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INSULATION OF MOBILE HOMES SUBJECTED TO MILITARY AIRCRAFT NOISE

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INTRODUCTION

The Ministry of Defence provides grant assistance for acoustic secondary glazing for homes most affected by aircraft noise in the vicinity of military airfields. The criterion used to define the qualifying area of a noise insulation grant scheme is the $L_{Aeq,12hr}$ 70 dB contour.

In recent years there has been a general increase in the number of mobile home sites around the country. Some of these sites have developed close enough to RAF Stations to be situated within the boundary of existing noise schemes, but there is currently no provision within MOD policy to cover the sound insulation of mobile homes. Conventional sound insulation measures are considered insufficient to attenuate aircraft noise because the acoustic qualities of the main structure of the mobile home are inferior to that provided by secondary glazed windows. It was recognized that there is a wide variation in the size and quality of mobile homes and the study was therefore initiated to assess the level of attenuation achieved by each of the different types of home construction and to consider whether it would be possible to identify a cost-effective method of improving the sound insulation of homes of non-traditional construction.

MOBILE HOME CONSTRUCTION

Two different categories of mobile home can be identified, these being single units and twin units. Single units vary in width from about 10 ft to 14 ft and in length from 25 ft to 44 ft. Twin units are approximately twice as wide as single units. Figures 1 and 2 show typical room layouts, and figure 3 shows a section through a twin unit.

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Homes are constructed on a steel framework with timber bearers and floor, the outer walls being double-leaf. The roof and ceiling can also be regarded as forming a double-leaf. The floor may be constructed of chipboard or plywood, which is usually 15 mm thick, together with a 25 mm layer of glass-fibre or expanded polystyrene to provide thermal insulation. The outer leaf consists of a 1-2 mm thick layer of aluminium or alternatively, a 4-6 mm layer of plywood which may have a 6-9 mm layer of stucco finish. Another material used is "Stenni" which consists of layers of stone chippings and glass-fibre manufactured to thickness of 4, 6 and 9 mm. The inner leaf is usually 5 mm plywood or hardboard with a vinyl face. The cavity, which is typically 50 mm thick, is filled with a thermal insulation material such as rockwool. The roof is constructed in a similar manner to the walls but is thicker, usually 9 mm, and is covered with roofing felt or another weather-proofing material. Some homes have a tile effect pitched roof made of galvanised steel to which a layer of stone chippings is bonded. The majority of the windows in mobile homes are single glazed in an aluminium frame. Thermal double glazed units are common, provided as either original equipment in the new homes or as replacements for the original windows.

ACOUSTIC CHARACTERISTICS

Compared with a home of traditional construction a mobile home is lightweight and will naturally have poorer acoustic qualities. These inherent qualities are further reduced by resonances which can arise in 2 ways. The first are resonances within the wall or roof cavities which occur when the air space is approximately a multiple of half a wave length.

The second kind occurs above the critical frequency of the materials used in the construction. For each material used there is a corresponding critical frequency above which the bending wave travelling in the material may be reinforced by the incident sound wave, resulting in increased sound transmission, an effect known as coincidence. The transmission loss curve at the critical frequency is known as the coicidence region, here the transmission loss can be reduced by 5 to 15 dB.

REVERBERATION TIMES

The reverberation times (RTs) in mobile homes were found to be low (0.4 sec) over most of the frequency range as can be seen in figure 4. A notable feature is that these low RTs extend to the low frequency bands because the wall construction consists of loosely mounted lightweight panels which act as panel absorbers at these frequencies. In contrast, a room in a conventional home has stiffer and heavier walls which do not provide the same absorption.

METHOD

On Site

A sample of 20 rooms were chosen for the study to represent the 4 different construction types below.

1. Twin units with pitched "tiled" roofs.
2. Twin units with conventional roofs.
3. Single units with conventional roofs and internal layout.
4. Single units with conventional roofs and unusual internal layout.

Noise measurements in 1/3 octave frequency bands from 100 Hz - 4 kHz were made inside and outside each mobile home simultaneously. Measurements were made in the 2 largest rooms, ie main bedroom and main living room.

The internal noise levels were recorded at 3 positions in each room at heights between 1.2 m and 1.5 m to give a reasonable sample of the sound field in the room. The external microphone was positioned 3 m above the ground and at least 3 m from any reflecting surface. Time histories of noise levels for a number of aircraft movements, including take-offs, overshoots, rollers and landings were recorded. In addition, noise measurements in 1/3 octave frequency bands from 25 Hz to 100 Hz were made inside each mobile home. Measurements were made using 4 Bruel & Kjaer type 4165 microphones linked to 2 Nortronics type 830 dual-channel 1/3 octave analysers via B&K 2639 preamplifiers.

Reverberation times were measured in each room in 1/3 octave bands, the normalized level difference (NLD) in 1/3 octave frequency bands being determined from the above measurements using 1/2 sec correction for room absorption. RT measurements were made for each room in the same condition as that which prevailed during the aircraft measurements. A Nortronics analyser was connected to an amplifier and loudspeaker system to enable reverberation time measurements to be made using the integral random noise source. The RTs were measured by exciting the loudspeaker with random noise and initiating an automatic sequence on the analyser which recorded a short sample of the steady-state noise in the room and then cut off the signal to the loudspeaker. The subsequent noise level decay was then recorded.

Laboratory Analysis

The data from the Nortronic analyser's disks were transferred to a hard disk on an IBM-compatible PC computer in order that each event for each room could be further analysed. Firstly the maximum value of the external spectrum for each band was determined. To prepare for this the FAST time samples were exponentially averaged to emulate the SLOW time constant as quite large pertubations were found in the level. After averaging the external time history, the maximum value was determined and its position in time in the series of samples noted.

The 3 corresponding internal spectra were similarly averaged over a range of samples either side of the position of the external maximum. The maximum value of this section of the internal time history was then determined for each microphone position. This process was carried out separately for 1/3 octave bands over the range 20 Hz-4 kHz. For each event the 3 internal spectra were logarithmically averaged to produce an average internal spectrum. This spectrum was then subtracted from the single external spectrum to determine the level difference over the range of 1/3 octave bands 100 Hz-4 kHz. Finally the level difference spectrum was normalised to a reverberation time of 0.5 seconds using the RTs measured for each band by applying a correction of 10 log(T/0.5), where T is the reverberation time for the room in that band.

RESULTS

For each of the 20 rooms the following data has been produced:

1. External maximum spectrum for each event.

2. Internal low frequency maximum spectrum for each event.

3. Normalised level difference for each event.

For each room the internal low frequency maximum spectra were arithmetically averaged as were the normalised level differences. The final phase of the analysis was to average the mean NLDs for rooms of the same category. Secondly, the low frequency maximum spectra at each airfield were averaged.

DISCUSSION

There is a wide variation in the NLDs obtained for a given room from all events. For each event the power setting and flight path of an aircraft will be slightly different. Therefore, not only will the peak level be different, but it will occur when the source is in a different location relative to the home and to the external microphone. At least part of the variation in NLD is due to the source position, which unfortunately obscures differences due to the building construction.

There is also a wide variation between the NLDs within each category of mobile home, many exhibiting dips in their NLDs at frequencies of 2-4 kHz. These are probably due to coincidence effects, as the coincidence frequencies of the materials used in the construction fall in this range, see table below.

Material (mm)	Surface Mass (kg/m^2)	Critical Frequency (Hz)
Glass (4)	10	4000
Ply (4)	2.3	3250
Ply (6)	3.5	2170
Ply (9)	5.2	1444
Steel (0.4)	3.1	30000
Aluminium (2)	5.3	6100

The NLD in all cases is poor, especially at low frequencies.

The table below shows estimated mean NLDs in 3 frequency ranges for the 4 categories of mobile homes.

Categories	100-160 (Hz)	400-630 (Hz)	2500-4000 (Hz)
I	17.0	22.7	24.4
II	14.3	20.3	22.3
III	10.1	16.4	23.8
IV	11.3	18.0	22.5

As a result of the variations in the Normalised Level Differences within the categories, it was considered inappropriate to compare the NLDs between categories using the category mean. Therefore various statistical analyses were carried out on the low frequency mixima and NLDs between the following physical parameters of each room: volume, ceiling area, external wall area, and door/window area. However no significant correlation was found. A further test using the ratio of volume/external wall area did show a strong positive correlation with NLD between 250 Hz and 1.25 Hz.

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The study was not designed to examine the noise insulation characteristics of each home in detail, ie the sound transmission paths. Therefore it is not possible to state with any certainty what has given rise to the observed differences in NLD. Indeed, in some homes the NLD varies throughout an event and the relative NLDs at the 3 internal microphones also vary. Clearly these variations are important.

Obviously, the various components of the home will have intrinsically different sound reduction indices and, at any instant, the NLD will be largely dependent on the component receiving the greatest sound intensity. Furthermore, weaknesses in the structure have a great effect on the insulation achieved, eg ventilators, gaps around doors and windows, and between component panels all cause significant reductions in NLD.

As mentioned, resonances can occur in the building components and also in the furniture and fittings, which give rise to rattling, buzzing etc across a broad band of frequencies at intense levels. In addition, room modes can be excited.

CONCLUSIONS

Overall, the sound insulation of mobile homes is poor. Within the results of the category means, some homes displayed markedly high or low insulation values. A further examination of these homes is required for the purpose of evaluating structural, maintenance and other defects which could shed light on the results obtained.

such an investigation, followed by statistical analysis, might reveal whether minor improvements, ie draught proofing etc and measures to avoid resonances, could achieve worthwhile improvements at low cost.

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A number of sound insulation treatments have been suggested, but it can be seen in the table below that the cost of treatment to large areas of a home would be high. It is therefore important to learn more about the relevance of the various transmission paths in the building.

Treatment	Estimated Cost Per Home (£)
Pitched "tiled" roof	2000-2500
Replacement UPVC windows	2500
External cladding	1200-2000

The sound insulation achieved by installing the standard noise insulation package in conventional homes, as specified in the Noise Insulation Regulations (1975) of the Land Compensation Act (1973), cannot be replicated in mobile homes even when using all the suggested treatments. However, it is considered that the acoustic weaknesses due to the construction of mobile homes should be investigated further.

Perhaps the most important of these is to carry out detailed study of sound transmission paths within a particular room - mobile homes are not rigid structures as are buildings of traditional construction. Also, there is an absence of "wet" finishing (plastering), which would normally ensure good sealing of small gaps between building elements. Sound intensity techniques would reveal the presence of such leakage paths and assist in the understanding of the relative importance of transmission through the varius building elements.

ACKNOWLEDGEMENT

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TYPICAL SINGLE UNIT

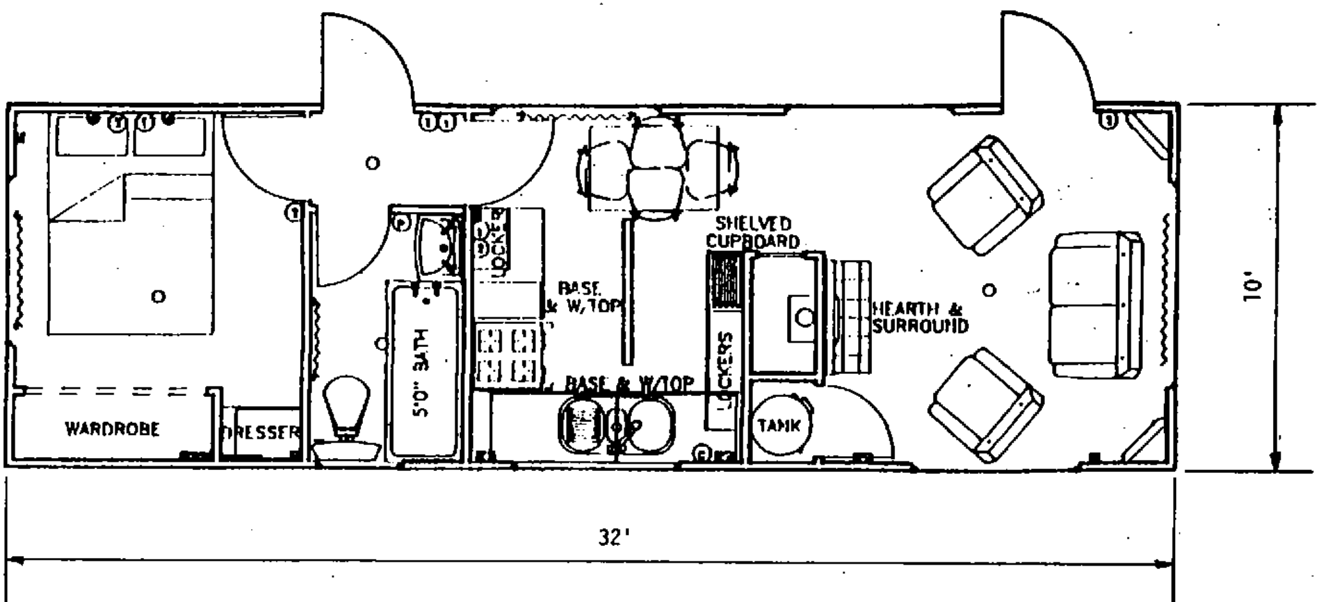

FIG 1

TYPICAL TWIN UNIT

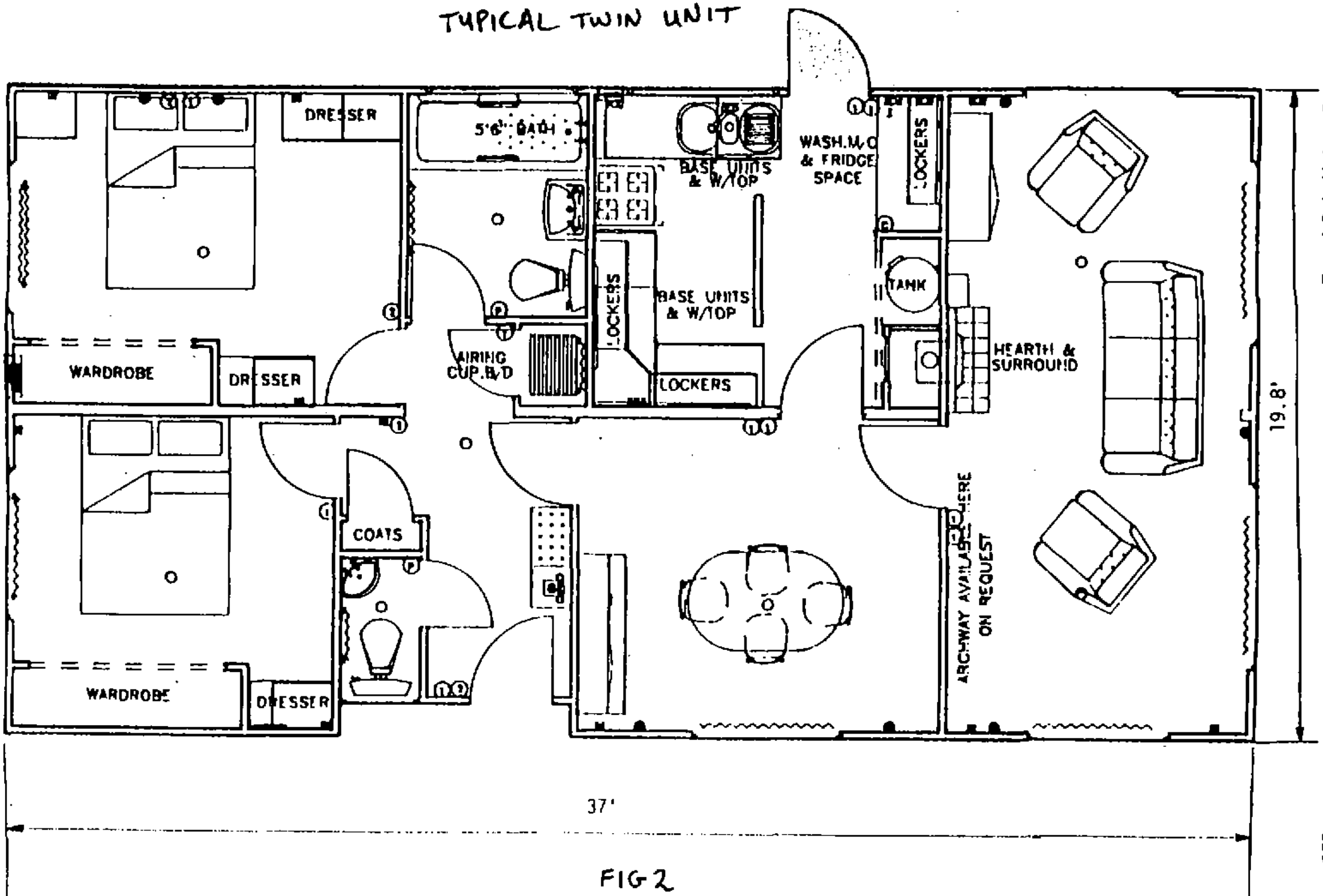

FIG 2

CROSS-SECTION THROUGH A TYPICAL "TWIN" UNIT MOBILE HOME

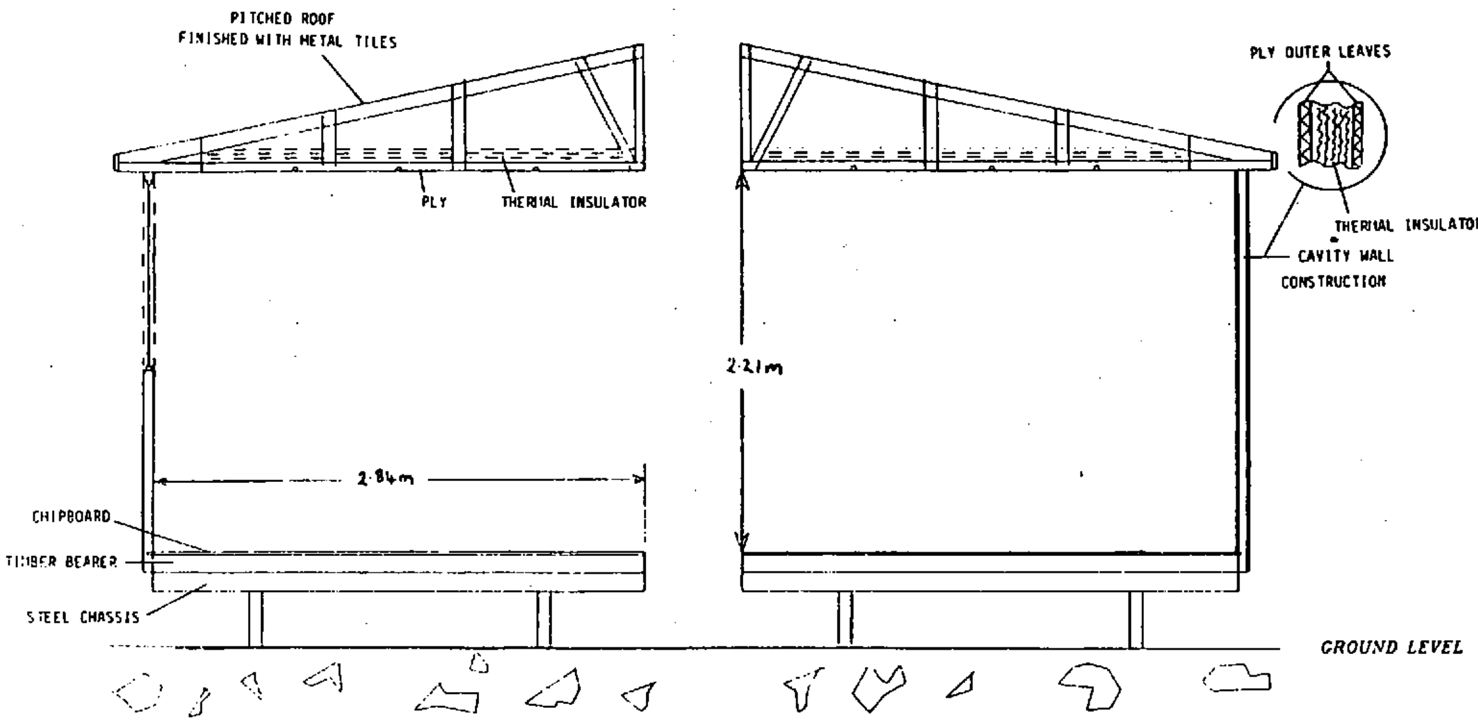

FIG 3

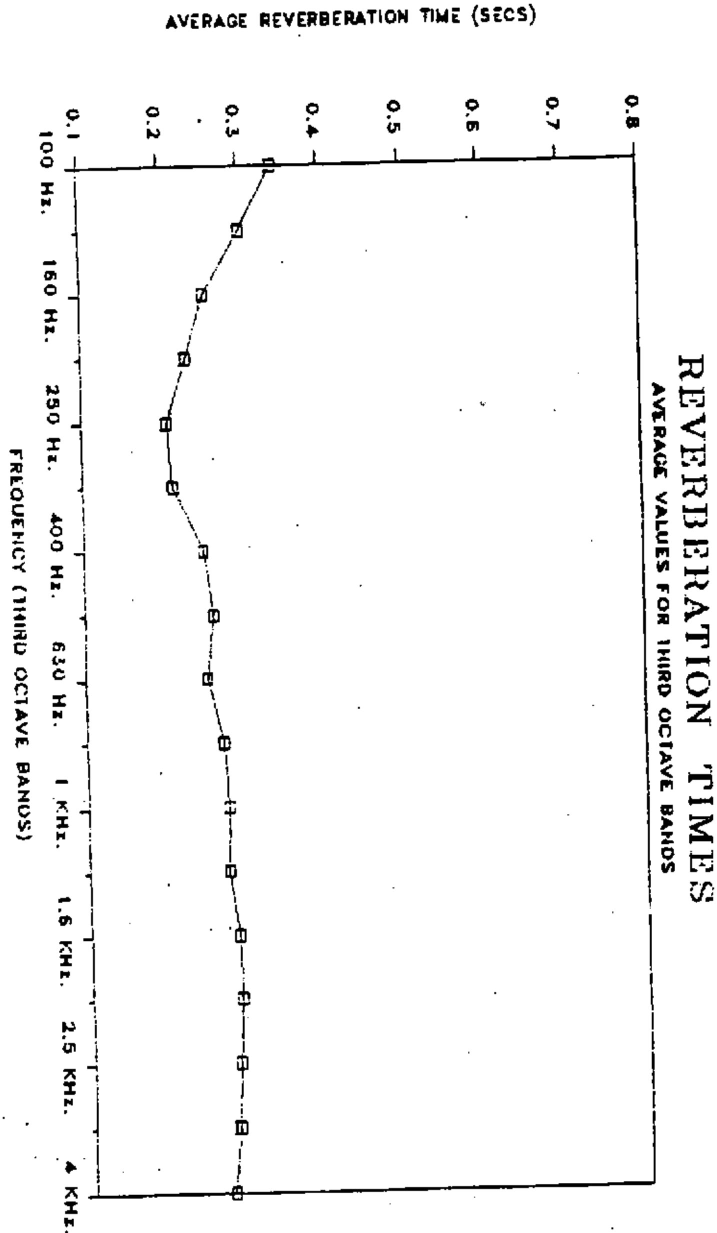
REVERBERATION TIMES
AVERAGE VALUES FOR THIRD OCTAVE BANDS
AVERAGE REVERBERATION TIME (SECS)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
100 Hz.
160 Hz.
250 Hz.
400 Hz.
630 Hz.
1 KHz.
1.6 KHz.
2.5 KHz.
4 KHz.
FREQUENCY (THIRD OCTAVE BANDS)

FIG 4

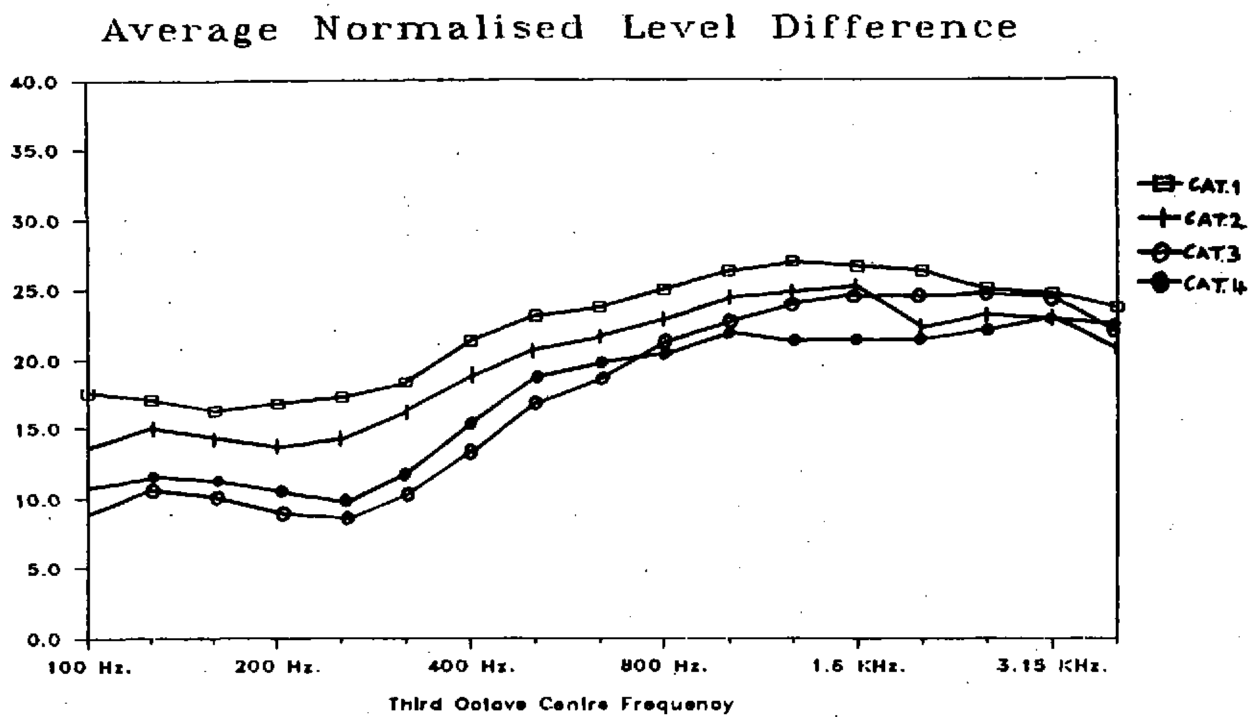
Average Normalised Level Difference
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
A. N. L. D. (dB)
100 Hz.
200 Hz.
400 Hz.
800 Hz.
1.6 KHz.
3.15 KHz.
Third Octave Centre Frequency
CAT.1
CAT.2
CAT.3
CAT.4

FIG 5

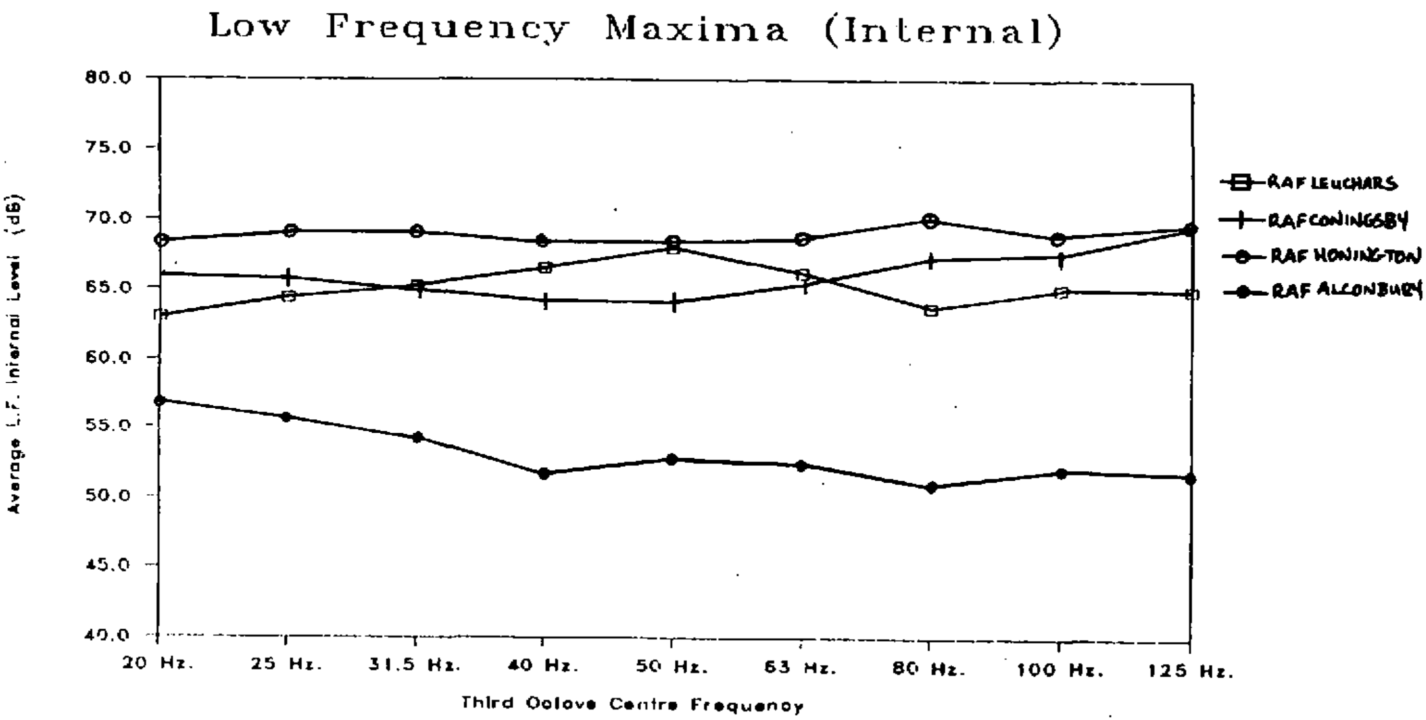
Low Frequency Maxima (Internal)
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
Average L.F. Internal Level (dB)
20 Hz.
25 Hz.
31.5 Hz.
40 Hz.
50 Hz.
63 Hz.
80 Hz.
100 Hz.
125 Hz.
Third Octave Centre Frequency
RAF LEUCHARS
RAF CONINGSBY
RAF HONINGTON
RAF ALCONBURY

FIG 6