A Survey of Railroad Occupational Noise Sources

STEPHEN C. URMAN

Measured noise levels are presented for various railroad industry noise sources, including railroad classification yards, locomotives, and cabooses. Alternative control methods for sound reduction are outlined.

Various safety acts and regulations have been passed to improve working conditions in the railroad industry. These reforms date back to the late 19th century when the Interstate Commerce Commission was directed to enforce statutory provisions requiring the use of various safety appliances on railroad cars and engines for the protection of employees and travelers. The Federal Railroad Administration (FRA) is responsible for issuing and enforcing regulations governing the safety of rail operations. As a result, FRA has been called upon frequently to respond to complaints that noise levels within locomotives, cabooses, or railyards are excessive.

INJURY AND ILLNESS STATISTICS

The industry is subject to expensive reporting requirements in the area of railroad safety. Federal regulation requires that all railroads file monthly accident-incident reports with FRA (U.S. Code of Federal Regulations, Title 49, Chapter II, Part 225). The purpose of reporting the occupational injuries and illnesses of employees, damage to railroad equipment and structures, and injury to nonrailroad persons arising from the operation of a railroad is to carry out the intent of Congress as expressed in the Federal Railroad Safety Act of 1970 (Public Law 91-458, 91st Congress, S. 1933, Oct. 16, 1970). For those occupational injuries and illnesses meeting the threshold of reportability, railroads must itemize appropriate job, nature of injury, and casualty occurrence codes, as well as the number of lost work days resulting from each incident. (Data from these reports are used by the Department of Labor to calculate industrywide occupational injury and illness incidence rates.)

The recording and reporting of occupational hearing loss present measurement problems because, unlike injuries, such hearing losses may develop over a period of years. Identification is made even more difficult because an employee may leave the job where the harmful exposure occurred and may work in another area under different working conditions.

The three main areas in which employees are exposed to noise in the railroad industry are maintenance of way, maintenance of equipment, and transportation.

Maintenance-of-way employees are involved in the repair and maintenance of railroad structures such as bridges, trestles, tunnels, and communications and signal systems, as well as the maintenance and laying of the track system. Typical job classifications are carpenter, painter, signalman, lineman, track laborer, and so on.

Maintenance-of-equipment employees are responsible for the repair and maintenance of railroad rolling stock. Their typical duties are those normally associated with the repair of heavy equipment—use of welding, cutting, or grinding equipment; material handling; painting; heavy machining; and so on. Typical job classifications include machinist, electrician, coach cleaner, and carman. Carmen also participate as part of "wreck crews," which are involved in derailment clean-up operations, and as car inspectors.

Transportation employees are directly concerned with the movement of railroad rolling stock over the rails, either in yards or along the right-of-way. The engineers, conductors, firemen, and brakemen in this category work with moving locomotives and railcars as part of their normal routine.

Noise-induced hearing loss ("disorders associated with repeated trauma") does not rank high in the tabulation of occupational illnesses. However, many cases contracted at the work site may not be recognized and consequently not be reflected in those estimates. In addition, if an employee does associate the hearing loss with his job, he may not report it in the earlier stages because he does not want to jeopardize his job.

The extent of the problem becomes more significant when compensation data are examined. The railroad industry is not subject to the normal procedures on workman's compensation. Rather, personal injury claims are handled under the Federal Employer's Liability Act (FELA). The limit of compensation is not set, but is determined in a trial by jury. Activities by the unions have aided employees in this regard.

A recent analysis of the cases of five railroad employees seeking compensation for occupational hearing loss showed that they suffered from 37- to 82-dB hearing losses and received awards of a mean value up to $16,000. These employees were in their late fifties; one equipment operator who suffered hearing damage in part because of faulty silencing equipment *(1)* was younger.

RAILROAD NOISE SURVEYS

Noise surveys were performed in railyards, locomotives, and cabooses.

Federal Railroad Administration, U.S. Department of Transportation, 400 Seventh Street, S.W., Washington, D.C. 20590.

Classification Yards

The noise sources of yard operations are many and are unpredictable in terms of cycling and duration of any one cycle. Typical noise levels in railroad yards are as follows:

Noise-Producing Operation	*Noise Level at 100 ft [dB(a)]*
Switcher engine movement	
Steady pull through yard	76-80
Classification start-stop cycle	80
Idling locomotive	
Road	71
Switcher	65
Car impacts	
Coupling	91
Chain reaction	91
Car retarders	
Master	110
Group or individual track	110
Inert or pull-out	95
Other	
Loudspeakers and PA systems	90-95
Engine load tests	92

The major activity in a classification yard is the receiving and rerouting of freight cars. The rerouting process consists of disengaging cars from incoming trains and reassembling them into outgoing trains bound for different destinations. A typical retarder hump yard is shown in Figure 1. A switcher locomotive pushes a string of cars up a man-made hill (or hump) on a single lead track. At the crest of the hump the first car is manually uncoupled and allowed to roll by gravity down the opposite slope of the hump through a series of switches into one of the many tracks in the classification yard.

Retarders

Because rail freight cars differ in size, weight, rolling friction, and so on, and because each car has a different distance to travel from the crest of the hump into the classification yard where it self-couples with a waiting car of its new train, some means must be employed to control its speed. This is accomplished by a mechanical braking device known as a retarder. This is essentially two steel rails attached to an actuating device located astride each rail of a section of track. The retarder slows a moving car by squeezing the lower portion of the wheels of the car between the lengths of steel rail with a particular force. The first retarder is called the master retarder.

After a car has passed the master retarder, it goes through one or more switches and then makes a pass through a "group" retarder. Master and group retarders are usually of identical construction and operated by pneumatic or hydraulic cylinders. Because hump yards have a slight grade, inert retarders are required to hold a classified cut of cars from rolling out the bottom of the yard. Inert retarders are either a constant retardation spring type or a self-energizing weight-sensitivity controlled type.

This braking action produces noise emissions known as "retarder squeal," which is similar to that produced by a steel-wheeled car on steel track negotiating a tight turn. Maximum sound pressure levels appear to be the same for both master and group retarders, although inert retarders are nominally about 15 dB(A) lower (see previous tabulation). Inert-retarder squeal may occur in two situations: (a) when a cut of cars is being pulled out of the classification tracks and (b) when a car being humped collides with a stationary cut of cars, thus forcing the end car to move slightly in the inert retarder. The lowered car speed and requisite retardation force most likely account for the difference in sound pressure level from active retarders. The duration of master and group retarder squeal usually varies from 1 to 5 sec, and may yield noise levels that exceed 110 dB(A) at 100 ft.

The duration of squeal is considerably longer for inert retarders. The frequency at which the retarder squeals occurs is between 2,000 and 4,000 Hz. Noise levels in railroad yards due to other sources and operations are identified in the earlier tabulation.

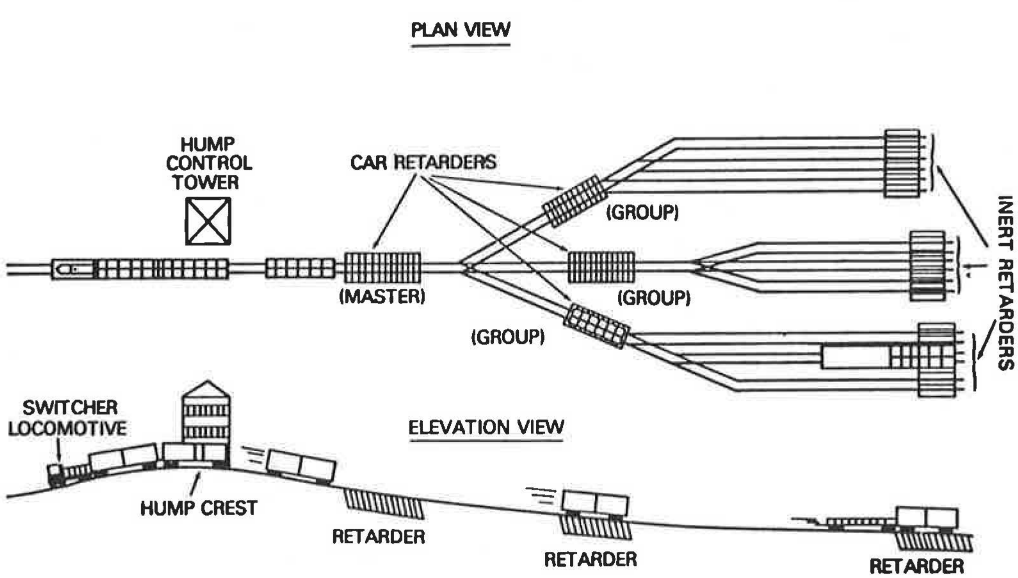

FIGURE 1 Hump yard retarder system.

Road and Switcher Engines

Both road engines and switcher engines are operated within the yard property. The engines, dependent on design, will generally run at a number 1–2 throttle setting (275 to 400 rpm), which produces a noise dominated by a low-frequency content with a primary peak at 100 Hz and a secondary peak at 500 Hz *(2)*. Average noise levels in the range of 76 to 80 dB(A) at 100 ft are emitted by switcher operations of this nature that involve steady pulling at low speeds.

It is common practice in railroad yards to leave road engines and switchers idling while not is use. These engines are left running because diesels can become difficult to start when cold, and starting a cold engine can cause excess wear. Noise generation by idling locomotives is attributed to several sources—exhaust outlet, cooling fans, and mechanical radiation from side panels. Standard idling revolutions per minute for road engines and switchers varies between 275 and 450, depending on the model of locomotive. As indicated earlier the noise output of idling road engines is approximately 6 dB(A) above that emitted by switchers.

Car Impacts

Car impacts produce noise either when two cars are coupled or when the slack in the coupler assembly of a line of cars is suddenly taken out or in. The impact from coupling is the predominant type of impact in a hump yard. However, when a car being humped couples with a cut of stationary cars, a chain reaction of impacts often occurs.

The impact noise is due to the impulse, seen in the couplers as the knuckles meet, that transmits vibration into the body of the car. Typical impacts last about 1 sec, with a frequency content of 2,500 Hz.

Other Sources

Public address (PA) loudspeakers typical of those utilized in railroad yards will reproduce speech with sufficient fidelity to maintain a high degree of intelligibility. To meet speech intelligibility requirements, PA system levels of 90 to 95 dB(A) at 100 ft must be generated.

Diesel locomotives are generally subject to a series of static performance tests and functional inspections during engine service or repair operations. These include tests of engine performance under load. By the nature of their traction motor propulsion system, locomotives can be essentially dynamometer tested at all throttle settings, including full power, by routing the electric power generated into resistor banks, termed "load boxes," adjacent to the test site. The time required for a locomotive to complete load testing may be up to 60 min or more, with at least 50 percent of the time spent at the highest throttle setting.

In summary, these surveys found the retarders to be clearly the dominant source of yard noise to employees. Also, because of its intensity and frequency content, retarder noise is perceived to be even more annoying then indicated by the A-weighted levels.

Noise Control and Regulation

Retarder noise levels are influenced by car type, car weight land loading, type of wheels, structure and composition of the retarder, and the decelerating force that the retarder applies to moving cars. Although lubricating and damping the retarder shoes have not been successful in reducing the level of the noise generated for a given retarder squeal, they have tended to reduce the probability of occurrence of squeal from a given car when retarded. The use of lined barriers, when practical, has resulted in attenuation of retarder sound level by 20 dB or more. Mechanical release devices have been installed on some inert retarders that permit strings of cars to be pulled through the retarders without retarder squeal. Other methods that have been tried with varying degrees of success include the use of ductile iron shoes and retarder control by computers.

A retarder without a clasp was developed in the United Kingdom and has been installed in one U.S. railyard. This system, which acts like an adjustable shock absorber, is made up of a series of movable mushroom-shaped heads that are forced down on the wheel on contact with the flange. Because the wheel is not squeezed, retarder squeal does not occur. Application of this retarder has not been widespread because of maintenance difficulties as well as operating problems under heavy snow conditions.

On January 6, 1980, the Environmental Protection Agency (EPA) issued railroad noise emission standards (U.S. Code of Federal Regulations, Title 45, Part 1252) that set limits on noise from four railyard sources: active retarders, load-cell test standards, car-coupling operations, and switcher locomotives. FRA under Section 17 of the Noise Control Act has responsibility for enforcing these standards, which became effective on January 15, 1984.

These standards are "triggered" at the receiving property of the affected public. Thus, they are not expected to have a significant impact on railroad employee noise exposure.

Locomotive Cabs

Typical noise levels in locomotive cabs are as follows:

Noise-Producing Operation	*Noise Level [dB(A)]*
Engine noise	80-90
Locomotive horn	110-120
Air brake operation	
Service application	105-115
Release	100-105
Emergency application	110-115
Release of independent brake	100-110
Engine room	115-120

Diesel-electric locomotives have a diesel engine driving an electric alternator or generator, which in turn powers electric traction motors on the wheels. The electric system acts as an "automatic transmission" and in a given throttle setting maintains a constant load on the engines for differing train speeds. These throttle settings, eight plus an idle notch, relate to engine speed and horsepower.

Thus, as the throttle setting is increased, the engine speed and horsepower increase, which results in an increase in in-cab noise levels. The noise level increases approximately 2 dB(A) per throttle setting. Although the train is under way, the majority of time is spent in throttle 8, followed by idle or throttle 1. The window position influences in-cab noise levels at throttle 8 more than at the lower settings.

In-cab noise levels show little speed dependency because wheel-rail noise is lower than that from other sources. Noise levels due to the diesel engine were not significantly different at the engineer's position or the brakeman's position in the cab. This was expected because of the hard, reverberant surfaces in the cab. As indicated earlier, sound produced by the locomotive diesel engine is dominated by low-frequency components. The other major sources of in-cab noise that contribute to the occupants' exposure dose are the horn and brake.

Air horns are used on the majority of locomotives in the United States as audible warning devices. They operate by the use of an air stream that causes a metal diaphragm to vibrate. A trumpet is incorporated to couple the sound energy to the outside air, to modify the tone of the horn, and to provide directivity. Frequency analysis shows that the energy in a multichime horn peaks at about 1,000 Hz, and the lowest pitch is seldom less than 220 Hz *(3)*. Manufacturers rate their locomotive horn sound levels at 114 dB 100 ft forward of the locomotive. Noise levels as high as 120 dB(A) were recorded in the cab. Noise exposure in the cab, of course, depends on the location of the horn, whether the windows are opened or closed, the number of times the signal is sounded, and so on. For example, closing the window was noted to reduce noise levels by as much as 10 dB(A) in some cases. Differences in horn-blowing techniques also affect the duration of the blasts.

Train brakes are applied by pneumatic operation through a brake pipe system that is pressurized to about 80 psi and runs the length of the train. The brakes are applied by venting a specific amount of air from the brake pipe system through the automatic and independent brake valves in the locomotive cab. The air escaping from the brake lines during application creates high-frequency noise that can be quite high depending on the particular brake application. Its duration and intensity depend on the length of the train and the type of application. For example, "emergency" reductions involve a very high rate of venting so that the brakes will be quickly applied. Typical noise levels due to air-brake operation range from 95 to 115 dB(A), in some cases as high as 120 dB(A).

The fireman or engineer on occasion will go into the engine compartment of the locomotive, where the noise level exposure is very high—up to 120 dB(A).

On March 31, 1980, FRA incorporated noise exposure limits as part of its Locomotive Safety Standards *(2)*. An 8-hr time-weighted average of 90 dB(A) with a doubling rate of 5 dB(A) was specified. Under the Hours of Service Act, the maximum work day for operating employees is 12 hr. Therefore, the 5-dB doubling rate was extended to a duration of 12 hr with an allowed exposure of 87 dB(A).

Locomotive manufacturers have achieved significant reduction in interior noise levels in recent years by additional insulation installed in the cab roof and electrical cabinets, piping the brake valve exhaust out the cab, and horn location.

Major locomotive manufacturers now offer, as an option, a method for piping the automatic brake valve service application and independent brake valve exhaust into the subbase of the locomotive. This option provides an audible indication of brake performance and, at the same time, has been estimated to reduce the cab occupants' noise dosage by 15 to 20 percent.

Excessive air horn noise in the cab is most easily controlled by proper location of the horn on the locomotive. It should be located away from air vents and not on the cab roof in close proximity to any crew member's seat. On some locomotives, the horn was located near the window where the engineer sits. A preferred location in locomotives operated with the long hood in front is the end of the hood to reduce the nuisance of the horn to the crew and improve performance.

Cabooses

Interior noise levels in cabooses moving at high speeds can make radio communication difficult and generally degrade working conditions for the crew. Sound levels typically range from 84 to 93 dB for speeds greater than 45 mph. Contact between wheels and rails, which causes structure-borne vibration, is the primary cause of noise in railroad cabooses. Effective isolation of the car body from the tracks is necessary to achieve substantial interior noise reduction. G. E. Warnaka *(4)* demonstrated that noise levels in cabooses can be lowered by the use of vibration isolation, structural damping, and acoustic absorption measures to levels at which conversation can be held at nearly normal speaking volume.

CONCLUSIONS

Efforts to reduce noise exposure have been limited by factors unique to the railroad industry. For example, poor maintenance of equipment is cited in employee complaints as a source of excessive noise levels. Of course, it must be realized that the very nature of the industry makes maintenance a problem. Because this is a "moving industry," an engine or caboose on which a complaint has been registered may be out of state the nex day, making it difficult to effect repairs. Nevertheless, significant noise reduction has been achieved in the industry, often without the imposition of excessive costs. Of course, costs involved in lowering employee exposure may be balanced by reduced compensation costs associated with high-noise work environments.

REFERENCES

1. A. S. Campanella. *Compensation for Occupational PTS for Several Railroad Engineers and Fireman.* Acoustical Society of America, Providence, R.I., 1978.
2. P. J. Remington and M. S. Rudd. *Assessment of Railroad Locomotive Noise.* Report DOT-TSC-OST-76-4/FRA-OR&D-76-142. U.S. Department of Transportation, 1976.
3. J. P. Aurelius and N. Korobow. *The Visibility and Audibility of Trains Approaching Rail-Highway Grade Crossings.* Report FRA-RP-71-2. U.S. Department of Transportation, 1971.
4. G. E. Warnaka. Interior Noise Reduction in Rail Vehicles—A Specific Example. Paper 64. Presented at American Society of Mechanical Engineers Vibrations Conference, Philadelphia, Pa., 1969.

Publication of this paper sponsored by Committee on Transportation-Related Noise and Vibration.