Brief Report

Noise Exposures of Rail Workers at a North American Chemical Facility

Paul Landon, MHS,[1] Patrick Breysse, PhD,[1]* and Yuju Chen, MHS[2]

Background *Both continuous and impact noise exposures of rail yards and railways have been historically understudied. We summarize noise exposures to rail workers at a large chemical facility in North America.*
Methods *Rail workers were surveyed over the course of three 12-hr shifts. Personal noise dosimeters were used to derive a 12-hr time-weighted average (L_{AVG}), an 8-hr time-weighted average (L_{TWA}), and a percent dose. Peak and maximum sound levels were also recorded during each sampling period. Six workers were sampled on three separate days for a total of 18 full-shift noise samples.*
Results *Full-shift noise exposures were all below the Occupational Safety and Health Administration's (OSHA) permissible exposure limit (PEL) and action level for a 12-hr workday. Peak impact sound levels exceeded 140 dB in 17 of 18 samples (94%) with a mean peak sound level of 143.9 dB. Maximum continuous sound levels were greater than 115 dBA in 4 of 18 samples (22%) with a mean maximum sound level of 113.1 dBA. The source of peak impact sound levels was a daily exposure to a concussion caused by a sudden break in a freight airline.*
Conclusions *Rail workers at this facility are at risk of noise induced hearing loss from high impact noise exposures. Peak impact and maximum continuous sound levels can be attenuated through the use of hearing protection or by increasing distances from railroad noise sources.* Am. J. Ind. Med. 47:364–369, 2005. *© 2005 Wiley-Liss, Inc.*

KEY WORDS: noise; hearing conservation; personal noise exposure; noise exposure standards; hearing loss; noise-induced hearing loss

INTRODUCTION

There are currently 276,000 railroad workers in the United States. Rail yards and railways have many high noise sources such as locomotives, rolling stock, car coupling concussions, car retarders, wheel squealing, train horns, public address systems, and air braking systems as well as noise from tools such as pneumatic drills, grinders, and chippers.

There are few data on noise exposure to railroad workers in the published literature. The limited data that exist are primarily for in-cab locomotive noise. These data suggest that engineers and conductors in locomotives are exposed to mean noise levels between 85 and 87 dBA [Aurelius, 1971; Jankovich, 1972; Kilmer, 1980; Sechagiri, 2003]. These exposures exceed the Occupational Safety and Health Administration's (OSHA) action level for inclusion in a hearing conservation program. There have been no published studies of noise exposure to rail yard workers where many of the railroad workers are employed.

[1]Department of Environmental Health, Division of Environmental Health Engineering, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland
[2]E.I. Du Pont De Nemours and Company, Wilmington, Delaware
*Correspondence to: Dr. Patrick Breysse, Department of Environmental Health, Division of Environmental Health Engineering, Johns Hopkins Bloomberg School of Public Health, 615 North Wolfe Street, Baltimore, MD 21205-2179. E-mail: pbreysse@jhsph.edu

Accepted 10 January 2005
DOI 10.1002/ajim.20152. Published online in Wiley InterScience (www.interscience.wiley.com)

There is an increased general concern about occupational noise exposures and hearing loss with the widespread recognition that current noise exposure standards are not protective. In 1998, the National Institute for Occupational Safety and Health (NIOSH) criteria document on occupational noise exposure indicated that there is a 25% excess risk at the 90-dBA permissible exposure limit (PEL) currently enforced by OSHA [NIOSH, 1998]. In addition, there is growing evidence suggesting that a combination of elevated continuous noise exposures and high peak or impact noise, such as found in rail yards, is particularly hazardous to hearing [Price and Wansack, 1989].

The purpose of this study is to present a summary of personal noise exposures of rail service workers at a chemical facility, and to map sound pressure levels and characterize any potential sources of high continuous and impact noise.

BACKGROUND

This survey was conducted in a rail yard at a large chemical facility in the United States. This facility is over 85 years old and has its own rail system with over 26 miles of broad gauge track, two small switcher type locomotives, a car repair shop, and between 350 and 400 rail cars on site on any day. The rail cars were of two types—185,000 lb (full) tank cars and 219,000 lb (full) hopper cars.

Work is organized into three-man crews who each work three or four 12-hr shifts a week. Rail service work goes on every day at this facility, day-shift only. The three-man crews are organized into three occupations per day: an engineer who operates the locomotive; a conductor, who switches track and couples/uncouples cars to the rear of the locomotive; and a brakeman, who switches track and couples/uncouples cars in the front of the locomotive. The workers rotate jobs every day.

The conductor and brakeman jobs require the workers to ride on the outside of the locomotive or rail cars and then walk and physically throw track switches, apply chocks and brakes, and couple and uncouple rail cars. Hand signals are used to communicate between the men on the ground and the engineer in the locomotive during coupling and uncoupling. Radios are only used once a day when a train of freight is long enough (15+ cars) that a line of site from the conductor/brakeman to the engineer is obstructed. These non-verbal and verbal communications result in the movement of freight around the plant in usually 1–3 hr intervals. After one series of jobs is completed, the workers go back to the rail services building to wait for more freight jobs to be called in from around the plant. Wait/break times can range from 30 min to 1 hr.

Rail yard noise sources at this chemical facility are a mixture of continuous noises (locomotive sounds, rolling rail cars, etc.), intermittent noises (steel wheels on track sounds, bells, whistles, etc.), and sharp impact noises (coupling concussions, airline breaks, etc.). All rail workers are currently enrolled in a hearing conservation program that requires annual noise monitoring and audiometric testing.

Federal Railroad Administration (FRA) and OSHA regulations require that workers wear hearing protection if noise exposures exceed 90 dBA for an 8-hr time-weighted average (87 dBA for a 12-hr work shift). The OSHA ceiling limit for continuous noise is 115 dBA and 140 dB for impact noise [OSHA, 1971]. The OHSA action level for inclusion into a hearing conservation program is 85 dBA for an 8-hr average (82 dBA for 12-hr shift) with an 80 dBA threshold.

MATERIALS AND METHODS

Personal noise dosimeters (Quest Electronics Model M-27/M-28, Oconomowoc, WI) were used to monitor noise exposures. The dosimeters meet the American National Standards Institute (ANSI) Standards 1.4-1983, Type II.

Since many of the sources in a rail yard produce short-term intense noises as well as impact noises, we focused on including these sources in our assessment. Maximum continuous noise levels were recorded during each shift as well as peak impact noise, which is the highest unweighted and unaveraged impact noise. An impact noise was defined as any noise whose interval is less than 1 s in duration.

A sound level meter (General Radio Precision Sound Level Meter & Analyzer, Model 1982) was used to measure and record area sound pressure levels. This instrument was able to measure the ''true peak'' of an impulse, that is it can adequately measure pulse times less than 1 s in a duration.

Dosimeters were calibrated before and after each 12-hr shift, and they were placed on the belt of the worker with the microphone clipped to their shoulder. Workers were instructed to wear the dosimeter all day, including lunch and break periods. Six rail workers at the site were each sampled for three days (12-hr shift) and for different jobs (engineer, conductor, brakeman) for a total of 18 full-shift samples.

All sound measurements were taken during the months of July and August 2003, when the weather was hot and dry. Mean temperature for all sampling days was 75°F.

RESULTS

Personal exposure results using OSHA integration criteria for the rail-yard workers are summarized in Tables I and II which present noise exposure results using a 90 and 85 dBA thresholds, respectively. The sampling time, job title, the 12-hr average (L_{AVG}), and 8-hr equivalent (L_{TWA}) along with the corresponded dose are presented. There is an unequal distribution of jobs for the six different workers because not all of the workers were available for sampling on every day. The L_{AVG} is a continuously equivalent sound pressure level during the time sampled. L_{TWA} is

TABLE I. Summary of Rail Yard Worker Noise Exposures Using a 90 dB Criteria Level, a 5 dB Exchange Rate, and a 90 dB Threshold Level

Worker	Job	Time (min)	L_{TWA}	L_{AVG}	Dose (%)	Peak	Max
1	Engineer	586	74.4	72.9	11.5	145.1	114.0
	Conductor	593	82.4	80.8	35.0	145.1	113.6
	Conductor	661	78.9	76.5	21.4	133.8	113.6
	Brakeman	665	81.5	79.1	30.9	145.1	109.8
2	Engineer	661	78.8	76.4	21.0	143.2	111.3
	Conductor	677	83.5	80.9	40.6	145.1	116.1
	Brakeman	586	82.2	80.7	33.7	145.1	114.0
	Brakeman	671	77.1	74.6	16.7	145.1	118.1
3	Engineer	665	68.1	65.1	4.8	145.1	108.7
	Conductor	678	79.6	77.0	23.5	144.3	117.0
	Brakeman	668	80.6	78.2	27.1	145.1	113.6
4	Engineer	591	71.1	69.5	7.2	143.2	110.6
	Conductor	660	78.1	75.7	19.1	144.0	111.0
5	Engineer	676	72.8	70.3	9.2	141.3	113.2
	Engineer	670	67.1	64.7	4.2	145.1	110.6
	Brakeman	660	79.0	76.6	21.6	144.7	113.2
6	Conductor	672	75.7	73.2	13.7	143.6	111.0
	Brakeman	660	80.3	78.0	26.2	145.5	117.3

the equivalent sound pressure level for an 8-hr work day; L_{TWA} is calculated according to Equation 1:

$$L_{TWA} = L_{AVG} + Q\left[\frac{\log t}{480\,\text{min}}\right] \quad (1)$$

Where, $Q = 16.61$ for 5 dB exchange rate; $t =$ total time sampled, minutes.

Table I also presents the peak impact noise in dB as well as the maximum continuous noise sound pressure levels in dBA. Full-shift average noises and their corresponding 8-hr equivalents using the 90 dBA threshold are all well below OSHA—the criteria level. However, the maximum continuous sound pressure levels approached or exceeded 115 dBA and the peak impact exposures were consistently greater than 140 dB.

The L_{AVG} using a 90 dBA threshold comparing engineers, conductors, and brakemen are presented in Table I and Figure 1 with a mean L_{AVG} for engineers of 70.0 dBA, conductors of 77.4 dBA, and brakemen of 77.9 dBA. All of the exposures are below the OSHA PEL of 87 dBA for a 12-hr shift. The L_{AVG} using an 80 dBA threshold comparing engineers, conductors, and brakemen is presented in Table II and Figure 2 with a mean L_{AVG} for engineers of 77.5 dBA, conductors of 80.4 dBA, and brakemen of 80.6 dBA. Four of 17 exposures (23%) are above the OSHA HCA action level of 82 dBA for a 12-hr shift.

Peak impact (dB) and maximum continuous sound levels (dBA) are also presented in Tables I and II, and in Figures 3 and 4. The mean peak sound pressure level for engineers, conductors, and brakemen was 143.7, 142.7, and 145.1 dB, respectively. Seventeen of 18 (94%) of the peak impact noise exposures were above 140 dB—the level that OSHA and NIOSH set as the recommended upper limit on impact noise exposures [OSHA, 1971; NIOSH, 1998].

TABLE II. Summary of Rail Yard Worker Noise Exposures Using a 85 dB Criteria Level, a 5 dB Exchange Rate, and a 80 dB Threshold Level

Worker	Job	Time (min)	L_{TWA}	L_{AVG}	Dose (%)
1	Engineer	586	NA	NA	NA
	Conductor	593	84.5	82.9	46.6
	Conductor	661	81.7	79.3	31.5
	Brakeman	665	84.5	82.1	46.4
2	Engineer	661	83.0	80.6	37.9
	Conductor	677	85.6	83.1	54.5
	Brakeman	586	84.2	82.7	45.0
	Brakeman	671	80.2	77.8	25.8
3	Engineer	665	78.1	75.7	19.3
	Conductor	678	83.2	80.7	39.0
	Brakeman	668	83.2	80.8	38.9
4	Engineer	591	80.2	78.7	25.8
	Conductor	660	81.8	79.4	31.8
5	Engineer	676	81.1	78.6	29.1
	Engineer	670	76.5	74.0	15.3
	Brakeman	660	81.9	79.5	32.3
6	Conductor	672	79.3	76.8	22.8
	Brakeman	660	83.2	80.9	39.0

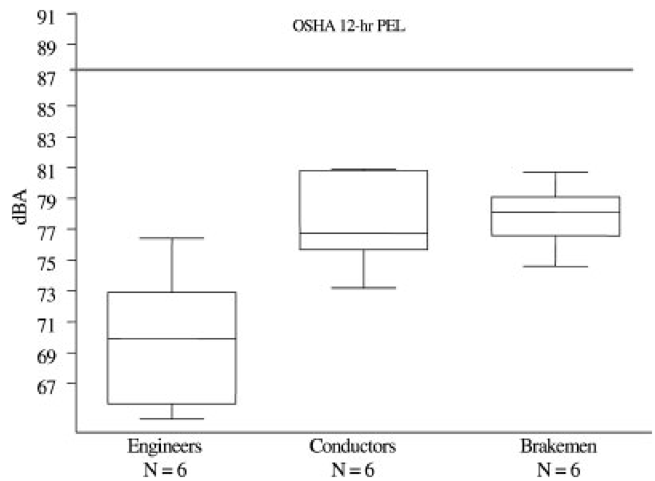

FIGURE 1. L_{AVG} by job noise exposures integrated using 90 dB criterion/5 dB exchange rate and 90 dB threshold.

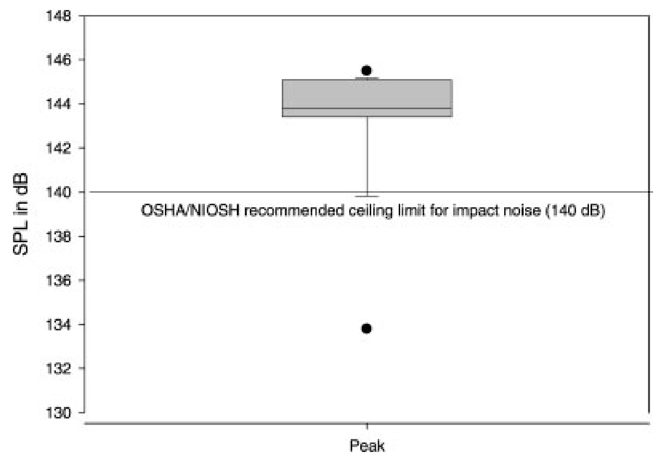

FIGURE 3. Summary of peak impact noise SPL in dB (n = 18).

The mean maximum sound level for engineers, conductors, and brakemen was 111.9, 113.7, and 114.3 dBA, respectively with 4 of 18 (22%) exposures being above 115 dBA—the OSHA ceiling limit on continuous noise exposure for any length of time [OSHA, 1971].

Analysis of variance (ANOVA) of peak noise exposures with Bonferroni adjustments showed that there was no statistically significant difference between jobs, sampling days, or workers. These results suggest that the sources of the peak noise exposures apply to all jobs within this rail yard.

Based on surveys using a sound level meter, specific operations that were associated with peak impact and maximum continuous noise sources were isolated and are summarized in Table III. Activities associated with high continuous noise exposure include wheel squealing, locomotive noise, airbrake release, and horn blowing. Of these sources only wheel squealing and horn blowing were found to produce sound pressure levels in excess of 100 dBA. Sources of peak impact noise included airline breaks and coupling concussions. Airline breaks, also known as airline break concussions, were the source of highest peak impact sound levels. An airline, or trainline, is a pressurized rubber hose connection between the freight cars and the locomotive braking system. The airlines contain approximately 80 psi of air for long freight trains. Either the conductor or brakeman must physically couple the airline between the locomotive and the first freight car; when freight is cut from the locomotive, the airline is broken when the locomotive pulls away. This causes the couple to break instantly and release all of the pressurized air into the environment. The result is a

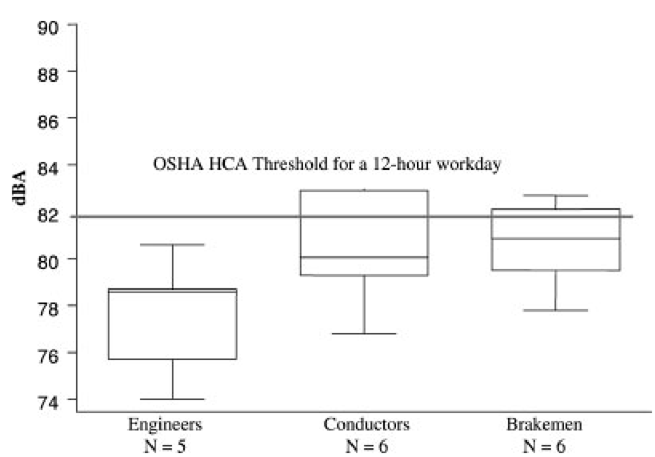

FIGURE 2. L_{AVG} by job noise exposures integrated using 80 dB criterion/5 dB exchange rate and an 80 dB threshold.

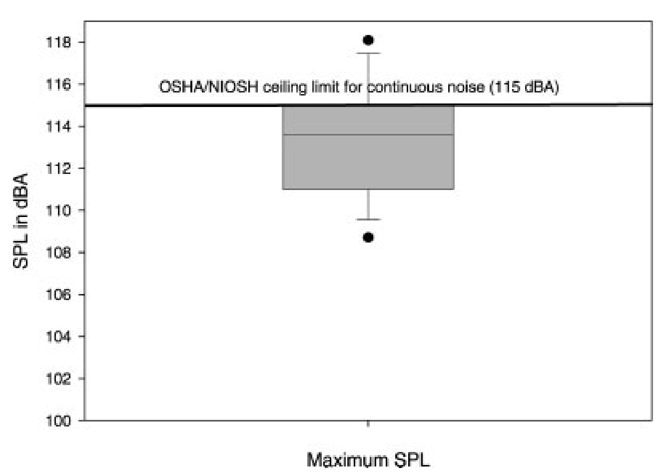

FIGURE 4. Summary of maximum continuous SPL in dBA (n = 18).

TABLE III. Summary of Sources of Maximum and Peak Impact Sound Levels

Source (n)	Mean maximum ($\pm$SD) dBA	Peak ($\pm$SD) dB
Airline break (7)	NA	144.1 $\pm$ 6.4
Coupling concussion (9)	NA	120.8 $\pm$ 14.5
Wheel squealing (21, 10)	105.3 $\pm$ 2.9	NA
Locomotive @ idle (5)	89.3 $\pm$ 5.6	NA
Locomotive @ speed (5)	98.6 $\pm$ 4.5	NA
Airbrake release in locomotive (4)	96.0 $\pm$ 2.5	NA
Train horn (3)	117.2 $\pm$ 6.6	NA

concussion and pressure wave, which is the cause of the high peak exposures to the workers, who are always standing within 3 ft of the airline.

Further investigation of exposures to breaking airline concussions evaluated the decline in peak impact noise levels with distance from the airline increased indicating that peak noise levels dropped below 140 dB between 7 and 10 ft from the airline.

DISCUSSION

Results of this study suggest that continuous average noise exposures of rail service workers are below the OHSA criteria level and generally below the 85 dBA action level for entry into a hearing conservation program. For all exposure metrics, the conductors and brakemen had higher exposures than the engineers. The mean L_{AVG} noise level for all 18 samples collected using a 90 dBA threshold is 79.6 dBA, which is well below the OSHA PEL of 87 dBA for a 12-hr work shift. The mean L_{AVG} using the 80 dBA threshold approaches the HCA action level of 82 dBA. Roughly a quarter of the measurements, all associated with conductor and brakeman jobs, exceed the OSHA action level. These results suggest that the previous decision to include these workers in a hearing conservation program was appropriate.

These results are in general agreement with previous studies. Aurelius [1971], Jankovich [1972], Kilmer [1980], and Sechagiri [2003] all show that locomotive crew in-cab noise exposures were below the OSHA PEL of 90 dBA for an 8-hr TWA but above the HCA action level, which requires enrollment in a hearing conservation program. However, these studies fail to address railroad worker noise exposures on the ground, specifically those of conductors and brakemen. Only two studies, attempted to characterize noise sources at rail yards for workers on the ground who were outside of a locomotive cab [Swing and Pies, 1973; Urman, 1978]. These authors found that rail yard workers standing 15 ft from the side of a train or rail car experienced sound pressure levels of 109 dBA from car coupling concussions, 110 dBA from wheel/track interactions (wheel squealing), and 122 dBA from train horns. Urman [1978] measured maximum continuous noise exposures for in-cab locomotive crews of 90 dBA for engine noise, 120 dBA for the locomotive horn, and 115 dBA for the airbrake application.

The most significant findings are the identification of the high peak impact and maximum continuous noise levels for nearly every worker on every day (94%) of sampling. The highest peak airline break sound level was 145.1 dB with a mean of 143.8 dB; the highest maximum sound level was 114.9 dBA and with a mean of 113.2 dBA. The mean peak sound level for all six workers, 143.8 dB, is in excess of OSHA PEL and other guidelines.

There is increasing awareness of the importance of the combined insult associated with elevated continuous noise in combination with impulsive noise. Two animal studies suggest that a combination of continuous and impulsive noise have a synergistic effect on hearing loss [Price and Wansack, 1989; Roberto et al., 1995]. In addition, several occupational studies have shown that exposures to both continuous noise and impact noises greater than 140 dB can cause more severe permanent threshold shifts in workers. In a study of 133 railroad trainmen who also hunted for sport, Prosser et al. [1988] found that hunters (those exposed to impact noises exceeding 140 dB) had significantly greater hearing loss than nonhunters. Kryter [1991] examining a database originally researched by Clark and Popelka [1989] also studied the effect of gun use on the hearing of railroad workers in locomotive cabs. He found that there was more hearing loss among the ‘‘trainmen’’ who were exposed to impact noise in the form of firearm concussions. Finally, in a review of the literature, Starck et al. [2003] showed that, in general, impact noises cause about 5–12 dB more severe hearing loss than continuous noise.

CONCLUSIONS

This study presents one of the few published assessments of noise exposure to rail yard workers. The results of this survey indicate that exposure to engineers, conductors, and brakemen are below the OHSA PEL for continuous noise exposure. Approximately 25% for the 12-hr shift samples were in excess of the action level indicating the need for a hearing conservation program. Of particular interest is the observation that peak impact (dB) and maximum continuous sound levels (dBA) are elevated in this group of workers. The mean peak sound pressure level for engineers, conductors, and brakemen was 143.7, 142.7, and 145.1 dB, respectively. Almost all full-shift samples had peak impact noise exposures above 140 dB. Twenty-two percent of the full-shift samples had maximum continuous sound levels above 115 dBA—the OSHA ceiling limit for continuous noise exposure.

The source of the peak exposures is airline breaks and horn sounds. It was recommended that engineers, conductors, and brakemen working in rail yards limit their exposure to peak and maximum noise levels by moving at least 10 ft away from any uncoupling airlines. Furthermore, it was recommended that locomotive engineers use short horn blasts.

ACKNOWLEDGMENTS

The authors thank Leena Choi, a Biostatistics PhD student at The Johns Hopkins Bloomberg School of Public Health for her help with the statistical analysis of the data. Finally, we thank the men and women of the Rail Services Division at the North American chemical facility that was the subject of this study for their donating time, energy, and patience for the completion of this study.

REFERENCES

Aurelius JP. 1971. The sound environment in locomotive cabs. U.S. Department of Transportation Report No. FRA-RP-71-2A. New York. Systems Consulting, Inc.

Clark WW, Popelka GR. 1989. Hearing levels of railroad trainmen. Laryngoscope 99:1151–1156.

Jankovich JP. 1972. Human factors survey in locomotive cabs. U.S. Department of Transportation Report No. FRA-OPP-73-1. Crane Ind. Naval Ammunition Depot.

Kilmer RD. 1980. Assessment of locomotive crew in-cab occupational noise exposure. National Bureau of Standards, Report no. FRA/ORD-80/91. Washington D.C.: U.S. Department of Transportation.

Kryter KD. 1991. Hearing Loss from gun and railroad noise—relations with ISO Standard 1999. J Acou Soc Am 90(6):3180–3195.

NIOSH. Occupational Noise Exposure, Revised Criteria. 1998. US Department of Health and Human Services, Centers for Disease Control and Prevention, The National Institute of Occupational Safety and Health. Cincinnati, Ohio.

Price GR, Wansack S. 1989. Hazard from an intense midrange impulse. J Acou Soc Am 86:2185–2191.

Prosser S, Tartari MC, Arslan E. 1988. Hearing loss in sports hunters exposed to occupational noise. B J Audiol 22:85–91.

Roberto M, Zito F, Hamernik R, Ahroon B, Case C. 1995. Impulsive noise: PTS and anatomic correlations. Acta Otohinolaryngol Italia 15(2):61–64.

Sechagiri B. 2003. Exposure to noise on board locomotives. AIHA J 64:699–707.

Starck J, Toppila E, Pyykko I. 2003. Impulse noise and risk criteria. Noise Health 5(20):63–73.

Swing JW, Pies DB. 1973. Assessment of noise environments around railroad operations. Report WCR-73-5. Wyle Laboratories. El Segundo, CA.

The Occupational Safety and Health Act. 1971. Amended 1983; 29 CFR 1910.95.

Urman S. 1978. The control of railroad occupational noise. Prof Saf Oct 47–51.