Low-Frequency Aircraft Noise

LAX Community Noise Roundtable
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Low-Frequency Aircraft Noise Overview

- Residences located near runways can experience high levels of low-frequency noise (LFN)
- LFN can induce “feelable” vibrations
- Standard sound insulation does not sufficiently reduce LFN
Low-Frequency Aircraft Noise Studies

- HMMH Collected data on LFN and associated induced structural vibrations
- Measurements were made at MSP, SFO and BWI, listening tests were conducted in an aircraft noise simulator and laboratory studies were conducted
Low-Frequency Aircraft Noise Studies - Aspects Examined

• Measured sound, vibration, insulation efficacy and resident’s judgments
• For each takeoff, determined:
  – Sound Level (A- and C- Weighted)
  – Induced Vibration Levels
  – Resident’s “Rating” of sound
• Correlated Sound Levels with Vibration Levels and Resident Ratings
Low-Frequency Aircraft Noise Studies - Measurement Locations

• LFN levels may produce perceptible vibrations at considerable distances from the runway end
  – Only in limited directions due to the directional sound pattern produced by jet engines
  – Vibrations could occur 7,000 to 8,000 feet from the start-of-takeoff-roll
• Well outside the 65 DNL (CNEL) contour
Low-Frequency Aircraft Noise Study
Measurement Locations – BWI Takeoffs
Low-Frequency Aircraft Noise Studies
Principal Findings

• Start-of-takeoff-roll, acceleration and thrust reversal generate high levels of LFN
  – Aircraft ground operations
• LFN below 200 Hz
  – Human hearing range is from 20 Hz – 20,000 Hz
• Low-frequency sounds propagate further and with less reduction due to their longer wavelength
• Standard A-weighting is unlikely to relate people’s reactions to these low-frequency sounds
Low-Frequency Aircraft Noise Studies - Principal Findings

• Vibration/rattle due to LFN
  – Hubbard exterior sound level criteria
• C-Weighted Lmax correlated better with wall vibration and with resident ratings
• HMMH work for BWI and SFO suggest 75 dB to 85 dB maximum C-weighted levels result in perceptible window and wall vibrations
• C-Weighted levels preferable for estimating resulting vibration and annoyance potential
Low-Frequency Aircraft Noise Studies Results – Vibration vs Maximum Sound Level

![Graph showing the relationship between South Wall Max RMS Accel. Levels (dB) and Outdoor Lmax (dBC) for ANSI S3.29 and Tactile Threshold.](image)

- **ANSI S3.29**
  - Range of Thresholds

- **Tactile Threshold**
  - Hubbard Range for Tactile Threshold
Low-Frequency Aircraft Noise Studies - Comparison with Human Judgments

Event 2 Indoors - Rating 90, $C_{\text{max}} = 82$ dB

Event 1 Indoors - Rating 80, $C_{\text{max}} = 83$ dB

Event 3 Indoors - Rating 30, $C_{\text{max}} = 76$ dB

(Tokita & Nakamura thresholds)
Conclusions From PARTNER LFN Study

- Low-frequency sounds propagate further than high-frequency sounds and can annoy people far from the runway
- The Hubbard criteria work well for screening for vibration/rattle due to LFN
- A-Weighted and C-Weighted maximum noise levels work for predicting laboratory response at lower A-weighted noise levels (60 dB – 80 dB)
- For high levels use C-Weighted maximum levels or Tokita & Nakamura thresholds
Conclusions

- C-Weighted maximums are most effective metric for screening for possible LFN problems
- Use C-Weighted maximum of 80 dB as screening threshold
- If possible, also measure associated A-Weighted maximum levels for additional screening information
  - C-Weighted minus A-Weighted indicates significance of LFN
Conclusions

- C-Weighted better correlated with induced vibrations and resident ratings than A-Weighted
- Perceptible wall vibrations likely to occur for C-Weighted Lmax exceeding 75 dB – 85 dB
- C-Weighted Lmax possible predictor of subjective judgments of takeoff noise
Questions?