LOW FREQUENCY NOISE LOUDNESS VS ANNOYANCE

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1. INTRODUCTION

There has been much interest recently in the choice of a room criterion assessment method, particularly with respect to low frequency noise problems. This follows on the inclusion of both the RC and NCB criteria methods in ANSI S12.2-1995. The main divergence between the two criterion curves occurs at low frequencies, i.e. below 100 Hz. The reason for this divergence is that the NCB curves are based on the assumption that loudness and annoyance are equivalent while the RC is empirically based and reflects the assumption that, at low frequencies, in particular, loudness and annoyance are not equivalent [1,2]. The great interest in achieving an acceptable Sound Quality environment, has led to a recognition by many researchers that annoyance is more than just loudness. For example, Zwicker [3] pioneered recognition that to determine annoyance, sound quality factors such as fluctuation strength and sharpness would need to considered in addition to a simple loudness metric. This recognition has not yet resulted in a change away from the old and purely loudness-based assessment metrics such as the dBA or NCB.

Below we report on the results of a pilot study conducted as the initial research of Phase 2 of the ASHRAE sponsored research “The Determination of the Relationship Between Low Frequency HVAC Noise and Comfort in Occupied Spaces - Subjective Phase“. The results shed some light with respect to assessment of low frequency noise, in particular.

2. NOISE STIMULI

For the purpose of the testing, 12 samples of HVAC noise with varying degrees of low frequency content were used. These were based on a sample of over 70 HVAC noises that were collected during Phase 1 of the ASHRAE sponsored research [4].

For this testing, three sequences of the 12 test stimuli, were generated with the only proviso being that the Sound Pressure Level difference between any two samples should not be more than 40 dB. Within each sequence, each noise stimulus was presented for 10 seconds, followed by a 7 second period of silence during which the subjects rated the test stimulus. Table 1 below shows the first sequence.

Two test series were conducted. For the December, 1997, tests, each subject was presented each of the three sequences on separate occasions. All tests were repeated for both loudness and annoyance. Only the latter two sequence results were used in analysis. For the April, 1998, tests, the same test sequences were used except that each subject rated Sequence 1 and 3, always in that order (played back in one session lasting six minutes) and both sets of data were used in the analysis. All tests were repeated for both loudness and annoyance.

3. RESPONSE RATING

To determine the subjective response of subjects for both loudness and annoyance, the Absolute Magnitude Estimation method was used. In this psycho-acoustical method, the subject assigns a rating number to the perceived loudness or annoyance without the use of a reference. This method has been used previously to characterise perception of loudness eg [5]. For this testing, the subjects were asked to rate loudness as follows. "For each of the sounds, record its loudness as defined as the perceptual aspect of the noise that is changed by turning the volume knob on a radio or T.V." For annoyance, the task was to "record the annoyance defined as the nuisance aspect of the sound experienced. Imagine you are in an office and are seated in your chair while working. Please estimate how annoyed **you** would feel when exposed to each sound".

Table 1. Sequence Details for the Pilot Study

SEQUENCE 1		
Description	**Sample Numbers**	**Overall SPL dB(A)**
Rumble w/40Hz Tone	7	54.9
63Hz Tone (76dB)	6	47.3
Rumble w/63Hz Tone	2	44.8
31.5Hz Tone (81dB)	1	40.6
Rumble	8	47.3
Roar	11	61.4
Rumble/Roar	12	58.8
25Hz Tone (92dB)	9	44.7
Roar w/ 50Hz Tone	10	51.4
50Hz Tone (81dB)	4	45.8
Rumble	3	47.5
Rumble w/50Hz Tone	5	52.8

4. TEST METHOD

The subjects were seated in the ASHRAE test room. This room has a double wall construction and is floated on isolators so as to minimise any noise intrusion from the outside. The room is 6700 long by 3100 wide by 2350 high and is a reasonably sized meeting room. The noise stimuli are played back to the subjects via two loudspeakers, each one located above a diffuser located in the ceiling on either side of the room width-wise. The subjects sat in one of three seats at a desk, these seats having been pre-qualified as nominally providing the same acoustic stimulus to the subjects independent of seat location. Up to three subjects were tested at any one time.

To aid in the response rating, a cue light located on the desk came on when the noise stimulus ended so as to indicate to the subjects that the time to fill in the response ratings had begun. In this way, no stimuli were missed.

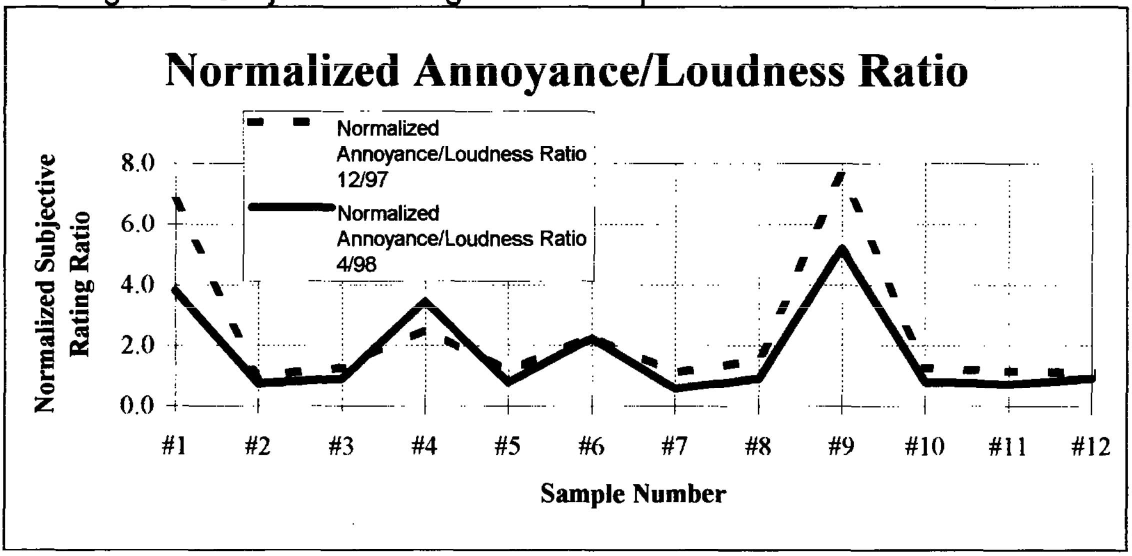
5. TEST SUBJECTS

For the December, 1997, tests there were four male subjects, average age 23 years. For the April, 1998, tests, there were 7 subjects, 3 males, 4 females, average age 28.3 years. All subjects had normal hearing.

6. TEST RESULTS

The rating results were normalised using a geometric mean analysis. This analysis accounts for the different range of numbers used by each subject. The mean loudness and annoyance ratings for each noise stimulus were then calculated and the ratio of annoyance to loudness plotted against noise stimulus. It can be seen from Figure 1 that for both the December and April studies, there are some noise stimuli for which the annoyance is significantly higher than the loudness and that there is a good correspondence between the results of both studies. In all cases, the Annoyance-to-Loudness ratio is of the order of 1 or above.

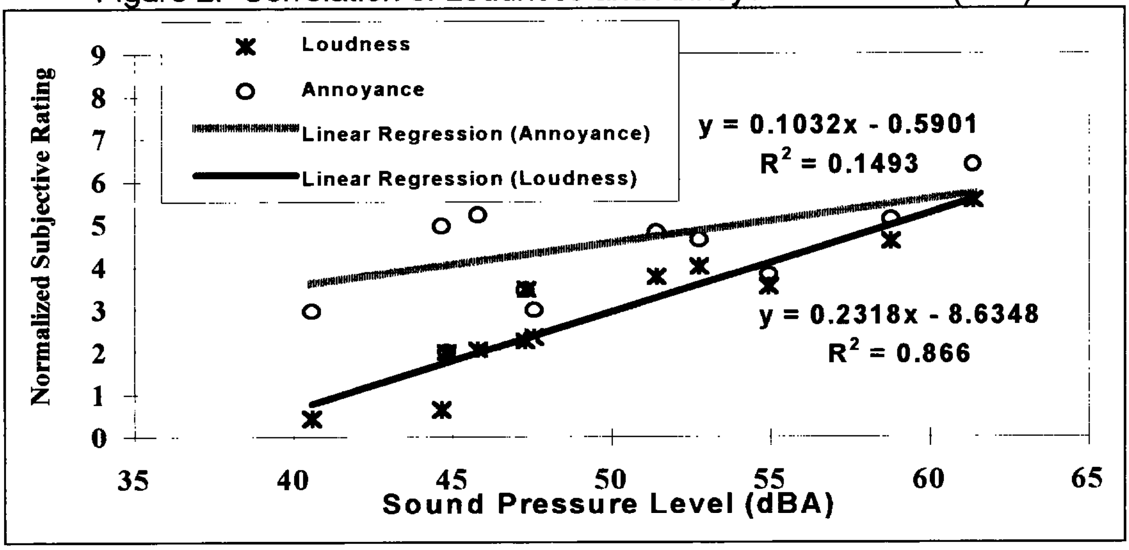
Figure 1. Subjective Rating versus Sample Number for the Pilot Tests



7. LOUDNESS VS ANNOYANCE AND THE dBA

To determine the relationship between the subjective rating and the dBA (loudness) metric, as an example, a correlation was run. Figure 2 below shows the result. The dBA metric was highly correlated with the subjective rating of loudness but only poorly correlated with the subjective annoyance. This result was replicated for other purely loudness-based metrics such as the Stevens Mark 7 loudness metric which forms the basis for the NCB.

Figure 2. Correlation of Loudness and Annoyance with SPL(dBA)



8. CONCLUSION

The strong implication of these results is that, for HVAC noises with rumble, the loudness and annoyance cannot be assumed to be the same as has been assumed. The RC Mark 2 method of assessing HVAC noise accounts for this while the NCB curves at low frequencies (below 100 Hz) do not.

9. REFERENCES

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