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Research Results

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Railroad Horn Systems

SUMMARY

From 1992 to 2002, the Federal Railroad Administration (FRA) Office of Research and Development (ORD) sponsored a multi-dimensional study of horns as warning devices, conducted by the Volpe Center. The purpose of the study was to assess ways to provide adequate warning. The results were used as the basis for an interim rule, established in December 2003, for sounding audible warnings before a train arrives at a grade crossing.

The study consisted of two components: (1) technology assessment and (2) human perception and recognition. The technology assessment addressed physical characteristics. It consisted of (1) measurement of the acoustic properties of three typical railroad horns and prototype automated horn systems (AHS), (2) measurement of the insertion loss and interior noise levels of several 1990 and 1991 motor vehicles, (3) laboratory studies to assess the effectiveness and detectability of horn signals, and (4) measurement of horn sound levels at multiple measurement locations. The human perception and recognition research addressed the effectiveness of those systems as warning devices and their impact on the daily activities of residents. It consisted of (1) use of video cameras at selected grade crossings to observe driver behavior after sounding of three-chime train horns and AHS mounted on the wayside and (2) surveys of residents along railroad corridors about the effects of those two horn systems on their daily activities.

The wayside AHS was shown as a potential solution for providing an effective, detectable warning to motorists with acceptable community noise levels. AHS installed on the wayside can be directed down the roadway toward oncoming traffic to greatly reduce the amount of community exposure.

The technology assessment showed the sound level of a wayside AHS that used a digital recording of a five-chime train horn was equal to or exceeded that of a train-mounted three-chime horn for drivers approaching a crossing. The laboratory studies showed a five-chime train horn to be far more effective in warning motorists than a three-chime train horn or a single-tone AHS. The technology assessment also showed that wayside AHS lowered community noise levels. The human perception and recognition tests showed that wayside AHS significantly reduced violations at grade crossings and reduced the disruption of daily activities experienced by nearby residents. The digital five-chime AHS was developed as a result of the tests performed.

Figure 1. Five-Chime Train Horn

Figure 2. Three-Chime Train

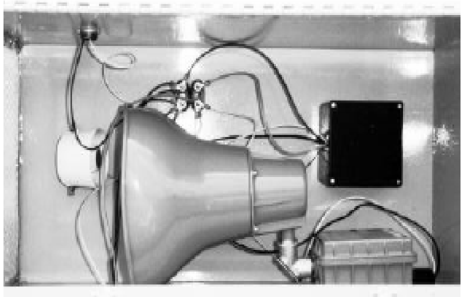

Figure 3. Automated Wayside Horn

BACKGROUND

In 1980, the FRA regulation requiring that all trains have a horn mounted on the lead vehicle was expanded to require that the horn must produce a signal with a minimum sound level of 96 dB at 100 feet forward of the train in its direction of travel.

In 1991, the FRA Office of Safety requested FRA ORD to study the ability of train-mounted horn signals to penetrate motor vehicle interiors and other background noise and the impact of the signals on motorist behavior and community noise levels. At that time, the Union Pacific (UP) Railroad was evaluating a prototype single-tone AHS as an alternative or supplement to train horns and offered it for testing.

Results of tests of the prototype AHS showed that it was not a viable alternative to train-mounted horns. Efforts were then initiated to develop a more effective, potentially viable AHS. Several years later, a prototype AHS was developed that used a digital recording of a five-chime train horn. The new prototype was offered to FRA for testing in Illinois.

RESEARCH OBJECTIVES

Technology Assessment:

- Characterize the acoustic properties of traditional locomotive horns and potentially viable alternative systems, and create a database of the acoustic information.
- Determine the insertion loss characteristics of late-model motor vehicles.
- Determine the probability of detection of railroad horn systems by motorists as a danger warning.
- Calculate the effectiveness of railroad horn systems in reducing accidents at grade crossings.

***Human Perception and Recognition*:**

- Compare the effect of a train horn and a wayside AHS on driver behavior at grade crossings.
- Determine the impact of a train horn and wayside AHS on the activities of residents near grade crossings.

RESEARCH METHODS

Technology Assessment:

Field Measurements of Acoustic Characteristics:

In 1992, sound level and frequency spectrum measurements were recorded for a five-chime train horn, a radio frequency (RF) three-chime train horn, a conventional three-chime train horn, and a prototype single-tone AHS. The test sites were all isolated from competing sound sources. Data were collected within a 30.5-meter radius circle around each horn system to provide information on its spectral output, the directivity of the source, the drop-off rate, the maximum sound pressure level produced, and the sound exposure level.

In 1992, baseline interior noise levels and sound insulation (insertion loss) characteristics were also established for several model year 1990 and 1991 motor vehicles. The interior noise levels were measured while the motor vehicles traveled at a constant speed of 30 mph with windows closed, ventilation systems off, and radios off. The sound levels were measured at a reference position inside the vehicle and at the same position with the vehicle removed. The recorded levels were used to populate an insertion loss model.

Laboratory Tests:

The horn acoustic measurements and the vehicle insertion loss calculations were used to predict the probability of a motorist detecting the signals of the three train horns and the prototype AHS. The information was also used to predict the effectiveness of the horn systems in reducing grade crossing accidents. Detectability and effectiveness were predicted for the three traditional horns mounted on the top at the front of in-service locomotives approaching both passive and active crossings at speeds from 20 to 110 mph (in 10-mph increments). The predictions were also performed for motorists approaching active crossings with an AHS mounted on a wayside utility pole at speeds from 20 to 110 mph (in 10-mph increments). The horn acoustics data were also used to predict the noise impact of the four horns on the community.

Data Collection in Gering, NE

In 1995, the single-tone AHS was mounted on wayside utility poles at three crossings in Gering, NE. Sound levels were measured from the AHS and from traditional three-chime horns mounted on UP revenue-service locomotives. Two sets of measurements were taken for both horn systems perpendicular to the track at 14 wayside locations surrounding the three crossings—one set in November 1995 and the other in February 1996. This information was coupled with the number of trains traversing the crossing to compute the community noise exposure, in terms of an average day-night sound level, in the vicinity of the crossings.

Data Collection in Mundelein, IL:

In 2001, an enhanced wayside AHS using a digital recording of a five-chime train horn was installed at three crossings in Mundelein, IL. Sound level and frequency spectrum measurements were taken to characterize the acoustics of the AHS.

Sound levels were then measured on the roadway approaches to the three crossings for both the AHS and a conventional three-chime horn mounted on UP revenue-service locomotives. Sound levels were also measured at residences in Mundelein for both horn systems over a 2-week period, in the fall of 2001 and again in the spring of 2002. Readings were taken in 1-second intervals for 24 hours at nine locations. The residences were located between 500 and 1,500 feet from the track where use of a train horn was expected.

***Human Perception and Recognition*:**

Data Collection in Gering, NE

Video cameras were installed at two of the UP crossings in Gering where the single-tone AHS was installed. Motorist behavior was recorded following activation of the three-chime train horn for 12 weeks from November 1994 through January 1995. Motorist behavior was also recorded following activation of the single-tone wayside AHS for a total of 12 weeks between May and October 1995.

In July 1994, a telephone survey was conducted of residents in the vicinity of the crossings concerning the impact of the UP train horns on their lives for the entire time they had lived at that location. During the following summer, another telephone survey was conducted of the same residents about the sound from the AHS.

Data Collection in Mundelein, IL

Video cameras were installed at the three UP crossings in Mundelein where the digital five-chime AHS was installed. Motorist behavior was recorded following activation of both the enhanced wayside AHS and the three-chime in-service train horns—between September and December 2001 and again between April and July 2002.

Figure 4. Three-Chime Train Horn Tested in Mundelein

Figure 5. AHS Installation in Mundelein

Surveys were distributed to examine opinions of both the wayside AHS and its perceived safety effectiveness to more than 1,250 Mundelein residents.

The results of these studies were used by the FRA Office of Safety in its rulemaking activities resulting in 49 CFR Parts 222 and 229, *Use of Locomotive Horns at Highway-Rail Grade Crossings*.

Technology Assessment:

The acoustic properties were characterized for three typical railroad horn systems and two prototype AHS. Notable findings included the following:

- The five-chime train horn had a broader-band spectral output that was more likely than that of the three-chime train horn to penetrate background noise.
- The single-tone AHS had a bandwidth that made penetration of background noise difficult. That AHS also produced a signal that was quite different from that of train horns and is possibly not recognizable as a train horn.
- The wayside digital five-chime AHS had a sound level that was equal to or exceeded that of the three-chime train horn for a driver approaching a crossing. It also had a broader-band spectral output that was more likely than that of the three-chime train horn to penetrate the background noise.
- Detectability and effectiveness probabilities for the five-chime train horn were 99 and 80 percent, respectively; the three-chime train horns were 96 and 75 percent, respectively.
- The single-tone AHS was predicted to be undetectable by a motorist at motor vehicle speeds of 30 mph and over.
- The area near the tracks affected by noise decreased by up to 85 percent in Mundelein when the digital five-chime AHS was sounded instead of the train horn.
- Mounting the train horn as far front and as high as possible on the locomotive produced the most sound output forward of the locomotive.

FINDINGS AND CONCLUSIONS

- Motor vehicle insertion loss ranged from 25 to 35 decibels.

***Human Perception and Recognition*:**

Notable findings included the following:

- The video data from the evaluation of the digital five-chime AHS showed a 70 percent decrease in violations of grade crossing laws.
- A substantial majority of the Mundelein residents who responded to the survey found the wayside horn much less annoying than the train horns.
- Motorist behavior in Gering in response to the single-tone AHS was slightly better than the behavior response to the train horn.

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