

LOW FREQUENCY NOISE PROPAGATION FROM MODERN MUSIC MAKING

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1. INTRODUCTION

It is widely known that the principal problem associated with "entertainment noise" is the fundamental low frequency throb of the bass guitar, bass synthesiser and/or kick drum and floor tom-toms. Yet for some reason we continue to measure music noise levels in A-weighted units. This paper will analyse the characteristics of the source material, consider its impact upon the buildings used to contain such activities, and the resultant propagational mechanisms and behaviour.

2. CHARACTERISTICS

If we look at the broadband SPL at which rock music has been played over the last 30 years, we find very little change. The Medical Research Council study [1] shows 100dB(A) to be typical whilst Dibble 1988 [2] and Griffiths & Staunton, 1993 [3] (see Fig.1) show that not much has changed. Yet if this is compared to the electrical power used to generate this level over the same period of time we find vast differences.

1960s:	50 - 200W	95 - 100dB(A)
1970s:	5 - 30kW	100 - 110dB(A)
1980s:	<120kW	100 - 110dB(A)
1990s:	<400kW	100 - 110dB(A)

So what is happening to all those kilowatts? Is this the cause of the global warming problem by which means the environmental lobby seek to instill fear and trepidation in us all?

Apart from a change in the way in which pop music is presented and the increase in venue size, the answer is to be found in the energy vs frequency domain. Fig. 2 shows an amalgam of the spectral energy distribution as found by by Bickerdike & Gregory [4] and Cabot et al [5] in the late 1970s, taken from the MRC report [1]. Note that the distribution is fairly uniform with a small emphasis at 125Hz.

By comparison, if we look at the spectral distribution over the last 10 years we find a very different situation. The upper plot of Fig. 3 shows a typical sample taken from the 1988 BEDA survey [3] and the lower, a typical "rave" situation. Note that discotheque music shows an energy peak centered typically at 63Hz which is some 20dB above the mid-band mean level whilst "rave" music shows a 30dB peak centered on 50Hz. If these spectra are translated into amplifier power we find:-

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20dB = 100 fold increase in power, ie 100W becomes 10kW

30dB = 1000 fold increase, ie 100W becomes 100kW

+6dB for improved headroom = 40kW and 400kW

So clearly, the media hype about $1\frac{1}{2}$ a megawatt here or 250kW somewhere else, amounts to nothing more than scaremongering. The numbers may sound horrific but the A-weighted performance levels have not increased over the last 30 years. The LF that was missing from the '60s sound systems has been put back and more headroom provided to address the high level of distortion prevalent in the 1960s.

3. EFFECTS ON HEARING & MEASUREMENT

These spectral characteristics are quite unlike anything else and extend the "audibility window" into previously uncharted areas in both frequency and energy domains as shown at Fig 4. It is generally accepted that exposure to SPLs above 120dB will result in actual physical pain, but this is certainly not the subjective case at these very low frequencies. The only research the author has been able to locate into the effects of exposure to very high SPL at very low frequencies is that by von Békésy [6] the results of which are shown at Fig.5. He shows that at 50Hz the hearing threshold is 2 dynes/cm² (about 80dB) and that this changes to a sensation of "tickle" at 3000 dynes/cm² (140dB). 120dB corresponds to 300 dynes/cm² and 130dB to 600 dynes/cm². My conversions are approximate.

According to von Békésy then, rave music in particular should be close to becoming a physical sensation about the head rather than being perceived as sound per se. But von Békésy makes no mention of the risk of hearing impairment at these pressure levels at these low frequencies. However, referring to the Dadson & Robinson Equal Loudness Contours [7], which are reproduced at Fig 6, we find that the ear is markedly non-linear at pressure levels below about 100dB. If we superimpose an inverted A-weighting curve - which is used in virtually all commercial measurement irrespective of range in a crude attempt to compensate for the equal loudness contours - over a typical discotheque spectrum, as shown at Fig. 7, we find that the dB(A) result bears absolutely no relationship to the quantity we are trying to measure. So why do we continue to use a unit of measurement which clearly has no relevance? Is it any wonder that BS4142 doesn't work or that enforcement authorities resort to subjective assessment methods such as "inaudibility".

4. THE EFFECT ON ENCLOSURES

Fig 8 shows the basic mass law behaviour of a partition. Over the mass controlled region the standard mass law is obeyed where transmission loss increases at

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approximately 6dB per octave, whilst in the stiffness region the behaviour is highly erratic due to panel resonances. It is in this region that the majority of roof constructions lie. At 50Hz or 63Hz the entire roof resonates and re-transmits the bass component into the outside atmosphere.

Even a more substantial roof construction will lie at the very bottom end of the mass controlled region where the transmission loss performance is poor, even if it is not actually resonating, and so its flexural modes have the same effect. Even high mass cavity walls do not provide good isolation at these long wavelengths and at these high energy levels. Fig 9 shows a typical transmission loss condition inside and outside a purpose designed nightclub building and shows the basic characteristic of the residual noise that gives rise to the majority of complaints. The A-weighted broadband SPL is usually the same whether the disturbance is present or not.

In the case of lightweight warehouses and marquees such as those used for "rave" parties, the situation is much worse, as illustrated at Figs. 10 and 11.

Once a large surface area is set in resonance or, severe flexural modes are excited, it behaves just like a gigantic loudspeaker cone. Thus the resultant energy can be substantial and can travel large distances unabated, especially over water, grass, or other areas where relative humidity is higher than normal. Most of the path attenuation factors such as ground cover attenuation and barrier effects are ineffective at these long wavelengths - eg 6.8m at 50Hz, leaving inverse-square loss, wind speed and direction and humidity and temperature gradients as the primary factors. In practice however, calculation rarely seems to provide a result which agrees with what happens in practice and humidity in particular appears to be a greater influence than the theory would suggest.

By way of example, Fig 12 shows the site plan of an all-night "rave" event staged at the former Melton Mowbray wartime airfield. The site is in rural Leicestershire some 4km due south of Melton Mowbray, 2.5km from the nearest occupied residential premises and is screened from both, and from several villages, by the landscape topography. The site was orientated with the loudspeakers systems facing due north in expectation of a slight breeze from the SW. We expected that some sound would be audible at the outskirts of Melton Mowbray and Burton Lazars but that this would fall within the criterion agreed with the local authority. As the event got underway at about 2100hrs, and up to 0100hrs all was fine. A problem on the outskirts of Melton was discovered at 0130hrs and the bass compressor device re-adjusted. Fig 13 shows the spectral conditions which prompted the complaint and the conditions which were accepted by the residents and EHO after adjustment - following which all settled down again. Then, shortly after 0300hrs, we started to receive complaints from Sowerby, a tiny village some 15km due south-east of the site, where it was claimed they could dance in the streets to the bass beat. Sowerby was not even on our "at risk" list.

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The wind had got up and shifted to the NE so that Little Dalby, Somerby and Borough-on-the-hill were now suddenly and unexpectedly affected. It was necessary to reduce the broadband level to 95dB(A) - which is on the margin of acceptability for this type of music - in order to contain the problem. Even then it was audible against a typical background level of 40dB LA90, but the residents were prepared to accept the improvement as long as they could not hear it inside their homes.

Which leads into another problem. All too often the residual bass level inside a dwelling is higher when the window is closed than when it is open - especially when large "picture windows" are involved. This is due to the glass pane being activated by the external pressure wave, and compressing and rarefying the air pressure of the closed space.

5. CONCLUSION

The propagation behaviour of low frequency sources of the type described in this paper is dependent upon a large number of factors and is frequently unpredictable. It has been found that effective control has more to do with experience and on-the-ground solutions than it has with prediction by theoretical means. Certainly however, an understanding of the basic mechanisms and thorough pre-event planning is essential to provide some sort of starting point. Matters would be greatly assisted by the following:-

1. A move away from A-weighted measurement to a measure which will better describe the characteristics of the complaint.
2. The extension of materials and product TL and absorption test data, in $1/3$ rd octave bands, down to 50Hz. Single figure ratings such as R_w , $D_{nt,w}$ and STC are worthless in this type of work.
3. A better understanding of the mechanisms by which such sources propagate.
4. Easier access to more reliable long-range weather forecasting.

6. REFERENCES

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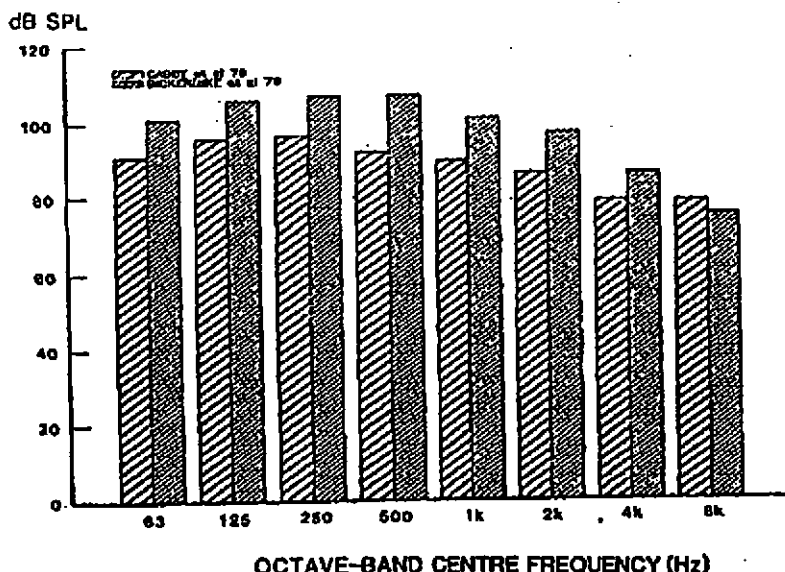


Fig. 2. MRC Amalgam of Bickerdike & Gregory & Cabot et al Octave-Band Results

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Table 1. Venue volume levels

MEASUREMENT LOCATION	MEAN SPL	MEAN Devn	MAX SPL	MIN SPL	NO. OF SMPLS
Dance floor	103 dB(A)	1.5	107	99	12
DJ console	98 dB(A)	1.6	104	98	12
Bar servers	90 dB(A)	4.2	100	73	36
Lounges	90 dB(A)	4.5	98	75	32
Restaurants	84 dB(A)	6.1	89	70	10

Table 1. Summary of the sound levels measured at the concerts

CONCERT ID*	AUDIENCE CAPACITY	CONCERT DURATION (MIN)	L _{Aeq} BARRIER	L _{Aeq} MIXER	L _p BARRIER	L _p MIXER
1RI	SMALL	159	104.6	94.4	132.3	123.5
2RO	LARGE	306	102.9	99.8	137.8	127.8
3RI	SMALL	195	105.2	101.7	141.1	133.1
4RO	LARGE	465	107.0	102.0	140.0	132.0
5RO	LARGE	591	108.9	94.0	140.3	126.5
6RI	MEDIUM	141	109.9		136.0	
7RI	MEDIUM	202	104.3		137.3	
8PO	LARGE	374	106.9	97.5	138.6	124.1
9PI	SMALL	184	105.0	102.0	135.6	126.5
10PI	SMALL	160	113.0	101.0	146.0	134.0
11PI	MEDIUM	160	102.8		131.3	
12PI	MEDIUM	126	101.6		133.6	
13MI	MEDIUM	186	98.5		126.6	
14MI	MEDIUM	140	99.8		124.5	
15MI	SMALL	170	94.4	92.1	122.9	117.8
16AI	SMALL	121	112.0	104.0	142.5	133.0
17AI	MEDIUM	180	102.8		141.1	
18HI	SMALL	190	106.0	107.0	137.0	133.0

*Concert ID: R-rock, P-pop, M-middle of the road, A-rap, H-house, O-outdoor, I-indoor

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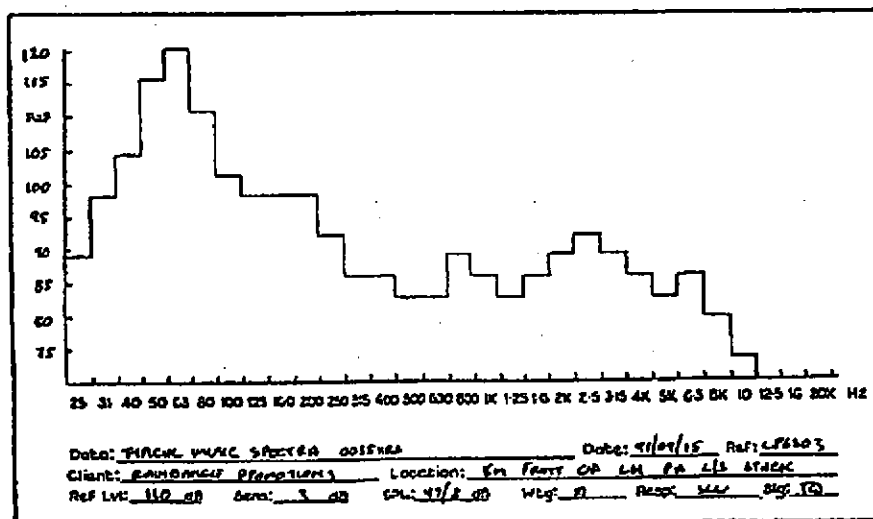
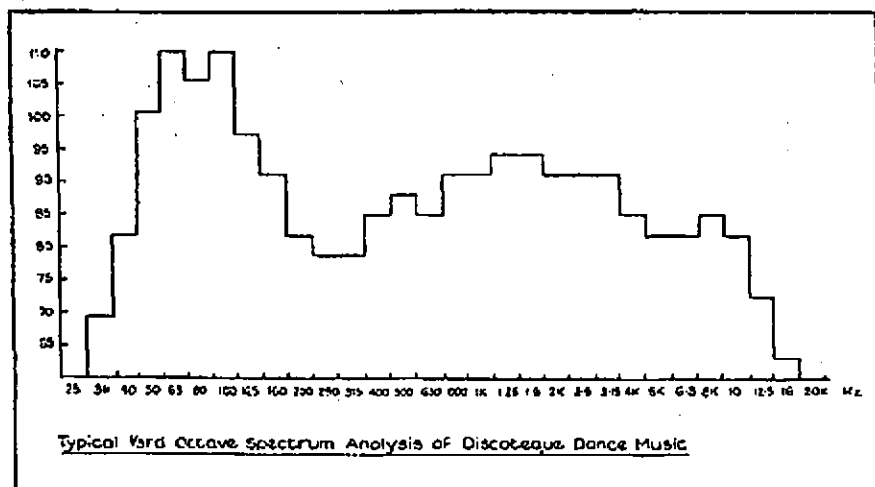


Fig 3. Typical Disco (upper) and Rave (lower) Spectral Energy Distribution.

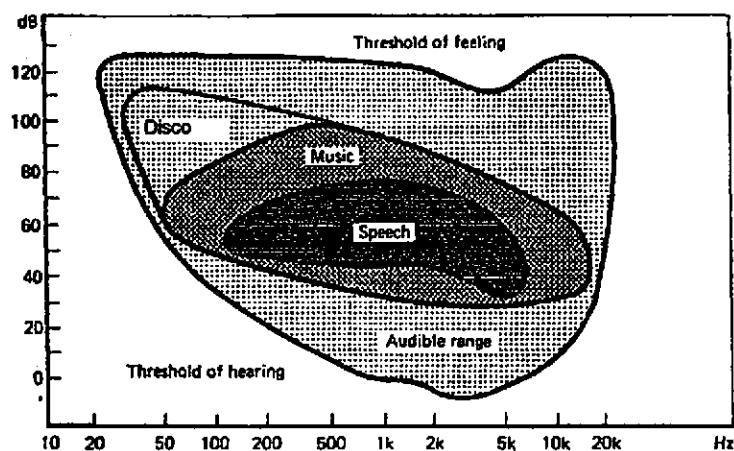


Fig. 4. Spectral Occupancy Contour Map

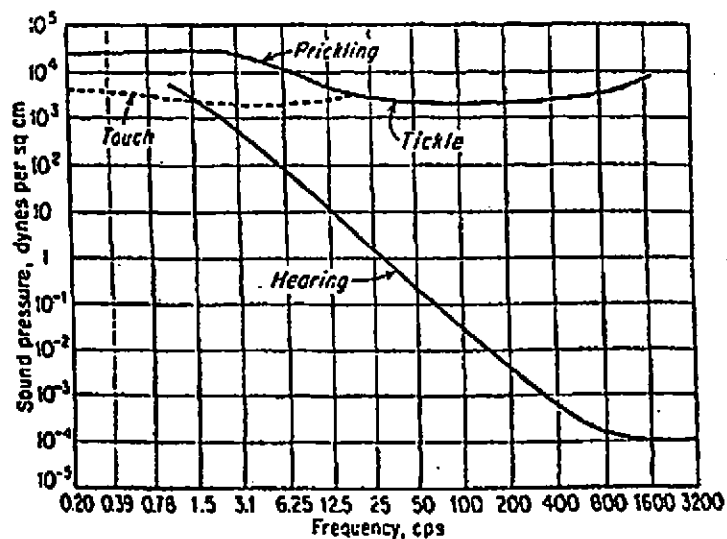


FIG. 7-18. Thresholds for various sensations aroused by low tones.

Fig. 5. von Békésy LF Thresholds

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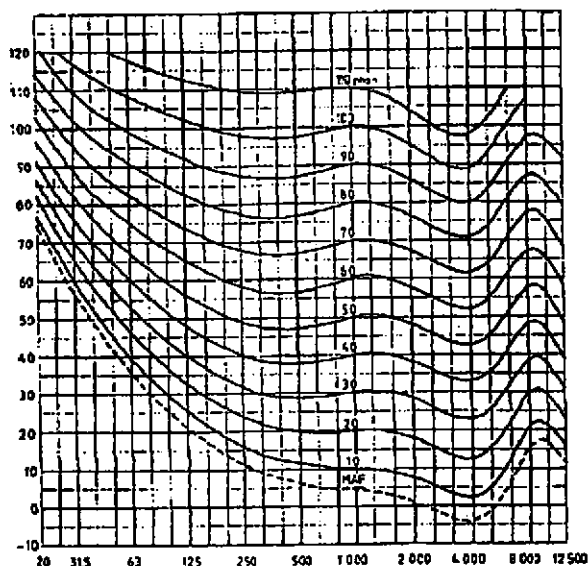


Fig. 6. Equal Loudness Contours after Dadson & Robinson.

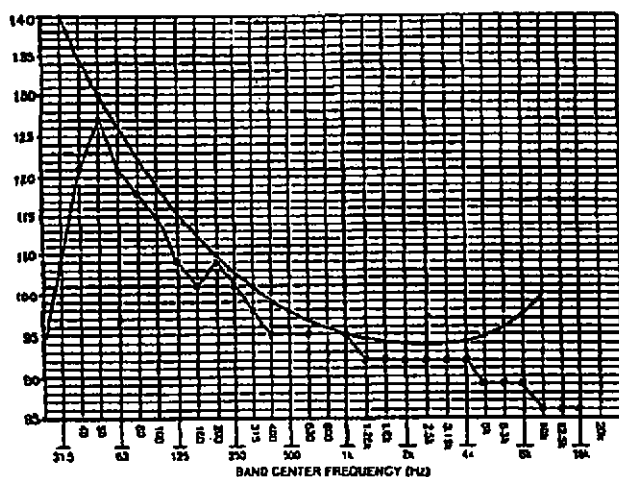


Fig. 7. A-weighting vs Typical Disco Spectrum.

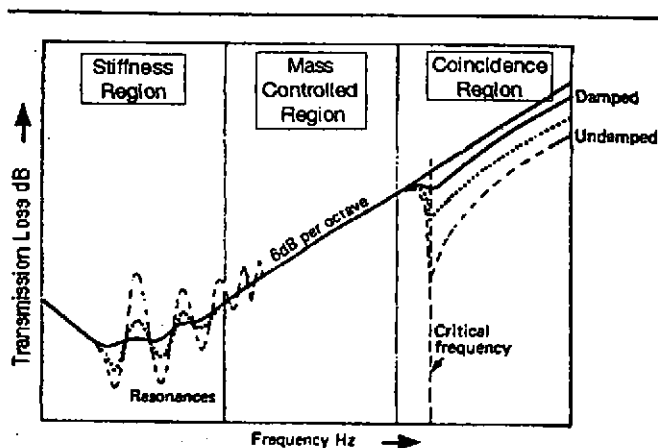


Fig. 8. Mass Law - Partition Behavioural Modes

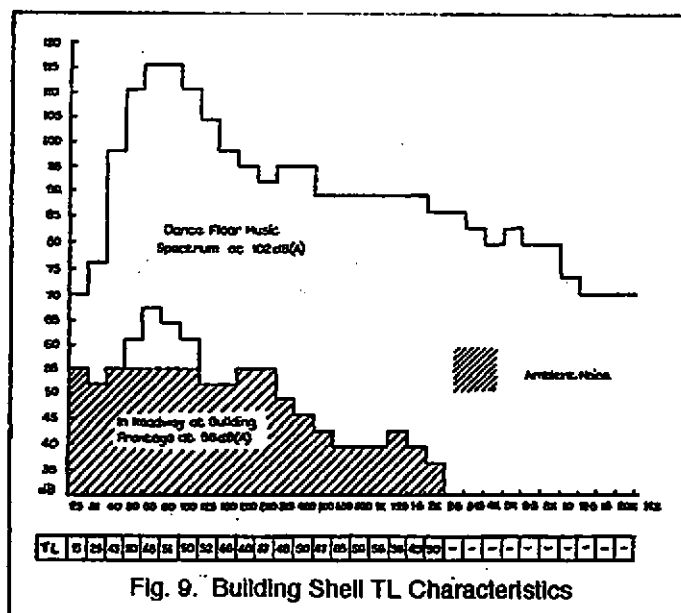


Fig. 9. Building Shell TL Characteristics

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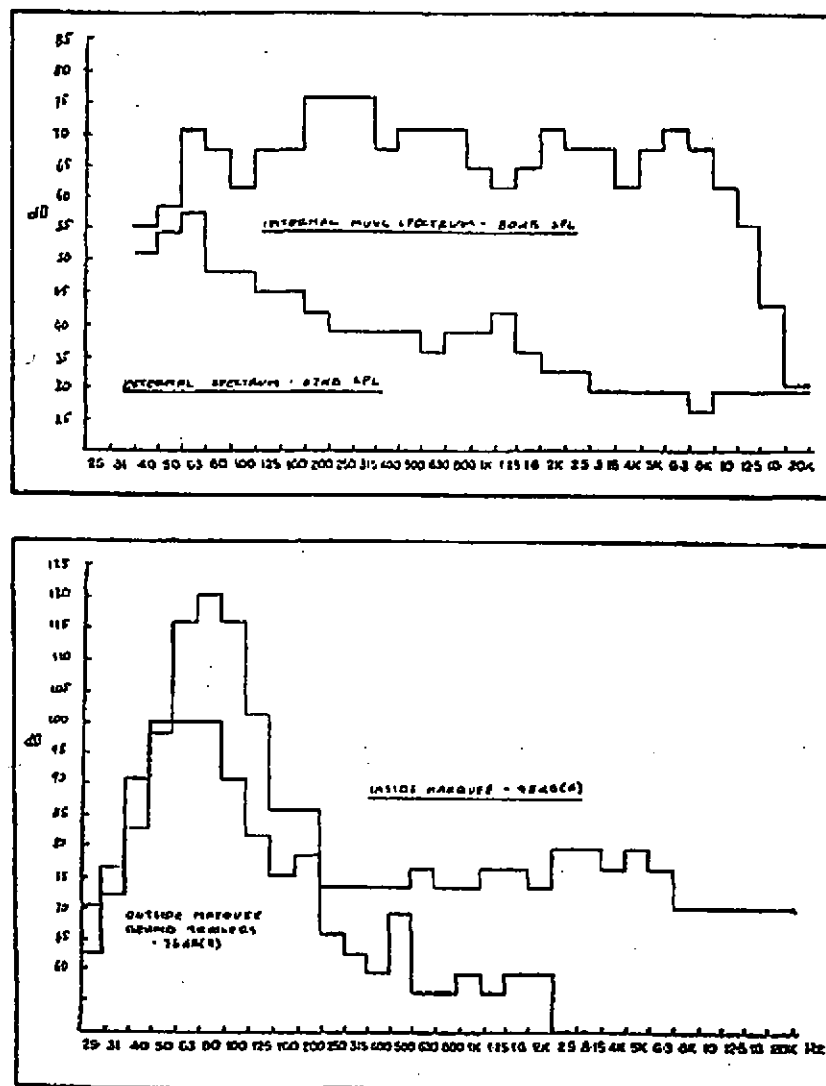


Fig. 10. Warehouse Building & Marquee + Screening TL Performance.

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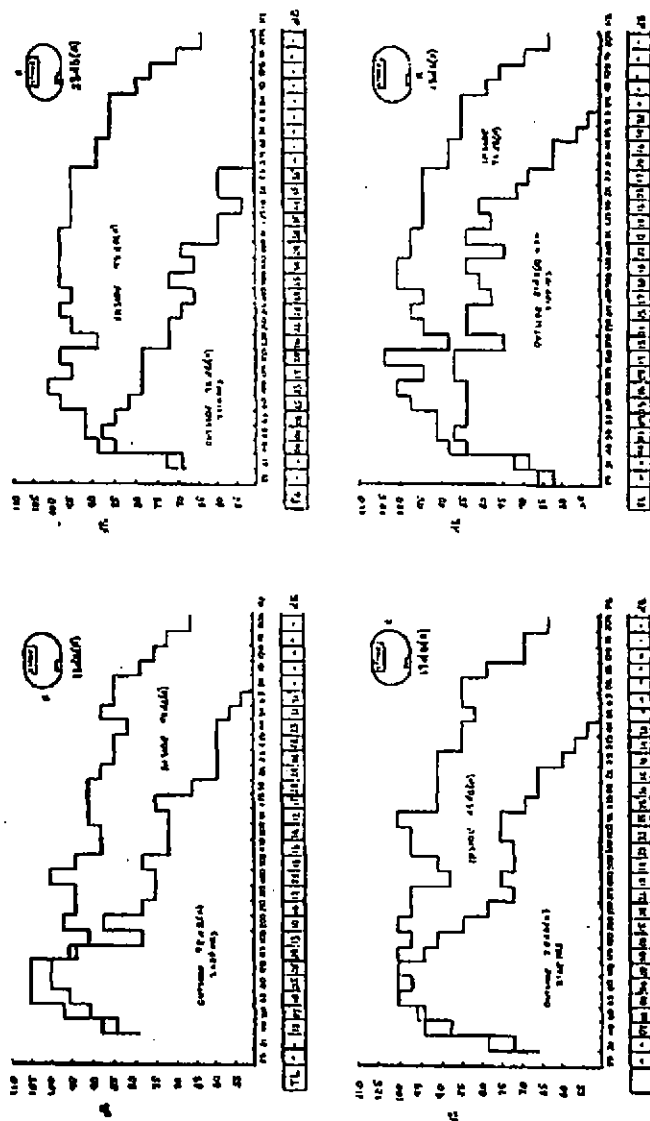


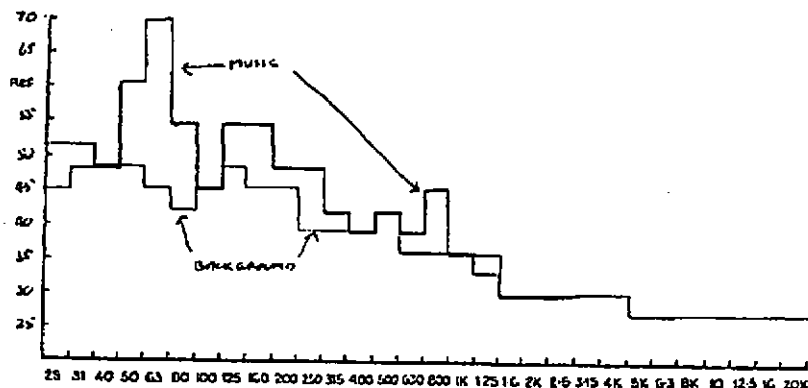
Fig. 11. Marquee Enclosure Characteristics.



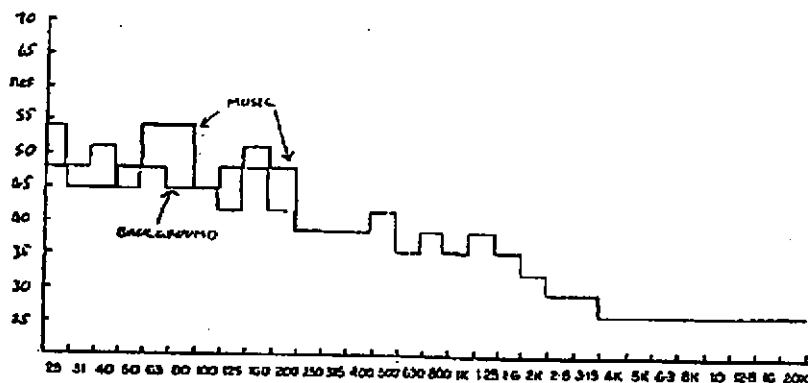
Fig. 12. Melton Mowbray Rave Site Plan.

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DATE: MUSIC EXCEEDANCE OF BACKGROUND, 03/04/03 DATE: 4/10/03 REF: CF6302
 CLIENT: PHARMACY PROMOTIONS LOCATION: MELTON LANE TORRANCE ROAD
 Ref Lvl: 60 dB Sns: 3 dB SPL: 88/83 dB Wtg: A Resp: 20W Sig: 10



DATE: MUSIC EXCEEDANCE OF BACKGROUND, 03/04/03 DATE: 4/10/03 REF: CF6302
 CLIENT: PHARMACY PROMOTIONS LOCATION: MELTON LANE TORRANCE ROAD
 Ref Lvl: 60 dB Sns: 3 dB SPL: 85/81 dB Wtg: A Resp: 20W Sig: 10

Fig. 13. Melton New Year Rave - Typical Residual Spectra.

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