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THE DOMINANT ACOUSTIC RADIATION SURFACES OF A HELICOPTER CABIN

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SUMMARY

Internal noise in helicopters is often reduced by the use of acoustic transmission barriers attached to the inside surfaces. In order to successfully optimise such soundproofing schemes it is necessary to know which cabin surfaces are radiating noise and by how much. A simple experimental technique can be used to gather such information. This technique, which involves measurements being taken with all the surfaces bar the one under investigation being acoustically blanked off, was used on a Lynx helicopter. The flight results so obtained are presented in this paper together with other relevant results from ground experiments.

The rear half of the roof, the sides and milled frames, and the rear bulkhead are all important radiating surfaces; whereas the forward half of the roof and the doors are shown to be insignificant radiators of noise. A further conclusion is that at low frequencies it may not be possible to ignore the sound radiated by the cabin floor; the results show that at 450 Hz the floor radiates nearly as much noise as the roof.

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1 INTRODUCTION

Internal noise in helicopters is often reduced by the use of acoustic transmission barriers attached to the inside surfaces. This treatment is generally applied in a uniform manner over the walls and roof of the cabin. The authors[1] have already described a simple experimental technique for detecting the dominant acoustic radiation surfaces of a helicopter structure. This technique, which involves measurements being taken with all the surfaces except the one under investigation acoustically blanked off, was verified on a ground based Lynx using simple mechanical excitation.

This paper describes a subsequent flight experiment based upon the same technique. The twofold objective was to verify the technique in flight and, by using a Lynx, to help in any improvements to the Lynx soundproofing scheme.

2 EXPERIMENTAL DETAILS

Lynx XX910 was used as the flight test aircraft. The existing soundproofing scheme was removed with the exception of the door coverings and the quilt between the cabin and the cockpit. Various cabin configurations were tested, using acoustic barriers over the different cabin surfaces. The barriers were not designed for possible production use, but for high acoustic transmission loss with little regard for weight. They comprised 50mm thick foam over which was placed a lead vinyl sheet of surface density 5 kg/m^2. They were held in position by a combination of Velcro and cord. Table 1 gives the configuration details for the trial programme of 13 flights. It should be noted that the cabin structure was considered to be made up of six parts; the front half of the roof, the rear half of the roof, the sides including the milled frames, the back or rear bulkhead, the doors and the floor.

The port cockpit seat was repositioned to face aft since, when the doors of the cabin were covered, the only access to the cabin was via the cockpit. The flight observer occupied this seat during take-off and landing, but moved into the cabin when the aircraft was on condition. One of the flight observers tasks was to reposition the quilt between the cabin and the cockpit correctly before operating the recording equipment.

The upper photograph of Fig 1 shows the bare aircraft cabin before the rear roof soundproofing bags were removed. The lower photograph shows the fully covered cabin. In the top left-hand corner can be seen the detachable cover necessary for access to the switches for the aircraft experimental supply.

Six ½ inch microphones were randomly positioned in the cabin and some of these can be seen in the photographs of Fig 1. A single ½ inch microphone was also mounted in the rear of the cockpit.

All seven microphones were elastically supported to eliminate microphony. The signals from the microphones were passed through a seven channel 6dB stepped attenuator box and then into a seven channel FM tape recorder.

On each flight, measurements were taken with the aircraft in hover at 500 ft and with the aircraft in forward flight at 120 kn and 1000 ft.

3 ANALYSIS

The results were analysed on a Digital Fourier Analyser using a 12.5 Hz bandwidth and a total integration time of 16 s. A certain type of analysis was used which, in effect, takes a running average in the frequency domain to give results as illustrated in Fig 2. The effective bandwidth is about four times the Fourier bandwidth; that is about 50 Hz. The great advantage of this type of analysis is that the true rms level of each sine wave component is accurately obtained provided all such components are dominant and at least 50 Hz apart. The main disadvantage is the poor frequency definition.

One of the cabin microphone channels was intermittently faulty and was eliminated from all the results. The remaining five cabin microphone measurements were energy averaged to give the spatially averaged cabin noise level. The one exception to this was condition 12 of Table 1 where unfortunately one further microphone channel failed and cabin results related to this condition were obtained by energy averaging only four microphone measurements.

Cabin reverberation times were measured for all cabin conditions. However, differences were so small that no correction to the results was necessary.

Production soundproofing schemes are designed to have an absorbent surface facing inwards and thus, compared to a bare aircraft, produce short cabin reverberation times. The acoustic barriers used in the tests reported here were deliberately designed to have a reflective surface facing inwards so that variations in cabin reverberation could be ignored.

4 RESULTS AND DISCUSSION

Fig 2 shows the results for the cabin in the conditions of bare and fully covered. Comparison of these spatially averaged cabin results verifies the overall technique and shows that the barriers used were sufficient as there is at least 10 dB difference at 450 Hz and 20 dB at higher frequencies. The peaks are identified with their gearbox source; that is, 1C refers to the fundamental tooth meshing frequency of the conformal gear, 2C to its second harmonic etc and 1B to the fundamental tooth meshing frequency of the input bevel gear.

The cockpit microphone results are compared with the averaged cabin results in Fig 3 for the bare aircraft condition. This shows that the forward quilt is doing a good job of screening the cockpit from the much higher noise levels in the cabin. It also implies that not much noise is generated in the cockpit other than through the cockpit/cabin interface. No further reference will be made in this section to the cockpit microphone results.

The variability and repeatability of the experimental data is demonstrated in Fig 4. Each cross represents an individual cabin microphone result for condition 11B and the two lines represent the averaged cabin result for conditions 11A and 11B. The crosses show spreads of up to 20 dB at low frequencies and this should be borne in mind when studying later graphs.

As planned, measurements were taken with the aircraft in the bare condition on the first and last flights of the programme, see Table 1. However, after the first three flights the aircraft had to have an engine replaced, and this may be partly the reason for the differences shown on Fig 4 between conditions 11A and 11B.

The cabin conditions 7, 8, 9, 10 and 11B of Table 1 have been used as consistency checks. Equivalent energy levels can be derived from the results of conditions 1, 2, 3, 4, 5, 6 and 12; for example

$$X_7' = X_5 + X_6 - X_{12} \quad , \tag{1}$$

and

$$X_8 = X_3 + X_5 + X_6 - 2X_{12} \quad , \text{ etc} \tag{2}$$

where the subscript refers to condition number and a dash refers to derived results. Fig 5 shows the dB difference between derived and measured results. As can be seen, the consistency is not very good in places, particularly at low frequencies. Considering these results and bearing in mind the results of Fig 4, an accuracy of ±3 dB is about all that can be assumed. This is one reason for the continued inclusion of both the forward flight and the hover results, even though they are similar.

The measured levels of noise at 5C and 6C were sufficiently small compared to other components to be ignored. The remainder of the results for the spatially averaged cabin levels at all conditions are given in Table 2. Fig 6 displays these results in bar chart form for conditions 1 to 6, and represents the main summary of all the results.

Fig 7 relates the flight results of Fig 6 to the ground results already reported[1]. The upper two graphs are simply the results of Fig 6 subtracted from the bare aircraft results of condition 11B. The lower graph is the equivalent ground result, the various one-third octave results have been averaged as indicated to line up with the gear teeth meshing frequencies. It should be noted that these ground results were obtained by using mechanical excitation at the gearbox feet which is unrepresentative. However, in the broad, the ground results are similar to the flight results; they at least highlight the same two dominant surfaces of sides and rear roof.

Returning to Fig 6, at all frequencies the doors and forward half of the roof are unimportant, and thus extra soundproofing in these areas is wasted weight. At high frequencies the sides, rear roof and back dominate and these areas must be treated in order to reduce, for example, the 1B component. However, the most worrying component has to be 1C, firstly because it exhibits the highest noise level and, secondly, because such low frequency noise cannot easily be absorbed. Concentrating on this 1C component, not only must the sides, rear roof and back be treated but also the floor.

Soundproofing the floor is much more difficult to achieve than soundproofing any other area because of the load carrying requirement. It is therefore worthwhile considering the results concerning the floor in more detail. For simplicity we will concentrate on the hover results for component 1C shown in Table 2. The 5 dB difference between conditions 3 and 11B shows that if the floor remains untreated, the best soundproofing scheme will only achieve a 5 dB reduction if internal absorption is ignored. Furthermore, conditions 7 and 8 show that a further 6 dB reduction could have been obtained if the floor had been treated to the standard of these tests. The equivalent figures for the forward flight results are 7.5 dB and 4.5 dB respectively; and the ground results give an equivalent first figure of 6.5 dB, with no equivalent second figure.

It should be noted that these results relate the sound-proofed aircraft to a bare aircraft and not to an aircraft with a standard acoustic fit.

Furthermore, this maximum reduction of about 6 dB if the floor remains untreated only relates to a soundproofing scheme that does not include internal absorption. For schemes which include for example a 50mm layer of foam open to the cabin a further reduction of about 6 dB at 450 Hz would be expected. Thus if a reduction in excess of about 12 dB is required the floor must be soundproofed in some way. This result is not too surprising, since at these low frequencies any vibrational energy in the main frames will be transmitted by them to the floor with little attenuation. For future aircraft this floor problem can be readily solved by vibration isolation techniques; that is by a floating floor. It is not so easy to find a practical solution for current in-service helicopters and more research is required to study this problem.

5 CONCLUSIONS

The following conclusions are based on comparative results with respect to a bare aircraft and do not relate to any existing soundproofing schemes. The figure of 12 dB quoted below is based on the addition of the measured 6 dB of the acoustic barrier alone and an assumed value of 6 dB for the internal absorption of a practical soundproofing scheme.

(1) The technique used for detecting the dominant radiation surfaces was found to work satisfactorily in flight.

(2) The doors and forward half of the roof are unimportant radiators of noise.

(3) The sides, rear roof and back must be soundproofed.

(4) If the floor is untreated then a maximum noise reduction of about 12 dB from the bare aircraft noise is all that can be achieved at low frequencies.

(5) For future helicopters a floating floor should be seriously considered.

(6) More research is required to determine the optimum floor treatment for current aircraft.

REFERENCE

1	K.H. Heron R.J. Pallant D.R.B. Webb	A technique for detecting the dominant acoustic radiation surfaces of a helicopter structure. RAE Technical Memorandum Aero 1775 (1978)

Table 1

FLIGHT PROGRAMME

Condition	Date of flight	Exposed surfaces					
		Sides	Rear roof	Floor	Back	Front roof	Doors
1	11.12.79	✓					
2	7.12.79		✓				
3	14.12.79			✓			
4	12.12.79				✓		
5	25.10.79					✓	
6	13.12.79						✓
7	18.12.79					✓	✓
8	18.12.79			✓		✓	✓
9	19.12.79			✓	✓	✓	✓
10	17.12.79	✓		✓	✓	✓	✓
11A	2.10.79	✓	✓	✓	✓	✓	✓
11B	19.12.79	✓	✓	✓	✓	✓	✓
12	16.10.79		NO SURFACE EXPOSED				

Table 2

SOUND PRESSURE LEVELS (dB)

Condition	Hover					Forward flight				
	1C	2C	3C	4C	1B	1C	2C	3C	4C	1B
1	114	106.5	96.5	89	103.5	112	104.5	97	91	103.5
2	113.5	106	98	91	102.5	110	104.5	98	91	102
3	114	101	86	80	91	108.5	97	87.5	77.5	89
4	110.5	·99.5	95.5	89	100	106	100	92	90.5	97
5	105	89.5	85	80.5	90.5	105	96.5	85	82	90.5
6	105.5	95.5	85	81.5	84.5	102.5	90.5	85.5	80	86
7	106	99	89	83.5	92.5	104	96.5	88	82	92
8	112	99.5	90	82	89.5	108.5	100	89.5	81.5	89
9	109.5	101.5	96	91	99	106.5	99	94.5	90.5	99.5
10	111	106.5	98.5	94	103	110.5	104.5	99.5	94	103.5
11A	116	107.5	103	98.5	105.5	115	107	103	100.5	105
11B	119	108.5	101	96	107.5	116	109.5	102.5	98	108
12	105.5	88	83	75.5	83	103.5	90.5	79	75	84.5

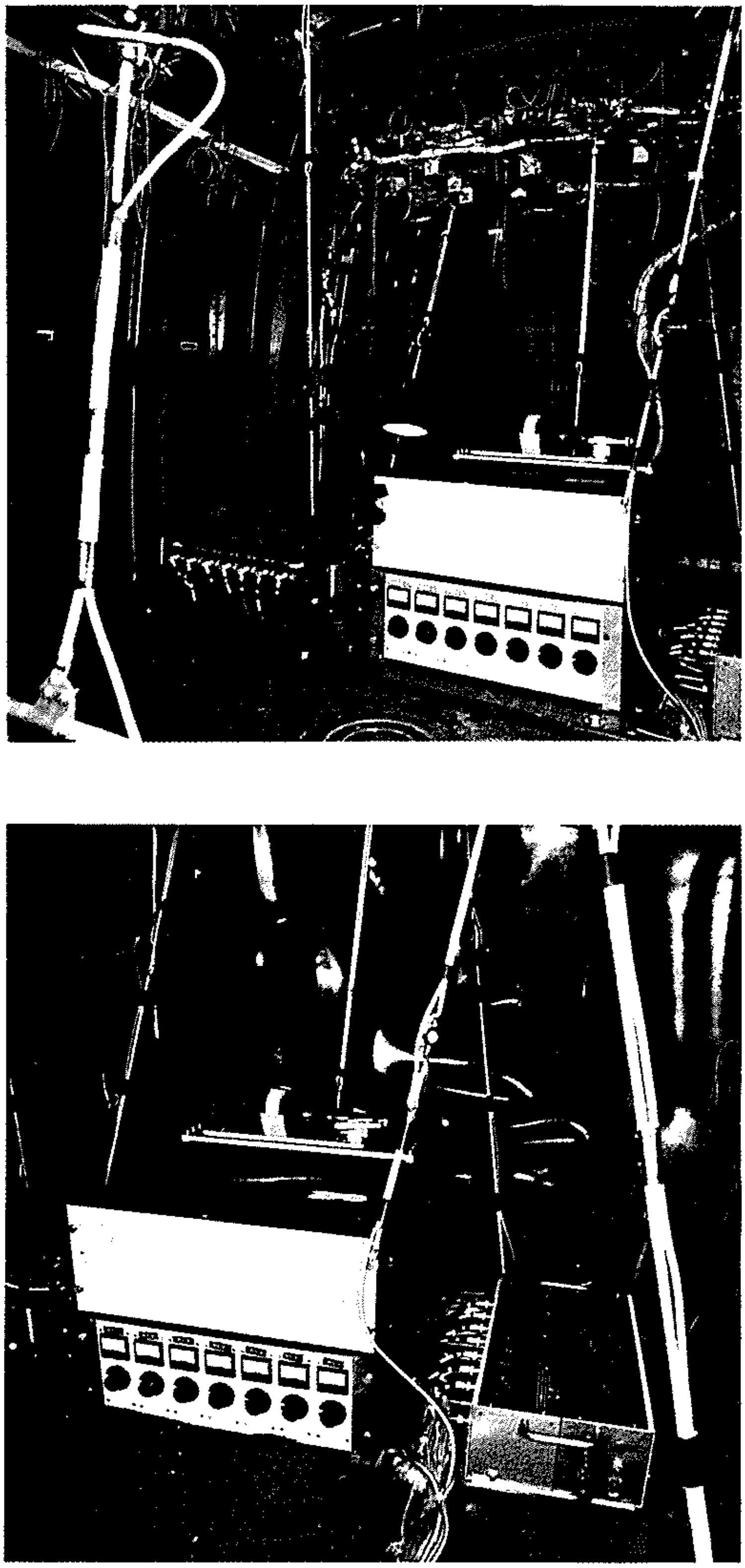


Fig 1   The aircraft cabin

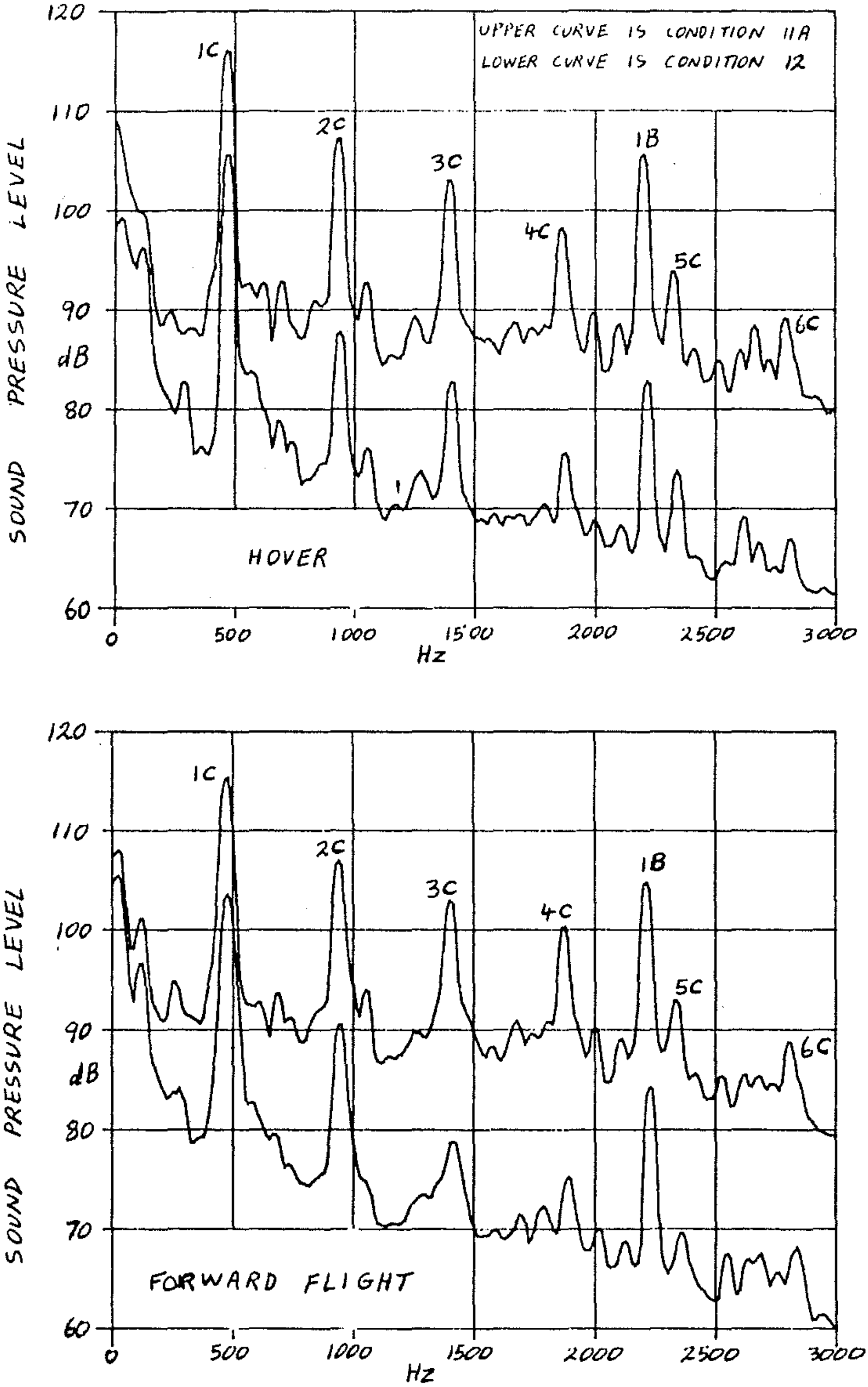


Fig 2 Comparison of bare and fully covered configurations

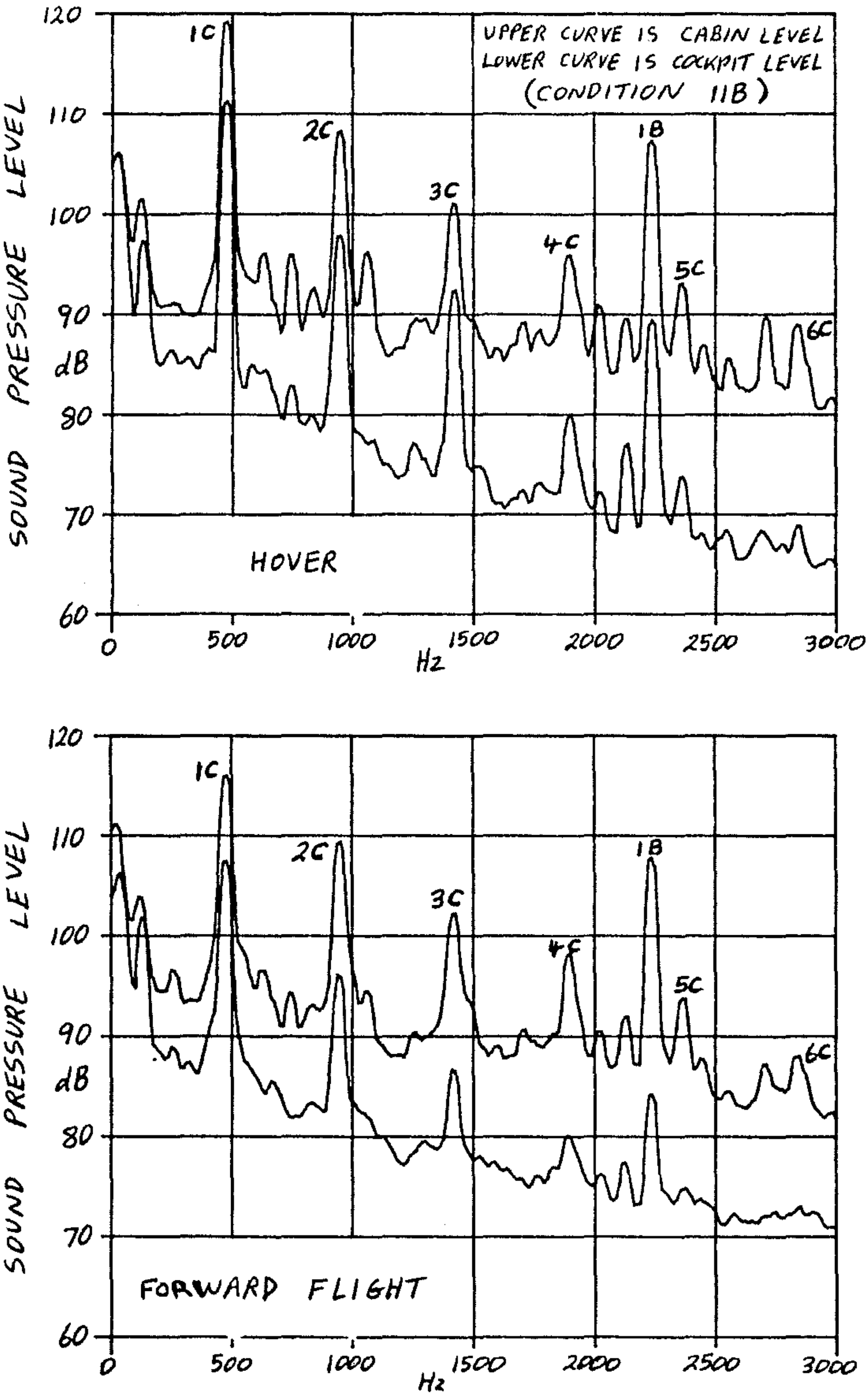


Fig 3 Comparison of cockpit and cabin sound pressure levels

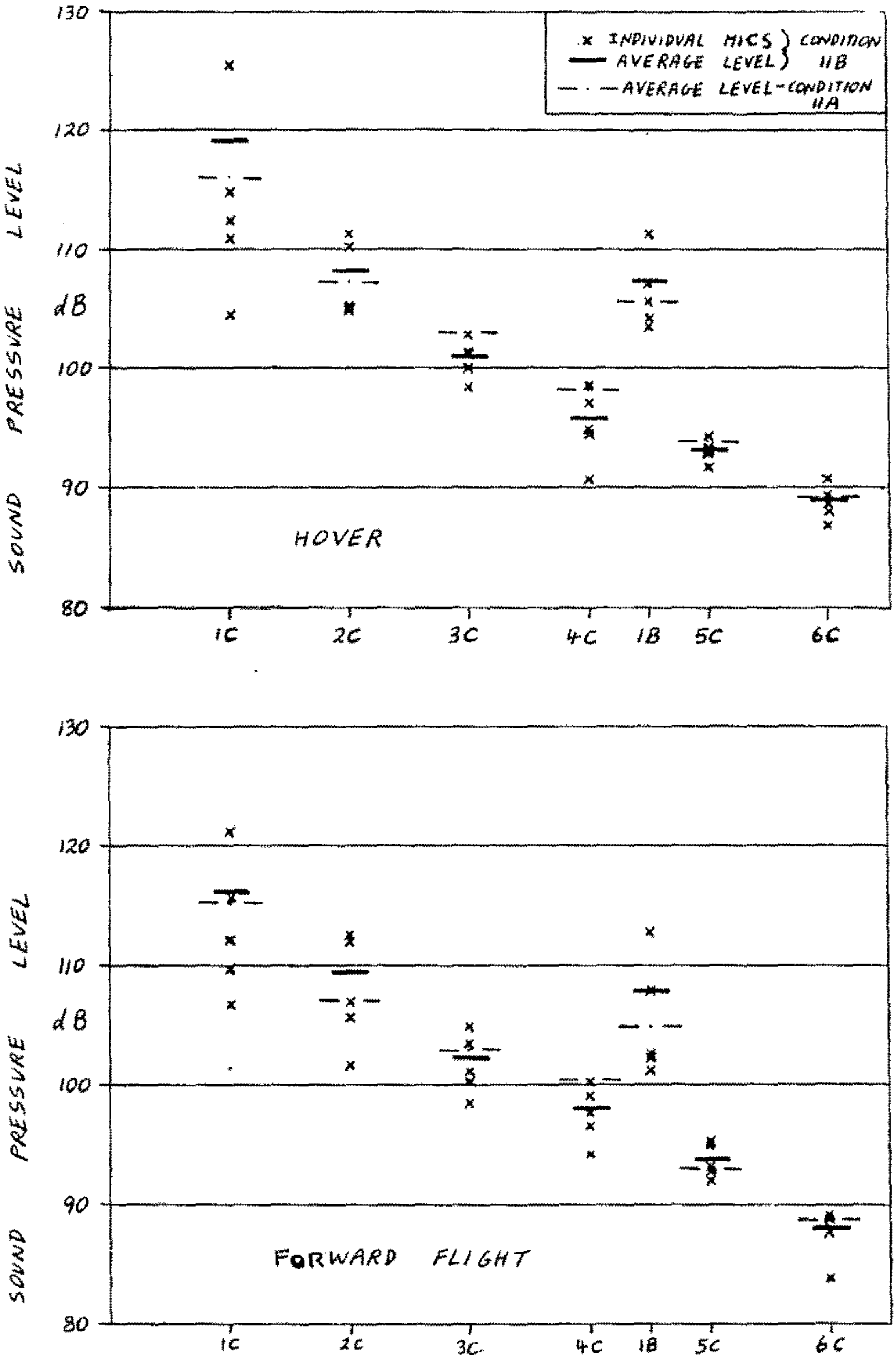
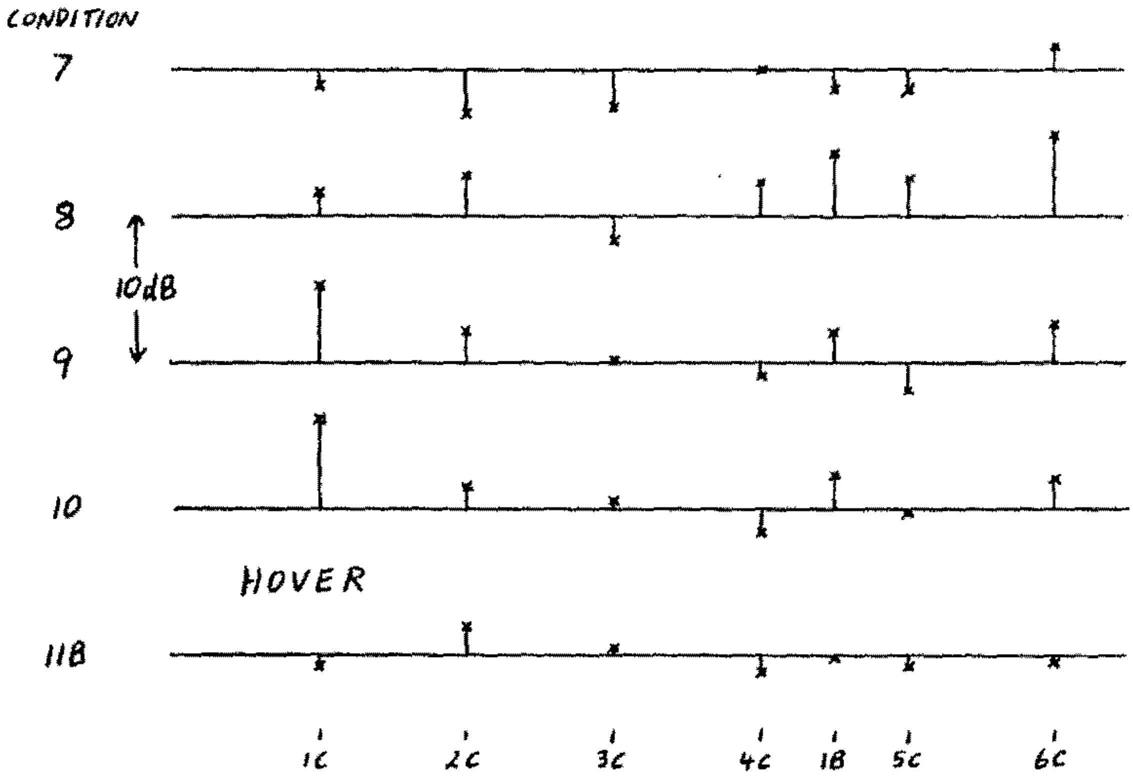


Fig 4 Microphone variability and repeatability



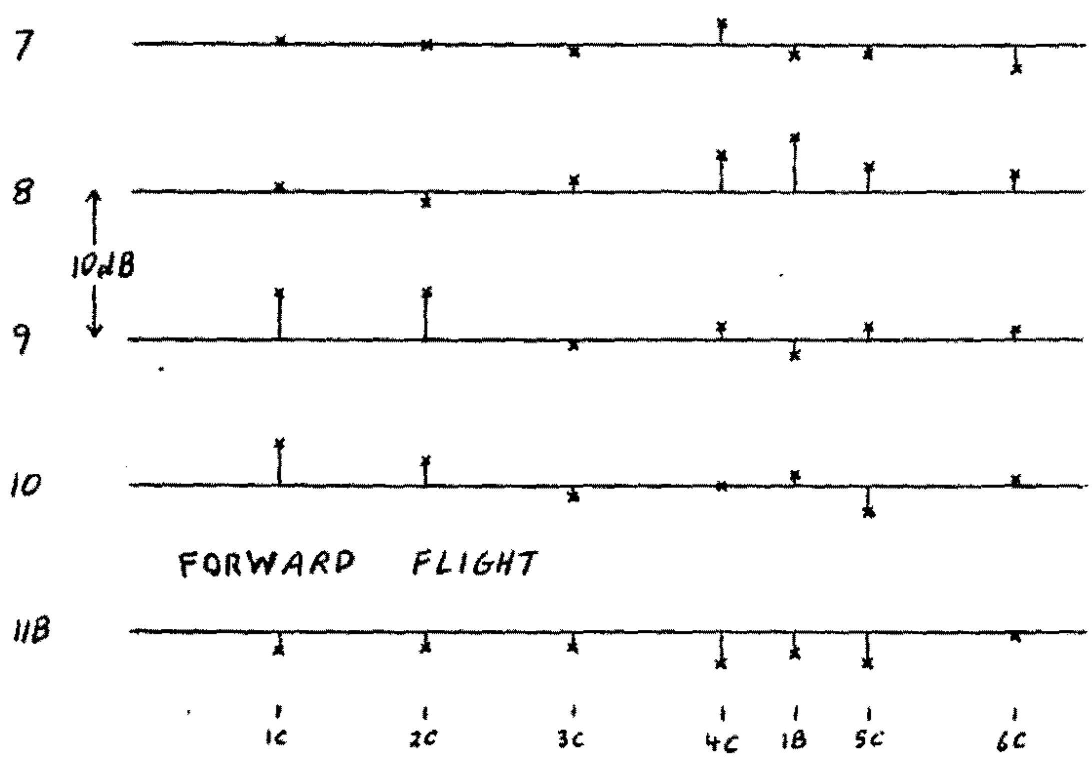


Fig 5 Consistency checks

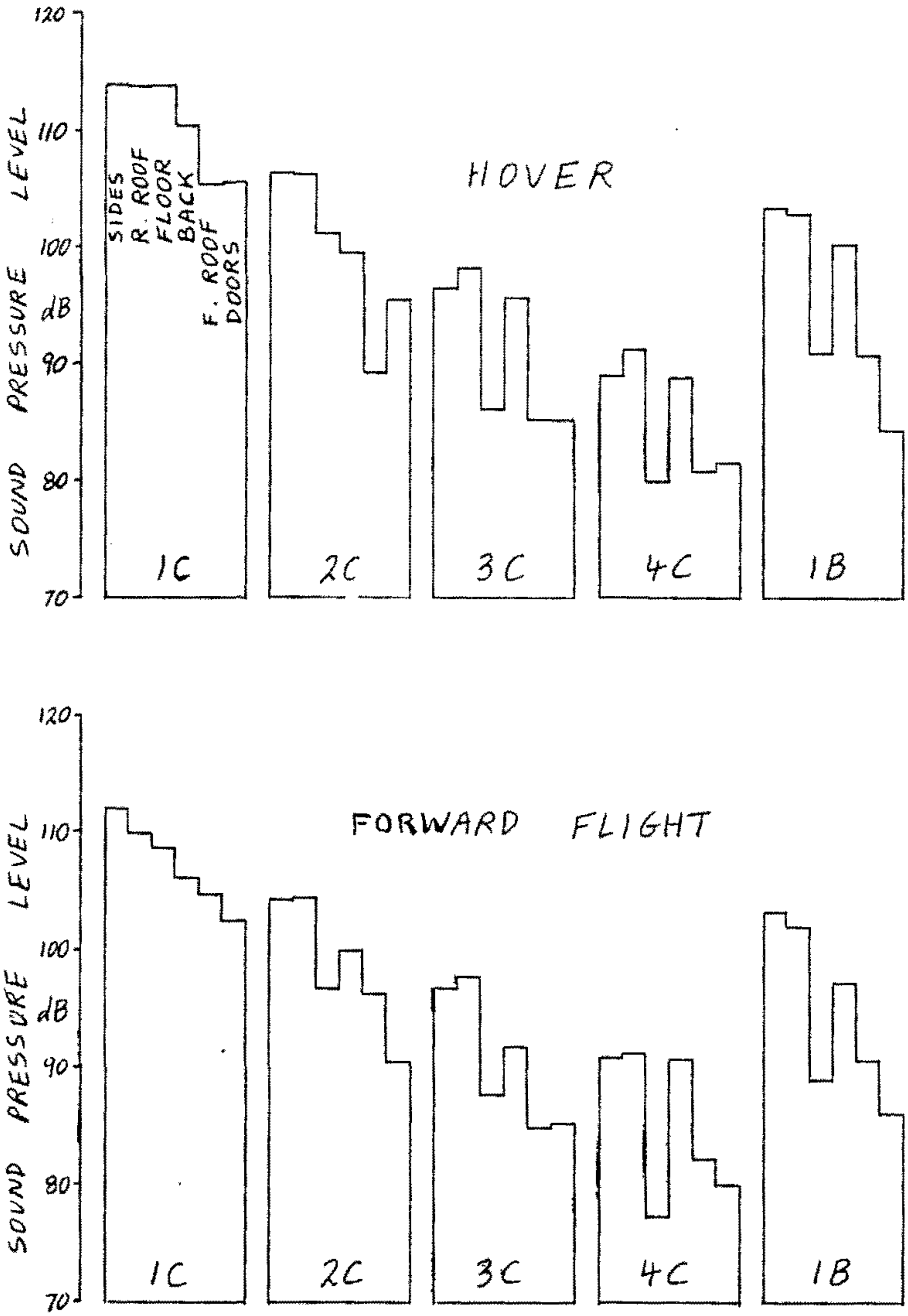


Fig 6 Exposure test results

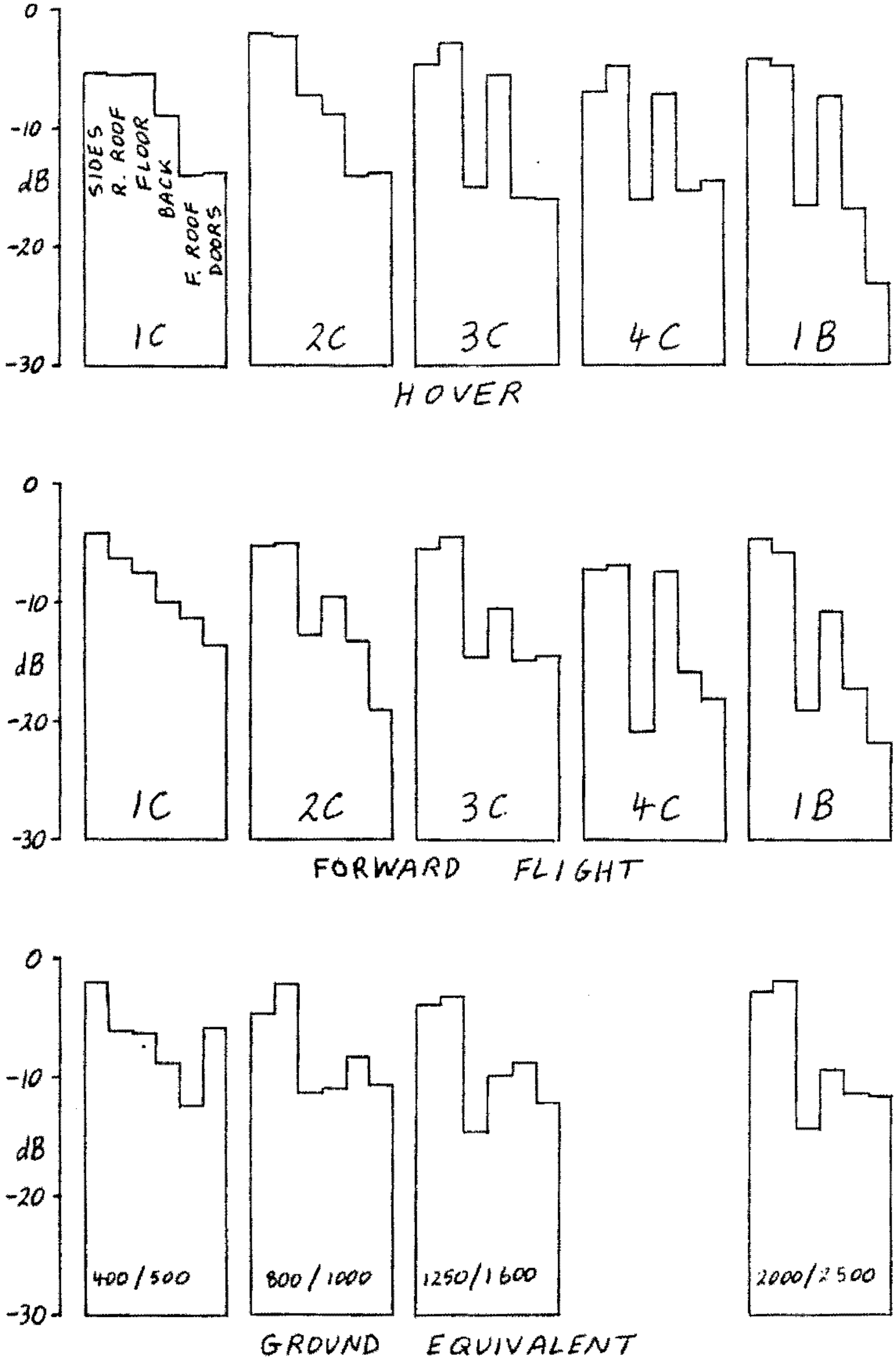


Fig 7 Comparison with ground results