of the top quarter panel and the roof panel there was a gap of about 2 in. which from the acoustic point of view was covered only by the metal frame. Thus in addition to there being only very limited soundproofing in this region, any vibrations from the structure which were not effectively isolated by the vibration mounts would be transmitted directly to the inner surfaces of the cabin and hence radiate noise. Since the support frames ran the full length of the cabin on each side and also across the cabin at regular intervals, the total exposed radiation surface was relatively large and a loss in effectiveness of the soundproofing at mid and high frequencies could be expected.

High frequency noise attenuation is usually controlled by the amount of absorption material present in the cabin. The absorption is provided mainly by the foam materials but, in order to satisfy the requirements for a hard trim, it was necessary to cover the foam with sheets of perforated Fromoplas and a cloth trim. Ideally the foam should be covered with a porous material which is hard wearing and resistant to stains, etc. At the same time, however, the foam should be rigid enough so as not to require additional support.

With the present VIP treatment the helicopter cabin noise levels are at the upper boundary of the fixed wing aircraft cabin noise levels (see Figures 1 and 12). If particular attention is paid to the weak areas in the soundproofing referred to above then another 5dB attenuation can probably be obtained in the mid and high frequency regions to give the helicopter comparable noise levels to the fixed wing aircraft.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

1. H.C. Attwood. On the Specification of Maximum Noise Levels in Aircraft. RAE Technical Report 72089. June 1972.

2. C.R. Wills. Vibration Transmission Paths. WHL Research Paper 523. June 1976. (Limited Circulation Only).

3. J.S. Pollard. A Preliminary Study of Helicopter Internal (Cabin) Noise. WHL Research Paper 514. March 1976.

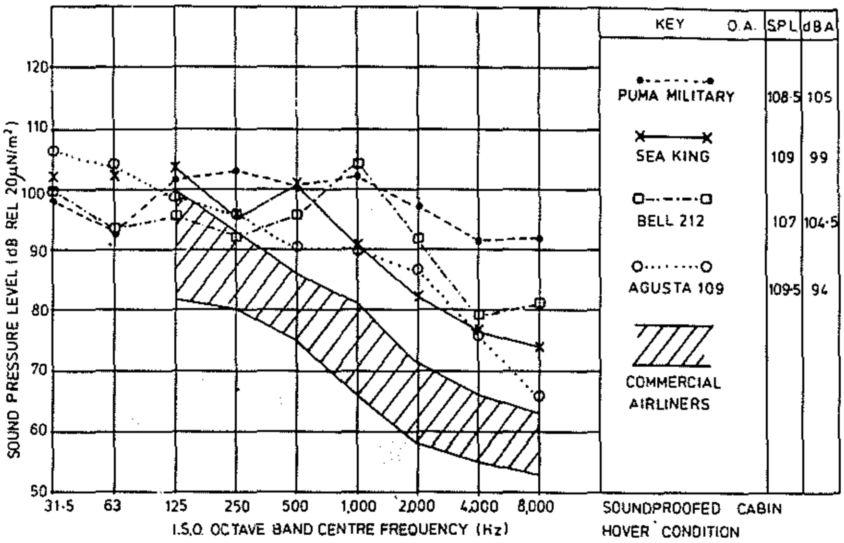


FIG. 1. COMPARISON OF HELICOPTER CABIN NOISE LEVELS WITH LEVELS IN COMMERCIAL AIRLINERS

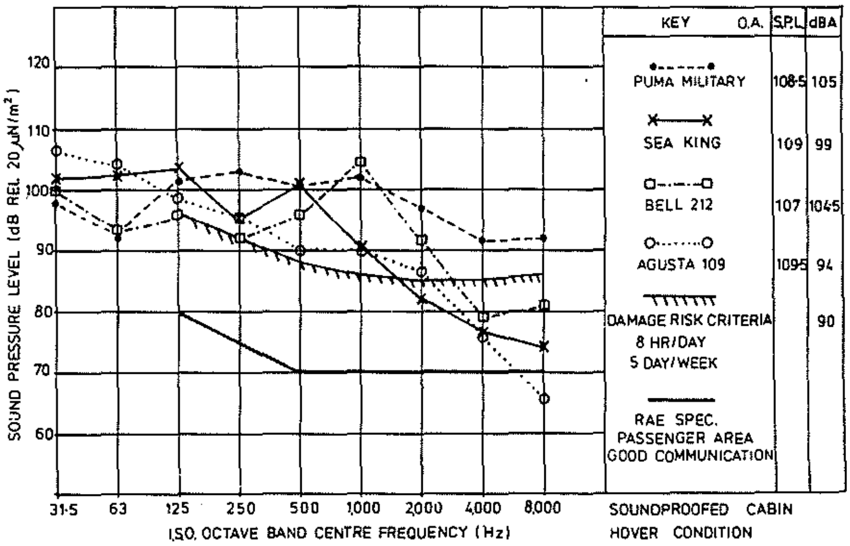


FIG. 2. COMPARISON OF HELICOPTER CABIN NOISE LEVELS WITH DAMAGE RISK CRITERIA AND R.A.E. SPECIFICATION

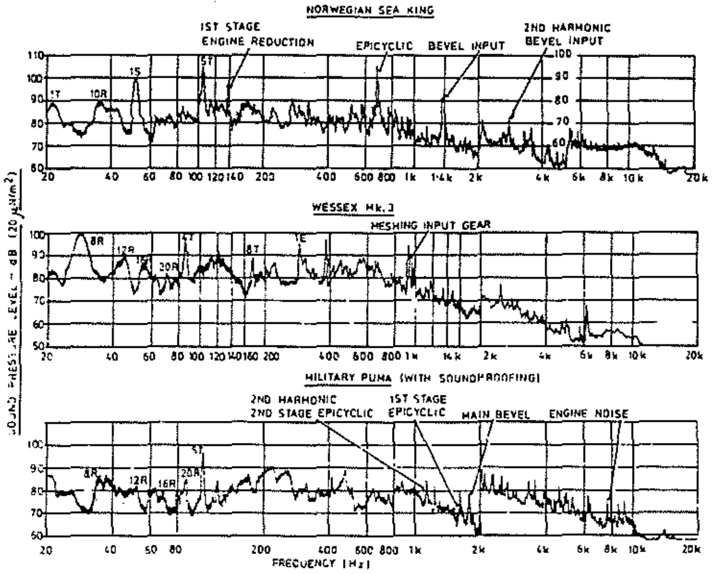


FIG. 3. NARROW BAND ANALYSIS OF CABIN NOISE. HOVER CONDITIONS. NO SOUNDPROOFING

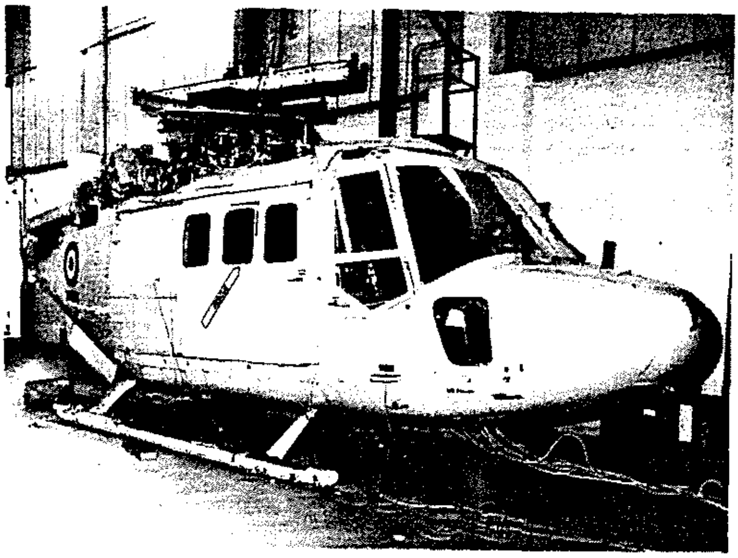


FIG. 4. TEST SPECIMEN - LYNX SHAKE TEST

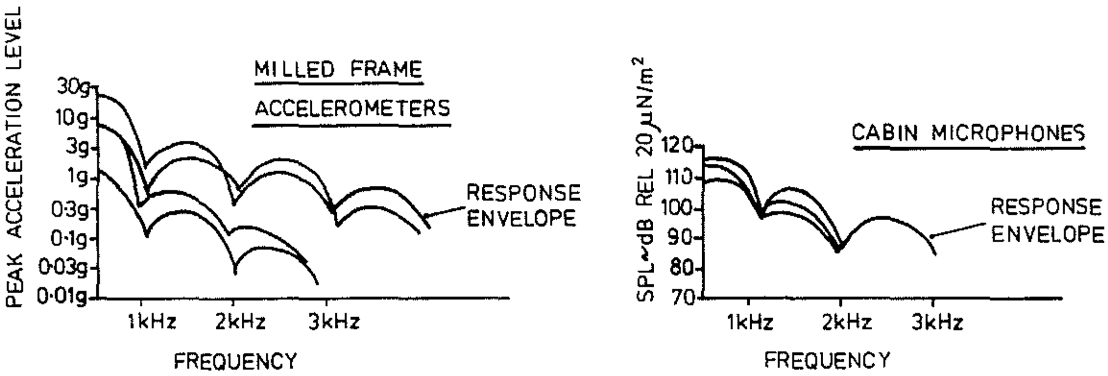
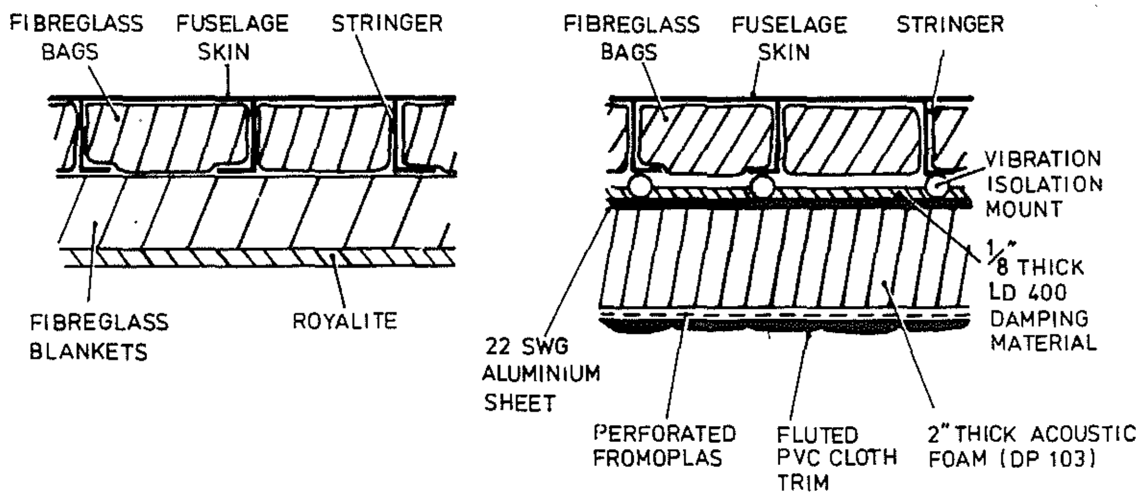


FIG. 5. NOISE AND VIBRATION RESPONSE TO SWEPT FREQUENCY VIBRATION INPUT. LYNX SHAKE TEST



MILITARY SOUNDPROOFING (CONVENTIONAL)

VIP SOUNDPROOFING (ISOLATED INNER CABIN)

FIG. 6. DIAGRAMMATIC REPRESENTATIONS OF SOUNDPROOFING SCHEMES

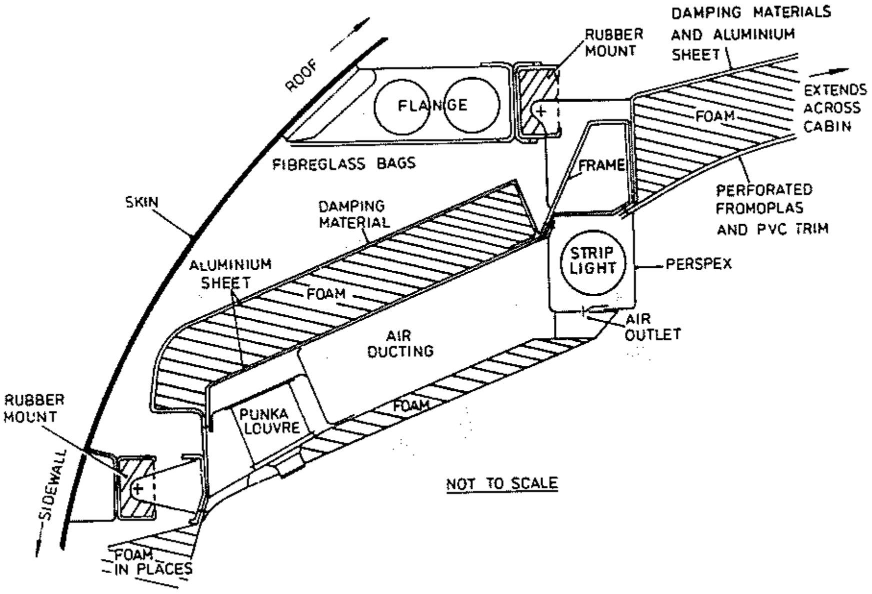


FIG. 7. MOUNTING ARRANGEMENT OF SOUNDPROOFING PANELS

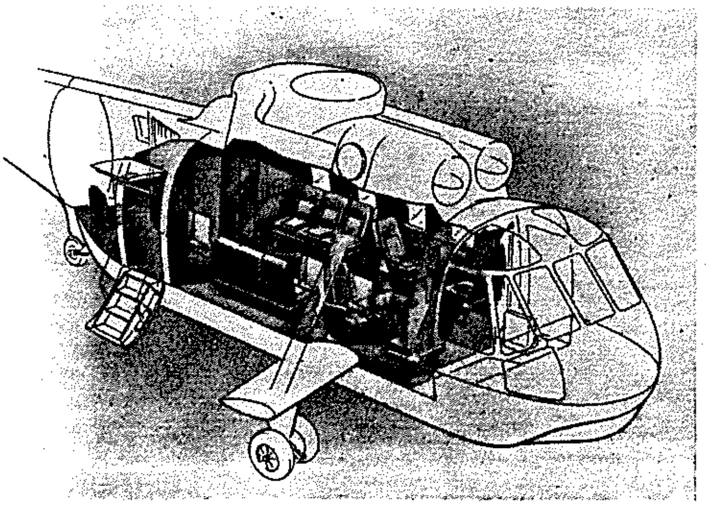


FIG. 8. INTERIOR LAYOUT OF VIP COMMANDO

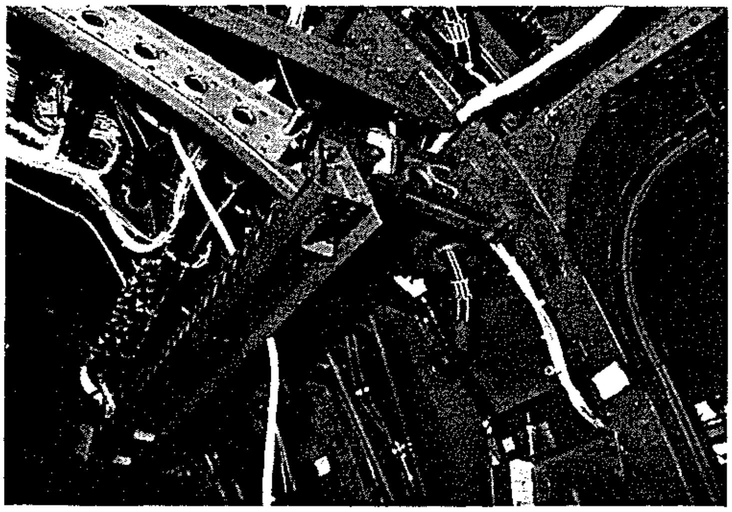


FIG. 9. MOUNTING ARRANGEMENT OF VIBRATION ISOLATORS

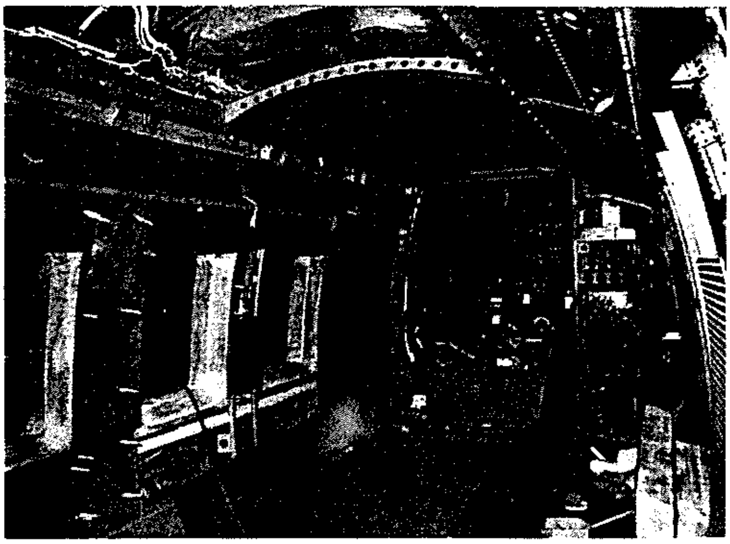


FIG. 10. INSTALLATION OF ROOF SOUNDPROOFING PANELS

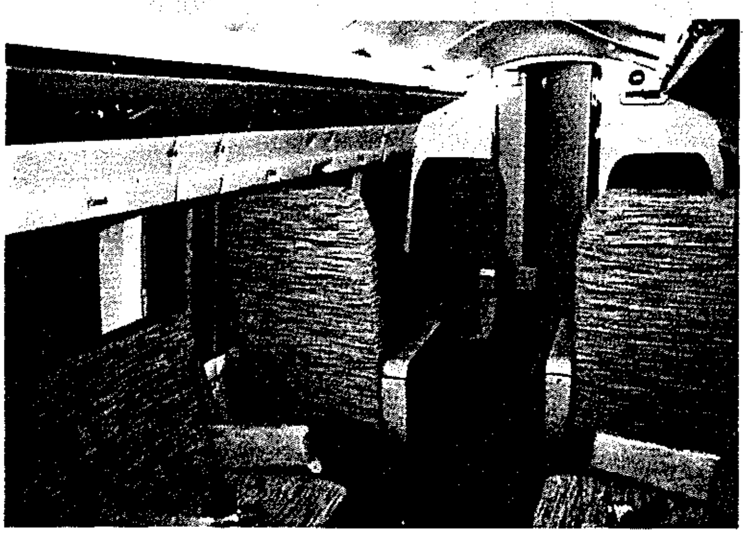


FIG. 11. FINISHED VIP COMMANDO SOUNDPROOFING TREATMENT

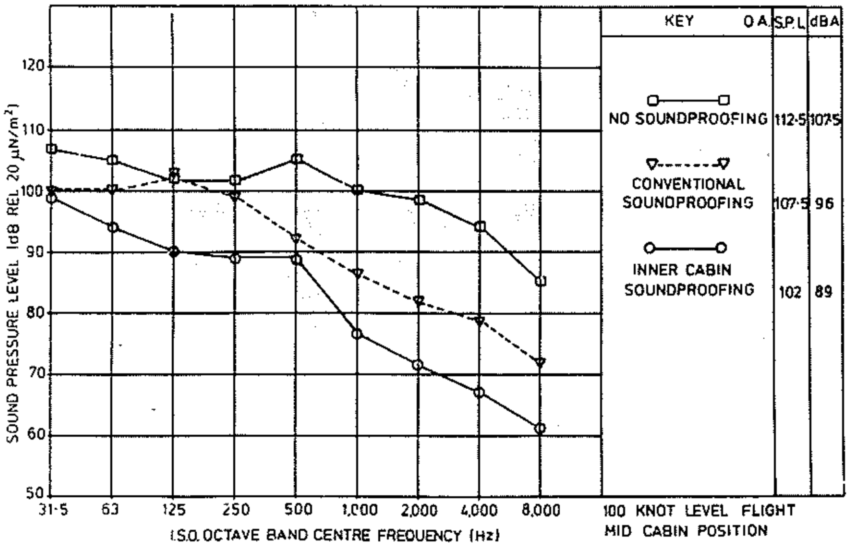


FIG. 12. EFFECTS OF SOUNDPROOFING ON CABIN NOISE LEVELS OF COMMANDO HELICOPTER