CURRENT LOW FREQUENCY NOISE (LFN) ASSESSMENT GUIDELINES AND THEIR USE IN ENVIRONMENTAL NOISE IMPACT ASSESSMENT

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1. The Nature of Low Frequency Noise

Discussed herein are current low frequency noise (LFN) noise assessment rating schemes, and key issues.

LFN is not clearly defined, but generally covers noise in frequencies below 100 to 150 Hz. Infrasound (i.e., sub 20 Hz) is not usually audible but may still produce impacts through perceptibility. Infrasound LFN can produce resonances in human organs and tissues. (Berglund et al, 1996). One feels the noise as pressure sensations (DEFRA, 2001). LFN can also rattle windows, dishes, etc. through sympathetic resonances, increasing annoyance (Bergland). Thus, LFN rating schemes typically go as low as 10 to 16 Hz.
Typical rural sound environments have few man-made noise sources (e.g., traffic and industrial noise) and generally have "flat" frequency spectra. In urban environments, significant levels of ambient low frequency noise exist but are generally less perceptible than in remote areas, due to masking by higher frequency noise within the "urban hum". LFN may be acceptable outdoors, particularly in urban environs. Indoors, building envelopes readily transmit LFN while higher frequency noises are blocked. This removes the masking effect of the high frequency noise, and can therefore increase the noticeability and related annoyance associated with the LFN portion of the spectrum. Closing the windows to block LFN noise only makes the problem worse.

LFN annoyance research suggests that for humans the doubling rate of perceived loudness is 4 to 5 dB for LFN vs 10 dB at 1KHz.(Bergland).

Balanced noise spectra at the receiver are needed to reduce the likelihood of annoyance and LFN complaints. Overall linear SPL and A-weighted SPL differences should be limited to 20 dB for low indoor A-weighted levels (Broner and Levanthall, 1983; Broner, 1994).

2. Comparison of Current LFN Guidelines

Table 1 and Figure 1 summarize the most widely used LFN guidelines. Most are noise criteria curves given the importance of spectral balance.

Table 1: LFN Impact Assessment Criteria

Criteria	Reference	Spectrum	Assessed Location
Overall Sound Level	ANSI B133.8	75 dBC Overall Limit	Outdoor
Vibration in light-weight structures	ANSI S12.2	1/1-Octave for 16, 31.5, 63 Hz bands	Indoor / Outdoor
NCB "balanced" noise criteria curves	ANSI S12.2 (Beranek)	1/1-Octave	Indoor
RC room criteria curves	ASHRAE 1995 and ANSI S12.2	1/1-Octave	Indoor
RC Mark II room criteria curves	ASHRAE 1999 Blazier	1/1-Octave	Indoor
RNC room criteria curves	Schomer	1/1-Octave	Indoor
LFNR low frequency noise rating curves	Broner and Leventhall	1/3-Octave	Indoor
LFRC low frequency room criteria curves	ASHRAE (Broner)	1/3-Octave	Indoor

Figure 1 shows huge discrepancies among the curves with a range of over 30 dB between RC Mark II and NCB at 16 Hz. Who's right? Both Broner and Beranek have compared the various ranking schemes, and found the other party's deficient (Broner, 1994, Beranek, 1997). Broner's and Blazier's curves are based on laboratory tests while Beranek's are based on reported annoyance with real-world HVAC systems. Note that the RC Mark II curves lie well below the threshold of hearing in the 16 Hz band. Beranek has argued against limiting noise to levels below the threshold of hearing (Broner, 1994). Broner and others have responded that LFN impacts at levels below the threshold of hearing are possible, due to sensation of the noise and the feeling of envelopment.

The RNC curves (Schomer, 2000) attempt to bridge the gap between the two systems, by providing base curves similar to the NCB system, for "well-behaved" HVAC systems, and then applying temporal variation penalties for annoyance due to large turbulent fluctuations at low frequencies.

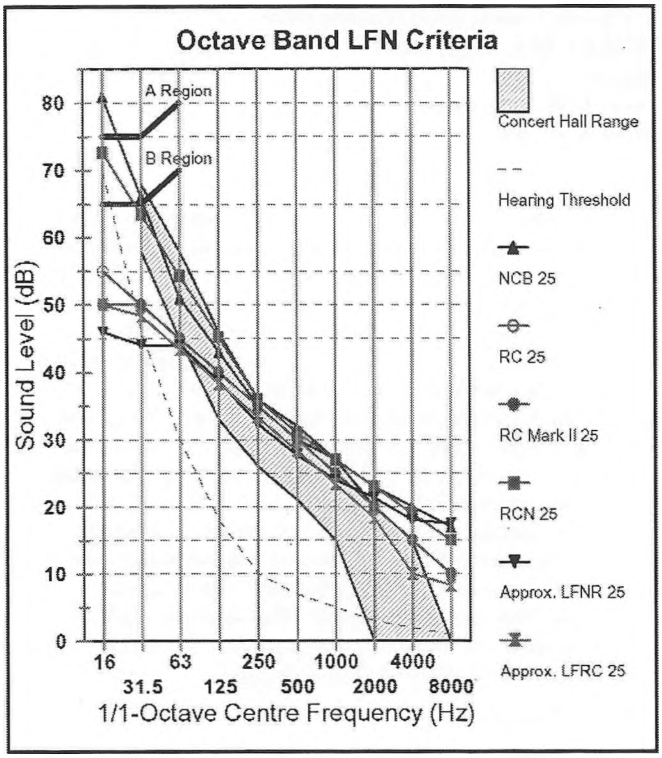

Figure 1: LFN Criteria Curves Compared

Note: LFNR and LFRC curves approximated by assuming that the lowest 1/3-octave value in each 1/1-octave band is representative of the equivalent 1/1-octave band guideline level.

Figure 1 also compares the various criteria against the range of measured ambient noise in eight world-class concert halls (Beranek, 1997). The data set only extends down to 31.5 Hz. However, the results are extremely interesting. The NCB 25 curve lies at the upper boundary of the measured concert hall range for low frequencies down to the 31.5 Hz band, and based on inspection of the spectrum shape, it seems likely that this would hold true for the 16 Hz band as well. The RC curves may be seen in this context as over-design – why should a bedroom have to perform better than a concert hall? While some audience members may fall asleep in concert halls, the primary use of the space is not for this purpose. Therefore, the audience may be more amenable to LFN in this context, rather than in their homes. Many of the long-term effects of LFN seem to be related to duration of exposure (ASHRAE, 1999).

The range of measured concert hall values presented above extends into the 'B' region representing moderately noticeable vibrations in the ANSI S12.2 standard. No complaints have been reported in these halls. Beranek conducted further comparisons of measured HVAC noise versus the 'B' range, and concluded that based on real-world data, there is little justification for including the 'B' range in the specification (Beranek, 1997). Schomer's proposed RNC curves do not include the 'B' range in their specification.

3. Proposed Facilities: Estimating LFN Impact

LFN impacts are best assessed indoors. However, two criteria could be used to limit outdoor impacts:

- ANSI B133.8: limits outdoor sound levels from gas turbine installations to 75 dBC at residential points of reception (to control sound-induced vibrations); and
- ANSI S12.2: ideally restricts LFN to "moderately noticeable" Region B, but in no case should they extend past the "clearly noticeable" Region A.

Predicting LFN indoor impact is more complex, given criteria differences. Our Canadian values suggest a compromise:

- The criteria choice should consider the existing ambient environment. Receptors in urban areas or near existing industry are likely to have relatively "high" existing LFN in their ambient sound environment. LFN from new facilities, may be more readily tolerated since the change from existing conditions would be smaller. Use of the NCB or RNC criteria in these locales seems reasonable. In rural areas with "flat" ambient spectra, and little LFN content, RC or RC Mark II curves would be appropriate.

  The type of noise source should also be considered. For example, a power plant having a few gas turbines and individual exhaust stacks would be less likely to produce time varying noise than one with several large diesel engines and bundled stacks (higher likelihood of beats).
- It seems reasonable to base assessments on total (plant + ambient) levels, requiring representative 1/1-octave band levels and overall dBA measured ambient noise levels. Where possible, maintain a balanced frequency spectrum (dBL - dBA • •20 dB, per Broner, 1994).
- Indoor levels can be estimated using typical building noise reduction characteristics. Where LFN impacts are likely, consider examining specific construction at worst-case receptors, and existing indoor noise levels.
- Limit LFN levels to the NCB 25 curve at low-frequencies (at or below 31.5 Hz), using a "tangency" approach and where economically and technically feasible, mitigate as close to the target RC Mark II value as possible.

4. References

Due to space constraints, a detailed reference list is not provided, but available upon request.