DEARBORN, MICHIGAN
Sound Quality Symposium
SQS 2002
2002 August 22

LOW FREQUENCY NOISE - ARE LOUDNESS AND ANNOYANCE THE SAME?

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INTRODUCTION

There has been much interest over recent years in the issue of assessment of low frequency noise. One of the main issues is whether Loudness and Annoyance is the same at low frequencies (< 100 Hz) as has been assumed by some researchers eg [1]. Other researchers have established that annoyance is more than just loudness. For example, Broner and Leventhall [2] established that loudness based metrics did not properly assess low frequency noise complaints. In a similar way, Zwicker [3] pioneered recognition that to determine annoyance, sound quality factors such as fluctuation strength 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 some research sponsored by ASHRAE on "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.

NOISE STIMULI AND SUBJECT TESTING

For the purpose of the testing, 15 base samples of HVAC noise with varying degrees of low frequency content were used. These were drawn from the noise recordings of over 70 HVAC noises that were collected during Phase 1 of the ASHRAE sponsored research [4]. The samples were converted to a ".wav" format and additional temporal shaping was conducted using the Sound Forge sound processing software.

A total of 60 stimuli were thus created. For the purpose of testing, these were further randomly divided into groups of 15, thus generating four Sequences designated A, B, C and D. The only proviso was that more or less equal numbers of each type of stimulus (Neutral, Neutral marginal, Rumble, Strong Rumble) should occur in each of the four sequences.

For the actual testing, three orders of presentation of the 15 test stimuli (thus 45 test stimuli for each Sequence) were generated with the only proviso being that the Sound Pressure Level difference between any two samples should not be more than 40 dB. Each noise stimulus was presented for 10 seconds, followed by a 10 second period of silence during which the subjects rated the test stimulus for both Loudness and Annoyance and other attributes. Each Sequence thus lasted for 15 minutes. Figure 1 below shows a SPL vs Time trace for part of one the sequences. The figure shows five stimuli separated by five periods of silence. The different temporal characters of the stimuli can be easily seen.

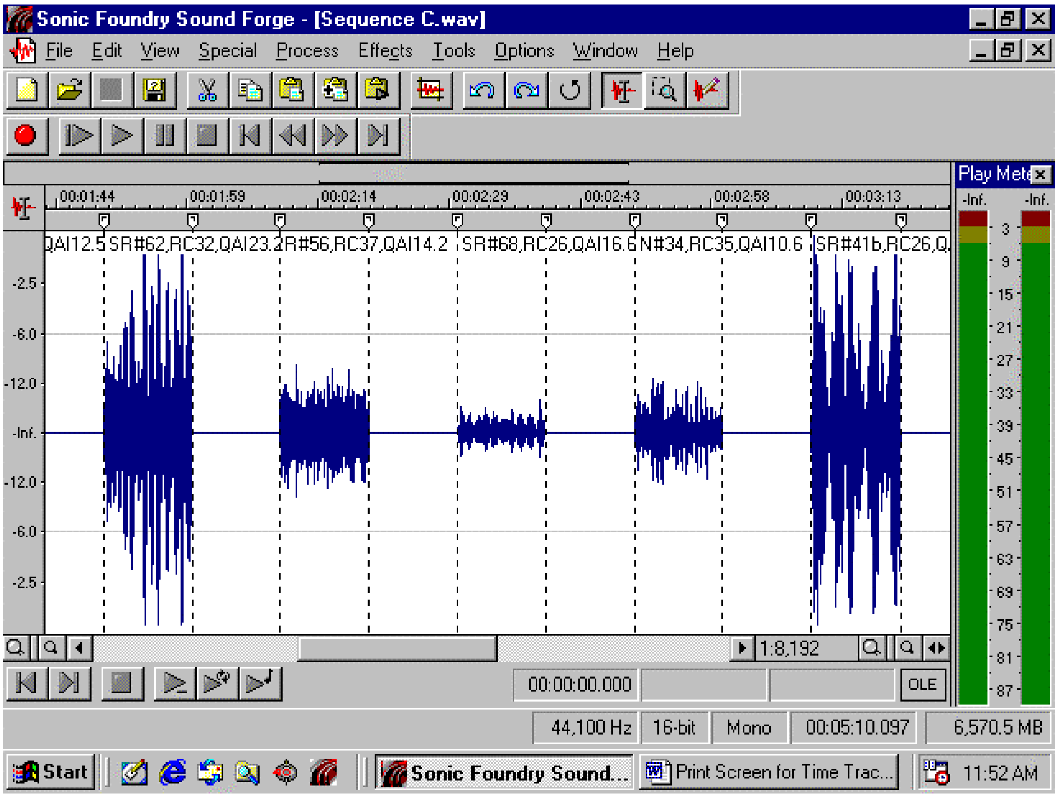

Figure 1: SPL vs Time trace for part of Sequence C .

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.

Prior to the conduct of the main Subject testing, each Subject was also given a trial run in which they followed the above instructions and rated the Loudness and Annoyance only for nine samples of white noise varying in SPL between 32 dBA and 72 dBA. Given that the Loudness response to white noise is well known eg [5], it was possible to assess whether the Subjects were indeed following the response rating instructions adequately.

TEST METHOD

The subjects were seated in the Vipac psycho-acoustic 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 one loudspeaker, which is located above a diffuser located in the ceiling on one side of the room width-wise. The subjects sat at a desk and completed the rating task by means of keyboard on a laptop computer.

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.

TEST SUBJECTS

Eleven male subjects average age 36 years and ten female, average age 30 years were used. All subjects reported normal hearing.

TEST RESULTS ANALYSIS

The rating results from the first presentation of the 15 stimuli within each Sequence were ignored. The response rating for each of the stimuli in the second and third presentations (both a different order of presentation from the first set of 15 stimuli) were then geometrically averaged. The Group Mean Loudness and Annoyance for each stimulus was then obtained by taking the geometric mean of all of the Subject means. As we are particularly interested in the difference between Loudness and Annoyance, the Annoyance-to-Loudness (A/L) ratio was also calculated. The subjective responses were then plotted against various noise metrics to determine if any relationships existed.

LOUDNESS VS ANNOYANCE AND THE dBA

To determine the relationship between the subjective rating and the dBA the Loudness and Annoyance Group Mean Ratings were plotted against the A-weighted SPL for each stimulus. Figure 2 shows the result. It can be seen that the Annoyance and Loudness ratings are generally different for each stimulus. Figure 3 shows that the A/L ratio varies over a range of 0.9 to 2.0 and that the A/L ratio can be quite different for stimuli with very similar A-weighted SPL. Indeed, the coefficient of determination is very close to zero, thus showing that the A-weighted SPL alone will not be a good predictor of response, and in particular, of Annoyance relative to Loudness.

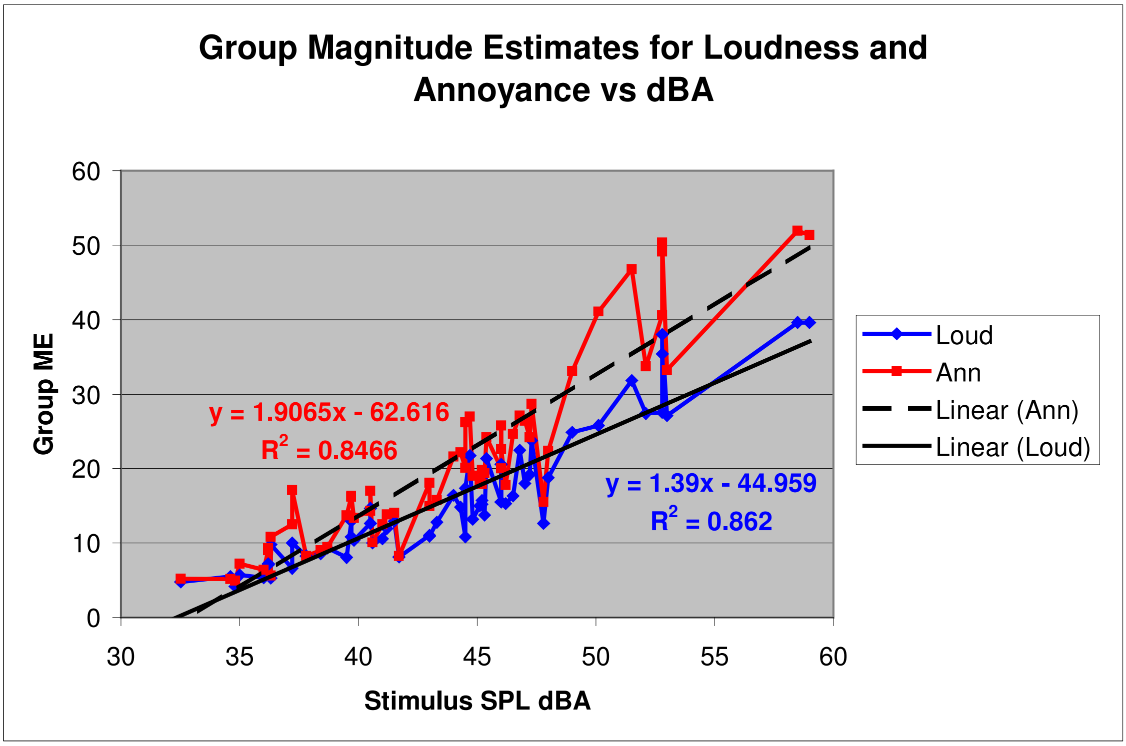

Figure 2: Loudness and Annoyance Ratings versus SPL (dBA)

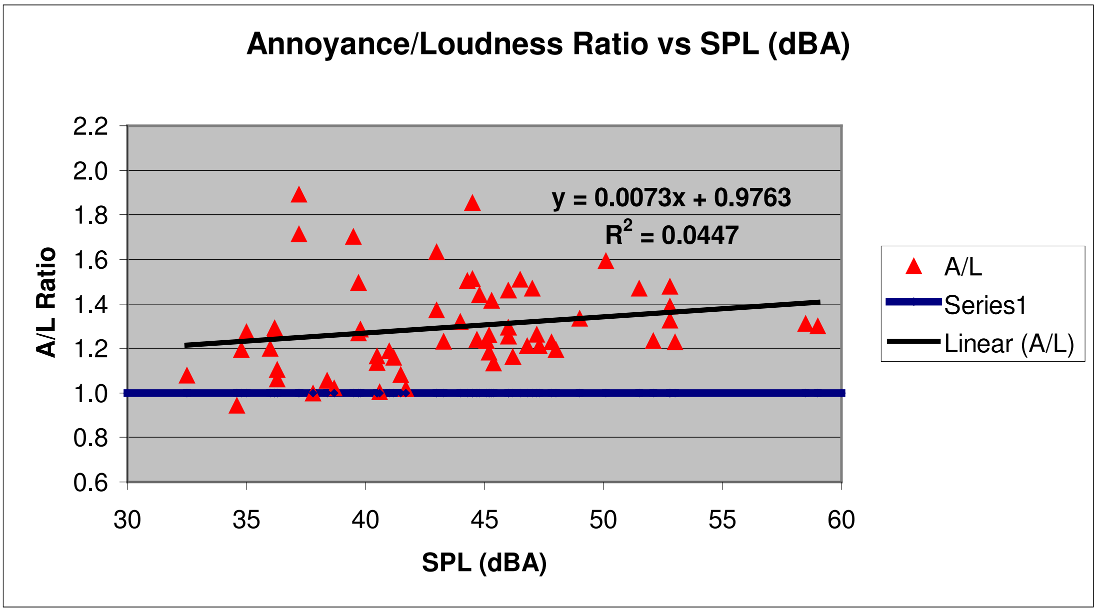

Figure 3: Annoyance/Loudness Ratio versus SPL (dBA)

The strong implication of these results is that, for HVAC noises with rumble and temporal variations, the loudness and annoyance **cannot** be assumed to be the same.

These results shed some light on the resolution of the confusion that results from the application 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. < 100 Hz, with results differing by up to 15 dB. The RC method of assessing HVAC noise [6] appears to account for the difference in loudness and annoyance of low frequency noise (< 100 Hz) while the NCB curves do not. This research suggests that a revision to the NCB curves at low frequencies (< 100 Hz) may be appropriate.

ACKNOWLEDGMENT

This work was conducted as part of the Research Project 879RP sponsored by ASHRAE.

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