Wayside Noise Measurements of High-Speed Trains

David A. Towers

Harris Miller Miller & Hanson Inc., 15 New England Executive Park, Burlington, Massachusetts 01803 USA

Abstract: Wayside noise measurements of high-speed train operations were carried out for the German Intercity Express (ICE), Swedish X2000, U.S./French RTL-2 Turboliner, French TGV (Nord), British/French Eurostar and Italian Pendolino ETR-450 trainsets. The results indicate that the TGV, ICE and RTL-2 trains had similar A-weighted noise emissions and were typically the quietest of the trains tested. The results also suggest that these trains are in compliance with the U.S. Federal Railroad Noise Emission Standard at speeds up to about 250 km/h (155 miles/h), and that A-weighted noise levels were not significantly affected by low-frequency aerodynamic noise for train speeds up to nearly 300 km/h (186 miles/h).

BACKGROUND

Wayside noise measurements of high-speed trains were carried out in the USA for the ICE, X2000 and RTL-2 trainsets, and in Europe for the TGV, Eurostar, Pendolino and X2000 trainsets. The measurements in the USA were made as part of the Northeast Corridor (NEC) Project and those in Europe were made to develop noise-prediction models for a new guidance manual to be published by the U.S. Federal Railroad Administration (FRA) on "High Speed Ground Transportation Noise and Vibration Impact Assessment." All of the trains tested were electrically-powered from overhead catenary, except for the gas-turbine driven RTL-2. The X2000 and Pendolino trains had tilting cars. The tests included measurements of train noise at various distances and elevations with respect to the track at a variety of sites. All noise measurements were made using one-half inch pre-polarized condenser microphones protected by foam windscreens. The signals from the microphones were amplified and recorded on magnetic tape using digital audio tape (DAT) recorders. Calibrations, traceable to the U.S. National Institute of Standards and Technology (NIST), were carried out in the field. Train speeds were measured using a radar speed detector and/or video camera. The tape-recorded data were analyzed in the laboratory using a sound level meter and graphic level recorder to obtain A-weighted sound level data and using a Fast Fourier Transform (FFT) analyzer to obtain one-third octave band frequency spectra.

RESULTS

An overview of the A-weighted train noise measurement results is given in Figure 1. This figure provides a graph of $L_{1max}$ (the maximum pass-by noise level measured with "slow" averaging time) as a function of train speed, normalized to a reference distance of 30.5 m (100 ft). Also shown in the figure are train noise level versus speed curves for the X2000, ICE and RTL-2 trainsets, generated by the noise model developed for the U.S. Northeast Corridor Project (1,2). All data are based on measurements made at a microphone height of 1.4 to 1.5 m (4.5 to 5.0 ft) above the ground.

![Graph showing train noise levels as a function of speed.](image)

**FIGURE 1.** High-Speed Train Noise Levels as a Function of Speed
The results in Figure 1 indicate that the European train noise data generally fall within the range of the NEC Project curves. The results also show that the TGV trains were typically the quietest of the trains tested in Europe, with noise emissions similar to the ICE and RTL-2 trains tested in the USA. Wayside noise levels for the X2000 and Pendolino trains averaged about 5 decibels higher, with noise emissions similar to the X2000 train tested in the USA. The data for the Eurostar trains showed the greatest variation, with noise levels scattered over the range for the other trains. This variation may reflect two versions of the Eurostar trainsets that were in operation during the measurements.

Representative one-third octave band maximum noise level spectra for all six trainsets, measured at similar distances and speeds, are provided in Figure 2. The spectra for the electric trainsets have generally similar characteristics, with peaks below 500 Hz due to aeroacoustic effects and peaks above 500 Hz due to mechanical sources (e.g. cooling fans) and wheel/rail interaction. Among these spectra, notable differences include a peak at 315 Hz for the Eurostar trains that appears to result from aerodynamic sources. At higher frequencies, mechanical noise and wheel/rail noise for the X2000 and Pendolino trains stand out. For the gas-turbine powered RTL-2, noise levels exceed those for the electric trainsets between 125 Hz and 250 Hz and at frequencies above 10 kHz, most likely due to the turbine engines and auxiliaries. However, the overall A-weighted noise levels are generally determined by the mechanical and wheel/rail noise sources at frequencies between 1000 Hz and 4000 Hz, even at speeds up to 300 km/h (186 miles/h).

Finally, the results suggest that at speeds up to about 250 km/h (155 miles/h), most of the trains measured are in compliance with the U. S. Federal Railroad Noise Emission Standards (3). The limiting standard (for locomotives) is 90 dBA with a 2-decibel tolerance, yielding an absolute limit of 92 dBA in terms of $L_{\text{max}}$ (the maximum pass-by noise level measured with "fast" averaging time). Given that the measured $L_{\text{max}}$ were generally 2 decibels greater than the measured $L_{\text{max}}$, the absolute limit would be 90 dBA in terms of $L_{\text{max}}$. Of the representative data shown in Figure 1, only the X2000 and Pendolino trains exceed this limit at speed below 250 km/h (155 miles/h).

**ACKNOWLEDGMENTS**

The work reported herein was performed by Harris Miller Miller & Hanson Inc., on behalf of the U. S. Department of Transportation Federal Railroad Administration, under separate subcontracts to De Leuw, Cather & Company and to the joint venture of Daniel, Mann, Johnson, and Mendenhall/Frederic R. Harris, Inc.

**REFERENCES**