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Railroad Noise Control

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Handbook for the Measurement, Analysis and Abatement of Railroad Noise

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16. Abstract

This handbook gathers together in one place the necessary background material, the required measurement and analysis procedures, and the currently available abatement techniques to respond to and meet current railroad noise regulations.

The first chapter of the handbook briefly describes its development, arrangement, and suggested use. The second chapter provides an introduction to the field of acoustics. Numerous examples are provided to clarify the concepts which are developed.

The remaining three chapters of the handbook describe the existing railroad noise regulations themselves. For each regulated noise source, the following items are provided: a summary of the pertinent regulation; a description of the acoustic metric; a description of the required measurement site conditions; a listing of the necessary instrumentation; a description of measurement procedures; a summary of the existing data base describing noise from the source; and suggestions on possible techniques of controlling noise emission from the source. Where appropriate, sample worksheets and data sheets are provided.

In addition to the five major chapters of the handbook, four appendices provide: a glossary of terminology which briefly defines those terms employed in the regulations; a set of three programmable calculator programs which can be used to carry out some of the more common arithmetic operations on sound levels; a reproduction of the pages in the Federal Register in which each regulation was announced; and a list of suggested books and journals for further reading on the subject of noise measurement and control.

A companion document entitled "Pocket Manual for the Measurement and Analysis of Railroad Noise" (DOT/FRA/ORD-82/02/M) provides abbreviated instructions for the field measurement and evaluation of railroad noise.*

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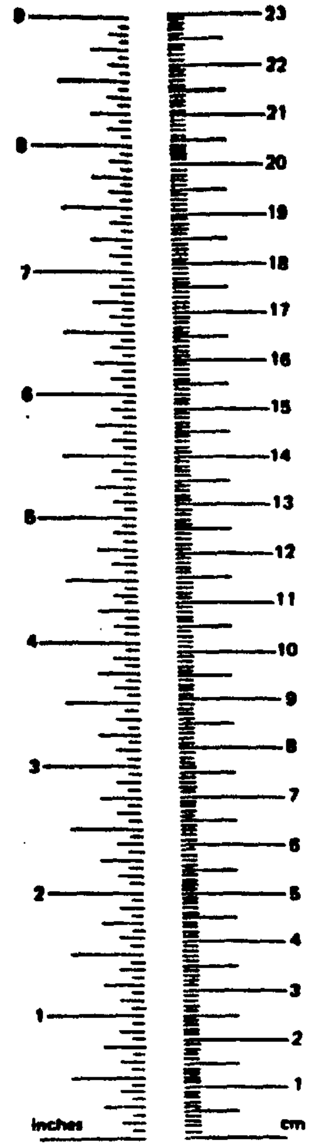
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

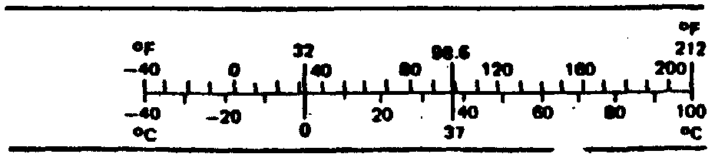
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in. = 2.54 cm (exactly). For other exact conversions and more detail tables see NBS Misc. Publ. 286, Units of Weight and Measures. Price $2.25 SD Catalog No. C13 10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This handbook was developed by Wyle Laboratories under Contract No. DOT-TSC-1786 with the U.S. Department of Transportation, Transportation Systems Center and sponsored by the Federal Railroad Administration. Its intent is to gather together in one document the necessary background material, the required measurement and analysis procedures, and the currently available abatement techniques to respond to and meet federal regulations governing noise emissions from railroad noise sources.

Mr. Robert Mason served as the Transportation System Center's technical monitor for much of the program. Mr. John Koper of the Office of Research and Development of the Federal Railroad Administration was technical monitor for the latter part of the program. Both made important contributions to the handbook through their guidance and careful reviews.

Mr. Peter Conlon, Manager of the Environmental and Special Studies Division of the Association of American Railroads, also played an important role in the development of this handbook. He not only provided valuable suggestions as to its format and contents, but was also instrumental in soliciting the cooperation of representatives of various railroad companies.

In addition, the authors would also like to acknowledge the contributions of the other members of the government/industry committee who assisted in the design and development of this handbook. They are: Mr. Jack Buckingham and Dr. Conan Furber of the Association of American Railroads; Mr. Thomas Pendergast of CONRAIL; Mr. Stephen Urman of the Federal Railroad Administration; Mr. Robert Pooler of the Santa Fe Railway Company; and Mr. Ray Plunkett, Mr. F.M. Roach, Jr., and Mr. Dick Shelton of the Southern Railway Company.

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CHAPTER 1

INTRODUCTION

With the recent introduction of a variety of federal regulations governing noise emissions from railroad noise sources, the need has developed for a handbook which gathers together in one place the necessary background material, the required measurement and analysis procedures, and the currently available abatement techniques to respond to and meet these regulations. The publication of this Handbook for the Measurement, Analysis, and Abatement of Railroad Noise along with the accompanying Pocket Manual for the Measurement and Analysis of Railroad Noise (DOT/FRA/ORD-82/02/M) is an attempt to meet that need.

In this chapter are described the development of the handbook, its arrangement, and the procedure for effectively using it. Also described is a summary of the legislative history of the current railroad noise regulations.

1.1 Development of the Handbook

This handbook was developed by Wyle Laboratories for the Department of Transportation, Transportation Systems Center and sponsored by the Federal Railroad Administration. As part of this contract, a joint government/industry committee was formed to provide experience and advice from individuals in government agencies and within the railroad industry responsible for railroad noise control. The committee met in two workshops to discuss the development of the handbook.

During the first workshop, an outline of the handbook was developed in such a way that all topics of interest to the railroad noise control community would be included.

Prior to the second workshop, an interim version of the handbook was distributed to members of the committee for their review. At the second workshop suggested improvements in format and additions to the contents of this document were discussed. Also discussed at this workshop were the topics to be included in the Pocket Manual for the Meausurement and Analysis of Railroad Noise, which is a companion document to this handbook containing abbreviated instructions for the field measurement and evaluation of railroad noise.

The final product of this procedure is the handbook which you are now reading and its accompanying pocket manual. It is hoped that the inputs from this committee will have provided documents that are useful to both government officials charged with the enforcement of the noise regulations and the railroad industry who must meet them.

The authors would like to acknowledge and express their appreciation to the members of the government/industry committee by recognizing them here:

- Mr. Jack Buckingham, Association of American Railroads
- Mr. Peter Conlon, Association of American Railroads
- Dr. Conan Furber, Association of American Railroads
- Mr. John Koper, Federal Railroad Administration
- Mr. Robert Mason, Transportation Systems Center
- Mr. Thomas Pendergast, CONRAIL
- Mr. Ray Plunkett, Southern Railway Company
- Mr. Robert Pooler, Santa Fe Railway Company
- Mr. F.M. Roach, Jr., Southern Railway Company
- Mr. Dick Shelton, Southern Railway Company
- Mr. Stephen Urman, Federal Railroad Administration

1.2 Arrangement of the Handbook

The first chapter of the handbook briefly describes its development, arrangement, and suggested use. This chapter also provides a short overview of the history leading up to the current railroad noise regulations.

Since it is intended that the handbook be useful to those with little background in acoustics and noise control, as well as to experienced noise control engineers and officials, the second chapter provides an introduction to the field of acoustics. In this chapter the basic principles of noise measurement and control are introduced. Starting with the definition of sound itself, all quantities and concepts used in the measurement and control of railroad noise are defined and explained. Numerous examples are provided to clarify the concepts introduced here. It is intended that the level of detail in this chapter be sufficiently complete that an engineer or technician untrained in acoustics can understand it, yet succinct enough that a person experienced in acoustics will find it valuable for review and reference.

The remaining three chapters of the handbook describe the existing railroad noise regulations themselves. For each regulated noise source, the following items are provided:

- A summary of the pertinent regulation indicating the specified regulatory level(s);
- A description of the acoustic metric used in the regulation;
- A description of the measurement site conditions that must be satisfied for a valid measurement;
- A listing of the necessary instrumentation to carry out the measurement;
- A description of the required or suggested measurement procedures;
- A summary of the existing data base describing noise from the source; and
- Suggestions on possible techniques of controlling noise emission from the source.

Where appropriate, sample worksheets and data sheets are provided along with examples of their use. Also provided, for those unfamiliar with railroads, are brief descriptions of the nature and operation of the various noise sources.

Chapter 3 discusses those noise regulations pertinent to line-haul operations. These include regulations on exterior noise emission into the community from moving locomotives and railroad cars as well as interior noise exposure within moving locomotives and railroad cars.

Chapter 4 discusses those noise regulations that apply to railroad yard operations. These include regulations on exterior noise emission from moving and idling locomotives and from locomotive load cell test stands and regulations on noise emission from car-coupling impacts and retarders.

Chapter 5 discusses two miscellaneous railroad regulations: that contolling interior noise levels within railroad employee sleeping quarters and that requiring mininum sound levels for audible warning devices on locomotives.

In addition to the five major chapters of the handbook, four appendices are provided. Appendix A is a glossary of terminology which briefly defines those terms employed in the regulations and identifies the pages in Chapter 2 where a more complete explanation of the acoustic terms is contained. Appendix B provides a set of three programmable calculator programs which can be used to carry out some of the more common arithmetic operations on sound levels. Appendix C provides copies of the various railroad noise regulations discussed in the text, as published in the Federal Register, along with copies of some of the supplemental information that was provided with the final rules. Appendix D provides a list of suggested books and journals for further reading on the subject of noise measurement and control.

1.3 How To Use The Handbook

This section of the handbook provides suggestions on its optimal use. The handbook has been designed for several different audiences, each with potentially different backgrounds. For noise control officials, who may be experienced in acoustic measurements but unfamiliar with the details of railroad operation, many descriptions are provided in Chapters 3, 4, and 5 of the function and operation of the various noise sources. Also provided, in Chapter 2, are common-sense safety suggestions for behavior on railroad property. For railroad personnel, who are familiar with railroad operations and procedures but inexperienced in noise measurement and control, a rather complete introduction to the field of acoustics is provided in Chapter 2.

All persons should read the introduction in Chapter 1 and skim the Table of Contents to see what is contained in the handbook. Those familiar with acoustic measurements and noise control should skim Chapter 2 to see what reference material is contained there. These people should then read the details of the noise source of interest in Chapters 3, 4, or 5.

Those unfamiliar with noise measurement and control should also study Chapter 2 carefully, being sure to carry out themselves the examples provided. This chapter is divided into three major sections:

- Basic concepts of sound,
- Noise measurement procedures, and
- Noise abatement techniques.

The first two sections should be read by all those interested in noise measurement and noise control. The third section need only be studied by those interested in noise control. Once the principles of noise measurement are understood, the reader may proceed to the section of Chapters 3, 4, and 5 of interest.

The major sections in Chapters 3, 4, and 5 have each been designed to be completely self-contained. Because of this, a certain amount of unavoidable repetition occurs, especially in the descriptions of measurement procedure. It was felt, however, that it would be valuable for all the material that is needed to properly measure the noise from a given source to be located in the section covering that source. Thus it is unnecessary to continually refer back to previous sections to obtain pertinent procedures and worksheets. As a result, when preparing to go into the field to measure noise from a particular source, only the section describing the source need be reviewed.

The worksheets provided in these chapters are quite general. For example, equipment that may only occasionally be needed, such as a flashlight and a ground cloth, are listed for completeness. These worksheets may be used as they appear in the handbook by copying the pertinent pages or may be used to supply ideas for designing a more personalized format.

In developing the concepts of acoustics in Chapter 2 and in providing analysis worksheets, where pertinent, in Chapters 3, 4, and 5, a departure from traditional procedure has been employed. Because of the logarithmic nature of the decibel, which is the unit used to quantify sound level, it is often necessary to perform logarithm and powers-of-ten arithmetic operations (i.e., log x and 10^x). In the past, handbooks similar in level to this one, have provided elaborate nomograms or approximation techniques to avoid having to carry out these operations.

With the current availability of inexpensive, portable, scientific calculators, which carry out these operations at the push of a single button, it was felt that the need for such nomograms and approximations no longer exists. Thus Chapter 2 and the analysis worksheets in Chapters 3, 4, and 5 make full use of log x and 10^x functions. The result is, generally, simpler computational procedures than were previously required with older methods.

Finally, for those owning more advanced programmable calculators, a series of three programs are provided in Appendix B for carrying out some of the most common operations on sound levels: decibel addition and subtraction, computation of energy-average sound level, and computation of day-night sound level.

1.4 History of Railroad Noise Regulations

To better understand the choice of contents and arrangement of this handbook, a brief review of the recent legislative history of railroad noise regulations is in order.

The Noise Control Act of 1972 identified noise as a growing danger and declared the policy of the United States to be "to promote an environment for all Americans free from noise that jeopardizes their health and welfare." Included in the Act was the authorization to establish federal noise emission standards for products distributed in commerce, and the mandate for the U.S. Environmental Protection Agency (EPA) to coordinate federal activities in noise control. Section 17 of the Act specifically required EPA to promulgate regulations setting limits on "noise emission resulting from operation of the equipment and facilities of surface carriers engaged in interstate commerce by railroad." It further required that such regulations include noise emission standards which "reflect the degree of noise reduction achievable through the application of the best available technology, taking into account the cost of compliance."

In accordance with Section 17 of the Act, the EPA issued final railroad noise emission standards on December 31, 1975. These standards applied to all railroad cars and all locomotives, except steam locomotives. On August 23, 1977, the Federal Railroad Administration (FRA) published Railroad Noise Emission Compliance Regulations setting forth procedures for enforcing the EPA standards.

In June of 1977 the Association of American Railroads, along with several railroad companies, challenged the EPA regulation in the U.S. Court of Appeals on the basis that it did not include standards for all railroad equipment and facilities as required by the Noise Control Act. The concern of the railroad industry was that, lacking federal preemption of all railroad noise source regulations, there could develop a great variety of differing and inconsistent standards in every jurisdiction along the railroad's routes. In addition, local communities would not necessarily be bound by the protective "best available technology, taking into account the cost of compliance" requirement of the Noise Control Act.

The judgment of the court was in favor of the railroad industry. As a result, EPA published proposed noise regulations for additional railroad equipment and facilities in April 1979. These regulations established standards for overall railroad facility and equipment noise, as well as specific standards for retarders, refrigerator cars, and car-coupling operations.

After an extended public comment period, EPA published final rules on January 4, 1980, establishing standards for noise from four specific sources, namely, locomotive load cell test stands, switcher locomotives, retarders, and car couplings. A property line standard, limiting the total noise emitted from railyard facilities, including sources which are not covered by the existing standards, will be issued by EPA after further assessment of the extensive comments received.

Concurrently with the development of railroad noise standards by EPA, the FRA was developing rules on permissible maximum noise levels within locomotive cabs and railroad employee sleeping quarters and safety standards setting minimum sound levels from audible warning devices on locomotives.

On July 8, 1976, provisions of the Hours of Services Act became effective, which make it unlawful for any common carrier "to provide sleeping quarters for employees ... which do not afford such employees an opportunity for rest, free from interruptions caused by noise under the control of the railroad. . ." and which prohibit the construction or reconstruction of railroad employee sleeping quarters "within or in the immediate vicinity (as determined in accordance with rules prescribed by the Secretary of Transportation) of any area where switching or humping operations are performed." On July 18, 1978, the FRA issued interpretive guidelines describing the noise level which will be regarded as the maximum level permitting "an opportunity to rest." In addition, on July 19, 1978, the FRA published final rules under which the Agency will consider whether proposed sites for the construction or reconstruction of sleeping quarters for railroad employees subject to the Hours of Service Act are "within or in the immediate vicinity ... of any area where railroad switching or humping operations are performed." As part of these rules, interior noise levels in the facility are considered when evaluating a petition for approval.

On March 23, 1978, the President issued Executive Order 12044, which directed all executive agencies to adopt procedures to improve existing and future regulations. In response to this Executive Order, FRA initiated a General Safety Inquiry for the purpose of evaluating and improving its safety regulatory program. After a series of hearings and proposed rulemakings, the FRA published final rules on Railroad Locomotive Safety Standards and Locomotive Inspection on March 31, 1980. One section of these rules requires that the permissible exposure to a continuous noise in a locomotive cab shall not exceed a stated average value. Another section of these rules requires that each lead locomotive be provided with an audible warning device that produces at least a minimum specified sound level.

CHAPTER 2

BASICS OF NOISE MEASUREMENT AND CONTROL

This chapter provides an introduction to the fundamentals of acoustics. The material presented here introduces the reader to the basic physical principles underlying the measurement, assessment, and control of railroad noise.

The chapter is divided into three sections. The first section, Basic Concepts of Sound, describes the various parameters used to characterize sound and its behavior. The metrics by which the intensity of sound is quantified are introduced and their uses are explained with numerous examples. The second section, Noise Measurement Procedures, describes the general items that must be considered in setting up a noise measurement program. General measurement and analysis procedures, safety considerations, and instrumentation are all described. The third section, Noise Abatement Techniques, introduces the reader to general procedures by which noise emissions can be controlled. Techniques for reducing noise at the source, along the propagation path, or at the receiver are each discussed.

2.1 Basic Concepts of Sound

The purpose of this section is to provide a brief introduction to the fundamental concepts of acoustics. Starting with a physical description of the nature of sound waves and the parameters by which they are defined, the section proceeds to define sound pressure and sound power. The concept of sound pressure level is introduced and procedures for adding and subtracting such levels are supplied. Next, various types of sound spectra are defined and their different uses explained. Examples of different types of spectra for typical railroad sources are shown.

The section continues with a brief description of the human perception of sound and of the A-weighted sound level scale. Examples of A-weighted levels of typical railroad and non-railroad noise sounds are provided. Next, the various metrics which are used to describe time-varying sounds are defined and examples given of their use. The section concludes with a discussion of the human response to sound and a general overview of the types of metrics that are employed in existing noise regulations.

2.1.1 Sound Waves

Sound consists of a series of pressure disturbances or waves moving through air or a similar fluid medium. These pressure waves consist of minute back-and-forth movements of molecules which are caused by the vibration or motion of the sound source. These disturbances differ from those associated with heat in that the molecular movements that are sound are organized throughout space, whereas those of heat are random.

A rough analogy to the motion of sound waves in air is the motion of water waves on the surface of a pond into which a stone is thrown. The outward moving circles formed by the peaks of the water waves correspond to high-pressure regions in the sound wave moving outward from a sound source; the outward moving troughs on the water wave correspond to low-pressure regions in the sound wave. The analogy is not quite complete, however, since the water waves form expanding circles on the surface of the pond while the sound waves form expanding spherical shells in space.

Figure 2-1 illustrates a schematic representation of the instantaneous cross-section of the sound wave emanating from a tuning fork showing that the wave consists of a series of outwardly moving crests and troughs of sound pressure. Since this particular sound is a pure tone, the spacing between pressure "crests" is constant and equal to the spacing between pressure "troughs". The distance between successive crests or successive troughs is called the wavelength of the sound wave and is usually designated by the Greek letter "lambda", λ.

This figure represents a cross-section of the wave at one instant of time. As time progresses, each feature of the wave will move outward, away from the source. Thus a particular crest or trough can be thought of as an expanding spherical surface, such as a balloon being inflated. The speed at which any feature of the wave moves outward is called the wave speed or sound speed, c. The value of the sound speed is a function of both the type of material through which the wave is propagating and the temperature.

For sound waves travelling through air, the speed is:

$$c = 49\sqrt{T_R} \text{ ft/sec} \qquad (2\text{-}1)$$

where T_R, the absolute temperature in degrees Rankine (^{o}R), is related to the Fahrenheit temperature, T_F, by the relation

$$T_R = T_F + 460^{o} \qquad (2\text{-}2)$$

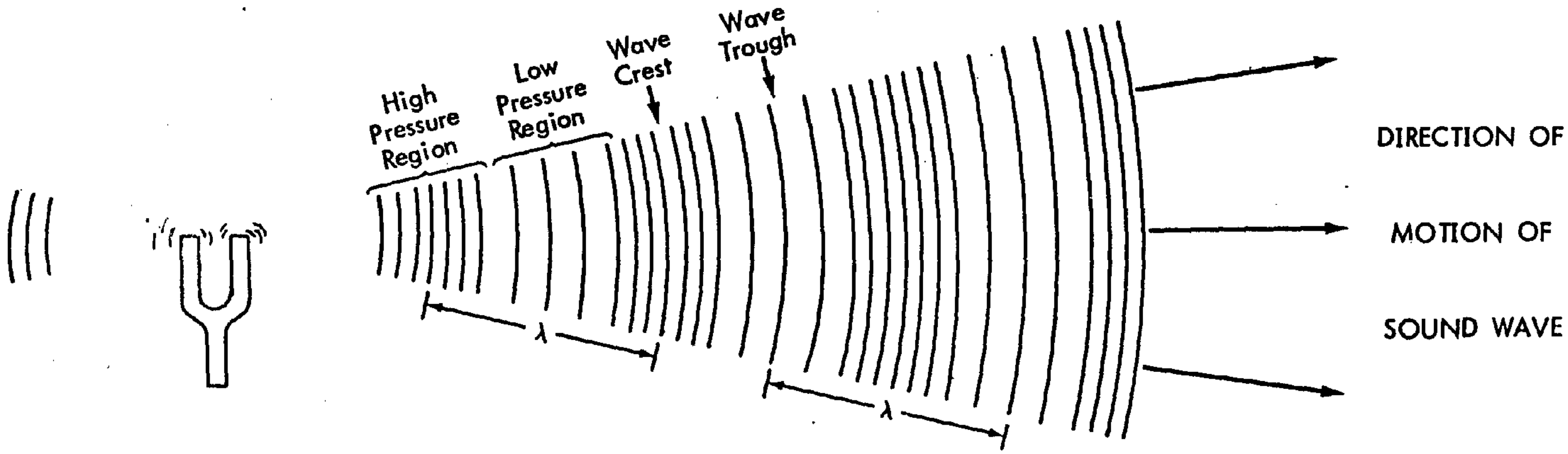


Figure 2-1. Schematic Representation of a Pure-Tone Sound Wave.

Thus, at a temperature of 70°F the speed of sound is:

$$c = 49\sqrt{70 + 460} = 1128 \text{ ft/sec}$$

As the wave travels past a fixed point in space, crests and troughs will continually pass. The time interval between two successive passages of a crest or a trough is called the period, T, of the wave. The number of crests, or troughs, that pass the point each second is called the frequency, f, of the wave. It is related to the period by the expression:

$$f = 1/T \qquad (2\text{-}3)$$

The period of a wave is usually measured in seconds, so that the unit of frequency is cycles per second or hertz (abbreviated Hz).

The wavelength, frequency, and speed of a wave are related by the equation:

$$\lambda f = c \qquad (2\text{-}4)$$

The range of audible frequencies is nominally 20 Hz to 20,000 Hz (corresponding to periods from 0.05 sec to 0.00005 sec). Since the speed of sound at 70°F is 1128 ft/sec, the range of audible wavelengths at this temperature is from 56 feet to 0.68 inch.

Sounds with low frequencies and long wavelengths are heard as low-pitched sounds. Those with high frequencies and short wavelengths are heard as high-pitched sounds. Sound below the lowest frequency at which the ear can respond is called infrasound; that above the highest frequency at which the ear responds is called ultrasound.

2.1.2 Sound Pressure and Sound Power

While the pitch of a sound is determined by its frequency, the intensity of a sound is determined by the difference between the pressure at the crest of the wave and the pressure of the undisturbed air (normal atmospheric pressure). This pressure difference is called the amplitude of the wave, A. Figure 2-2 shows how the pressure at a fixed point in space will vary with time as the crests and troughs of the wave in Figure 2-1 travel past.

A parameter that is often used to characterize the intensity of a sound wave is its root-mean square pressure, p_{rms}. This is defined as the square root of the mean value of the instantaneous pressure-squared, taken over one period of the wave. For a pure-tone wave, the rms pressure is related to the amplitude of the wave by:

$$p_{rms} = \frac{A}{\sqrt{2}} = 0.71A \qquad (2\text{-}5)$$

For more complex waves, there is no simple relationship between rms pressure and amplitude. Most modern sound level meters automatically determine the rms pressure by first averaging the squared-pressure of the wave over a predefined response time. Two such response times are in common use: slow response corresponds to an averaging time of about 1 second; fast response corresponds to an averaging time of about 1/8 second.

The meter-kilogram-second (mks) unit of pressure is the pascal (abbreviated Pa). One pascal is equal to a force of one Newton acting on a surface having an area of one square meter. The minimum discernible sound in quiet laboratory conditions has an rms pressure of about 2×10^{-5} Pa or 20 micropascals (abbreviated μPa). The threshold of hearing pain is considered to be approximately 200 Pa. Thus the range of sound pressures likely to be heard extends over seven orders of magnitude (10^7).

The intensity of a sound wave is defined as the average power per unit area being transmitted by the wave. For a spherical wave, such as the one depicted in Figure 2-1, the intensity, I, is related to the root-mean-square pressure by:

$$I = \frac{p_{rms}^2}{\rho c} \qquad (2\text{-}6)$$

where ρ is the density of the medium through which the wave is travelling and

c is the sound speed in that medium.

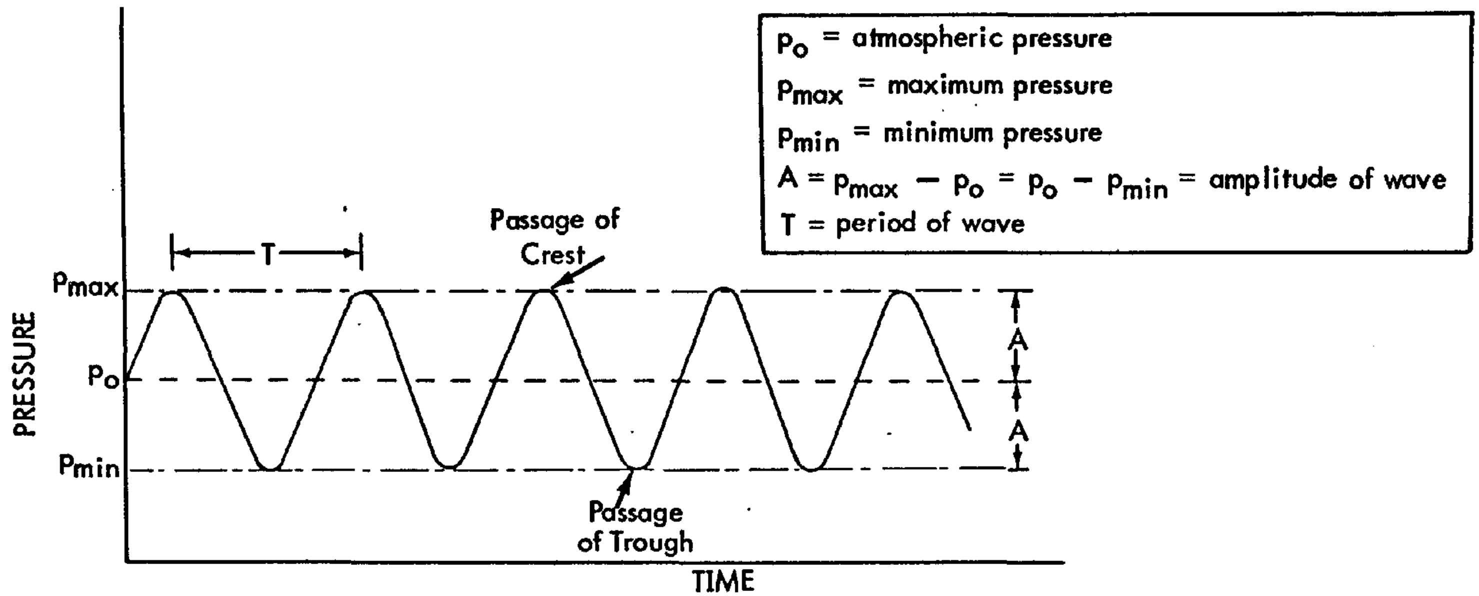


Figure 2-2. Pressure Changes at a Point Due to Passage of a Pure-Tone Sound Wave.

For air at 70°F and 1 atmosphere pressure, the intensity is given by:

$$I = \frac{p_{rms}^2}{406} \text{ watts/m}^2 \quad (2\text{-}7)$$

where p_{rms} is in pascals.

The total power emitted by a source can be determined by summing the intensity over a surface enclosing the source. For a source that radiates uniform spherical waves in all directions, the total power, W, emitted is related to the intensity (Figure 2-3a) by:

$$W = 4\pi R^2 \, I = \frac{R^2 \, p_{rms}^2}{32.3} \text{ watts} \quad (2\text{-}8)$$

where R is the distance, in meters, from the source to the point at which the sound pressure is measured. For such a source just above a plane acoustically reflective surface, i.e., the ground, the total power emitted is related to the intensity (Figure 2-3b) by:

$$W = 2\pi R^2 \, I = \frac{R^2 \, p_{rms}^2}{64.6} \text{ watts} \quad (2\text{-}9)$$

Example 2-1:

To communicate normally at a distance of 4 feet (1.2 meters), an rms sound pressure on the order of 0.02 pascals is required. In order to generate this sound pressure at that distance, the vocal cords must emit a sound power of:

$$W = \frac{(1.2)^2 \, (0.02)^2}{32.3} = 1.8 \times 10^{-5} \text{ watts}$$

As a second example, consider that rms sound pressures of 2 pascals are commonly measured at distances of 100 feet (30 meters) from squealing master retarders. This noise source is one of the loudest that occurs in railroad yards. The power emitted by the wheel-retarder-rail system in such an instance is:

$$W = \frac{(30)^2 \, (2)^2}{64.6} = 56 \text{ watts}$$

From these examples it can be seen that the actual power emission associated with sound is not very large. In fact, for most mechanical noise sources the ratio of sound power emission to total mechanical power is quite small, ranging from about 0.1 part per million for a quieted source such as a dishwasher to 100 parts per million for a noisy source such as a jet aircraft.

As a result, the problem of reducing noise emission from a mechanical process can be quite complex, because one must further reduce what is already a very small part of the total energy involved in the system.

2.1.3 Sound Pressure Level, Decibels

As was seen above, the range of rms sound pressures likely to be heard extends over seven orders of magnitude. In order to compress this tremendous range into a usable interval and because the brain does not interpret the ear response to changes in sound in a linear fashion, a logarithmic scale is normally used to measure rms sound pressure. The sound pressure level of a sound wave having an rms pressure p_{rms} is defined as:

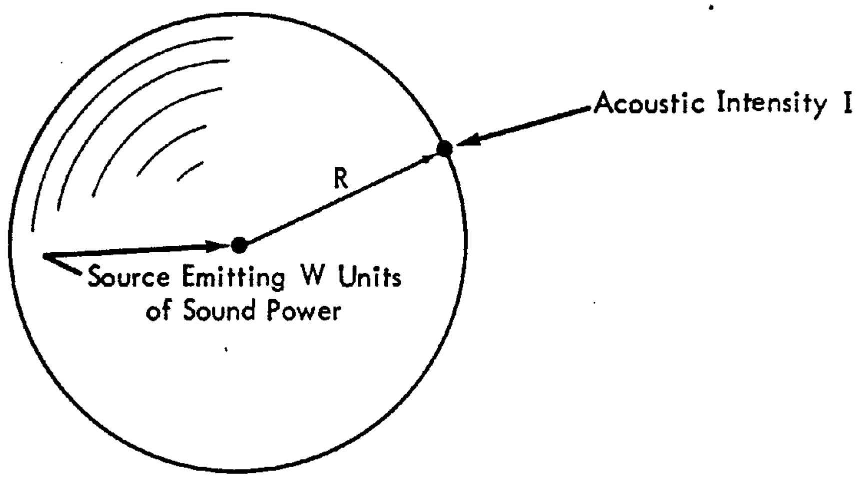
$$L = 10 \log_{10} \left[p_{rms}^2 / p_{ref}^2 \right] \quad (2\text{-}10)$$

where p_{ref} is a reference pressure normally defined as 20μPa (i.e., 20×10^{-6} Pa), which is approximately equal to the threshold of hearing in young persons. Although level is really a dimensionless quantity, being the logarithm to the base 10 of the ratio of two squared-pressures, it is normally indicated that the quantity is a level by calling it a decibel. Thus it is said that the sound wave has a sound pressure level of L decibels relative to 20μPa (abbreviated L dB re 20μPa). *

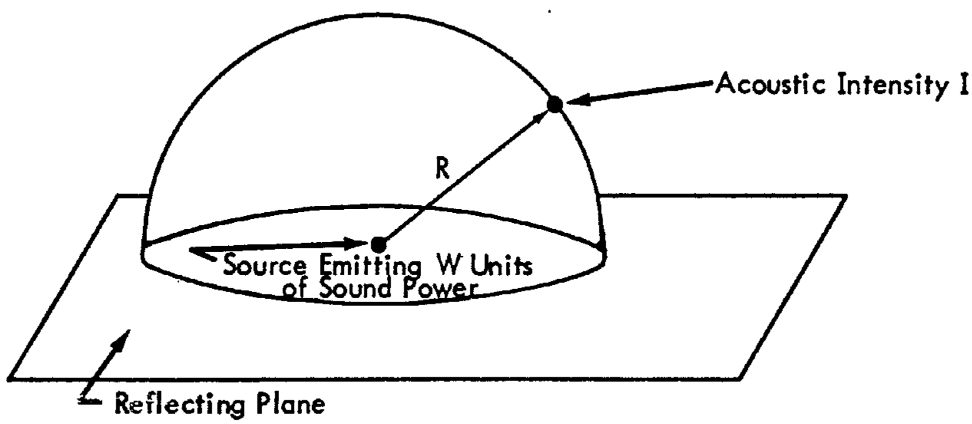
* The basic definition of a level is the bel, named after Alexander Graham Bell. It is defined as the logarithm of the ratio of two power-like quantities (i.e., functions proportional to the power carried by the wave such as power, power density, or energy):

$$\text{Level in bels re } W_{ref} = \log_{10} \left[\frac{W}{W_{ref}} \right]$$

where W is the power-like quantity, and W_{ref} is a reference value. In acoustics, the square of the rms pressure is used as the power-like quantity. In addition, since the bel turns out to be too large a unit for convenience, the decibel, which is 1/10 of a bel, is normally used as the unit of sound pressure level.



(a) Away From Reflecting Surfaces: $I = \frac{W}{4\pi R^2}$



(b) Near a Large Reflecting Plane: $I = \frac{W}{2\pi R^2}$

Figure 2-3. Sound Power For a Uniformly Emitting Source.

Example 2-2:

A sound wave corresponding to the minimum discernible sound pressure would have a level:

$$L = 10 \log_{10}\left[\frac{(20\mu Pa)^2}{(20\mu Pa)^2}\right] = 10 \log_{10}[1] = 0 \text{ dB re } 20\mu Pa$$

The sound pressure level corresponding to the threshold of pain is:

$$L = 10 \log_{10}\left[\frac{(200 \text{ Pa})^2}{(20\mu Pa)^2}\right] = 10 \log_{10}\left[\frac{200}{20 \times 10^{-6}}\right]^2$$

$$= 10 \log_{10}\left[10^{14}\right] = 140 \text{ dB re } 20\mu Pa$$

Often the reference pressure is omitted, so that the above examples might simply be referred to as 0 dB and 140 dB, respectively.

Example 2-3:

A typical sound in normal conversation might have an rms pressure of 0.02 Pa, so that its sound pressure level would be:

$$L = 10 \log_{10}\left[\frac{(0.02 \text{ Pa})^2}{(20\mu Pa)^2}\right] = 10 \log_{10}\left[\frac{0.02}{20 \times 10^{-6}}\right]^2$$

$$= 10 \log_{10}\left[10^{6}\right] = 60 \text{ dB}$$

2.1.4 Decibel Addition and Subtraction

Often more than one source contributes to the sound heard. Because the sound level scale is logarithmic, levels from two or more different sources do not combine additively. For example, the sum of two 60 dB levels is not 120 dB.

In order to determine the sum of two sound levels, each level must be converted to a squared-pressure; these can then be added.* To obtain the squared-pressure of a sound wave in terms of its level, Equation (2-10) is solved for p^2_{rms}:

$$p^2_{rms} = p^2_{ref} \times 10^{L/10} \qquad (2\text{-}11)$$

Applying this equation to each level individually, it can be seen that the squared-pressure that results when two sound waves, having levels L_1 and L_2, are summed, is:

$$p^2_{sum} = p^2_{rms,1} + p^2_{rms,2} = \left[p^2_{ref} \times 10^{L_1/10}\right] + \left[p^2_{ref} \times 10^{L_2/10}\right]$$

The resultant sound level is:

$$L_{sum} = 10 \log_{10}\left[\frac{p^2_{sum}}{p^2_{ref}}\right] = 10 \log_{10}\left[10^{L_1/10} + 10^{L_2/10}\right] \qquad (2\text{-}12)$$

* This assumes that the two sound waves are incoherent; i.e., unrelated to each other. This will normally be the case if the waves are generated by different sound sources.

Example 2-4:

The sum of 65 dB and 68 dB is:

$$L_{sum} = 10 \log_{10} \left[10^{65/10} + 10^{68/10}\right] = 10 \log_{10} \left[10^{6.5} + 10^{6.8}\right]$$

$$= 10 \log_{10} \left[3{,}162{,}277 + 6{,}309{,}573\right]$$

$$= 10 \log_{10} \left[9{,}471{,}850\right] = 69.8 \text{ dB}$$

Computations such as these can easily be performed on modern hand-held calculators which have built-in log and 10^x functions. A programmable calculator program to do decibel addition is given in Appendix B. Lacking a calculator, tables of logarithms or Figure 2-4 can be used.

Example 2-5:

As an example of the use of this figure, again consider the addition of 65 dB and 68 dB. The larger of the two levels to be summed is:

$$\max(L_1, L_2) = \max(65, 68) = 68 \text{ dB}$$

The absolute value of the arithmetic difference between the two levels, denoted by $|L_1 - L_2|$, is:

$$|L_1 - L_2| = |65 - 68| = |-3| = 3 \text{ dB}$$

From Figure 2-4, the increment to be added to the larger of the two levels to produce the sum is:

$$\Delta L_+ = 1.8 \text{ dB}$$

Thus the sum of the two levels is:

$$L_{sum} = \max(L_1, L_2) + \Delta L_+ = 68 + 1.8 = 69.8 \text{ dB}$$

Figure 2-4 can be contracted to a simple, easily remembered table, if only one decibel accuracy is being maintained in the calculation:

$\|L_1 - L_2\|$	0, 1	2, 3	4, 5, 6, 7, 8, 9	≥10
ΔL_+	3	2	1	0

Note that if differences greater than or equal to 10 dB exist, the lower level may be ignored. This is reflected in measurement criteria which require background sound levels to be at least 10 dB below the sound level of the source to be measured.

Example 2-6:

In the previous example, $|L_1 - L_2|$ is 3 dB, so that ΔL_+ is 2 dB. The sum of the two levels is therefore 2 dB greater than the larger of the pair, i.e., 68 + 2 = 70 dB. This is indeed the solution obtained if the more accurate result above is rounded to the nearest integer.

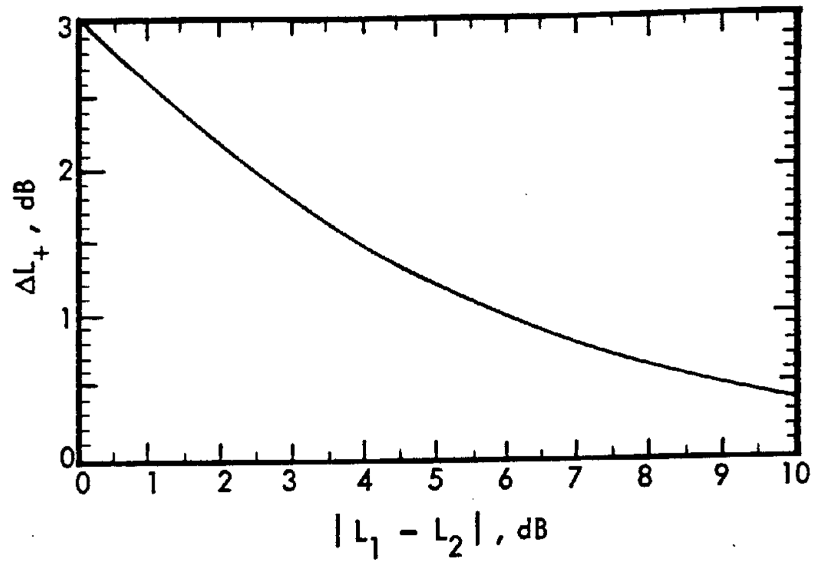


Figure 2-4. Summation of Two Sound Levels L_1 and L_2:

$$L_{sum} = \max(L_1, L_2) + \Delta L_+$$

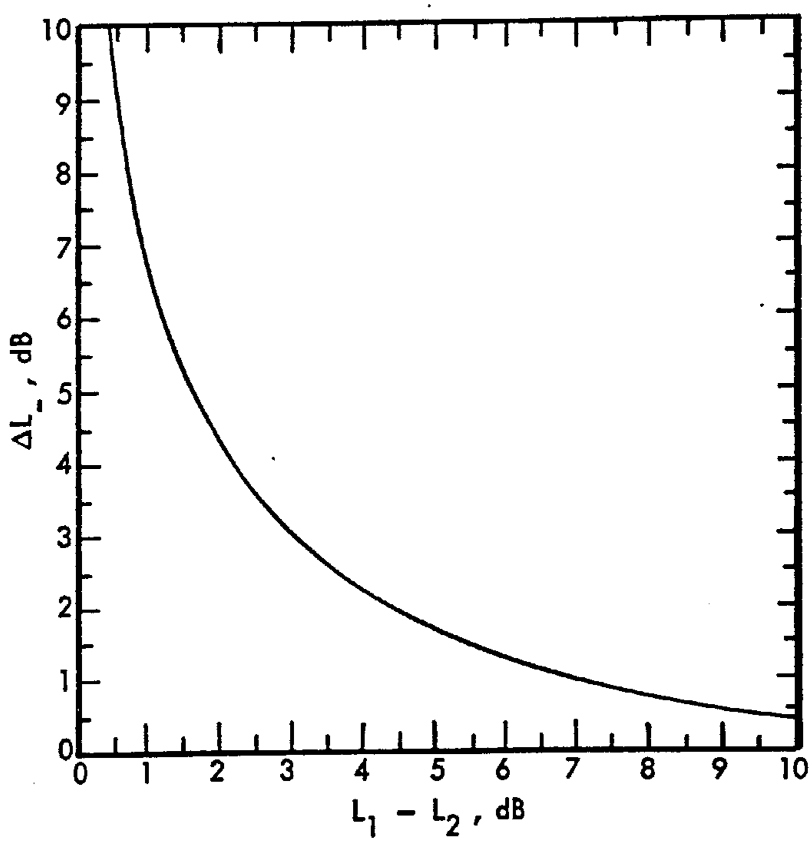


Figure 2-5. Difference of Two Sound Levels L_1 and L_2:

$$L_{dif} = L_1 - \Delta L_- \; ; \; L_1 > L_2$$

Subtraction of one sound level from a larger sound level is accomplished in a similar fashion. Both levels are converted to squared pressures and the resulting quantities subtracted; i.e.:

$$p_{dif}^2 = p_{rms,1}^2 - p_{rms,2}^2 = \left[p_{ref}^2 \times 10^{L_1/10}\right] - \left[p_{ref}^2 \times 10^{L_2/10}\right]$$

and:

$$L_{dif} = 10 \log_{10} \left[\frac{p_{dif}^2}{p_{ref}^2}\right] = 10 \log_{10} \left[10^{L_1/10} - 10^{L_2/10}\right] \; ; \; L_1 > L_2 \qquad (2\text{-}13)$$

Example 2-7:

The difference of 70 dB and 68 dB is:

$$L_{dif} = 10 \log_{10} \left[10^{7.0} - 10^{6.8}\right]$$

$$= 10 \log_{10} \left[10{,}000{,}000 - 6{,}309{,}573\right]$$

$$= 10 \log_{10} \left[3{,}690{,}427\right] = 65.8 \text{ dB}$$

As in the case of decibel addition, such calculations can easily be performed on hand-held calculators which have built-in log and 10^x functions. A programmable calculator program to do decibel subtraction is given in Appendix B. If a calculator is not available to perform these computations, the procedure in Figure 2-5 can be employed.

Example 2-8:

As an example of the use of this figure, again consider the difference of 70 dB and 68 dB. In the notation of the figure:

$$L_1 = 70 \text{ dB} \; , \quad L_2 = 68 \text{ dB}$$

and

$$L_1 - L_2 = 70 - 68 = 2 \text{ dB}$$

Thus, from the figure:

$$\Delta L_- = 4.3 \text{ dB}$$

so that:

$$L_{dif} = L_1 - \Delta L_- = 70 - 4.3 = 65.7 \text{ dB}$$

Because of the non-linear way in which sound levels add and subtract, some care must be taken in deciding which sources to quieten when several sources are present. In general, <u>the level of the loudest source is always reduced first.</u>

Example 2-9:

Consider a situation where two sources contribute to the noise at a given position – one generating a level of 80 dB, the other a level of 85 dB. The total sound level is the sum of the two levels:

$$L_{sum} = 10 \log_{10} \left[10^{8.0} + 10^{8.5}\right] = 86.2 \text{ dB}$$

Now suppose the sound level generated by the first source is reduced by 5 dB to 75 dB. The total level is now:

$$L_{sum} = 10 \log_{10} \left[10^{7.5} + 10^{8.5}\right] = 85.4 \text{ dB}$$

Thus the 5 dB noise reduction in the quieter source has produced a 0.8 dB reduction in the total sound level. If, instead, the sound level of the second source had been reduced by 5 dB to 80 dB, the total level would be:

$$L_{sum} = 10 \log_{10} \left[10^{8.0} + 10^{8.0}\right] = 83.0 \text{ dB}$$

In this case the total noise level has been reduced by 3.2 dB. By reducing the level generated by the louder source, an additional 2.4 dB of reduction was obtained in the total sound level.

2.1.5 Audible Effects of Sound Level Changes

As noted in the previous section, the ear does not respond to sound pressure changes in a linear fashion. Thus a doubling of the sound energy is not perceived as doubling of the loudness of the sound. The psychological response to changes in sound level is quite complicated, but, as a rough rule-of-thumb, the responses in Table 2-1 are appropriate.

Table 2-1

Typical Responses to Changes in Sound Level

Decibel Change	Increase In Sound Energy	Response
+3 dB	x 2.0	Just Noticeable
+5 dB	x 3.2	Clearly Noticeable
+10 dB	x 10	Twice As Loud
+20 dB	x 100	Much Louder

2.1.6 Sound Spectra — Types and Uses

So far, only pure tone sounds have been discussed. Most sounds are much more complicated and cannot be characterized by a single frequency or wavelength. However, no matter how complex the sound wave, it can always be described as a weighted summation of pure tones of various frequencies. The weighting factor for each frequency is a measure of how much sound power of that frequency is contained in the sound wave.

A plot of those weighting factors as a function of frequency is called the spectrum of the sound. For a pure tone, the spectrum would be sharply peaked, as shown in Figure 2-6(a). If many frequencies are present, the spectrum will be broadly spread across the audio frequency range as in Figure 2-6(b). Such sounds are called "broadband" sounds. The spectra of two common railroad sound sources are shown in Figure 2-6(c), which illustrates the spectrum of a retarder squeal, and Figure 2-6(d), which illustrates the spectrum of an idling locomotive.

Spectra such as these can often be used to determine the precise source of the sound on a machine, since any pure-tone components may correspond to resonant vibrations or rotational speeds of components of the machine. Spectra must be used to determine the reduction in level with distance due to air absorption and ground attenuation as sound propagates through the atmosphere. Finally, the spectrum of a source is necessary to determine the attenuation provided by a barrier or enclosure placed about the source.

In determining the spectrum of a source, the acoustic signal is passed through a set of filters. Each filter only allows sound at certain frequencies to pass, the range of such frequencies being called the passband of the filter. The difference between the frequencies of the upper and lower edges of the passband is called the bandwidth of the filter.

In practice, no filter completely stops sound at frequencies outside its passband, but sound at such frequencies is greatly reduced (attenuated) by the filter. The exact amount of attenuation outside the passband depends on the specific design of the filter.

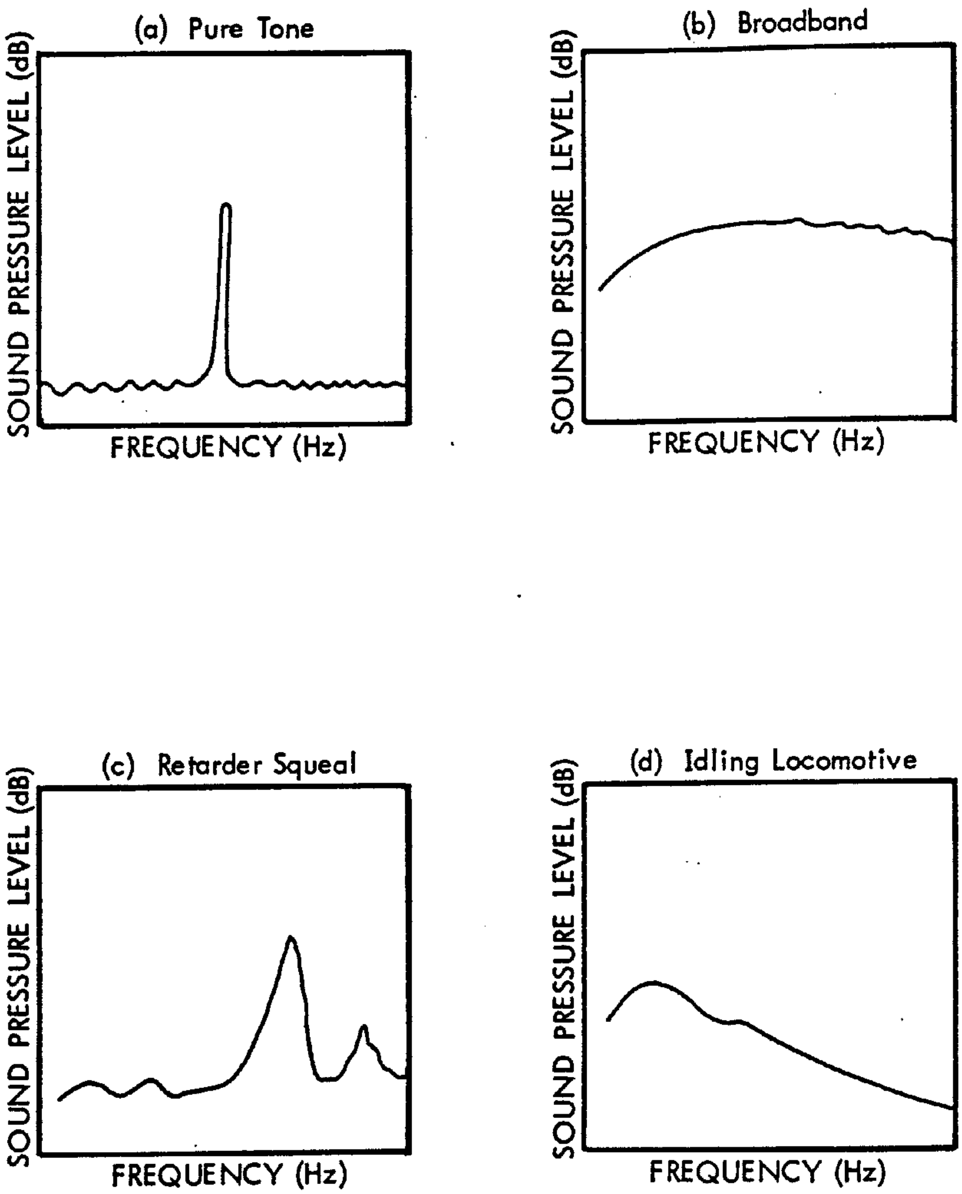


Figure 2-6. Types of Sound Spectra.

Two general types of filters exist, leading to two different types of spectral analysis. For a constant bandwidth filter, the bandwidth is independent of the actual passband. The center frequency of the passband is the arithmetic mean of the upper and lower band edges. Thus for a constant bandwidth filter:

$$f_u - f_l = \text{constant} \quad (2\text{-}14)$$

and

$$f_c = \frac{f_l + f_u}{2}, \quad (2\text{-}15)$$

where f_c = center frequency of a constant bandwidth passband,

f_l = frequency of the lower edge of the passband, and

f_u = frequency of the upper edge of the passband.

Figure 2-7(a) shows an example of the passbands of a 20 Hz constant bandwidth spectrum. Each band is exactly 20 Hz wide and the band center frequency is the arithmetic mean of the band edge frequencies.

The second type of filter is a constant percentage bandwidth filter, in which the ratio of bandwidth to center frequency is a constant. Thus, as the center frequency of the passband is increased, the bandwidth also increases by the same factor. For such a filter the center frequency is defined as the geometric mean of the two band edges. Thus for a constant percentage bandwidth filter:

$$\frac{f_u - f_l}{f_c} = \text{constant} \quad (2\text{-}16)$$

and

$$f_c = \sqrt{f_l \, f_u}, \quad (2\text{-}17)$$

where f_c = center frequency of a constant percentage bandwidth passband,

f_l = frequency of the lower edge of the passband, and

f_u = frequency of the upper edge of the passband.

Figure 2-7(b) shows an example of the passbands of an octave band spectrum. This spectrum is one of the two most common types of constant percentage bandwidth spectra, the other being the one-third octave band spectrum. The standard band edges and center frequencies for octave band and one-third octave band spectra are shown in Table 2-2.

Constant bandwidth spectral analyses are usually carried out when the purpose of the sound measurement is to obtain a detailed frequency analysis in order to identify the origin of the sound. Quite often the frequencies of the peaks of such a spectrum are related to the rotational speeds of components of the source or to vibrational resonances of the structure of portions of the source, and thus the specific component that is generating the sound can be located.

Constant percentage bandwidth analyses, such as those utilizing octave and one-third octave bands, are normally used when the purpose of the measurements is to assess human response to sound. In addition, such spectral analyses are usually sufficient to determine the effects on the total sound field of air absorption, ground attenuation, and barrier attenuation.

Figure 2-8 shows an octave band spectrum, a one-third octave band spectrum, and a 12.5 Hz constant bandwidth spectrum for a typical idling locomotive at a distance of 100 feet. Note the increasing detail evident in each spectrum as one progresses from the octave band spectrum to the 12.5 Hz constant bandwidth spectrum.

2.1.7 Human Perception of Sound, A-Weighted Sound Levels

Human response to sound is a complicated function of the physical properties of the sound, the perceptual process within the ear, and the psychological effect that the perceived sound elicits. The first two of these sets of parameters are well defined; the last is less so.

The physical properties of sound waves have been discussed in the previous sections. The loudness of a sound as perceived by the ear is a function of the level and spectrum of the sound. The ear is much less sensitive to low frequencies than it is to high frequencies. Thus, for example, a pure tone at 50 Hz would need to have a sound level about 30 dB higher than that of a tone at 1000 Hz to be perceived as equally loud.

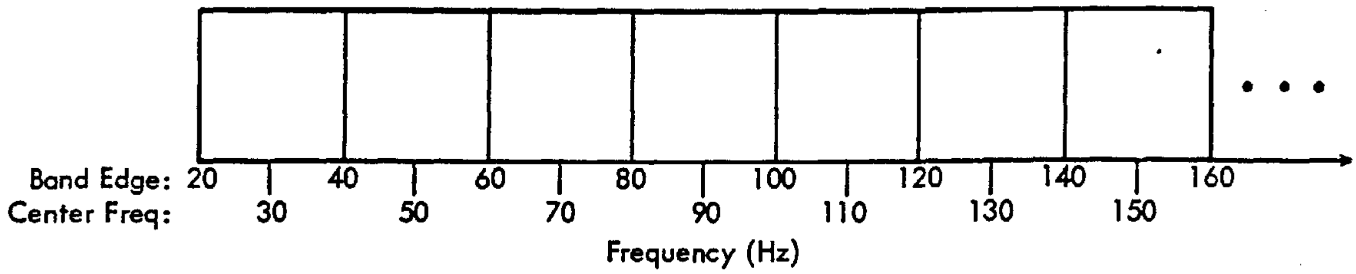


Figure 2-7(a). 20 Hz Spectrum Passbands.

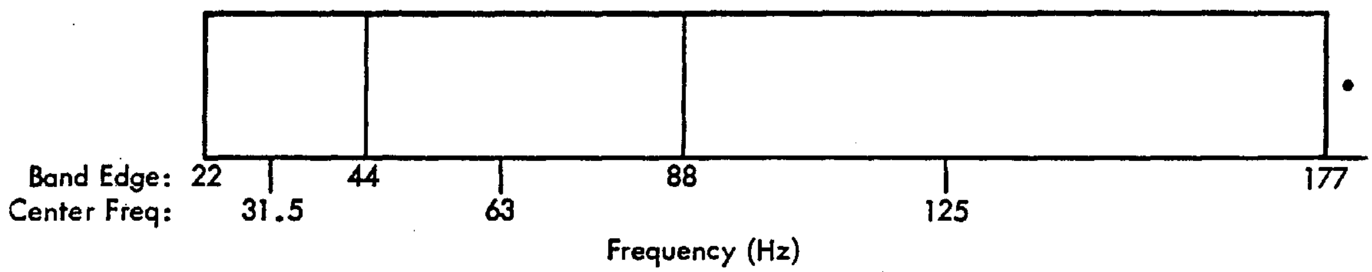


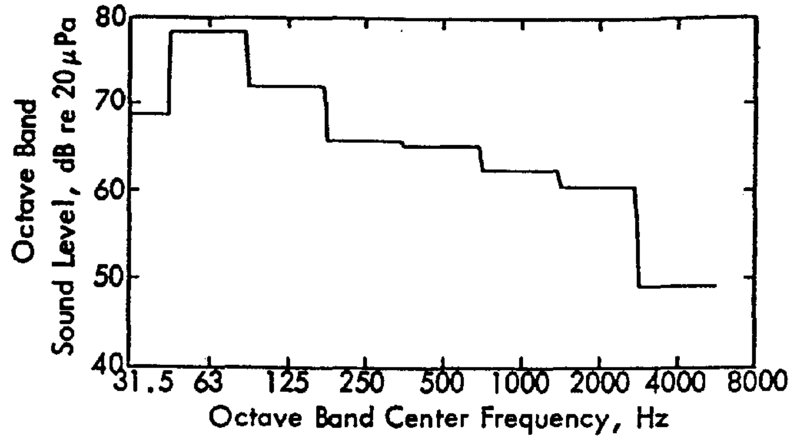
Figure 2-7(b). Octave Band Spectrum Passbands.

Table 2-2

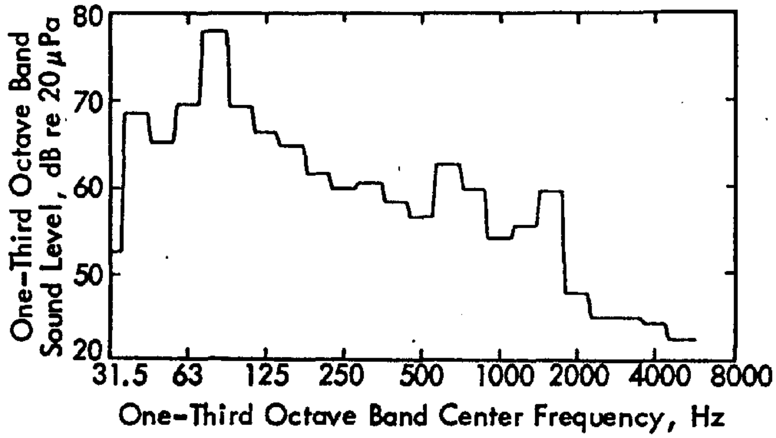
Band Edges and Center Frequencies for Octave and One-Third Octave Passbands[1] *

Octave Bands			One-Third Octave Bands		
Lower Band Edge (Hz)	Center Frequency (Hz)	Upper Band Edge (Hz)	Lower Band Edge (Hz)	Center Frequency (Hz)	Upper Band Edge (Hz)
22	31.5	44	22.4 28.2 35.5	25.0 31.5 40.0	28.2 35.5 44.7
44	63.0	88	44.7 56.2 70.8	50.0 63.0 80.0	56.2 70.8 89.1
88	125	177	89.1 112 141	100 125 160	112 141 178
177	250	355	178 224 282	200 250 315	224 282 355
355	500	710	355 447 562	400 500 630	447 562 708
710	1,000	1,420	708 891 1,122	800 1,000 1,250	891 1,122 1,413
1,420	2,000	2,840	1,413 1,778 2,239	1,600 2,000 2,500	1,778 2,239 2,818
2,840	4,000	5,680	2,818 3,548 4,467	3,150 4,000 5,000	3,548 4,467 5,623
5,680	8,000	11,360	5,623 7,079 8,913	6,300 8,000 10,000	7,079 8,913 11,220
11,360	16,000	22,720	11,220 14,130 17,780	12,500 16,000 20,000	14,130 17,780 22,390

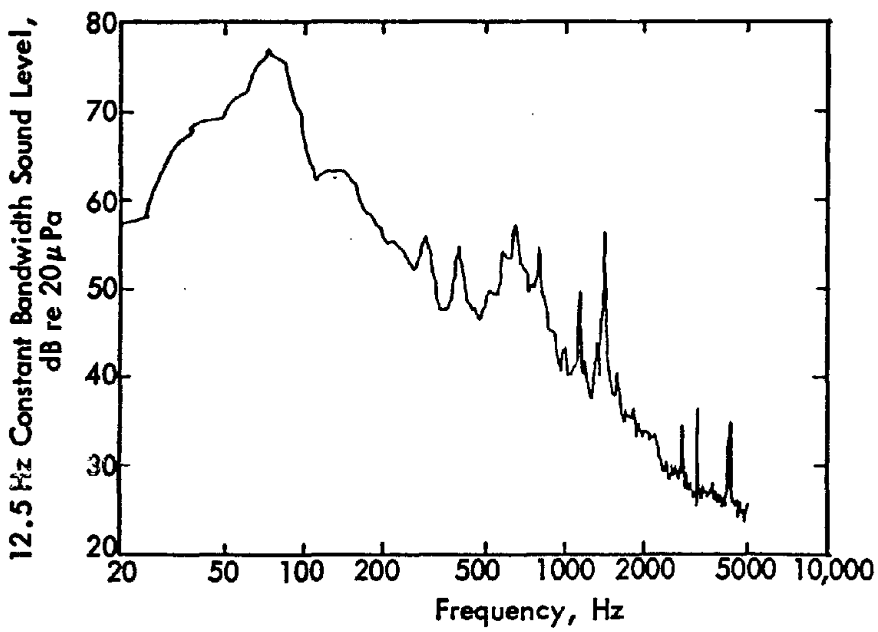
* Superscripts refer to references at end of chapter.



(a) Octave Band Spectrum.



(b) One-Third Octave Band Spectrum.



(c) 12.5 Hz Constant Bandwidth Spectrum.

Figure 2-8. Examples of Idling Locomotive Spectra.

In order to take the ear's sensitivity into account when discussing the effect of sound on humans, it is common to describe a complex sound by its A-weighted sound level. This is a weighted summation of all of the frequency components in the spectrum of the sound; the weighting function being directly related to the sensitivity of the ear. Table 2-3 shows the A-weighting coefficients as a function of one-third octave band center frequencies. These coefficients are added algebraically to the corresponding passband sound levels to obtain the A-weighted band levels. The decibel sum of all A-weighted band levels is the A-weighted sound level, usually symbolized by L_A. The decibel sum of all unweighted band levels is the unweighted sound level of the source, usually symbolized by L.

Example 2-10:

Table 2-4 shows an example of such computations for the octave band spectrum of an idling switcher locomotive shown in Figure 2-8a.

Most sound level meters contain electronic circuitry which automatically determines the A-weighted sound level of a sound wave. A-weighted sound levels of some typical sound sources are shown in Figure 2-9.

Although the units of both unweighted sound level and A-weighted sound level are the decibel, the symbols dB(A) or dBA are often used to indicate that the signal has been A-weighted. It should be remembered that dB, dB(A), and dBA all indicate the same unit – the decibel – and that the "A" only indicates that an A-weighting operation has been performed on the data. The U.S. Environmental Protection Agency and various standardization agencies tend to use only the symbol dB, choosing to indicate that the signal has been A-weighted by always referring to the level as the "A-weighted sound level"; however, this practice is not universal, so that some caution should be used in determining whether or not a level quoted in dB has been A-weighted.

All railroad noise regulations discussed in this handbook are written in terms of A-weighted sound levels or metrics derived from such levels.

2.1.8 Characterization of Time-Varying Sounds

Most sounds that occur in the environment are not constant, but rather their sound level varies with time. In order to characterize the level of such sounds, various metrics have been developed. Five such metrics, which are commonly used for regulatory purposes, will be described here. These are the exceedance percentile sound level, the energy-equivalent sound level, the day-night sound level, the noise dose, and the time-weighted average level.

2.1.8.1 Exceedance Percentile Sound Level

The exceedance percentile sound level, L_x, is the A-weighted sound level that is exceeded x percent of the time during the measurement period. Thus, for example, L_{10} is the sound level that is exceeded 10 percent of the time.

Community noise analyzers are available which will continuously monitor the sound at a given location and compute various exceedance percentile sound levels. Although some models of this equipment will determine up to 99 such levels (L_1, L_2, . . ., L_{99}), four exceedance percentile sound levels are most commonly used:

- L_{90}, the sound level exceeded 90 percent of the time, represents the background level for which no single source is identifiable;
- L_{50}, the sound level exceeded 50 percent of the time, is the median sound level during the measurement period;
- L_{10}, the sound level exceeded 10 percent of the time, is a commonly used measure of traffic noise; and
- L_1, the sound level exceeded 1 percent of the time, represents the rare loud noise events which occurred.

Example 2-11:

To understand the precise meaning of these exceedance percentile levels and to illustrate how they can be estimated from a plot of the temporal history of the sound level, consider the following example. Figure 2-10(a) illustrates the change in sound level with time for a flat yard switching cycle in which a switcher locomotive approaches with a cut of cars, brakes suddenly to release the car being classified, and moves away. This figure represents, for simplicity, a smoothed version of Figure 4-16.

During the time period shown, the sound level changes over a range of 25 dB. To estimate various exceedance percentile levels, one first determines for what amount of

Table 2-3

A-Weighting Coefficients[2]

One-Third Octave Band Center Frequency (Hz)	A-Weighting Coefficients (dB)	One-Third Octave Band Center Frequency (Hz)	A-Weighting Coefficients (dB)
25	-44.7	1,000	0
31.5	-39.4	1,250	+0.6
40	-34.6	1,600	+1.0
50	-30.2	2,000	+1.2
63	-26.2	2,500	+1.3
80	-22.5	3,150	+1.2
100	-19.1	4,000	+1.0
125	-16.1	5,000	+0.5
160	-13.4	6,300	-0.1
200	-10.9	8,000	-1.1
250	-8.6	10,000	-2.5
315	-6.6	12,500	-4.3
400	-4.8	16,000	-6.6
500	-3.2	20,000	-9.3
630	-1.9		
800	-0.8		

Table 2-4

Unweighted and A-Weighted Spectrum of An Idling Switcher Locomotive at a Distance of 100 Feet

Octave Band Center Frequency (Hz)	Octave Band Sound Level (dB re 20μPa)	A-Weighting Coefficient (dB)	A-Weighted Octave Band Sound Level (dB re 20μPa)
31.5	68	-39.4	28.6
63	78	-26.2	51.8
125	72	-16.1	55.9
250	66	-8.6	57.4
500	65	-3.2	61.8
1000	62	0	62.0
2000	60	1.2	61.2
4000	49	1.0	50.0
TOTAL	80(1)	---	67(2)

(1) The unweighted sound level for this spectrum is:

$$L = 10 \log_{10} \left[10^{6.8} + 10^{7.8} + 10^{7.2} + 10^{6.6} + 10^{6.5} + 10^{6.2} + 10^{6.0} + 10^{4.9}\right] = 79.8 \text{ dB}$$

Since the original octave band levels are only known to an accuracy of 1 dB, this result is rounded to the nearest integer value of 80 dB.

(2) The A-weighted sound level for this spectrum is:

$$L_A = 10 \log_{10} \left[10^{2.86} + 10^{5.18} + 10^{5.59} + 10^{5.74} + 10^{6.18} + 10^{6.20} + 10^{6.12} + 10^{5.00}\right] = 67.5 \text{ dB}$$

Again, since the original octave band levels are only known to an accuracy of 1 dB, this result is rounded to the nearest integer value of 67 dB.

	Decibels re 20μPa	
Threshold of Pain	140	
	130	Air-Raid Sirens, 100 feet away
	120	Jet Takeoff, 200 feet away
Sonic Boom, Thunder	110	Master Retarder, 100 feet away Riveting Machine*
Pneumatic Hammer*	100	Rail Car Impact, 100 feet away
LocomotiveLoad Test (Throttle 8), 100 feet away	90	Lawnmower, 5 feet away
Alarm Clock	80	Flat Yard Switch Engine Accel., 100 feet away Inside of Sport Car @ 50 mph
Vacuum Cleaner, 10 feet away	70	Refrigerator Car, 100 feet away Freight Train, 100 feet away
Freeway Auto Traffic, 100 feet away	60	Idling Locomotive, 100 feet away Conversational Speech
Light Traffic, 100 feet away	50	Business Office, Average Residences
	40	Bedroom
Recording Studio	30	Soft Whisper, 15 feet away
Rustle of Leaves	20	
	10	Breathing
Youth's Threshold of Hearing	0	

* Operator's Position

Figure 2-9. A-Weighted Sound Pressure Levels of Typical Sound Sources.

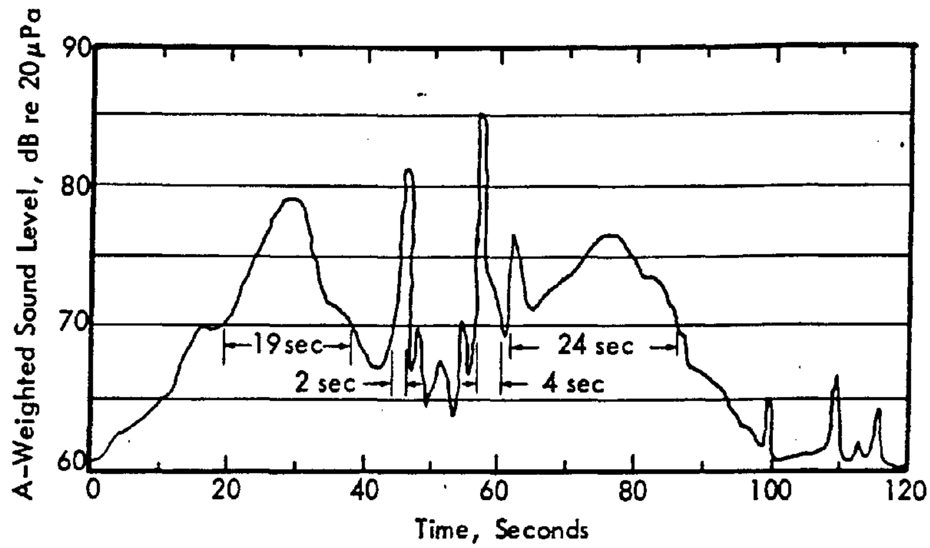


Figure 2-10(a). Time History of a Flat Yard Locomotive Switching Cycle.

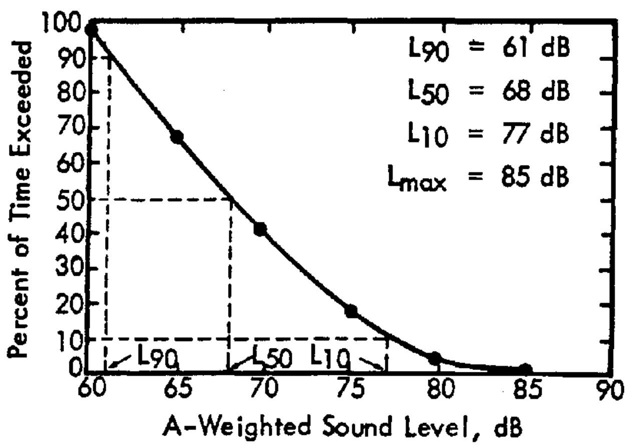


Figure 2-10(b). Exceedance Probability For Data in Figure 2-10(a).

time various sound levels are exceeded. In the figure, horizontal lines have been drawn at 5 dB intervals from 60 to 85 dB. The exceedance time is measured for each of these levels. For example, as shown in the figure, the 70 dB level is exceeded during four time periods, the durations of which are 19, 2, 4, and 24 seconds. Thus the total time for which this level is exceeded is 49 seconds, which represents 40.8 percent of the total 120-second measurement period.

Table 2-5 shows the exceedance times and percentages for each of the levels indicated in the figure. Also indicated is the percent of the total measurement period that the sound level was in each 5 dB interval. These are obtained by subtracting successive exceedance percentages in the third column.

Figure 2-10(b) shows a plot of the exceedance percentage as a function of sound level. A smooth curve has been drawn through the six points from Table 2-5. Such a figure is called a sound level exceedance probability curve. From this curve it can be determined that, for this example, the level exceeded 90 percent of the time (L_{90}) is 61 dB, that exceeded 50 percent of the time (L_{50}) is 68 dB, and that exceeded 10 percent of the time (L_{10}) is 77 dB, as is illustrated in the figure.

Had smaller intervals been chosen at which to calculate the amount of time exceeded, the exceedance probability curve would be more precise and the estimate of the percentile exceedance sound levels would be more accurate. Modern commercial community noise analyzers normally use 1 dB increments in computing the exceedance probabilities.

2.1.8.2 Energy-Equivalent Sound Level

The energy-equivalent sound level, L_{eq}, is the level of the continuous constant sound that would contribute to the environment the same amount of A-weighted acoustic energy as did the actual time-varying source. L_{eq} is sometimes referred to as the "average" sound level, although this can be confused with the arithmetic average sound level discussed below. L_{eq} is commonly computed by sampling the time-varying sound level at constant intervals and forming an energy-average of this set of sound levels.

The energy-average of a set of sound levels is the level corresponding to the arithmetic average of the intensities of those sound levels. As a result, the energy-average of a set of levels is always greater than the arithmetic average of those levels.

Example 2-12:

Figure 2-11 illustrates the difference between the energy-average of two levels, L_1 = 90 dB and L_2 = 80 dB,* and their arithmetic average. The arithmetic average ($\bar{L}$) of these two levels is:

$$\bar{L} = \frac{L_1 + L_2}{2} = 85 \text{ dB}$$

The energy-average is obtained by computing the acoustic intensities, I_1 and I_2, corresponding to these two levels and averaging the results:

$$I_1 = \frac{p_1^2}{\rho c} = \frac{p_{ref}^2}{\rho c} \times 10^{L_1/10} = 0.000985 \text{ watts/m}^2$$

$$I_2 = \frac{p_2^2}{\rho c} = \frac{p_{ref}^2}{\rho c} \times 10^{L_2/10} = 0.000098 \text{ watts/m}^2$$

$$\bar{I} = \frac{I_1 + I_2}{2} = 0.000542 \text{ watts/m}^2$$

$$L_{eq} = 10 \log_{10} \frac{\rho c \bar{I}}{p_{ref}^2} = 87.4 \text{ dB}$$

* Note that the notation now has a different meaning than in the previous section.

Table 2-5

Exceedance Data For Figure 2-10(a)

A-Weighted Sound Level (dB)	Exceedance Time (sec)	Percent of Time Exceeded (%)	Percent of Time In Interval (%)
85	0	0.0	
			1.7
80	2	1.7	
			14.1
75	19	15.8	
			25.0
70	49	40.8	
			25.9
65	80	66.7	
			33.3
60	120	100.0	

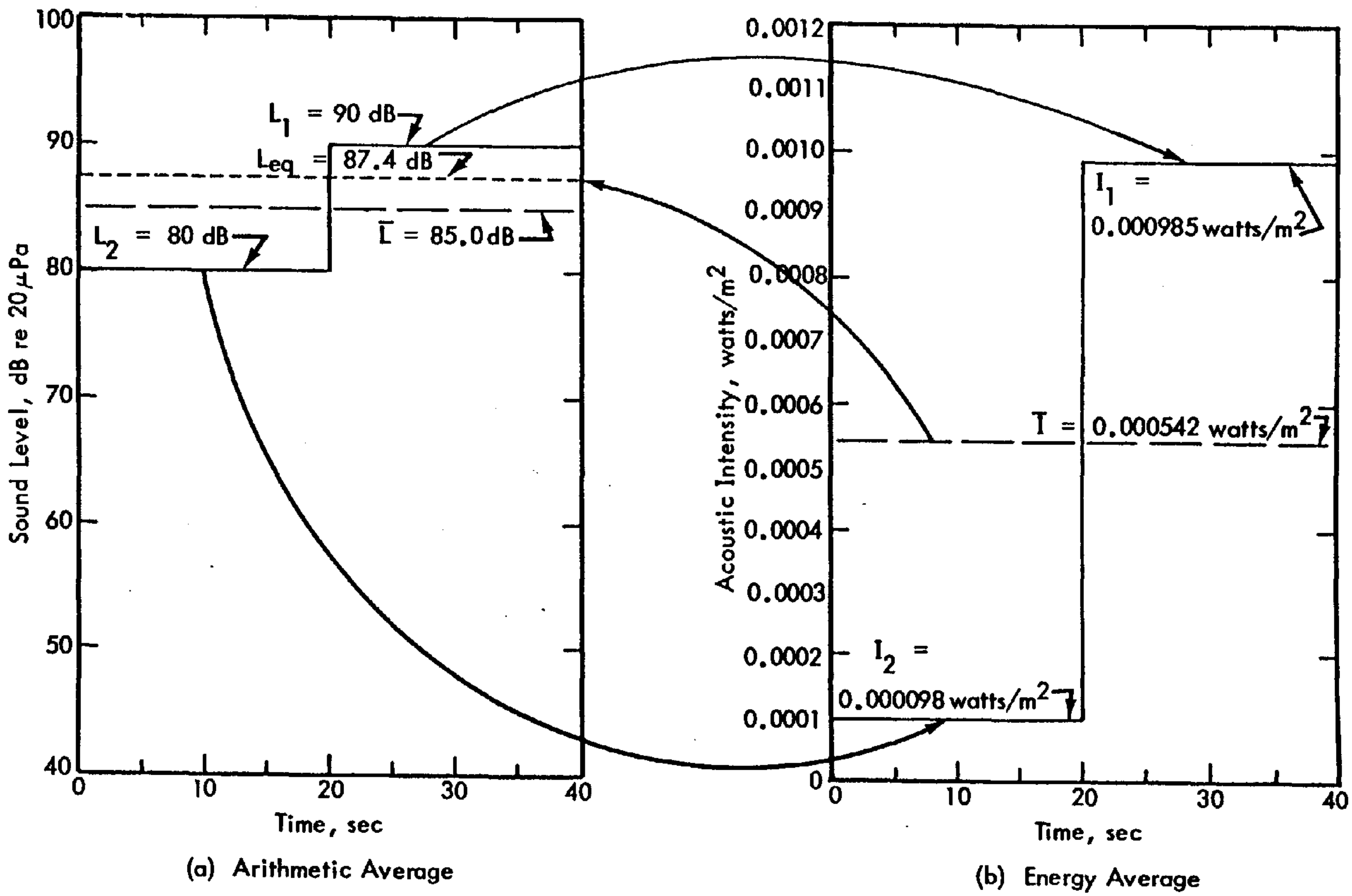


Figure 2-11. Difference Between Arithmetic Average and Energy Average of Sound Levels.

It is not necessary to actually convert levels to acoustic intensities each time an energy-average is computed. The squared-pressure is proportional to the acoustic energy, thus the energy-average of two levels, L_1 and L_2, is given by:

$$L_{eq} = 10 \log_{10} \left[\frac{1}{2} \left(\frac{p_1^2}{p_{ref}^2} + \frac{p_2^2}{p_{ref}^2} \right) \right] = 10 \log_{10} \left[\frac{1}{2} \left(10^{L_1/10} + 10^{L_2/10} \right) \right] \quad (2\text{-}18)$$

If $(L_1, L_2, \ldots, L_N)$ represents a set of N sound levels sampled at equal intervals over the desired period of time, the energy-equivalent sound level is:

$$L_{eq} = 10 \log_{10} \left[\frac{1}{N} \left(10^{L_1/10} + 10^{L_2/10} + \ldots + 10^{L_N/10} \right) \right] \quad (2\text{-}19)$$

The term in brackets is proportional to the average of the squared rms pressures corresponding to the N sound levels and thus is a measure of the average acoustic energy emitted during the measurement period.

A programmable calculator program to compute the L_{eq} of a sequence of sound levels is given in Appendix B.

The duration of the measurement period, in hours, is often indicated in a parenthesis following the subscript "eq". Thus, for example, $L_{eq(1)}$ indicates a one-hour average, $L_{eq(2)}$ a two-hour average, and $L_{eq(24)}$ a 24-hour average.

Integrating sound level meters are available which measure not only the instantaneous sound level but also the equivalent sound level during a given period of time.

In addition, the equivalent sound level can be estimated from the exceedance probability data for the period of interest. Such an estimate is given by a time-weighted average of the squared-pressures corresponding to the acoustic signal. That is, if the range of variation of the sound level is subdivided into N equal intervals, then:

$$L_{eq} = 10 \log_{10} \left[\sum_{i=1}^{N} f_i \times 10^{L_i/10} \right] \quad (2\text{-}20)$$

where f_i is the fraction of the time period that the level is in the i'th interval, and

L_i is the sound level at the center of that interval.

Example 2-13:

Consider again Example 2-11. The final column in Table 2-5 shows the percent of the measurement time period that the sound level was in each 5 dB interval. A histogram of these percentages is shown in Figure 2-12. Such a figure is called a probability density function.

The weighting factor for each interval, f_i in Equation (2-20), is just the percentage shown in the figure converted to a fraction. Thus, for the 60 to 65 dB interval, the weighting factor is 0.333. The level at the midpoint of this interval is 62.5 dB. Thus the contribution to L_{eq} from this band is $0.333 \times 10^{62.5/10}$. The estimate of the total equivalent sound level in this example is:

$$\begin{aligned} L_{eq} &= 10 \log_{10} \left[(0.333 \times 10^{6.25}) + (0.259 \times 10^{6.75}) + (0.250 \times 10^{7.25}) \right. \\ &\quad \left. + (0.141 \times 10^{7.75}) + (0.017 \times 10^{8.25}) \right] \\ &= 10 \log_{10} \left[592{,}167 + 1{,}456{,}464 + 4{,}445{,}698 \right. \\ &\quad \left. + 7{,}929{,}012 + 3{,}023{,}075 \right] \\ &= 10 \log_{10} \left[17{,}446{,}416 \right] = 72 \text{ dB} \end{aligned}$$

A more accurate estimate of L_{eq} could be obtained by using a smaller interval between levels than the 5 dB employed above.

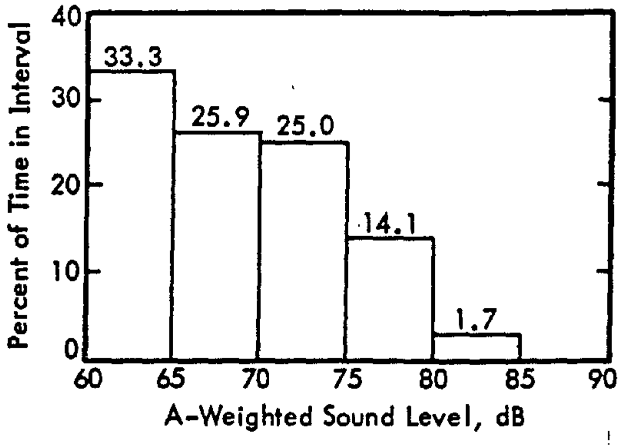


Figure 2-12. Probability Density For Data in Figure 2-10(a).

2.1.8.3 Day-Night Sound Level

Day-night sound level, L_{dn}, is similar to the energy-equivalent sound level defined for a 24-hour period, $L_{eq(24)}$, but sound levels occurring during the 9 nighttime hours (10:00 p.m. to 7:00 a.m.) are artificially penalized by the addition of 10 dB. If L_d is the energy-equivalent sound level for the 15 daytime hours (7:00 a.m. to 10:00 p.m.), and L_n is the energy-equivalent sound level for the nighttime hours, then the day-night sound level is defined as:

$$L_{dn} = 10 \log_{10} \left[\frac{15}{24} \times 10^{L_d/10} + \frac{9}{24} \times 10^{(L_n + 10)/10} \right] \qquad (2\text{-}21)$$

Community noise analyzers are currently available which will measure and store hourly equivalent sound levels, and after a 24-hour period compute the corresponding day-night sound level. A programmable calculator program is provided in Appendix B to calculate L_{dn} from the individual L_d and L_n values.

Example 2-14:

Suppose that the equivalent sound level at a given site during the daytime has been found to be 75 dB and that during the nighttime has been found to be 70 dB. The day-night sound level is thus given by:

$$L_{dn} = 10 \log_{10} \left[\frac{15}{24} \times 10^{75/10} + \frac{9}{24} \times 10^{(70 + 10)/10} \right]$$

$$= 10 \log_{10} \left[\frac{15}{24} \times 10^{7.5} + \frac{9}{24} \times 10^{8.0} \right]$$

$$= 10 \log_{10} \left[19{,}764{,}233 + 37{,}500{,}000 \right]$$

$$= 10 \log_{10} \left[57{,}264{,}233 \right] = 78 \text{ dB}$$

To see the effect of the 10 dB nighttime penalty, consider what the 24-hour energy-equivalent level would have been in this example. This 24-hour energy-equivalent level, as a function of L_d and L_n, is given by:

$$L_{eq(24)} = 10 \log_{10} \left[\frac{15}{24} \times 10^{L_d/10} + \frac{9}{24} \times 10^{L_n/10} \right] \qquad (2\text{-}22)$$

Thus:

$$L_{eq(24)} = 10 \log_{10} \left[\frac{15}{24} \times 10^{7.5} + \frac{9}{24} \times 10^{7.0} \right]$$

$$= 10 \log_{10} \left[19{,}764{,}233 + 3{,}750{,}000 \right]$$

$$= 10 \log_{10} \left[23{,}514{,}233 \right] = 74 \text{ dB}$$

For many railroad yards which operate continuously for 24 hours, the values of L_d and L_n are approximately equal. In such a case the value of L_{dn} is 6.4 dB greater than the value of $L_{eq(24)}$.

2.1.8.4 Noise Dose and Time-Weighted Average Level

The noise dose, D, differs from the previous three metrics in that it is not a level at all, but rather a summation of a series of ratios of time intervals. If a series of A-weighted sound levels ($L_1, L_2, \ldots, L_N$) occurs during the time of interest, the percent noise dose received during that time is defined as:[31]

$$D = 100 \times \left[\frac{C(L_1)}{T(L_1)} + \frac{C(L_2)}{T(L_2)} + \ldots + \frac{C(L_N)}{T(L_N)} \right] \qquad (2\text{-}23)$$

where $C(L_i)$ is the actual time interval over which level L_i occurred, and

$T(L_i)$ is the allowed time interval for that level.

The allowed times currently used in computing noise dose for the U.S. Occupational Safety and Health Administration (OSHA) regulation of workplace noise are given by the relation:[3]

$$T(L_i) = 8 \times 2^{(90 - L_i)/5} \text{ hours} \tag{2-24a}$$

or equivalently:

$$T(L_i) = 8 \times 10^{(90 - L_i)/16.61} \text{ hours} \tag{2-24b}$$

Thus a level of 85 dB is allowed for 16 hours, a level of 90 dB is allowed for 8 hours, a level of 95 dB is allowed for 4 hours, and so on, with a halving of time for each 5 dB increase in level. For the OSHA regulation, the summation in the noise dose calculation is over one of two sets of levels:

(a) To determine if a hearing conservation program must be initiated, levels between 80 and 130 dB must be included in the summation in Equation (2-23);

(b) To determine if administrative or engineering controls must be adopted to reduce noise exposure, levels between 90 and 115 dB must be included in this summation.

A noise dose in excess of 50 percent, calculated using (a) above, indicates that a hearing conservation program is required. A noise dose in excess of 100 percent, calculated using (b) above, indicates that an employee's noise exposure must be reduced using administrative or engineering controls.

Current Federal Railroad Administration (FRA) regulations on locomotive cab noise[4] use the OSHA definition of allowed time. However, they extend the summation in Equation (2-23) to levels between 87 dB and 115 dB. A noise dose exceeding 100 percent is a violation of the regulations and no non-impulsive levels over 115 dB are allowed.

Electronic instruments, called noise dosimeters, are available to monitor noise levels continuously and display the accumulated value of noise dose. Alternatively, if the temporal history of the sound level is sufficiently simple, the equations above can be used to calculate the noise dose.

Sometimes the noise dose is characterized in an alternate form as a dose-equivalent sound level. In a manner analogous to the energy-equivalent sound level, described above, the dose-equivalent sound level is the level of the continuous constant sound that would contribute to the environment the same noise dose as did the actual time-varying source. The dose-equivalent sound level, L_{deq}, is related to the dose by:

$$L_{deq} = 90 + 16.61 \log_{10} \left[\frac{8}{T} \cdot \frac{D}{100}\right] \tag{2-25}$$

where D is the percent noise dose received and

T is the total exposure time in hours.

A special case of the dose-equivalent sound level is defined in the OSHA regulation[3] and is called the 8-hour time-weighted average (TWA) level. For the 8-hour TWA the time, T, in Equation (2-25) is set equal to 8 hours, resulting in:

$$TWA = 90 + 16.61 \log_{10} \left[\frac{D}{100}\right] \tag{2-26}$$

Both OSHA and FRA regulations require that, if an employee's 8-hour TWA exceeds 90 dB, his noise exposure must be reduced until it is brought below 90 dB. OSHA regulations further require that if his 8-hour TWA exceeds 85 dB, he must be provided with a comprehensive hearing conservation program. The elements of such a program are described in Section 2.3.3.6.

Example 2-15:

Suppose that a locomotive engineer is exposed to the following noise sources during an eight-hour work shift:

Noise Source	A-Weighted Sound Level, dB	Exposure Time, Hours	Allowed* Time Hours
Horn	96	0.2	3.5
Brake	94	0.1	4.6
Engine — Notch 8	89	1.6	9.2
Notch 7 & 6	87	0.4	12.1
Notch 5 & 4	86	0.5	13.9
Notch 3	85	0.3	16.0
Notch 2 & 1	84	4.9	18.4

* See Table 2-8.

For the purpose of determining if the employee must be included in a hearing conservation program, the range of levels to be included in the summation is 80 to 130 dB, thus the dose is:

$$D = 100 \times \left[\frac{4.9}{18.4} + \frac{0.3}{16.0} + \frac{0.5}{13.9} + \frac{0.4}{12.1} + \frac{1.6}{9.2} + \frac{0.1}{4.6} + \frac{0.2}{3.5}\right]$$

$$= 100 \times \left[0.266 + 0.019 + 0.036 + 0.033 + 0.174 + 0.022 + 0.057\right] = 60.7\%$$

Since this dose exceeds 50 percent, this employee must be provided with a hearing conservation program. The 8-hour TWA corresponding to this dose is:

$$TWA = 90 + 16.61 \log_{10} \left[\frac{60.7}{100}\right] = 90 + 16.61\,(-0.217) = 86.4 \text{ dB}$$

For the purpose of determining if the employee's noise exposure must be reduced, the FRA regulation requires levels from 87 dB to 115 dB to be included in the summation. Thus the dose is:

$$D = 100 \times \left[\frac{0.4}{12.1} + \frac{1.6}{9.2} + \frac{0.1}{4.6} + \frac{0.2}{3.5}\right]$$

$$= 100 \times \left[0.033 + 0.174 + 0.022 + 0.057\right] = 28.6\%$$

Since this dose does not exceed 100 percent, the employee's noise exposure need not be reduced. The 8-hour TWA corresponding to this dose is 81.0 dB.

2.1.9 Effects of Sound on Humans, Noise

The effect of sound on a listener depends not only on the level and spectrum of the sound, but also on its information content and on the listener's interpretation of that content. Noise is generally defined as unwanted sound. However, although the physical properties of the sound can be precisely defined, the "wanted-ness" of the sound cannot. Thus the definition of noise depends on the nature of both the sound and the listener.

For example, a dripping faucet may have a sound level that is so low as to be almost immeasurable against the background noise, yet it can be extremely annoying to a person trying to concentrate and would certainly be considered as noise. On the other hand, a rock concert being played through a high-powered amplifier can have levels approaching the threshold of pain, yet may be quite enjoyable to a teenager. These two examples illustrate that the level alone is not sufficient to label a sound as noise.

As a further example, the sound of a car's engine may have a moderate level as measured by a sound level meter; yet it can be annoying to a passenger while at the same time being comforting to the driver, who, because of the information content of the sound, knows that his engine is operating properly. Thus the same sound can be noise to one person and useful information to another person.

Despite these examples, however, a loud sound is generally likely to be less desirable than a quieter sound. Very loud sounds can affect the listener's hearing, either permanently or temporarily, or can interfere with the activities of the listener. This section will briefly describe the following effects of sound on people:

- Hearing Loss
- Speech Interference
- Sleep Disturbance
- Task Interference
- Annoyance

2.1.9.1 Hearing Loss

Exposure to high level noise for long periods of time can produce physical changes in the structure of the inner ear that decrease the ability to hear. Some of these changes are temporary, with the hearing ability returning to normal sometime after the sound has stopped. If the sound is sufficiently loud or persistent, permanent changes may occur in the hearing ability. If the listener is often exposed to loud sounds, temporary hearing losses may become permanent.

A quantitative discussion of such hearing loss is beyond the scope of this handbook. Complete agreement does not exist between experts as to the levels, spectra, and exposure times that lead to different types of hearing loss. This is so because hearing loss is not completely deterministic; different people can be affected differently by the same sounds. In addition, it is not possible to perform controlled experiments which cause various degrees of hearing loss in subjects. Instead, statistical analyses must be performed on the hearing losses of people who have been exposed to various levels of sounds during the course of their working lives. Rarely is the noise exposure accurately known, especially since the noise received after working hours must also be considered. There is also a question of how much hearing loss occurs normally with age, independent of external noise exposure.

A qualitative estimate of the range of levels which could potentially lead to hearing losses can be obtained by considering the current regulations of the Occupational Safety and Health Administration, described in the discussion on noise dose in the previous section. These restrict an employee's maximum 8-hour time-weighted average level to a value of 90 dB. An employee may be exposed to louder sounds but only for shorter periods of time; the trade-off being a halving of time for each 5 dB increase in level. Current FRA regulations extend the OSHA limits to restrict an employee's maximum 12-hour exposure to levels of 87 dB.

These regulations attempt to minimize the cumulative hearing loss of employees over a 40-year working period. There is considerable controversy in the psychoacoustic community as to whether or not the OSHA regulations are sufficiently strict. Some would prefer to see a maximum allowed 8-hour level of 85 dB and a time/level trade-off in which a halving of exposure time occurs for each 3 dB increase in level. Others consider continued exposure to A-weighted levels above 70 dB to be potentially harmful. The U.S. Environmental Protection Agency identifies a maximum $L_{eq(24)}$ of 70 dB as being requisite to protect against hearing loss. OSHA has been deliberating for several years in an attempt to resolve this issue, but has not yet done so.

2.1.9.2 Speech Interference

Background noise can affect the ability of one person to understand the speech of another. This is especially true when much of the background sound energy is between 500 and 2000 Hz, which is the frequency range in which most speech lies. Whether or not a given sentence will be understood depends on the level and spectrum of the background noise, the level and spectrum of the speech at the listener's position, and the complexity of the sentence.

Figure 2-13 illustrates the difficulty of communicating at various distances for differing background noise levels. This figure shows, for example, that at a distance of 10 feet communication in a normal voice is possible with background A-weighted sound levels below 57 dB, communication in a raised voice is possible with background levels of 57 to 75 dB, communication with a shout is possible with background levels of 75 to 95 dB, and communication is generally impossible with background levels above 95 dB.

2.1.9.3 Sleep Disturbance

Whether or not one's sleep will be disturbed by noise depends on several factors other than the sound level. These include:

- Familiarity with the noise;
- The age of the sleeper;
- The amount of sleep deprivation;
- The stage of sleep; and
- The temporal nature of the sound.

One gradually becomes accustomed to background noises of low and moderate levels so that a familiar noise of a given level will be less likely to awaken a sleeper than an unfamiliar noise. The likelihood of awakening is also a function of the sleeper's age, older people being more sensitive to intrusive sounds. A person who has been deprived of sleep will be less likely to be awakened by sound of a given level than will a more rested person.

There are four recognized stages of sleep which correspond to various levels of brain wave activity. Generally people would be awakened from the first two stages by sounds that have A-weighted levels above 40 dB. In order to awaken from the two deepest stages of sleep, levels of 85 dB or greater must be experienced.

Finally, the temporal nature of the sound also determines the probability of awakening. Impulsive sounds are more likely to awaken a sleeper than are continuous or rhythmic sounds.

2.1.9.4 Task Interference

When a task requires conversation with others or the ability to hear an acoustic signal, noise of sufficient level to interfere with the understanding of the signal (see Figure 2-13) will cause task interference. In situations where tasks do not involve understanding acoustic signals, the effects of noise on performance have been found to be difficult to assess, since there is poor correlation between noise level and productivity.

In general, however, there is agreement on the following points:[6]

- Steady noises without special meaning do not interfere with human performance unless the A-weighted levels exceed 90 dB.
- Irregular bursts of noise are more disruptive than steady noises even when their A-weighted levels are below 90 dB.

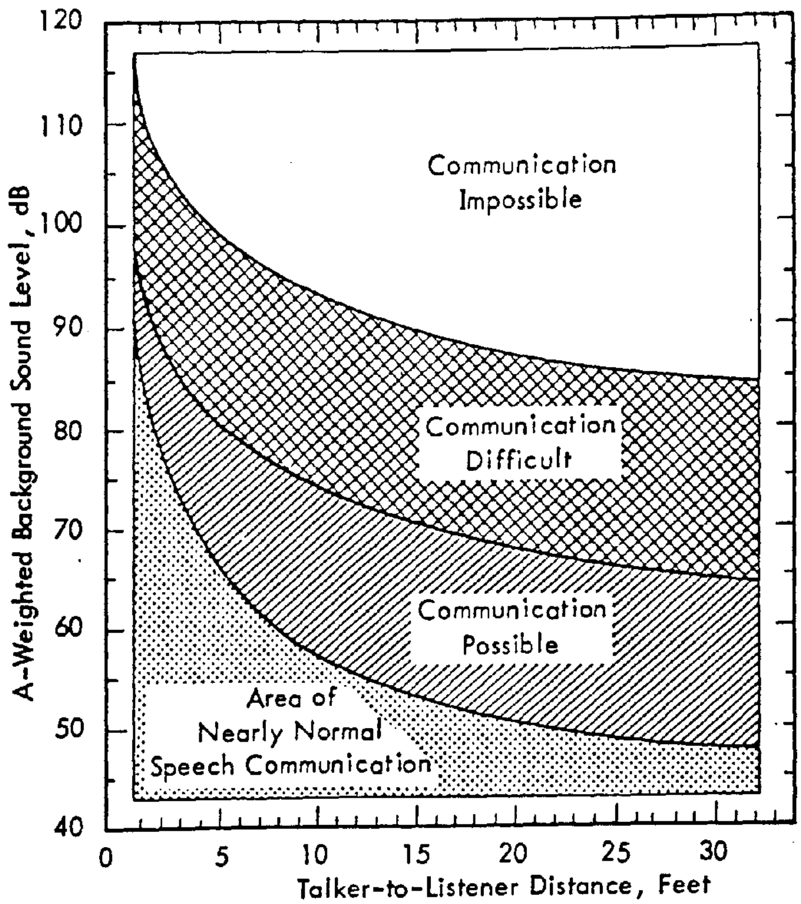


Figure 2-13. The Quality of Speech Communication in Relation to the A-Weighted Sound Level of Noise and the Distance Between The Talker and the Listener.[5]

- High-frequency components of noise (above 1000 Hz) produce more interference with performance than do low-frequency components.
- Noise does not seem to reduce the overall rate of work; instead high levels increase the variability in the work rate.
- Noise is more likely to reduce the accuracy of work than to reduce the total quantity.
- Complex tasks are more likely to be adversely affected by noise than are simple tasks.

2.1.9.5 Annoyance

An individual's annoyance to noise is a function of many factors, both acoustic and non-acoustic:

- Sound level and fluctuations in sound level with time;
- Spectral content and fluctuations in spectral content with time;
- Duration and changes in duration with time;
- Information content of signal (i.e., is noise of use to listener?);
- Localization of noise source (i.e., can a specific source be identified?);
- Relation of noise source to listener (e.g., is listener causing the noise? Is listener's job dependent on factory causing the noise?);
- Listener's activity;
- Predictability of noise (i.e., does the noise occur randomly or can listener predict when it will occur?);
- Differences between individuals (i.e., all persons do not react the same to the same noise).

There does not appear to be a critical sound level below which no one will be annoyed and above which everyone will be annoyed. Rather a continuous range of reactions to sound exists with level of annoyance increasing with increasing sound level. As an example, Figure 2-14 shows qualitatively the range of individual reactions to A-weighted aircraft sound levels.

Studies similar to that which produced Figure 2-14 have been conducted on communities as a whole. Typically, such studies consist of both community noise measurements and samplings of individual household responses as determined by a questionnaire. The community noise levels are quantified using one of the metrics for time-varying sound; the community response is also quantified. Relations are then obtained between the response and the metric describing the community noise. Figure 2-15 shows the results of a series of such studies carried out in communities near airports.

Figure 2-16 shows a synthesis of eleven different studies carried out in communities in Europe and the United States, some of which were near railroad noise sources. One can see that although there is a wide scatter of points about the average of the data, there is a consistent trend of increased annoyance with increased day-night sound level.

2.1.10 Noise Standards and Regulations

The purpose of this section is to describe, in general terms, the types of acoustic metric used in various federal, state, and local noise standards and ordinances, and to indicate the range of noise criteria commonly used for these metrics.

2.1.10.1 EPA Recommended Noise Levels

The Noise Control Act of 1972 directed the Administrator of the U.S. Environmental Protection Agency to "publish information on the levels of environmental noise the attainment and maintenance of which in defined areas under various conditions are requisite to protect the public health and welfare with an adequate margin of safety."

In response to this directive, EPA published in March 1974 a document entitled "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety". Table 2-6 summarizes the noise levels identified in this document. In order to protect against activity interference and annoyance, a 24-hour equivalent sound level metric is used for areas in which sleeping normally does not occur, while a day-night sound level metric is employed in areas where sleeping does occur. To protect against hearing loss, a 24-hour equivalent sound level metric is used.

It should be emphasized that the levels presented in Table 2-6 are not to be construed as regulations since they do not take into account cost or technical feasibility. Rather, they should be considered as desirable ultimate goals. In addition, they should not be considered as levels controlling discrete events. The metrics employed are 24-hour energy averages and, thus, periods of instantaneous sound levels higher than the figures indicated in the table may be averaged out by periods of time when the instantaneous sound levels are lower than these levels.

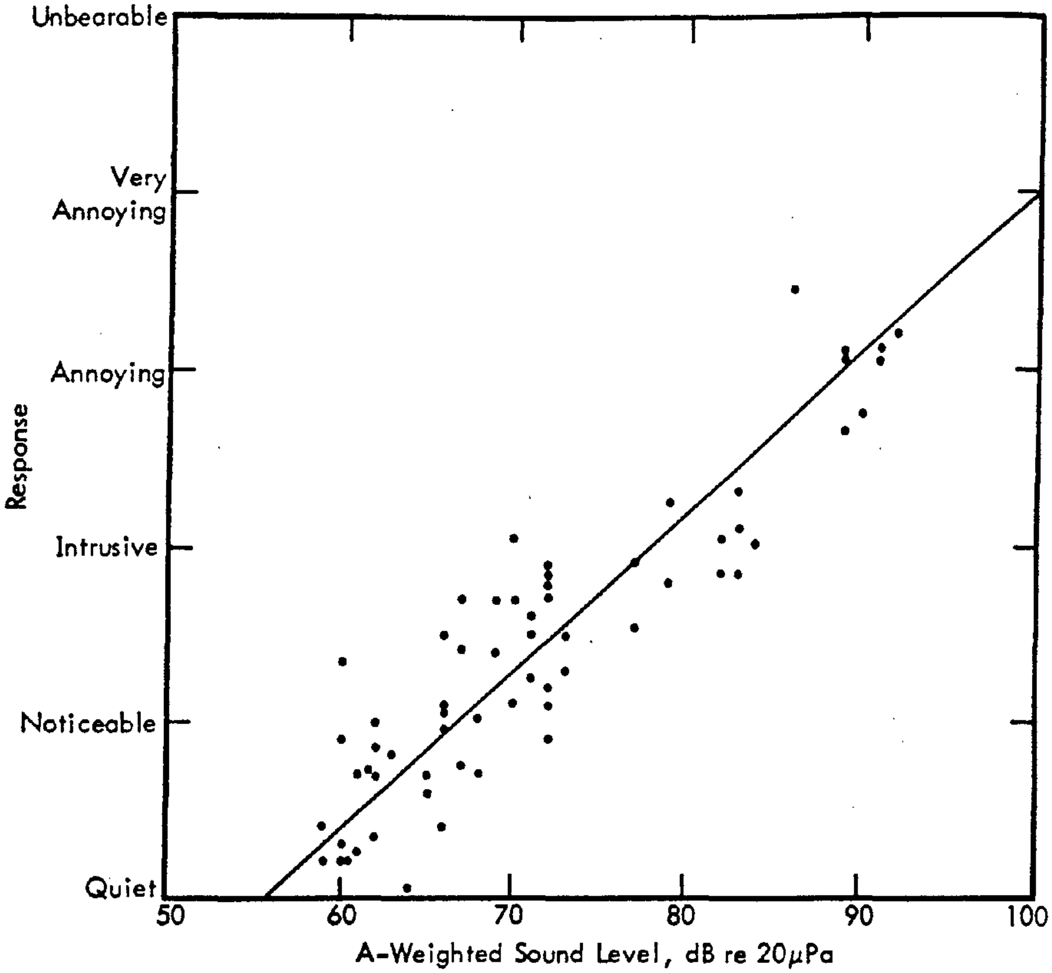


Figure 2-14. Example of Individual Reactions to Aircraft Noise.[7]

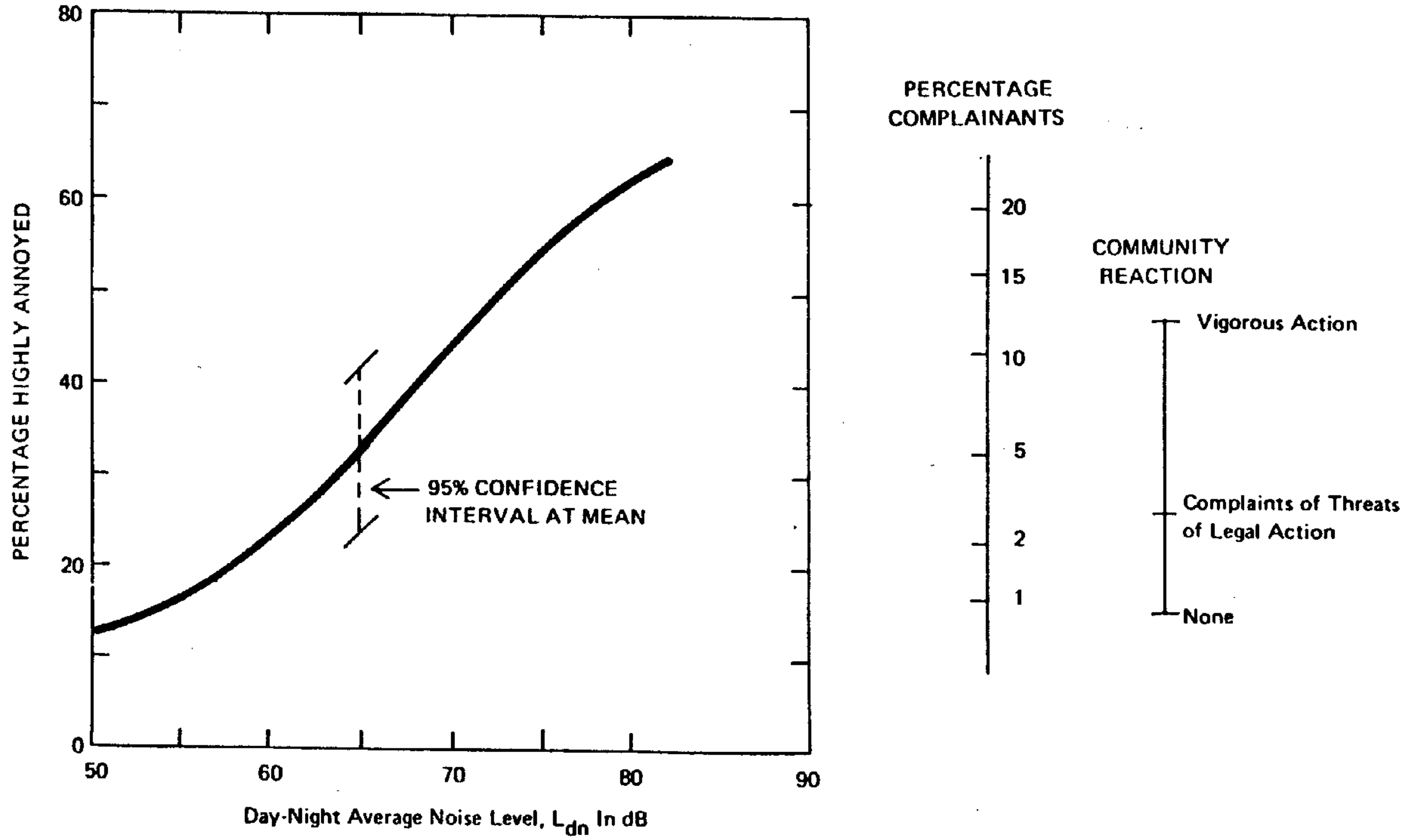


Figure 2-15. Comparison of Various Measures of Individual Annoyance and Community Reaction As a Function of the Day-Night Average Noise Level.[5]

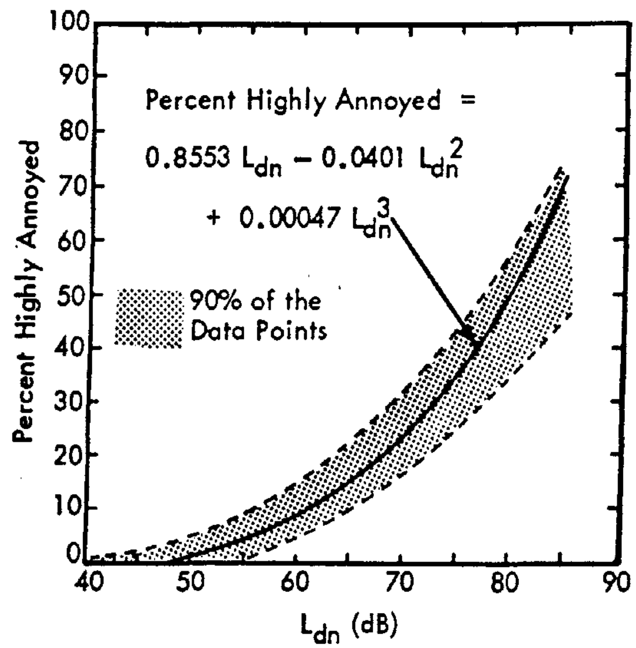


Figure 2-16. Community Response to Transportation Noise.[8]

Table 2-6

Summary of Noise Levels* Identified as
Requisite to Protect Public Health and Welfare
With an Adequate Margin of Safety[9]

Effect	Level	Area
Hearing Loss	$L_{eq(24)} \leq$ 70 dB	All areas.
Outdoor Activity Interference and Annoyance	$L_{dn} \leq$ 55 dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eq(24)} \leq$ 55 dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor Activity Interference and Annoyance	$L_{dn} \leq$ 45 dB	Indoor residential areas.
	$L_{eq(24)} \leq$ 45 dB	Other indoor areas with human activities such as schools, etc.

* Note that these are not regulations since they do not take into account cost or technical feasibility.

The $L_{eq(24)}$ level identified as protecting against hearing loss was determined from the following considerations:

- An $L_{eq(8)}$ of 73 dB, averaged over a 40-year working life, protects 96 percent of the population from greater than a 5 dB permanent hearing loss at 4000 Hz, the frequency at which the human ear is most sensitive;
- An increase of 5 dB above this level is allowed in order to account for the fact that most environmental noise is intermittent and that an intermittent noise causes less hearing damage than a continuous noise of the same L_{eq};
- A reduction of 1.6 dB is introduced to correct for the fact that the 73 dB level above is based on 250 days of occupational exposure, whereas the EPA document must consider a 365-day-per-year noise exposure;
- A 5 dB decrease is introduced to convert from an 8-hour exposure to a 24-hour exposure (this assumes that the noise levels experienced outside of working hours are considerably lower than those experienced at work); and
- A 1.4 dB reduction is introduced to allow a margin of safety.

Thus the identified level is:

$$L_{eq(24)} = 73 + 5 - 1.6 - 5 - 1.4 = 70 \text{ dB}$$

The $L_{eq(24)}$ and L_{dn} levels identified as requisite to protect against indoor activity interference and annoyance are based primarily on the protection of speech communication. In order to provide for 100 percent intelligibility of speech sounds indoors, a background level of 45 dB or less is required. Thus a maximum $L_{eq(24)}$ of 45 dB is identified as the desired requisite level. By requiring an L_{dn} of 45 dB in residential areas, one also ensures that the indoor nighttime level will be on the order of 35 dB, a value consistent with available sleep criteria.

The $L_{eq(24)}$ and L_{dn} levels identified with protecting against outdoor activity interference and annoyance are consistent with the indoor levels if a typical 15 dB reduction in sound level between outdoors and indoors is assumed and a 5 dB margin of safety is applied. Thus an indoor level of 45 dB is associated with an outdoor level of 60 dB, which allows normal conversation at distances up to 6 feet with 95 percent sentence intelligibility. The 5 dB reduction to 55 dB in order to provide "an adequate margin of safety" takes into account other adverse effects on activity interference. Table 2-7 shows the expected human response to an L_{dn} of 55 dB.

Although the EPA "Levels Document" identifies $L_{eq(24)}$ and L_{dn} as the metrics by which noise levels are to be assessed, all of the regulations that have been promulgated by EPA are in the terms of either instantaneous A-weighted sound levels or in terms of an energy average of a small number of such instantaneous levels. In principle, the regulation of instantaneous levels will control the value of $L_{eq(24)}$ and L_{dn} in a given situation.

In addition to some of the regulations discussed in this handbook, EPA has promulgated final noise regulations on interstate motor carriers, portable air compressors, newly manufactured medium- and heavy-duty trucks, newly manufactured solid waste compactors (garbage trucks), and newly manufactured motorcycles and motorcycle replacement exhaust systems.

2.1.10.2 OSHA and FRA Noise Exposure Regulations

As mentioned previously in defining noise dose in Section 2.1.8.4, OSHA Regulations on occupational noise exposure[3] and FRA Regulations on locomotive cab noise[4] both use the noise dose metric to control the employee's noise exposure.

Both OSHA and FRA require that if an employee's noise dose exceeds 100 percent, his noise exposure must be reduced. OSHA further requires that if his noise dose exceeds 50 percent, the employee must be provided a comprehensive hearing conservation program. In each case the noise dose is defined as:

$$D = 100 \times \sum_{L=L_1}^{L_2} \frac{C\,(L)}{T\,(L)} \qquad (2\text{-}27)$$

where C (L) is the actual time duration over which level L occurred, and

T (L) is the allowed time duration for that level.

Table 2-7

Summary of Human Effects Associated With An Outdoor Day/Night Sound Level of 55 dB[9]

Type of Effect	Magnitude of Effect
Speech – Indoors	100 percent sentence intelligibility (average) with a 5 dB margin of safety
– Outdoors	100 percent sentence intelligibility (average) at 1 foot 99 percent sentence intelligibility (average) at 3 feet 95 percent sentence intelligibility (average) at 10 feet
Average Community Reaction	None evident; 7 dB below level of significant "complaints and threats of legal action" and at least 16 dB below "vigorous action"
Complaint Level	1 percent (dependent on attitude and other non-level-related factors)
Annoyance Level	17 percent (dependent on attitude and other non-level-related factors)
Attitudes Towards Area	Noise essentially the least important of various factors

The summation limits, L_1 and L_2, are defined as follows:

(a) OSHA Hearing Conservation: $L_1 = 80$ dB, $L_2 = 130$ dB.

(b) OSHA Noise Exposure Reduction: $L_1 = 90$ dB, $L_2 = 115$ dB.

(c) FRA Noise Exposure Reduction: $L_1 = 87$ dB, $L_2 = 115$ dB.

The allowed times in these dose calculations are given in Figure 2-17, which corresponds to a continuous curve through the points in Table 2-8.

2.1.10.3 State and Local Regulations

Several states and many local communities have quantitative noise ordinances controlling noise emissions from various noise sources. Most of these regulations use the instantaneous A-weighted sound level as their basic metric, although a few communities also use octave band sound levels and a few others use an energy-average equivalent sound level or a day-night sound level.

The regulations employing such quantitative noise metrics tend to be of two general types:

- An ordinance controlling the sound level at the boundary line between two properties with the allowed level being a function of both the land use (or zoning) of the adjacent properties and the time of day;

- Ordinances controlling the maximum sound level from specific sources (e.g., motor vehicles, recreational vehicles, etc.) as measured at a well-defined position relative to the source.

Allowed maximum levels in existing state boundary line noise regulations range from 45 dB to 80 dB depending on the zoning of the property and the time of day. Generally lower levels are required in residential areas than in commercial and industrial areas. It is best to check with local governmental officials to determine the exact nature of the noise ordinances that exist in the community of interest.

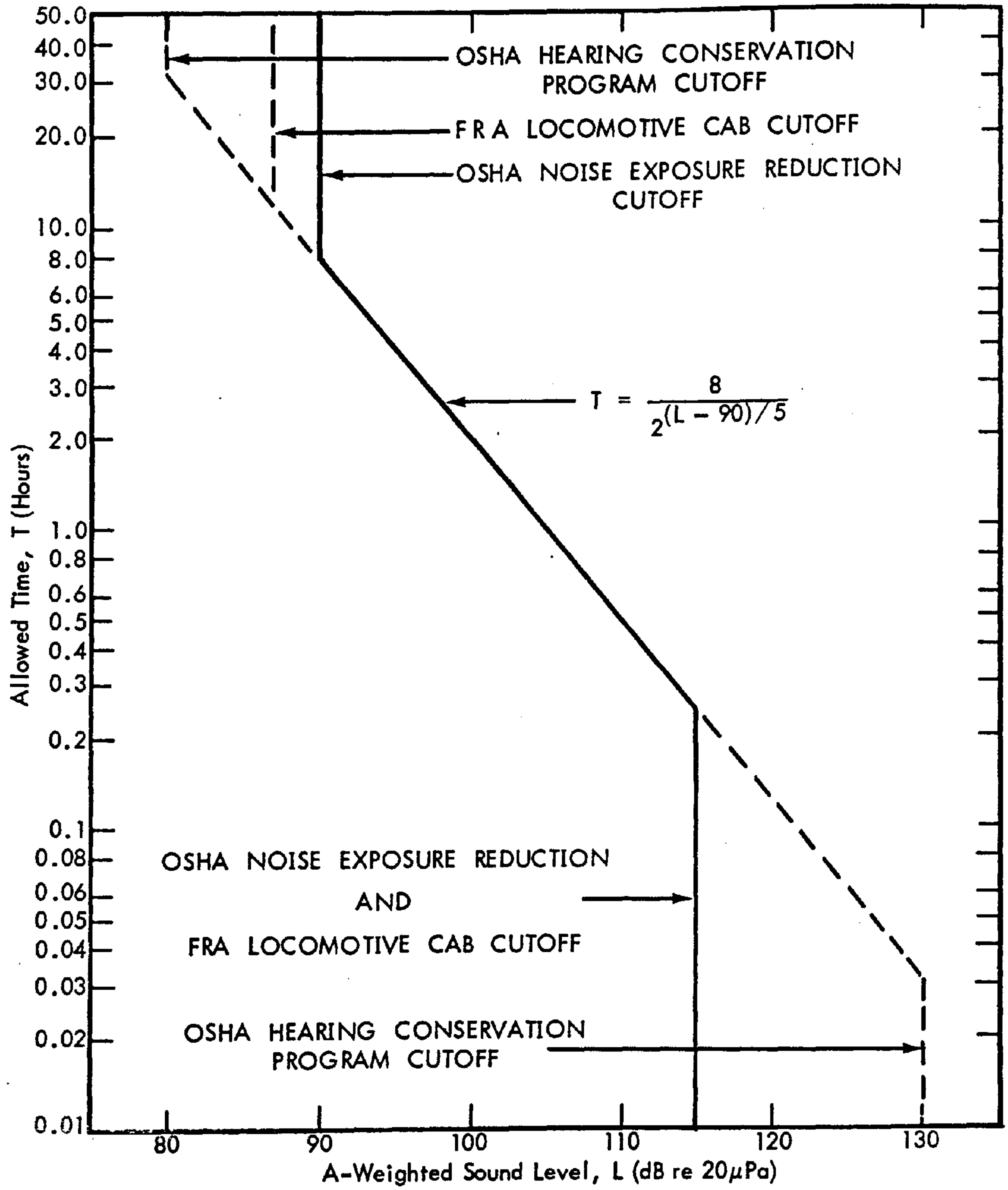


Figure 2-17. Allowed Time Periods for OSHA and FRA Noise Exposure Regulations.

Table 2-8

Permissible OSHA Noise Exposures[3]

A-Weighted Sound Level In dB, Slow Response	Allowed Time (Hours)	A-Weighted Sound Level In dB, Slow Response	Allowed Time (Hours)
80	32	106	0.87
81	27.9	107	0.76
82	24.3	108	0.66
83	21.1	109	0.57
84	18.4	110	0.5
85	16	111	0.44
86	13.9	112	0.38
87	12.1	113	0.33
88	10.6	114	0.29
89	9.2	115	0.25
90	8	116	0.22
91	7.0	117	0.19
92	6.2	118	0.16
93	5.3	119	0.14
94	4.6	120	0.125
95	4	121	0.11
96	3.5	122	0.095
97	3.0	123	0.082
98	2.6	124	0.072
99	2.3	125	0.063
100	2	126	0.054
101	1.7	127	0.047
102	1.5	128	0.041
103	1.4	129	0.036
104	1.3	130	0.031
105	1		

2.2 Noise Measurement Procedures

This section describes the general elements involved in planning, executing, and reporting a noise measurement program. The first subsection briefly describes the types of acoustic instrumentation commonly used for field measurements and for further analysis of recorded data in the laboratory. This is followed by a discussion of the steps that are required to properly design and carry out an acoustic measurement program. The third subsection summarizes the effects that environmental variables can have on the measured data. The section closes with a discussion of the general safety considerations that must be taken into account when one is on railroad property.

2.2.1 Instrumentation For The Measurement And Analysis of Sound

This section provides a brief description of the instruments required for the measurement and analysis of sound. Figure 2-18 illustrates a generalized acoustic instrumentation system, typical of the type used to study the instantaneous characteristics of noise sources. Information derived from such a system include the sound level and spectrum and their temporal characteristics.

The pressure fluctuations in the sound wave are first detected by a microphone where they are transformed into an electrical signal. This signal is then sent to a sound level meter for processing. At this stage, the sound level of the noise is determined. If required, a permanent record can be made by recording the signal on magnetic tape. A graphic level recorder and spectrum analyzer can be used to calculate and display the temporal and spectral characteristics of the noise. To measure parameters such as exceedance percentile sound level, equivalent sound level, or noise dose, specialized equipment such as community noise analyzers, integrating sound level meters, or noise dosimeters are used.

2.2.1.1 Microphones

The function of a microphone is to convert a varying sound pressure into an electrical signal. The electrical signal is a replica of the time history of the sound pressure. There are three types of microphones widely used for noise measurements: condenser, electret, and crystal.

All three types are cylindrical in shape, with typical diameters of 1 inch or 1/2 inch. Condenser and electret microphones can also be found in smaller diameters. As the diameter of a microphone decreases, its frequency response increases and its sensitivity (i.e., the output voltage for a given input sound pressure) decreases. One-inch and 1/2-inch microphones have sufficient frequency response and sensitivity for railroad noise measurements.

A condenser microphone consists of a thin metallic diaphragm and rigid backplate. The diaphragm and backplate are electrically insulated from each other and constitute the plates of a capacitor. Sound pressure forces the diaphragm to move with respect to the backplate, with a resulting change in capacitance. When a DC polarizing voltage is applied between the plates, this change in capacitance produces an electrical signal that is proportional to sound pressure.

Condenser microphones have a more linear frequency response and are more stable with time and temperature, than other types of microphones.

The condenser microphone does have some drawbacks, the most important of which is its sensitivity to moisture. For example, when a microphone is moved from a cold to a warm environment, condensation can form on the diaphragm, causing an electrical short circuit which superimposes a "crackling" or "popping" noise on the actual acoustic signal. To reduce the presence of moisture, small silica-gel chambers are available which can be attached to the microphones. Built-in heaters are also employed for the same purpose on some microphone systems.

The electret microphone functions very similarly to a condenser microphone; it differs by the fact that it does not require a polarization voltage. It uses a thin plastic sheet, which has a conductive coating on one side serving as one plate of the capacitor. The other side of the sheet rests on a perforated, metallic benchplate forming the other capacitor plate, supported by raised points. The long-term stability of this type of microphone is not quite as good as a condenser microphone.

The crystal microphone utilizes a piezoelectric crystal, which generates small currents in response to stresses applied through the diaphragm. Crystal microphones are cheaper and more rugged than condenser microphones, but do not exhibit the same precision or long-term stability. With the advent of inexpensive electret microphones, crystal microphones are becoming less common in modern equipment.

The microphone assembly often used for sound measurements consists of both a microphone cartridge and a preamplifier. The frequency response and the dynamic range of the assembly are related to the microphone diameter and to the type of preamplifier. For condenser and electret microphones, the lower frequency limit is generally determined by the particular preamplifier used while the upper limit may be determined by either the preamplifier or the microphone. Both 1-inch- and 1/2-inch-diameter microphones are typically used for railroad

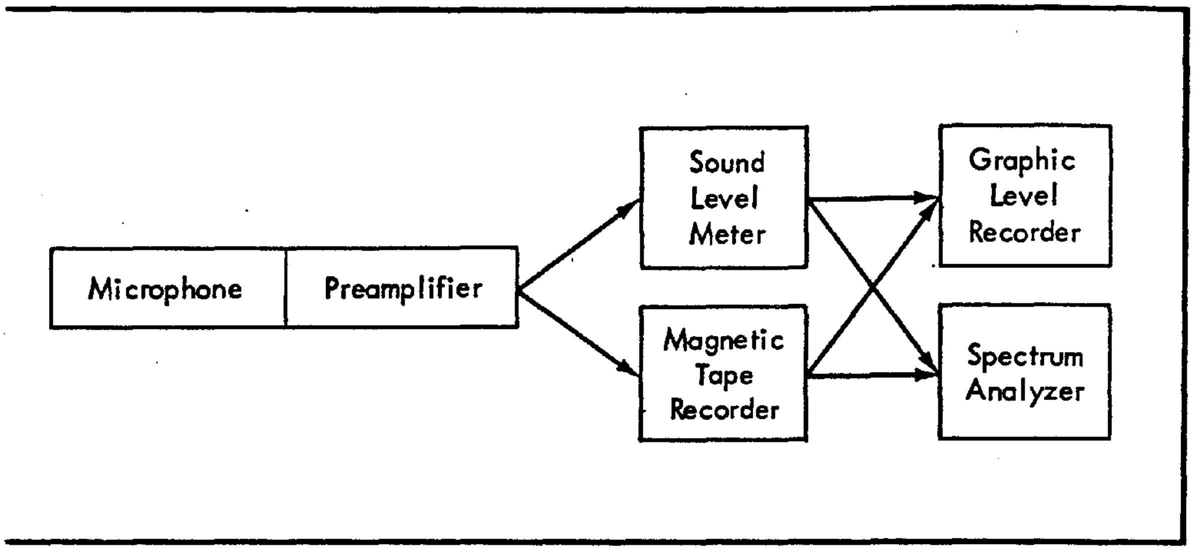


Figure 2-18. Generalized Instrumentation System.

sound measurements. The 1-inch microphone has a larger dynamic range, but a poorer high-frequency response than a 1/2-inch microphone. One-inch condenser microphones have a high-frequency cutoff typically around 10 kHz, while the 1/2-inch microphone can detect frequencies to 20 kHz.

The microphone preamplifier is used to amplify the electrical signal of the microphone cartridge and to match the impedance of the microphone to the following amplifier stage. Some preamplifiers have a built-in heating element to prevent the formation of condensation on the diaphragm of the microphone. The choice of preamplifier will depend on the microphone cartridge used; microphone manufacturers generally suggest an appropriate combination. Most sound level meters have a built-in microphone and preamplifier so no further choice is necessary.

2.2.1.2 Microphone Calibration

Several types of microphone calibrator have been developed, the two most common being a mechanical device, called a pistonphone, and an electrical device. Calibration with these devices involves placing a microphone inside a closed cavity where it is exposed to a known sound pressure level at one or more frequencies. Typical calibration levels range from 90 to 125 dB at frequencies between 250 and 1000 Hz with an accuracy of up to ± 0.2 dB. The levels are high so that calibration can be performed in noisy environments.

2.2.1.3 Sound Level Meters

The basic instrument used for measuring sound is the sound level meter. It is generally a small, portable, battery-powered unit. Figure 2-19 illustrates the basic components of the instrument.

The sound level meter consists of a microphone/preamplifier system to detect sound pressure; a calibrated amplifier to raise the signal input to a useful level; weighting circuits to adjust the frequency response characteristics; a second calibrated amplifier to adjust the amplification to a value appropriate for the detector; a detection circuit to provide the desired response time (i.e., fast or slow); and an output meter to display the sound level. For outdoor measurements, a windscreen is commonly placed on the microphone to reduce wind-microphone interaction noise.

There are four classes of sound level meter in common use: Type 0 – Laboratory; Type 1 – precision field use; Type 2 – general field use; and Type 3 – survey applications. The main difference between these instruments is in the tolerances allowed by the International Electrotechnical Commission (IEC) Publication 651.[10] Type 1 and Type 2 sound level meters are typically used for railroad noise measurements.

The weighting circuits are used to select the frequency response of the meter. The common networks include A-, B-, C-, and linear weightings. As discussed in Section 2.1.7, the A-weighting network most closely represents the frequency response of the human ear to moderate-level sounds. Also, it has been found that the annoyance caused by environmental noise is most closely related to the A-weighted sound level. For these reasons, this is the most widely used network. The B-weighted network is rarely used; it was originally designed to simulate the ear's response to more intense sounds than those corresponding to A-weighting. The C-weighted network, which matches the ear's response to very intense sounds, is roughly flat over the audible frequency range. The linear response network is flat over the whole instrument range.

The sound level is displayed on either a meter or a digital readout. The output is designated as either "fast" or "slow" response. When on the "fast" setting, the output shows the level of the sound based on an rms pressure averaged over about 1/8 second. The "slow" setting provides for a longer term average of about one second.

Some sound level meters include a "peak hold" or "max hold" circuit which stores the value of the maximum sound level that occurred since the circuit was last reset. Such a feature is valuable for carrying out measurements of sources moving relative to the observer, in which the maximum passby level is desired. Some care must be taken, however, in using this feature since the maximum level will be retained whether or not it came from the desired source. For example, sounds made by the observer near the microphone may exceed those of the more distant source and will thus be retained as the maximum level. When using such a circuit, one must continually be aware of the sources of the louder sounds. By observing the range of instantaneous sound levels of the desired source as it passes and comparing them to the value retained in the peak hold circuit, one can ensure that the maximum value was indeed from the source of interest.

2.2.1.4 Magnetic Tape Recorders

Magnetic tape recorders are an integral part of many data acquisition systems. They are used to make permanent reproducible records of the sound that can be subsequently analyzed in the laboratory. In this way, detailed analysis may be performed using sophisticated instrumentation that is unsuited to field use.

To fulfill this function, it is necessary that the recorder accurately reproduce the original signal. The frequency response and the dynamic range of the recorder define how faithfully the signal is reproduced. The tape speed determines the frequency range over which the response is linear – the higher the speed, the broader the frequency range. Instrumentation recorders typically have speed ranges from 1-7/8 to 60 inches per second.

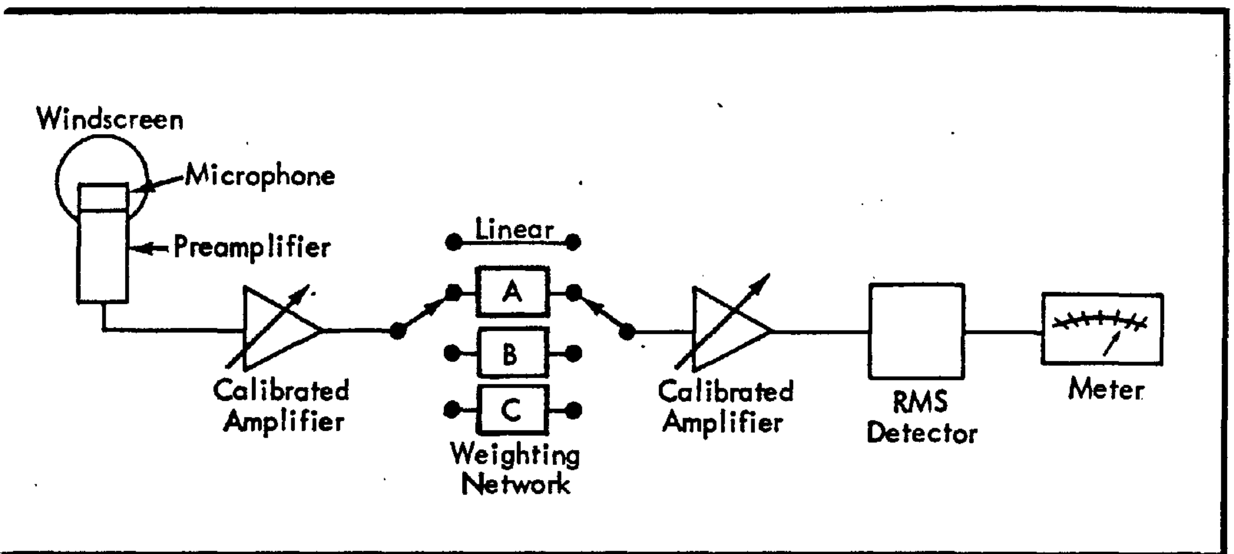


Figure 2-19. Block Diagram of a Sound Level Meter.

The two generic types of tape recorders commonly used for acoustic data collection use either amplitude modulation (AM) or frequency modulation (FM) of the signal in the recording process. Of these, the AM method is the most widely used. This type of recorder is considerably less expensive to buy and operate than an FM recorder. The FM recording system extends the linear frequency response down to very low frequencies and provides increased signal-to-noise ratio and dynamic range over that of AM recordings. However, these advantages are gained at the expense of a higher tape speed, thus requiring more tape than AM systems. A relatively new innovation, the PCM (pulse-coded modulation), or digital tape recorder, is currently being introduced to the marketplace. This type of recorder will provide a far better signal-to-noise ratio and dynamic range capability than even the FM recorder.

2.2.1.5 Spectrum Analyzers

The function of a spectrum analyzer is to determine the distribution of energy over the acoustic spectrum. An analyzer generally consists of one or more filters connected to one or more detectors. It is usually named according to the type of filter used; e.g., if an analyzer contains a set of filters passing octave bands, it is known as an octave-band analyzer.

The output of each filter contains only those frequency components of the input signal which fall within a restricted frequency range called the passband of the filter. These components are then detected to define the sound level at the center frequency of the filter. The process is repeated with other passbands until the entire frequency range has been covered.

Two types of filters which are used in spectrum analyzers are constant bandwidth and constant percentage bandwidth. A constant bandwidth filter is one in which the width of the passband is constant regardless of the center frequency. A constant percentage bandwidth filter is one in which the width of the passband is proportional to the center frequency; thus the bandwidth increases as the center frequency increases. Constant bandwidth analyzers utilizing narrow bandwidth filters are generally chosen when the purpose of the sound measurement is to obtain a detailed frequency analysis in order to determine the origin of the measured sound. Constant percentage bandwidth analyzers, such as those utilizing octave and one-third octave bands, are normally used when the purpose of the measurements is to assess human response to the sound.

2.2.1.6 Graphic Level Recorders

A graphic level recorder is used to produce a permanent paper chart record of the level of sound being analyzed. It functions as a recording voltmeter with a logarithmic scale. The range of levels that can be recorded is typically 40 to 60 dB. Used with the proper analyzer, many recorders can also plot the spectrum of the signal.

2.2.1.7 Other Instrumentation

Several other types of instrumentation are sometimes used for specialized analyses of acoustic signals. Integrating sound level meters, community noise analyzers, dosimeters, and oscilloscopes are examples of such equipment.

An integrating sound level meter generally provides all the functions of a normal sound level meter described above and, in addition, has the capability of computing the equivalent sound level for selected periods of time. When using an integrating sound level meter, it should be remembered that the instrument energy-averages the sound from all sources, not just the source of interest. Thus caution should be employed in interpreting the data if sound from several sources is present.

A community noise analyzer automatically samples the noise for extended periods of time and computes certain descriptors of the time-varying sound level, such as exceedance percentile sound levels and equivalent sound level. In addition, some community noise analyzers permit the automatic computation of the day-night level. As in the case of the integrating sound level meter, it should be remembered that sound from all sources is measured by such an instrument, not just sound from the specific source of interest. Thus one must use caution in interpreting the results of any measurement.

Noise dosimeters are small, portable devices which can be easily carried by workers or placed near a specific work station. These devices compute the accumulated noise dose for the measurement period. Many also indicate whether an A-weighted sound level of 115 dB has been exceeded. In choosing a dosimeter for locomotive cab noise measurements, care should be taken to ensure that the device can be adjusted to include sound levels between 87 dB and 115 dB in the dose calculation, as required by FRA regulations. In choosing a dosimeter to check conformance with OSHA requirements, one should choose a device that allows either the 90 to 115 dB range or the 80 to 130 dB range to be included in the dose measurement. In addition, the instrument must be designed so that all continuous, intermittent, and impulsive sound levels are integrated into the dose computation.

As in the case of community noise analyzers, care must be taken in interpreting the results of a dosimeter measurement. Such devices measure all sounds, including those of the employee who is wearing the dosimeter. Thus such employees should be instructed to avoid talking or whistling directly into the dosimeter's microphone and to avoid hitting or otherwise disturbing the microphone. Such actions can result in a dose measurement that is not representative of the actual noise field to which the employee was exposed.

An oscilloscope provides a display of the detailed time history of the sound wave on a small cathode-ray tube. No averaging is normally performed in this device, so that a picture of the instantaneous sound pressure is provided. Such devices are used to determine peak amplitudes of the wave and information about its frequency content. For rapidly changing sounds, a storage oscilloscope is quite convenient, since it provides the capability to capture the wave shape of a transient event.

2.2.2 Design of a Measurement Program

In the previous section, the various types of instrumentation available for making noise measurements were discussed. In this section, the general procedures used to conduct environmental noise measurements are described.

The procedures chosen for any particular noise measurement program depend on the desired goal of the program. One of the most common reasons for conducting railroad noise measurements is to assess whether a particular source is in compliance with applicable noise standards.

There are two types of measurements normally associated with railroad yard operations, namely: specific noise source measurements and overall site measurements. Source measurements are conducted to assess the sound level generated by individual sources such as idling locomotives or retarders. A single sound level measured at a specified distance (usually 100 feet) from the source is used to describe the source level. Overall site measurements are made when it is desirable to ascertain the sound emitted by the railroad yard as a whole. In this case, statistical descriptors, such as L_{90}, are used to characterize the sound at the yard boundaries.

While the specific noise measurement procedures adopted will vary from program to program, there are some general guidelines which should be followed for any measurement program. Specific program plans, checklists, and data sheets applicable to current railroad noise regulations are presented in Chapters 3, 4, and 5.

2.2.2.1 Program Planning

Before embarking on any measurement program, time should be spent considering exactly why the program is being conducted and to what use the collected data will be put. This information is vital when developing the test procedures to be followed. The number and location of sites to be monitored, the time of day at which measurements are to be made, the amount of time spent collecting data, the type of data collected, and the format in which the data are reported, reduced, and analyzed, all depend on the ultimate purpose of the program and must be defined at this time.

During this phase of a program, permission should be obtained, if necessary, for the measurement team to enter the chosen measurement sites. The number of people to carry out the measurements should be determined and specific individuals should be assigned to the measurement team. Most field measurements involving moving or changing sources require at least two people – one to observe and record the sound level measurements, the other to determine and note other characteristics of the noise source (e.g., type, identification, location, speed, etc.).

2.2.2.2 Instrumentation Setup

Before proceeding to the field for measurements, the instrumentation system should be thoroughly checked out and the manufacturer's instructions referred to for calibration and operational procedures. The batteries should be tested and all interconnecting cables and mounting hardware should be connected to assure that the correct plugs fit into the proper instruments, and that the overall system works as required. Accessories such as magnetic tape, extra batteries, note pads, tripods, adhesive tape, and the like, should be assembled. At this stage, it is good engineering practice to prepare a checksheet to be brought into the field. This assures that once the measurement program has begun no details will be forgotten.

Once in the field, the instrumentation system should be set up according to the manufacturer's instructions. The checksheet should be referred to at this time.

2.2.2.3 Measurement Position

The sound level meter should be mounted on a tripod with the microphone at the specified height above the ground. A windscreen should always be attached to the microphone. The sound level meter may be tilted to allow ease of reading, and the microphone should be oriented according to manufacturer's instructions. This is critical, since certain microphones (perpendicular incidence) are designed to be pointed directly at the major noise source, other microphones (grazing incidence) are designed to be pointed at right angles to the line between the observer and the noise source, and still others (random incidence) are designed to be oriented in a direction intermediate to these two.

The operator should stand as far away from the microphone as possible, consistent with his ability to make the sound level readings easily. When possible, the microphone/preamplifier assembly should be mounted remote from the sound level meter so that there is less chance of the observer's affecting the measured data.

Care should be taken to make sure that there is nothing between the microphone position and the sound source which may interfere with the sound propagation. Nearby reflecting objects, such as walls behind the microphone, should be avoided. When making source measurements, reflecting surfaces behind and to the sides of the source should be avoided.

2.2.2.4 Meter Calibration

The sound level meter should be calibrated by adjusting the meter to read the level generated by the calibrator, according to the manufacturer's instructions. This should be done prior to the beginning of measurements. Following the completion of measurements, a meter reading should be taken of the calibrator level and noted in the field log. This procedure documents any change in sensitivity which occurred during the measurements.

2.2.2.5 Site Description

A sketch should be drawn of the measurement area that includes all audible noise sources and their approximate location with respect to the measurement position. The location of all reflecting surfaces, barriers, and other factors that may affect the sound propagation should also be noted on the sketch. An exact scale map is not necessary, but a good representation of the area, with distances to outstanding landmarks indicated, is desirable. If a detailed map of the area is available, the site area should be located on it. If possible, photographs of the area should be taken to show the noise source. A very effective way to photograph the site is to stand at the microphone position and take a series of pictures which show the full 360° view from that spot. It is also helpful to document the microphone location by stepping behind the microphone and taking a picture which shows the microphone as well as the sound source being measured.

2.2.2.6 Data Log

A data log should be filled out at the beginning of each measurement. A typical data log sheet is shown in Figure 2-20. Such a log should contain the following information:

- Date of measurements.
- Name of person performing the measurements.
- Description of measurement location.
- Description of equipment under test including dimensions, name-plate data, speed, and power rating.
- Description of secondary noise sources such as location, type, and kinds of separation.
- Types, models, serial numbers, or other identification characteristics for all instrumentation.
- Barometric pressure, temperature, wind velocity, and humidity. (This information can be measured directly or, in many cases, can be obtained from local weather radio stations.)
- Results of calibration tests.
- Measured levels and background levels.
- Sketch of measurement site geometry.

A note pad should also be taken into the field and used to write extensive notes detailing anything going on which may have a bearing on the measurements or the interpretation of the data. Such incidents as unusually high railroad traffic or other atypical events are examples of the type of information which should be recorded.

2.2.2.7 Background Noise Levels

Generally a noise measurement consists of contributions from two components: (1) the noise from the desired sources, and (2) background noise from all other sources that may be present. Most regulations require that the background noise level be at least 10 dB below the noise level of the desired source. In such a case, the measured sound level represents the sound level of the desired source to an accuracy of 0.5 dB or better. The background level is determined by measuring the sound level when the desired source is absent. The acoustic metric used is generally the same as that to be used for the source measurement. For example, if an A-weighted, fast response sound level measurement is specified for a locomotive passby, an A-weighted, fast response sound level measurement of the background noise level should be made.

If the sound level in the absence of the source is constant, the background sound level is that constant level. However, this is quite often not the case. Usually the measured sound level in the absence of the desired source varies over a range of values. In this case, it is more difficult to define precisely the background level. For the purposes of characterizing the pervasive sound for which no specific source can be measured, the L_{90}

FIELD DATA LOG

Date: 8/14/79 Prepared By: S. L. METER

Location: 100 FEET WEST OF LOAD CELL TEST STAND AT MAIN STREET CLASSIFICATION YARD

MAJOR NOISE SOURCES:

Railroad: LOCOMOTIVE UNDERGOING LOAD TEST

Non-Railroad: HIGHWAY TRAFFIC in DISTANCE

Comments: LOCOMOTIVE NOISE DOMINATES TRAFFIC AT MEASUREMENT POSITION.

EQUIPMENT:

Instrument	Manufacturer	Model	Serial No.
Sound Level Meter	WESTERN	7149	34265
Microphone	WESTERN	14 B	7908
Calibrator	WESTERN	803	61954

WEATHER CONDITIONS:

	Time	Temperature	Relative Humidity	Barometric Pressure	Wind Speed	Wind Direction
Pre-Test	1330	70° F	65%	30.11" HG.	5 MPH	N
Post-Test	1450	72°F	63%	30.11" HG.	CALM	—

CALIBRATION: Calibrator Level: 114 dB Calibrator Frequency: 1000 Hz

Time	1335	1400	1430	1445		
Measured Level	114.0	113.9	114.1	114.0		

SOUND LEVELS:

Time	Source	Sound Level	Comments
1340	BACKGROUND	60	
1350	ENGINE – NOTCH 1	75	
1430	ENGINE - NOTCH 8	90	
1440	BACKGROUND	62	

SKETCH OF MEASUREMENT SITE GEOMETRY:

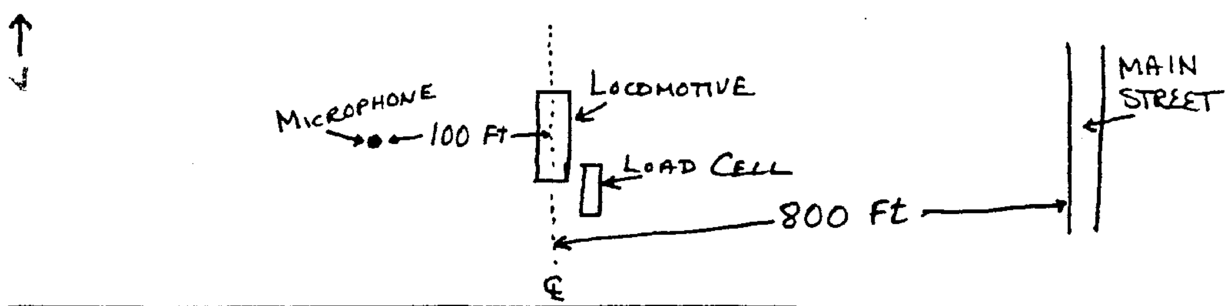


Figure 2-20. Sample of Field Data Log.

exceedance percentile sound level is often used. L_{90}, however, is not necessarily the best metric to use in attempting to assure that the specific source level will exceed the background level by a required amount. Instead, in such a situation, it is best to use a metric which approximates the loudest level likely to be heard in the absence of the specific source. A more appropriate metric, for example, might be the L_{10} level measured over a time period sufficiently long so as to contain all levels likely to be present in the absence of the specific source.

If, by observing the background noise over a period of time, it can be determined that it does not change rapidly and if the noise source to be measured is present for only a short period of time (e.g., retarder squeal, car-coupling impact, train passby), the background level during the desired noise event can be approximated by the sound level immediately before or after the noise event occurs. This is the procedure that is specified in the retarder squeal and car-coupling noise regulations.

If it is desired to estimate the source level when the background level is not 10 dB below the total measured sound level, decibel subtraction may be used, as was described in Section 2.1.4.

Example 2-16:

Suppose that the A-weighted sound level of a passing railcar plus background noise is measured at L_T = 70 dB and that, after the train has passed, the background level is measured to be L_B = 65 dB. Assuming that the background level has not changed since the train was present, the actual railcar level is:

$$L_{dif} = 10 \log_{10} \left[10^{L_T/10} - 10^{L_B/10}\right]$$

$$= 10 \log_{10} \left[10^{7.0} - 10^{6.5}\right] = 68.3 \text{ dB}$$

Since the original levels are accurate to 1 dB, this would be reported as 68 dB.

If a scientific calculator is not available to perform the above computation, Figure 2-5 (previously described) or Table 2-9 may be used to estimate the difference between the total and background levels.

Example 2-17:

In the previous example, the arithmetic difference between the total and background level is 5 dB. From Table 2-9, the number to be arithmetically subtracted from the total level in this case is 1.5 dB. Thus the railcar level is approximately:

$$L_{dif} = L_T - 1.5 = 70 - 1.5 = 68.5 \text{ dB}$$

or, to the accuracy of the original levels, the difference is 68 dB. Note that this result is equivalent to the result above.

If the background level is less than 3 dB below the total level, less than half the measured sound power is generated by the desired source. In such a case, an accurate measurement of the source sound level cannot be made. Efforts should be made to reduce the background level by shielding the microphone from other sources, measuring at a different time of day, or relocating the measurement site.

2.2.2.8 Exceedance Percentile Sound Level

Although community noise analyzers can be used to obtain accurately the percentile exceedance sound levels for a time-varying noise, an approximation of these levels can be obtained using a simple sound level meter. To accomplish this, readings are taken of the instantaneous sound level at a sequence of equal time intervals. This can be done efficiently by using a data sheet such as that shown in Figure 2-21.

The data in this figure were taken at 10-second intervals for a period of 15 minutes. Each of the 90 measured sound levels was recorded by entering an "x" at the appropriate sound level on the vertical scale. The resultant data sheet forms a histogram of the sampled levels in 1 dB increments.

Note that only the integer part of the sound level is included as part of the preprinted data sheet. The tens column is left blank, so that it can be completed in the field, where the range of data can be determined by observing the sound level meter for several minutes before beginning to collect data.

Table 2-9

Correction For Background Noise

Arithmetic Difference Between Total Noise Level and Background Noise Level	Number To Be Arithmetically Subtracted From Total Noise Level To Get The Noise Level Owing To The Source
8 – 10	0.5
6 – 8	1.0
4.5 – 6.0	1.5
4.0 – 4.5	2.0
3.5	2.5
3.0	3.0
<3.0	Source Level Cannot Be Accurately Determined

PERCENTILE EXCEEDANCE SOUND LEVEL DATA LOG

Location N.W. Corner of 7th and Main Streets
Across Street From Main Street Classification Yard

Prepared By S. L. Meter Date 8/15/79

Start Time 1730 Stop Time 1745

A-Weighted Sound Level	Occurrences	Count	Cumulative Count	Fraction Exceeding Level
79	X	1	1	0.01
78		0	1	0.01
77		0	1	0.01
76		0	1	0.01
75		0	1	0.01
74	X X X	3	4	0.04
73	X X	2	6	0.07
72	X X X X X X X X X X	10	16	0.18
71	X X X X X X X X X X X X X	13	29	0.32
70	X X X X X X X X X X X X X	13	42	0.47
69	X X X X X X X X X	9	51	0.57
68	X X X X X X	6	57	0.63
67	X X X X	4	61	0.68
66	X X	2	63	0.70
65	X X X	3	66	0.73
64	X	1	67	0.74
63	X	1	68	0.76
62	X X X X	4	72	0.80
61	X X	2	74	0.82
60	X X X	3	77	0.85
59	X X X	3	80	0.89
58	X X X	3	83	0.92
57	X X	2	85	0.94
56	X X	2	87	0.97
55	X	1	88	0.98
54	X	1	89	0.99
53	X	1	90	1.00
52				
51				
50				
49				
48				
47				
46				
45				
44				
43				
42				
41				
40				
	5 10 15 20 25 30	90	← TOTAL	

Number of Occurrences

Figure 2-21. Sample of Percentile Exceedance Sound Level Data.

Once the data have been collected, the total count in each line is entered in the first column at the right. Next, the cumulative count is determined by successively summing the count column from the top down. Finally, the fraction of the counts exceeding the given level is obtained by dividing the cumulative count by the total overall count at the bottom of the count column.

Note that for the data shown in the figure L_{10} is between 72 and 73 dB, L_{50} is between 69 and 70 dB, and L_{90} is between 58 and 59 dB. These percentile exceedance sound levels can be determined more precisely by plotting the "fraction exceeding level" as a function of level and interpolating between plotted points as was done in Example 2-11 of Section 2.1.8.

The equivalent sound level for this time period can also be estimated from these data using the procedure previously described in Example 2-13 of Section 2.1.8.

2.2.3 Effect of the Environment

The environmental conditions present at the measurement site may influence the noise levels measured and the operation of the instrumentation itself. The effect of the following parameters should be considered when making the measurements:

- Wind
- Precipitation
- Temperature
- Humidity
- Barometric Pressure
- Electromagnetic Interference (Radio Frequency Pickup).

2.2.3.1 Wind

High-speed wind blowing across the microphone can create "self-noise", which reduces the accuracy of the sound measurements. The wind noise increases as the wind velocity increases. To reduce the effect of the wind noise, a windscreen (commonly a 5-inch-diameter, open-cell foam ball) is attached to the microphone. With the windscreen in place, the airflow still generates noise; however, the turbulence is at the outer edge of the windscreen which is far enough away from the microphone that the noise level at the diaphragm is reduced. In any case, measurements should normally not be made if the average wind speed exceeds 12 mph or when wind gust speeds exceed 20 mph.

Should it be necessary to make measurements in higher winds, care should be taken to account for wind-induced background noise. Figure 2-22 shows the wind-induced A-weighted sound level as a function of wind speed for two types of windscreen. These levels must be subtracted from the measured level in order to obtain the actual source noise.

Example 2-18:

Suppose an A-weighted sound level of 65 dB is measured for a source when the wind speed is 30 mph using a foam windscreen. From Figure 2-22, the background wind-induced sound level at this speed is 60 dB; thus the actual source level is:

$$L_{dif} = 10 \log_{10} \left[10^{6.5} - 10^{6.0}\right] = 63 \text{ dB}$$

2.2.3.2 Precipitation

Sound measurements are not normally made during any type of precipitation. Since precipitation causes a change in background noise level and can cause changes in certain source levels, the resultant measured sound level is a false indication of the level that would exist in the absence of precipitation. Also, most instrumentation is not made to withstand the harsh environment and may not perform reliably or may be damaged if exposed to it.

2.2.3.3 Temperature

Microphones and batteries are affected by varying temperatures. The useful life of a battery decreases with a decrease of temperature. Thus it is important to carry extra batteries when performing measurements at very low temperatures. Microphone sensitivity varies little with changing temperature, and is usually neglected unless great precision is required. For example, a condenser microphone retains its calibration to within 0.5 dB over a temperature range of 40° to 300°F.

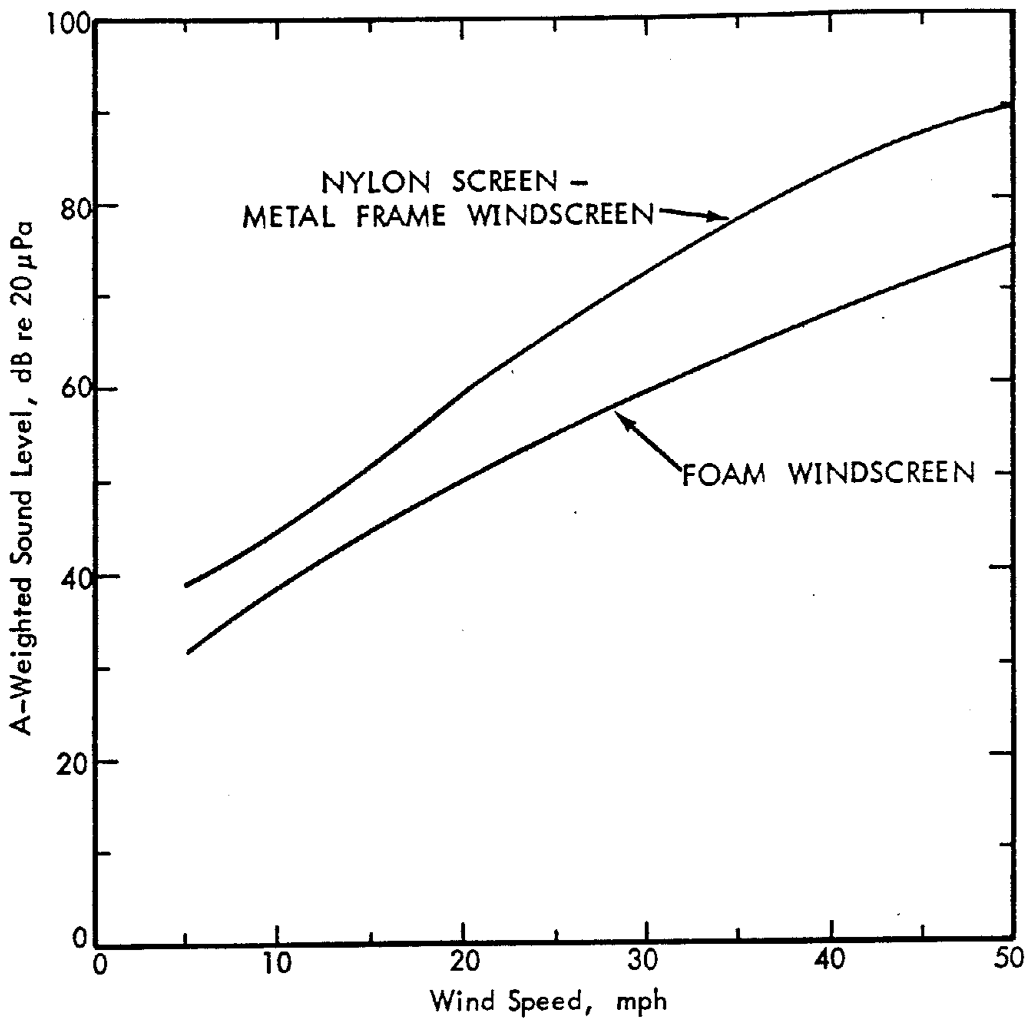


Figure 2-22. Wind-Induced Sound Levels With Windscreen In Place.[11]

2.2.3.4 Humidity

Condenser microphones are affected by high-humidity environments. Condensation on the condenser microphone's diaphragm results in a "crackling" or "popping" noise caused by an electrical short circuit between the condenser plates. This can be reduced by placing the microphone under a light bulb to dry the condenser plate before making the sound measurements, or by using specially designed microphone systems containing heaters, and/or dessicants, when measurements must be made in humid environments.

2.2.3.5 Barometric Pressure

Barometric pressure may affect the output of the microphone calibrator. The calibration level is usually rated at 760mm Hg. If the calibration is made at a significantly different pressure, a correction should be applied. The correction levels are provided with the calibrator.

2.2.3.6 Electromagnetic Interference (Radio Frequency Pickup)

Some measurements require long runs of cable between the microphone preamplifier and the sound level meter or a tape recorder. The cable sometimes serves as an antenna and the electronic components as a detector so that the sound level meter may pick up radio station broadcasts. This situation can be eliminated by utilizing shielded, balanced microphone lines.

2.2.3.7 Monitoring of Input Signal

In general, the input signal to the measuring equipment should always be monitored so that undesired effects, such as electromagnetic interference, wind-generated noise, and condensation popping can be detected. This can be accomplished with many sound level meters by monitoring the AC signal output using a set of earphones.

If electromagnetic interference is present it will be immediately detected as sound having no relation to the signal heard without the earphones. Wind-generated noise, especially that due to wind gusts, can be detected by listening for low-frequency "whooshing" sounds. In addition, sudden excursions of the sound level meter needle that are not correlated with increases in the signal that is heard without the earphones are indicative of wind-gust noise. Finally, short circuits resulting from condensation on the microphone diaphragm can be detected by the resulting "cracking" or "popping" noise heard in the earphones.

2.2.4 Safety Considerations

When conducting noise measurement programs on railroad property, certain safety guidelines must be followed by all personnel in order to assure the safe completion of the task. Because of the high electrical voltages and mobility of the rolling stock present on railroad property, the dangers to life and limb are very real and the constant awareness of safety considerations cannot be overemphasized.

This section contains a discussion of many of the various safety guidelines which should be adhered to. It is not, however, meant to be all inclusive, and should not be interpreted as containing all there is to know about railroad safety.

Before proceeding onto railroad property to conduct noise measurements, permission must be gained from the railroad official in charge of the facility. When entering the property, the yardmaster's office should be contacted and permission to enter the facility again requested. At this time a safety briefing should also be requested. This gives the host railroad company the opportunity to explain any hazards and operational or safety procedures which may be specific to that particular location. In some cases, an escort will be assigned to the noise measurement team. In this case his instructions should be followed explicitly.

The following is a list of general safety considerations applicable to railroad facilities.

- WEAR PROPER CLOTHING:
  - Protective gear such as hard hats and safety glasses should be worn when appropriate;
  - Reflective vests, hats, armbands, and legbands should be worn for easy visibility;
  - Pants legs should be secured with pant guards or string so that they cannot get caught in switches or other obstructions.
- BE OBSERVANT:
  - Expect rail equipment to move at any time on any track, therefore always look in both directions before crossing any track;
  - Never park closer than 10 feet from the centerline of any track;
  - Cross tracks only when absolutely necessary;

- Never cross between railroad equipment or closer than 10 feet from the end of a car or locomotive;
- Never cross under any rail equipment;
- Do not sit, stand, step, or walk on a rail, frog, switch, guard rail, interlocking machinery, or other such part of the track structure;
- Watch out for rail, ties, and other ground obstructions which may cause slipping, falling, or tripping;
- Walk only along designated paths;
- Keep a sharp lookout for close clearances. Avoid walking in any locations where the clearance between a wall and the track will not provide adequate safety.

- PROTECT INSTRUMENTATION SYSTEM:
  - Never lean any equipment against a parked railcar;
  - Choose the test site such that there is enough clearance between the equipment and the nearest track to allow for an unexpected train movement;
  - Watch out for wind gusts created by high-speed mainline passbys.
- USE CAUTION ON RAIL EQUIPMENT:
  - When it is necessary to mount equipment such as locomotives and cabooses, make sure equipment is at a complete stop;
  - Face the car when both mounting and dismounting the equipment;
  - Obey the engineer's and conductor's instructions;
  - Keep clear of all high-voltage areas.
- WORK AS A TEAM:
  - Work in groups;
  - Keep track of other people in your group;
  - Should someone in the group get lost, stop all work and find him before continuing.
- USE COMMON SENSE.

If all of the above-mentioned safety considerations are followed, the measurement program should proceed accident-free. Should an accident occur, however, obtain any first-aid necessary, then report the accident to the rail carrier's representative.

2.3 Noise Abatement Techniques

Noise control measures fall into three general categories of application:

- Reduction of noise at the source itself;
- Modification of the propagation path to interfere with the transmission of noise; and
- The protection of the receiver against the noise.

The placement of an abatement method into one of these categories is an operational, rather than a technical, judgment. Equipment enclosures and hearing protectors are technically noise path controls, but are operationally classified as source and receiver measures, respectively. All else being equal, source controls are the most desirable since they reduce the total noise emitted and do not raise any operational or personnel problems beyond the particular piece of equipment. Path controls, such as barriers, provide noise control which does not require action on the part of the receiver but which can impact other operations. Receiver controls generally provide the most localized abatement, and usually have definite side effects on the receivers.

The following sections describe various types of source, path, and receiver controls and their application to railroad noise.

2.3.1 Source Control

2.3.1.1 Modifications

The most desirable method of source noise control, if feasible, is to modify the equipment. It is rarely practical to take this approach for a single piece of equipment because of the source analysis and engineering efforts involved. Modifications identified from extensive analysis are generally incorporated by manufacturers into new models of equipment. Occasionally, retrofit kits are available based on such improved designs; it is worth checking with manufacturers, if a particular piece of equipment must be quieted.

Noise control modifications generally include the following types of changes:

- Replacement of fans, gearboxes, pumps, etc., with quieter designs;
- Reduction of operating clearances to minimize noise generation;
- Redesign of structure and enclosures to reduce vibration levels of surfaces which radiate noise;
- Substitution of materials, such as highly damped plastics instead of sheet metal;
- Addition of mufflers to engine-powered and compressed-air equipment.

The first step in determining if modifications are feasible is to determine what are the specific noise sources. The source component identification process can require considerable experience, and a full description is beyond the scope of this handbook. The techniques utilized depend on the case at hand, and include the following:

- Temporarily removing components, or turning off selected equipment;
- Wrapping part(s) of the source with lead (or other dense material), leaving selected areas uncovered;
- Near-field noise and vibration measurements;
- Narrow-band spectral analysis;
- Acoustic intensity and correlation measurements, utilizing specialized instrumentation systems.

In general, an extensive investigation of source components should be undertaken only by highly experienced and trained personnel; subtle effects can make identification difficult. It must also be kept in mind that subsequent modification of the equipment may be unfeasible or too costly, rendering the source component identification of academic interest only.

In some cases, noise sources can be easily identified by relatively inexperienced personnel using a sound level meter and common sense, so that it is often worth performing a quick inspection. The value of the human ear in such cases must not be underestimated. Maintenance-related noise problems, such as defective mufflers or broken engine mounts on powered equipment, are usually easy to find. Simple solutions to obvious faults may also be feasible. For example, if a large flat panel is vibrating and is clearly a noise source, then noise may be reduced by suitably bracing it or applying added mass and/or damping material. An expedient cut-and-try approach should be used initially. If a quick fix cannot be obtained, then it is more economical in the long run to have a noise control specialist develop an engineered solution.

There are two modification areas where a specialist may not be required. One is where the same noise problem has been previously solved for the same make and model equipment, and a retrofit kit is available. The other is in the case of exhaust noise from engine-powered equipment. Specialty muffler manufacturers can provide mufflers for a wide variety of applications, with suitability (e.g., acoustic performance and effect on exhaust backpressure) defined by engineering design and tests. Mufflers are also available for compressed air equipment. In these cases, modification can be accomplished by installing available parts. It is important, however, that the specifications of the modification be fully understood. Some manufacturers' presentation of noise data leaves much to be desired. The best approach when specifying noise reduction retrofit kits or mufflers from an outside supplier is to require an installed performance standard, i.e., one which refers to the total noise level after installation and not just to the supposed reduction that the kit will produce.

2.3.1.2 Enclosures

The most common source control method is to place the equipment in an enclosure. By completely enclosing the source and providing absorption within the enclosure to prevent reverberant buildup of acoustic energy, noise is reduced by an amount related to the transmission loss (TL) of the enclosing material. The TL for a given material is a function of panel dimensions and frequency — the values for several common materials are shown in Figure 2-23. Calculation of noise reduction requires the application of the TL curve of the enclosure material to each frequency band of the noise spectrum. The total noise reduction depends not only on the TL of the enclosing material, but on the characteristics of the receiving area. Generally, the noise reduction is somewhat less than the TL.

There are three distinct regions on the TL curve: a low-frequency region where TL depends only on the mass of the panel, a central region where there is a dip associated with coincidence between sound speed in air and wave speed in the panel, and a high-frequency region where TL is a function of panel stiffness and damping. For many railroad noise sources with predominantly low-frequency spectra, the most important part of the TL curve is the low-frequency range, where the mass law applies:

$$TL = 20 \log_{10}\left(\frac{\pi f m}{\rho c}\right) - 5 \text{ dB} \qquad (2\text{-}28)$$

where f = frequency of interest

m = mass of the panel per unit area

ρ = density of air

c = speed of sound in air

If m is in units of pounds per square foot and f is in Hz, then this equation may be written as:

$$TL = 20 \log_{10}(fm) - 34 \text{ dB} \qquad (2\text{-}29)$$

In the mass law regime, transmission loss is directly related to mass. If an enclosure is built from a single thickness of material, mass is the single most important parameter. Limpness is also significant; the coincidence dip seen in Figure 2-23 occurs at lower frequencies for stiff panels than for limp ones. This must be considered when selecting panels. A panel formed by bonding two thicknesses of material together will have 6 dB better TL at low frequencies, but will have this dip at a lower frequency due to the increased stiffness. Bonding the panels resiliently would minimize the stiffness increase. Mismatching the thickness of a doubled panel is also a good design technique, as this results in two small dips result rather than one large one.

The TL of a double thickness panel can be greatly improved by separating the panels. In the extreme of the panels being very far apart, each would behave independently and the total TL would be the sum of that of each panel. Practical double walls do not achieve this value because the panels are coupled through the air cavity between them. Including as large a gap as possible, mechanically isolating the panels from each other, and placing acoustic absorptive material in the cavity improve TL because they help isolate the panels from each other.

TL curves are available for a variety of materials, especially from materials marketed for noise control. A compedium of such data may be found in Reference 13.

An enclosure must include absorptive material on the inside surface to avoid reverberant buildup of interior noise which would correspondingly reduce its effectiveness. Table 2-10 lists absorption coefficients of several materials, selected from Reference 13. This reference has extensive tables of this type of data, identified by manufacturer and product name. Data for particular products are available from the manufacturers. In general, $S\alpha/A$ for all frequencies of interest should be at least 0.5 and preferably greater than 0.75, where S is the area of the absorptive material, α the absorption coefficient, and A is the total interior surface area of the enclosure.

Example 2-19:

A cubical enclosure with 5-foot square sides is to be lined with 1-inch fiberglass boards on three faces and 1/2-inch polyurethane foam on two faces. The other face is not acoustically absorbent. The area of each face is $5 \times 5 = 25$ ft^2. The total area, A, is six times this, 150 ft^2. From Table 2-10, the absorption coefficient at 500 Hz of 1-inch fiberglass boards is 0.69, while that of 1/2-inch polyurethane foam is 0.22. The total absorption, $S\alpha$, of the two types of panel is:

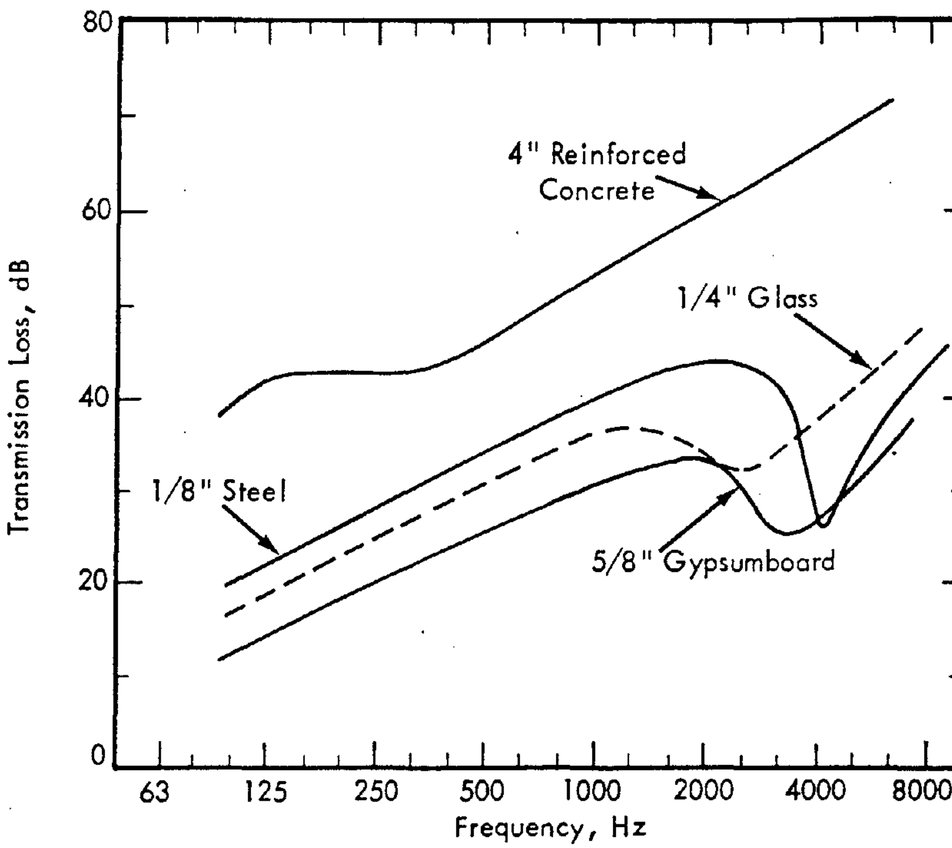


Figure 2-23. Transmission Loss of Several Materials.[12]

Table 2-10

Absorption Coefficients of Selected Materials [13]

Material	Frequency, Hz					
	125	250	500	1000	2000	4000
1/2" Polyurethane Foam	0.09	0.11	0.22	0.60	0.88	0.94
1" " "	0.22	0.35	0.60	0.98	0.94	0.99
2" " "	0.28	0.40	0.86	0.95	0.98	0.97
1" Alumina/Silica Insulation	0.34	0.70	0.79	0.84	0.74	0.90
3" " "	0.52	0.69	0.78	0.92	0.93	0.90
6" " "	0.70	0.84	0.83	0.94	0.89	0.90
2" Fiberglass Insulation Batts	0.21	0.63	0.99	0.74	0.33	0.17
4" " "	0.56	0.99	0.99	0.64	0.48	0.33
1" Fiberglass Board, 3 lb/ft^3	0.03	0.22	0.69	0.91	0.96	0.99
2" " "	0.22	0.82	0.99	0.99	0.99	0.99
4" " "	0.84	0.99	0.99	0.99	0.99	0.97
1" Mineral Fiber Board	0.10	0.29	0.73	0.97	0.97	1.00
2" " "	0.29	0.58	0.88	1.01	1.01	1.00
4" " "	0.63	1.10	1.17	1.06	1.04	0.99

Fiberglass:	3	x 25	x 0.69	=	51.75
Foam:	2	x 25	x 0.22	=	11.00
				Total:	62.75

Thus at 500 Hz, $S\alpha/A$ = 62.75 / 150 = 0.42. The absorption should be increased if this enclosure is to be effective at this frequency.

Placement of the material is not critical, so long as it is reasonably distributed within the enclosure and is of thickness commensurate with the lowest frequency to be absorbed. Note from Table 2-10 that there can be some trade-off between thickness and area covered. For example, if 2-inch fiberglass boards are available, lining all of an enclosure with one layer would be best at most frequencies, but lining half with a double layer would be best at 125 Hz.

The first step in designing an enclosure is to select a material with suitable transmission loss at the frequencies corresponding to maximum A-weighted passband levels. The next step is to prepare construction plans for the enclosure, allowing for service access to the equipment. Provision must be made for sealing any openings and joints in the enclosure. Overlapping joints and compressible rubber seals are useful in this regard. Cracks can be sealed with rubber caulking compound or overlapping plates. Sheet lead is very useful for this purpose.

Equipment which requires ventilation poses special problems for enclosure design. Openings must be provided, and these can drastically reduce acoustic performance. Baffling systems, as shown in Figure 2-24, can be used in some cases, although the flow restriction of such an arrangement can cause difficulties. In general, enclosure of equipment which requires significant ventilation or other openings is best designed by a specialist.

2.3.1.3 Change of Duty Cycle

Reducing the operating time of equipment is one method of reducing cumulative exposure indices such as noise dose, energy-equivalent sound level, or exceedance percentile levels. Halving operating time reduces L_{eq} by 3 dB. If a piece of equipment operates for P percent of the time, then it does not contribute to percentile level L_x so long as P is less than x.

Where exposure to railroad personnel is the critical factor, keeping equipment off while personnel are present can be effective. This is closely related to personnel scheduling, discussed in Section 2.3.3.

A crucial factor if an L_{dn} standard is to be met is the 10 dB nighttime penalty. One operation between 10:00 p.m. and 7:00 a.m. carries the same contribution to L_{dn} as ten operations from 7:00 a.m. to 10:00 p.m. Where operational requirements permit, noisy activities should be scheduled for the daytime period. For example, if an L_{dn} standard is such that ten locomotive tests during the day would cause a violation, then a single test at night would cause a violation. Under less formal circumstances, complaints from residential areas can often be reduced by scheduling intrusively noisy activities so as not to coincide with sleep periods and evening TV-watching time.

2.3.2 Path Controls

2.3.2.1 Relocation

Sound levels generally diminish as the distance between the source and receiver increases. There are three causes of this loss:

- Geometrical spreading;
- Attenuation due to air absorption; and
- Effects due to the ground.

The latter ground effects can be either an attenuation or an amplification of the sound level. The sound level, L(R), at a distance R in terms of the sound level, $L(R_o)$, at a reference distance R_o is given by:

$$L(R) = L(R_o) + \Delta L_s + \Delta L_a + \Delta L_g \qquad (2\text{-}30)$$

where ΔL_s is the change due to geometrical spreading of the sound energy;

ΔL_a is the change due to absorption by the air molecules, and

ΔL_g is the change due to attenuation or amplification by the ground.

Each of these factors will be described separately in the discussion that follows.

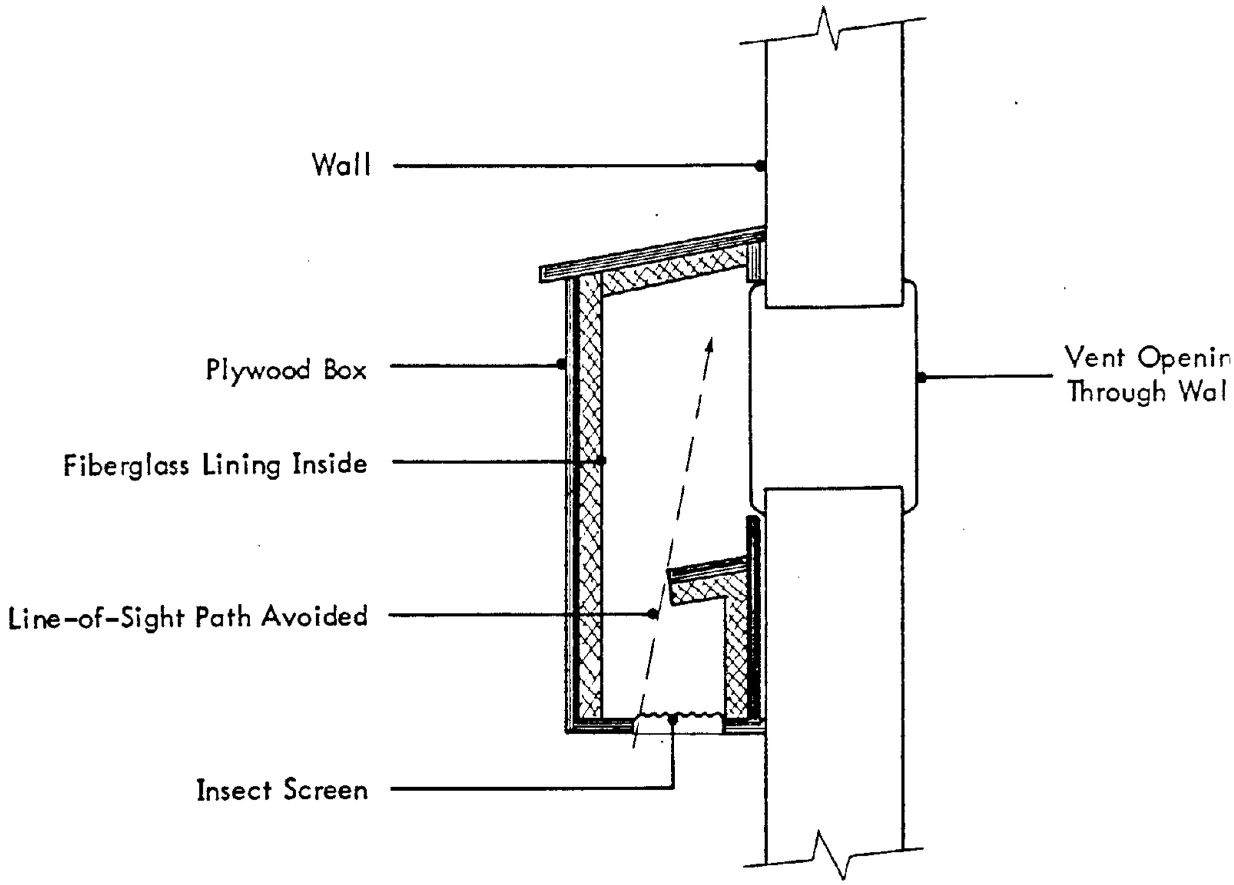


Figure 2-24. Noise Baffle Arrangement For Ventilation Opening.[14]

Geometrical spreading results in a decrease in sound level because the acoustic power radiated by the source is spread out over an increasing larger spherical surface as the distance from the source is increased. Thus the acoustic intensity, or power per unit area, on that surface decreases with a corresponding decrease in sound level.

To understand the quantitative effect of increasing the distance from a point source, consider Figure 2-3(a) in Section 2.1.2. At a distance R from the source, the acoustic intensity I is given by:

$$I = \frac{W}{4\pi R^2} \tag{2-31}$$

where W is the acoustic power output of the source. Thus as R increases, I decreases as $1/R^2$. The sound level corresponding to this acoustic intensity is:

$$L(R) = 10 \log_{10} \frac{\rho c \; W}{4\pi R^2 \; p_{ref}^2} \tag{2-32}$$

where ρ is the density of the medium through which the sound is travelling,

c is the speed of sound in that medium, and

p_{ref} is the reference pressure of 20μPa.

This equation gives L(R) in terms of the source acoustic power, W. Quite often, this parameter is not known; instead a sound level, $L(R_o)$, at a reference distance, R_o, is known. In terms of this parameter:

$$L(R) = L(R_o) + 10 \log_{10}\left(\frac{R_o^2}{R^2}\right)$$

$$= L(R_o) + 20 \log_{10}\left(\frac{R_o}{R}\right) \qquad \begin{bmatrix}\text{Point} \\ \text{Source}\end{bmatrix} \tag{2-33}$$

Thus the change in sound level due to geometric spreading for a point source is:

$$\Delta L_s = 20 \log\left(\frac{R_o}{R}\right) \tag{2-34}$$

Example 2-20:

The decrease in sound level with distance from a point source is often quoted as 6 dB per doubling of distance. To see why this is so, use Equation (2-33) to compute $L(2R_o)$ in terms of $L(R_o)$. Thus in the equation $R = 2R_o$ so that:

$$L(2R_o) = L(R_o) + 20 \log_{10}\left(\frac{R_o}{2R_o}\right) = L(R_o) + 20 \log \; (1/2)$$

$$= L(R_o) + 20 \cdot (-0.30) = L(R_o) - 6.0$$

or

$$\Delta L_s = -6.0 \text{ dB}$$

An extended source composed of like elements, such as the railroad cars in a train, is considered to be a collection of point sources. Mathematically, this behaves as a line source. An infinitely long line source exhibits an acoustic intensity that decreases as $1/R$, rather than as $1/R^2$. Thus the change in sound level is given by:

$$L(R) = L(R_o) + 10 \log\left(\frac{R_o}{R}\right) \qquad \begin{bmatrix}\text{Infinite} \\ \text{Line Source}\end{bmatrix} \tag{2-35}$$

Thus for an infinite line source:

$$\Delta L_s = 10 \log\left(\frac{R_o}{R}\right) \tag{2-36}$$

Example 2-21:

The decrease in sound level with perpendicular distance from an infinite line source is 3 dB per doubling of distance. To see why this is so, substitute $R = 2R_o$ into Equation (2-35) to obtain:

$$L(2R_o) = L(R_o) + 10 \log\left(\frac{R_o}{2R_o}\right) = L(R_o) + 10 \log (1/2)$$

$$= L(R_o) + 10 \cdot (-0.30) = L(R_o) - 3.0$$

Thus:

$$\Delta L_s = -3.0 \text{ dB}$$

Finite length line sources exhibit attenuation between these two extremes, depending on how long the source is relative to the distance R. Figure 2-25 shows the attenuation, relative to levels at 100 feet, for sources of varying lengths.

Example 2-22:

A consist of 7 locomotives, each about 70 feet long, is left standing on a track at the edge of a yard. Noise levels at residences 500 feet away exceed a noise standard by 4 dB. Parallel tracks further away are available. It is desired to determine where the locomotives should be placed to eliminate the problem, considering only geometrical spreading.

From Figure 2-25, the noise level from a 500-foot-long source at a distance of 500 feet relative to the sound level of the source at a distance of 100 feet is:

$$\Delta L_s = L\,(500\text{ ft}) - L\,(100\text{ ft}) = -11.5 - 0 = -11.5 \text{ dB}$$

Since the refrigerator cars exceed the ordinance by 4 dB an attenuation of:

$$\Delta L'_s = -11.5 - 4 = -15.5 \text{ dB}$$

is required. From the figure, this occurs at a distance of about 800 feet for a 500-foot-long source. Thus the locomotives should be placed on a track 300 feet further from the residences than the original one.

Air absorption is a complex function of the sound wave frequency and the air temperature and humidity. It occurs in addition to losses from geometrical spreading because some of the organized molecular motion that represents acoustic energy is gradually transferred to disorganized molecular motion which represents increased temperature of the air.

Table 2-11 presents air absorption coefficients, $\eta(f)$, as a function of frequency, ambient temperature, and relative humidity. These data are abstracted from extensive tables in Reference 15. The total air absorption ΔL_a for a pure tone of frequency f over a distance R (in feet) is:

$$\Delta L_a = -\eta\,(f)\ R/1000 \quad \text{dB} \qquad (2\text{-}37)$$

For a broadband source, this correction must be applied to each band in the spectrum. The adjusted band levels can then be summed, using decibel addition, to produce the overall sound level or they can be A-weighted and summed to produce the A-weighted sound level, as was illustrated in Example 2-10 in Section 2.1.7.

When broadband railroad noise sources, such as locomotives and car impacts, are considered, air absorption is a relatively small effect. Figure 2-26 shows the range of air attenuation computed for a variety of broadband railroad noise sources over the range of temperatures and humidities covered in Table 2-11. Even at a distance of nearly a mile, there is only 3 to 8 dB attenuation. For noise planning purposes, the center of this band – shown as a solid line – may be used.

Air absorption for retarder squeal is much greater and exhibits a much greater variation. Figure 2-27 shows the range calculated for a number of retarder squeals over the same range of atmospheric conditions. The large spread is due to both the range of frequencies involved (typically 2500 to 4000 Hz) and the sensitivity of the absorption coefficient to temperature and humidity. Unlike broadband sources, where the magnitude of

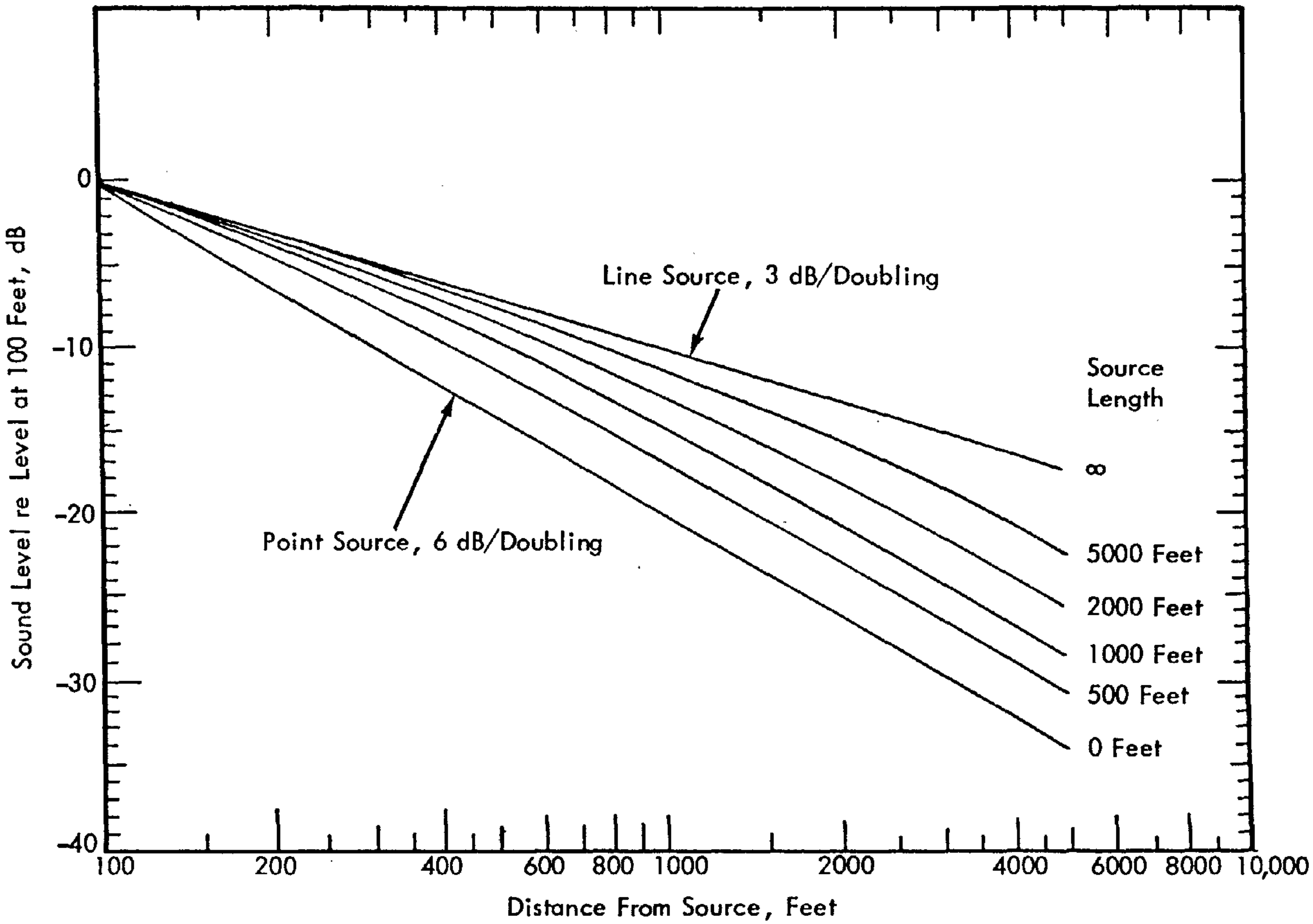


Figure 2-25. Geometric Spreading Loss.

Table 2-11

Air Absorption Coefficients, $\eta(f)$, in dB/1000 ft [15]

a. Temperature = 32°F

Frequency, Hz	Relative Humidity (%)			
	40	60	80	100
125	0.12	0.12	0.12	0.09
250	0.27	0.24	0.24	0.24
500	0.70	0.52	0.46	0.43
1000	2.35	1.49	1.16	0.98
2000	8.08	5.21	3.78	3.02
4000	22.65	17.77	13.51	10.73
8000	42.87	47.53	42.99	36.98

b. Temperature = 50°F

Frequency, Hz	Relative Humidity (%)			
	40	60	80	100
125	0.15	0.12	0.09	0.09
250	0.34	0.30	0.30	0.27
500	0.61	0.61	0.64	0.64
1000	1.46	1.19	1.13	1.16
2000	4.63	3.17	2.59	2.35
4000	16.34	10.76	8.17	6.80
8000	51.80	38.14	29.33	23.90

c. Temperature = 68°F

Frequency, Hz	Relative Humidity (%)			
	40	60	80	100
125	0.12	0.09	0.06	0.06
250	0.40	0.34	0.27	0.21
500	0.85	0.85	0.82	0.73
1000	1.49	1.59	1.68	1.74
2000	3.32	2.93	2.96	3.08
4000	10.27	7.53	6.49	6.10
8000	36.46	25.21	20.03	17.23

d. Temperature = 86°F

Frequency, Hz	Relative Humidity (%)			
	40	60	80	100
125	0.09	0.06	0.06	0.03
250	0.37	0.27	0.21	0.18
500	1.10	0.91	0.76	0.64
1000	2.20	2.29	2.20	2.04
2000	3.78	4.15	4.45	4.63
4000	8.29	7.59	7.74	8.14
8000	25.40	19.48	17.32	16.52

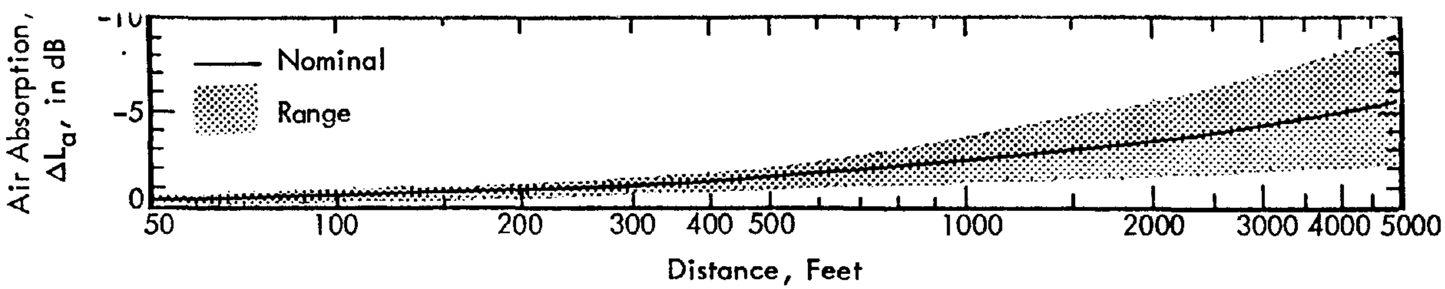


Figure 2-26. Air Absorption as a Function of Distance For Typical Broadband Railroad Noise Source Spectra.

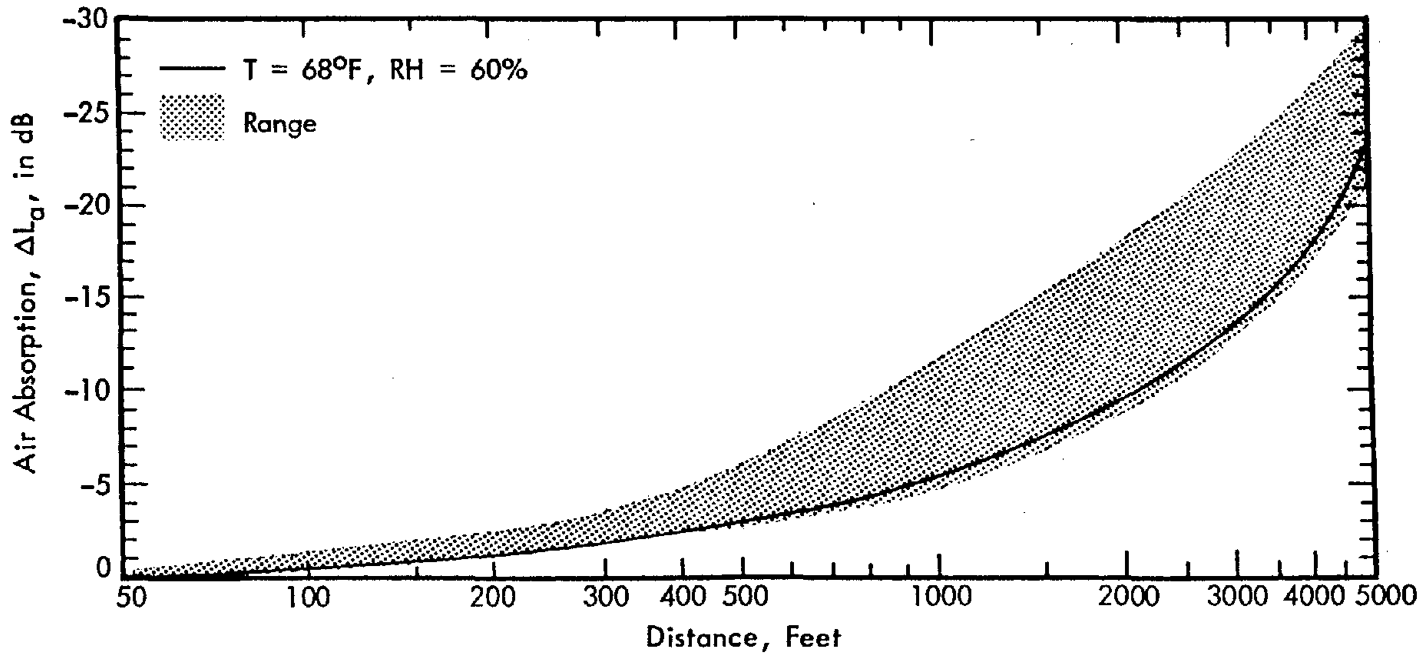


Figure 2-27. Air Absorption as a Function of Distance For Typical Retarder Squeal Spectra.

absorption is small enough so as to make the spread negligible, it is not reasonable to use one attenuation versus distance curve for all cases. For accurate results, Equation (2-37) must be used together with absorption values from Table 2-11.

Example 2-23:

A spectral analysis of the squeal sound from a master retarder shows the acoustic energy to lie predominantly in the 2000 Hz octave band. At a distance of 100 feet, an octave band sound level of 108.2 dB is measured at this band center frequency, corresponding to an A-weighted sound level of 107.0 dB.

The A-weighted sound level at a distance of 500 feet, taking into account the combined geometrical spreading and air absorption, can be calculated by the combined application of Figure 2-25 and Table 2-11. From the figure, the geometric spreading loss for a point source at 500 feet relative to the level at 100 feet is:

$$\Delta L_s = -14 \text{ dB}$$

From the tables, the air absorption coefficient at 2000 Hz, assuming a 68°F temperature and a 60-percent relative humidity, is 2.9 dB/1000 feet. Thus, from Equation (2-37), the total air absorption in 500 feet is:

$$\Delta L_a = -2.9 \times 500/1000 = -1.4 \text{ dB}$$

The A-weighted sound level at 500 feet, taking into account both geometric spreading and air absorption is:

$$L\,(500 \text{ ft}) = L\,(100 \text{ ft}) + \Delta L_s + \Delta L_a$$

$$= 107.0 - 14.0 - 1.4 = 91.6 \text{ dB}$$

Since the reproducibility of field measurements is generally 1 dB or less, this result would be reported as 92 dB.

In virtually all cases of noise planning, appropriate values of temperature and humidity are not known, and are not constant over a period of time. Using annual or seasonal average values of temperature and humidity may not be reasonable because of the non-uniform behavior of absorption with these parameters. Figure 2-28 shows the range covered by the absorption values in Table 2-11, as a function of frequency. The curves for particular values of temperature and humidity cross between the upper and lower bounds of the shaded region, and cross the curves for other values. A reasonable approach for nominal absorption values is to take an average value within the range shown. A straight line is shown on the figure, which runs approximately in the middle of the range and is given by the equation

$$\eta(f) = 1.417 \times 10^{-4}\, f^{1.37} \text{ dB/1000 ft} \qquad (2\text{-}38)$$

When computing air absorption for a tonal source, under nominal weather conditions, Equation (2-38) or Figure 2-28 may be used. If temperature and humidity are known – for example, if measured data are being analyzed – then Table 2-11, or the more extensive tables in Reference 11, should be used.

Example 2-24:

Consider the nominal air absorption for the retarder described in Example 2-23. From Equation (2-38) or Figure 2-28, the nominal air absorption coefficient for a 2000 Hz tone is:

$$\eta(f) = 4.7 \text{ dB/1000 ft}$$

Substituting into Equation (2-37):

$$\Delta L_a = -4.7 \times 500/1000 = -2.4 \text{ dB}$$

Note that this nominal value is 1 dB larger than that calculated for a 68°F temperature and a 60 percent relative humidity in Example 2-23.

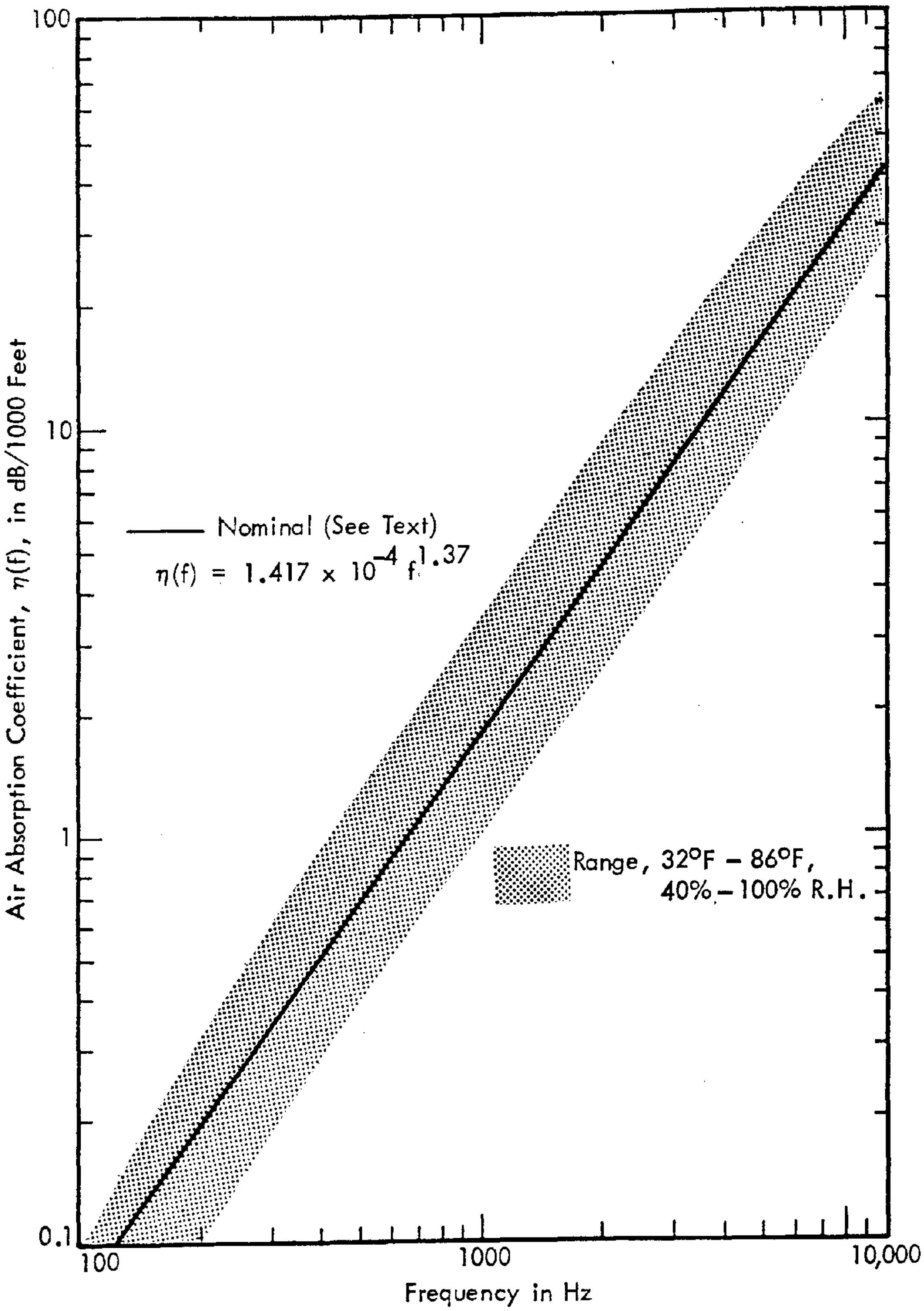


Figure 2-28. Range of Air Absorption Coefficient, and Nominal Curve.

Ground attenuation occurs because the acoustic ray which travels directly from the source to the receiver interacts with a second ray that is reflected from the ground surface. It is a very complex function of the frequency of the sound wave, the source and receiver geometry, and the physical properties of the ground. The equations describing the propagation of a sound wave in the presence of an absorptive ground surface cannot be solved exactly; thus various series approximations of the solution are used. The details of the computational procedure used to estimate ground attenuation are beyond the scope of this handbook.

Values of ground effect on sound level relative to free space, A_g, calculated for typical broadband railroad noise source spectra (locomotives, mechanical refrigerator cars, and car impacts) and for typical retarder squeal spectra are shown in Figures 2-29 and 2-30. The former figure gives the ground effects assuming a "soft" ground surface such as that of unpaved surfaces like grass, dirt, and gravel; the latter figure assumes a "hard" ground surface such as asphalt or concrete pavement. A receiver height of 4 feet has been assumed in both figures. Note that both attenuation (a negative number in the figures) and amplification (a positive number in the figures) of the sound level can occur.

The net change in sound level due to ground effect, ΔL_g, between a measurement position, R, and a reference position, R_o, is given by:

$$\Delta L_g = A_g(R) - A_g(R_o) \qquad (2\text{-}39)$$

Example 2-25:

From Figure 2-29, the sound level change relative to free space due to ground effect, A_g, for a retarder squeal, assuming an unpaved surface, is +3 dB at 100 feet and -8 dB at 500 feet. This means that at 100 feet the measured A-weighted sound level will be 3 dB higher than would have been measured if the ground were not there (or if the ground were perfectly absorptive). At 500 feet the measured A-weighted sound level will be 8 dB lower than would have been measured if the ground were not there. The net sound level change, ΔL_g, between the two positions is:

$$\Delta L_g = A_g(500\text{ ft}) - A_g(100\text{ ft}) = -8 - (+3) = -11\text{ dB}$$

In Example 2-23 we saw that a retarder squeal producing a measured A-weighted sound level of 107.0 dB at 100 feet would experience a geometric spreading loss of:

$$\Delta L_s = -14\text{ dB}$$

and an air absorption loss (at 68°F and 60 percent R.H.) of:

$$\Delta L_a = -1.4\text{ dB}$$

when measured at a distance of 500 feet. Thus at this distance the A-weighted sound level will be:

$$\begin{aligned} L(500\text{ ft}) &= L(100\text{ ft}) + \Delta L_s + \Delta L_a + \Delta L_g \\ &= 107.0 - 14.0 - 1.4 - 11.0 \\ &= 80.6\text{ dB} \end{aligned}$$

As in Example 2-23, this would normally be rounded to the nearest integer or 81 dB.

2.3.2.2 Barriers

One useful method of noise control is the placement of a barrier between the noise source and the receiver. By blocking the line of sight between the two, the receiver is in an acoustic shadow zone and thus shielded from the source. Because of the finite wavelength of sound, the edge of the shadow zone is not perfectly sharp; sound is diffracted into the shadow and reaches the receiver. However, the received sound can be much less than that which would exist in the absence of a barrier.

The shielding by a barrier is a function of the wavelength of the sound and the source/barrier/receiver geometry. A simplified calculation procedure is commonly used, where the geometry is represented by a single parameter based on the difference in length between a path over the barrier and direct line-of-sight path.[17] This is illustrated in Figure 2-31. The quantity required is path length difference δ:

$$\delta = (A + B - C) \qquad (2\text{-}40)$$

A, B, and C are computed accounting for the height of each point as well as horizontal position. If the barrier does not break the line of sight, δ is assigned a minus sign.

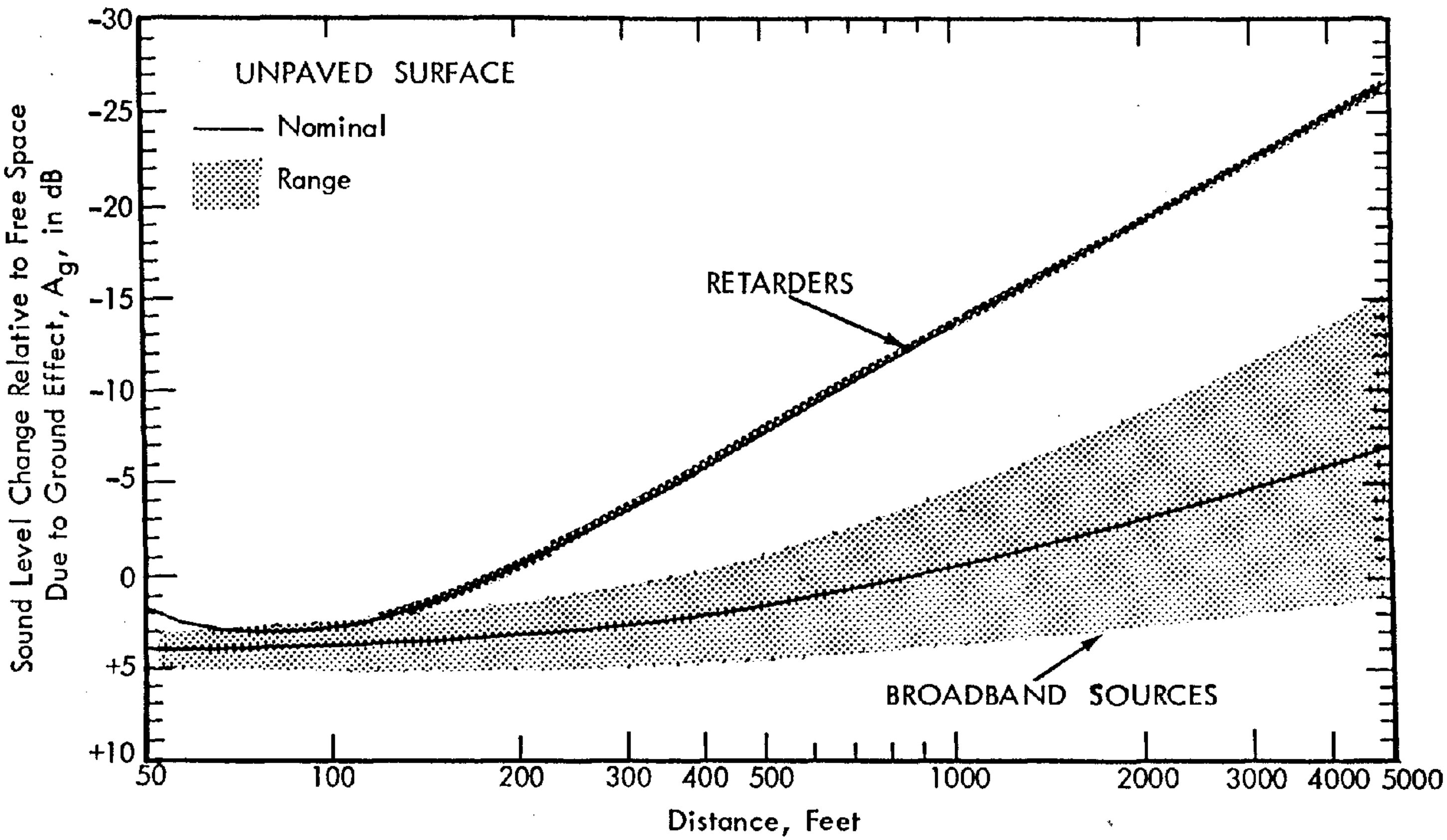


Figure 2-29. Ground Effect as a Function of Distance For Typical Railroad Noise Sources – "Soft" Ground Surface.[16]

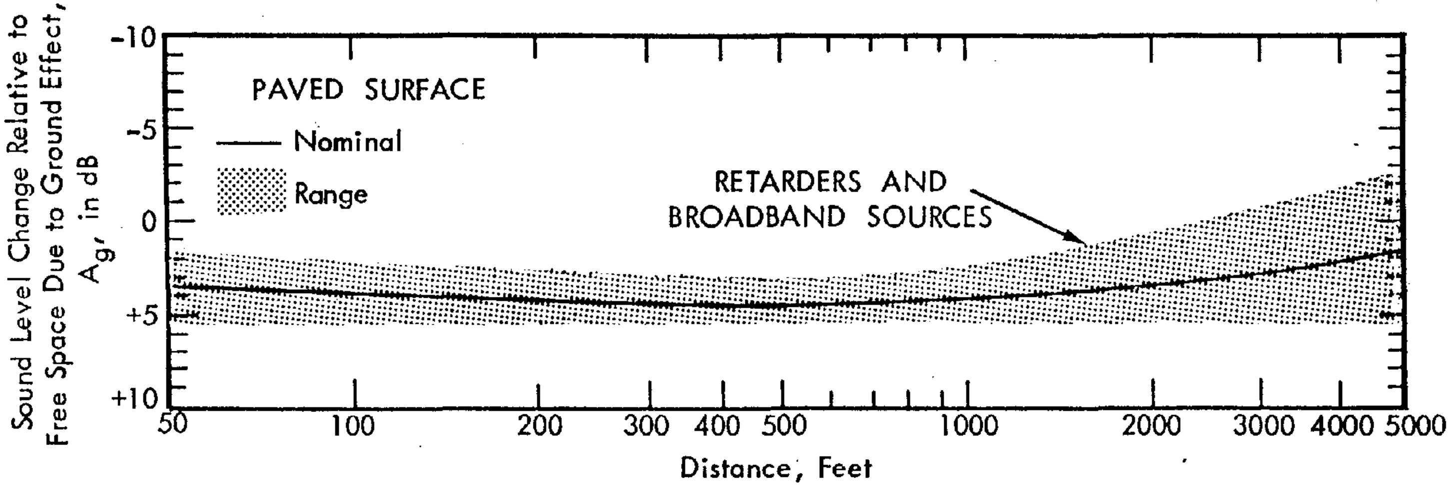
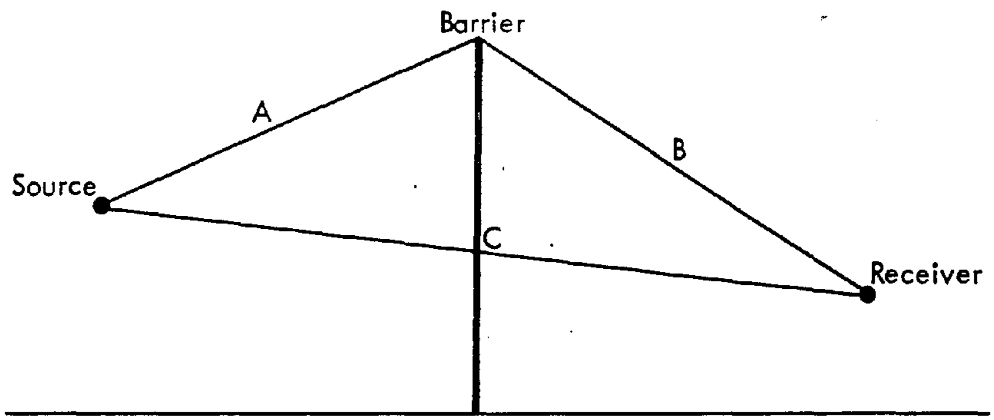


Figure 2-30. Ground Effect as a Function of Distance For Typical Railroad Noise Sources – "Hard" Ground Surface. [16]



Path Length Difference: $\delta = (A + B) - C$

Figure 2-31. Barrier Geometry and Path Length Difference.

The attenuation of a barrier is a function of Fresnel number N:

$$N = 2\delta/\lambda \tag{2-41}$$

where λ is the wavelength of the sound wave. Figure 2-32 shows barrier attenuation, ΔL_b, as a function of N.

Although a barrier blocks both the direct and the ground-reflected sound rays, the latter are attenuated much more than the former. Thus, to a good approximation, attenuation due to the ground effect no longer exists when a barrier is in place. The total propagation loss in a barrier situation consists of geometric spreading, air attenuation, and barrier shielding only:

$$L_b(R) = L(R_o) + \Delta L_s + \Delta L_a + \Delta L_b \tag{2-42}$$

where $L_b(R)$ is the level at a distance R, given that a barrier is in place between the source and receiver.

The insertion loss associated with a barrier is the sound level, L(R), without the barrier from Equation (2-30) minus the level, $L_b(R)$, with the barrier in place from Equation (2-42). Subtracting the two equations results in an insertion loss:

$$L_I = L_b(R) - L(R) = \Delta L_b - \Delta L_g \tag{2-43}$$

Serious errors in barrier design have been made by assuming the insertion loss to be equal to ΔL_b alone.

For a broadband source, the barrier attenuation on Figure 2-32 must be computed for each band in the spectrum. The adjusted band levels can then be summed to produce the overall sound level or A-weighted and summed to produce the A-weighted sound level, as was done in Example 2-10 in Section 2.1.7. For a limited range of spectra, the spectral calculation may be performed once as a function of δ. Figures 2-33 and 2-34 show shielding for the range of retarder and broadband railroad spectra used before. The spread within each category is small; a nominal value suitable for general calculations is shown on each figure.

Figures 2-32, 2-33, and 2-34 apply to fixed point sources. An extended source geometry of interest is that of a line source with a parallel barrier, representing shielding of railroad line operations. This geometry can be computed once in general, and presented as a function of δ based on the geometry of a perpendicular from the line to the receiver.[18] The line source shielding for broadband railroad sources is shown in Figure 2-35.

When computing δ from the site geometry, fairly high precision is required: δ is usually of the order of one foot or less, while A, B, and/or C may be hundreds of feet. A calculator with a sufficient number of significant figures should be used. A, B, and C are given by

$$\begin{aligned} A &= \left[d_{SB}^2 + (h_B - h_S)^2\right]^{1/2} \\ B &= \left[d_{RB}^2 + (h_B - h_R)^2\right]^{1/2} \\ C &= \left[(d_{SB} + d_{RB})^2 + (h_R - h_S)^2\right]^{1/2} \end{aligned} \tag{2-44}$$

where h_B = barrier height

h_S = source height

h_R = receiver height

d_{SB} = source to barrier horizontal distance

d_{RB} = receiver to barrier horizontal distance

as illustrated in Figure 2-36.

Table 2-12 lists appropriate source heights for railroad noise sources. In the absence of specific receiver heights, a height of 4 feet may be used for nominal calculations, since this is the microphone height specified for most railroad noise regulations.

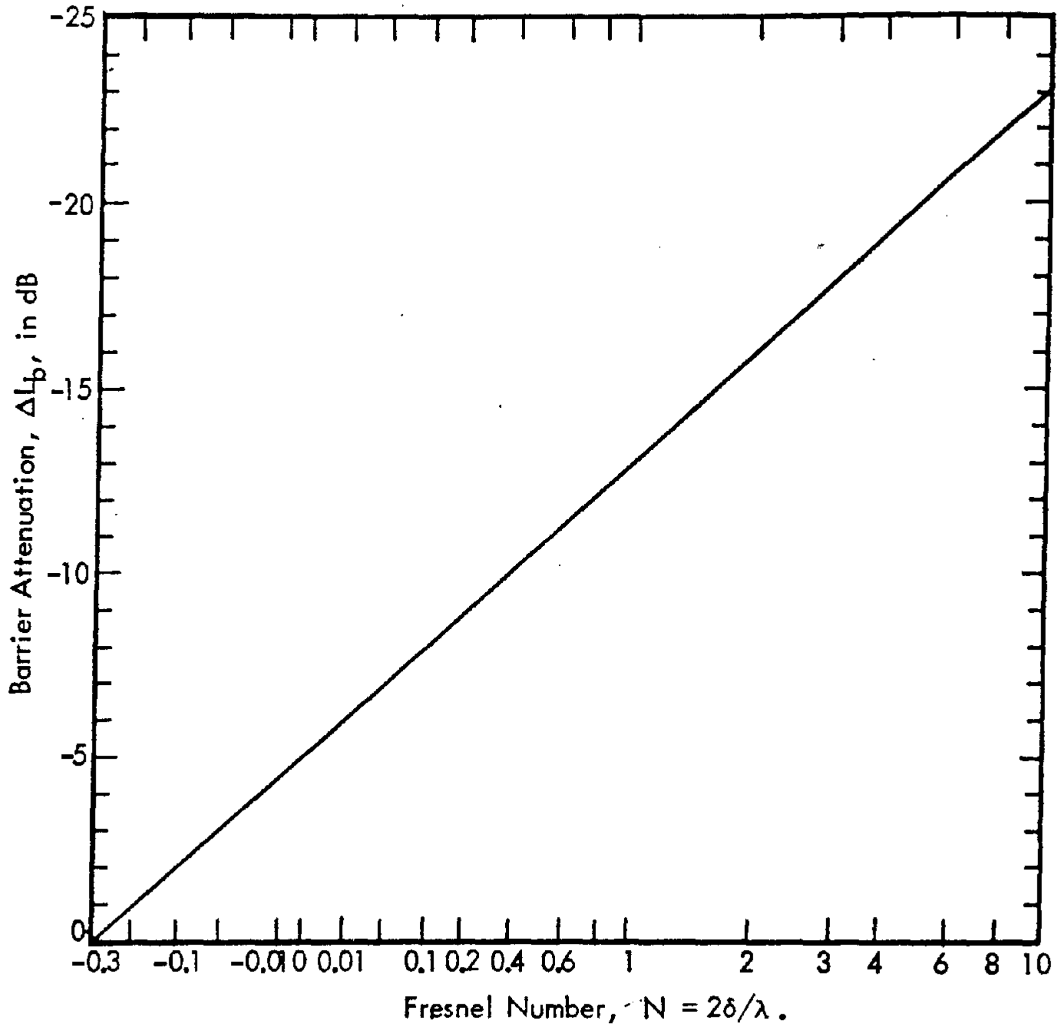


Figure 2-32. Barrier Shielding as a Function of the Fresnel Number.[17]

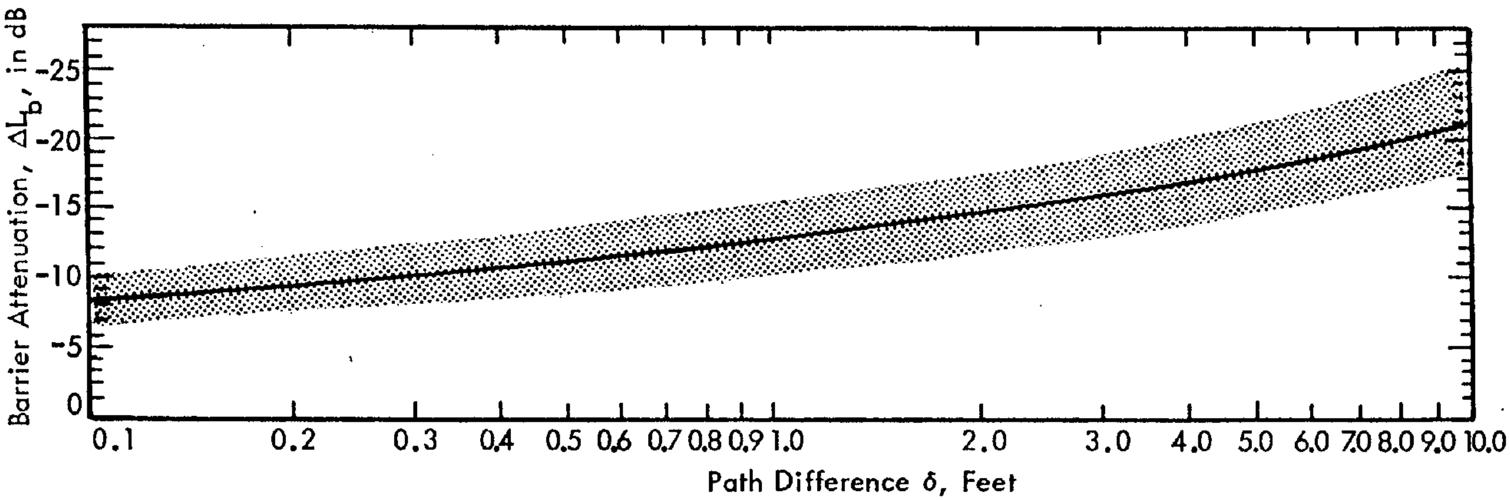


Figure 2-33. Barrier Shielding For Typical Broadband Railroad Noise Source Spectra.

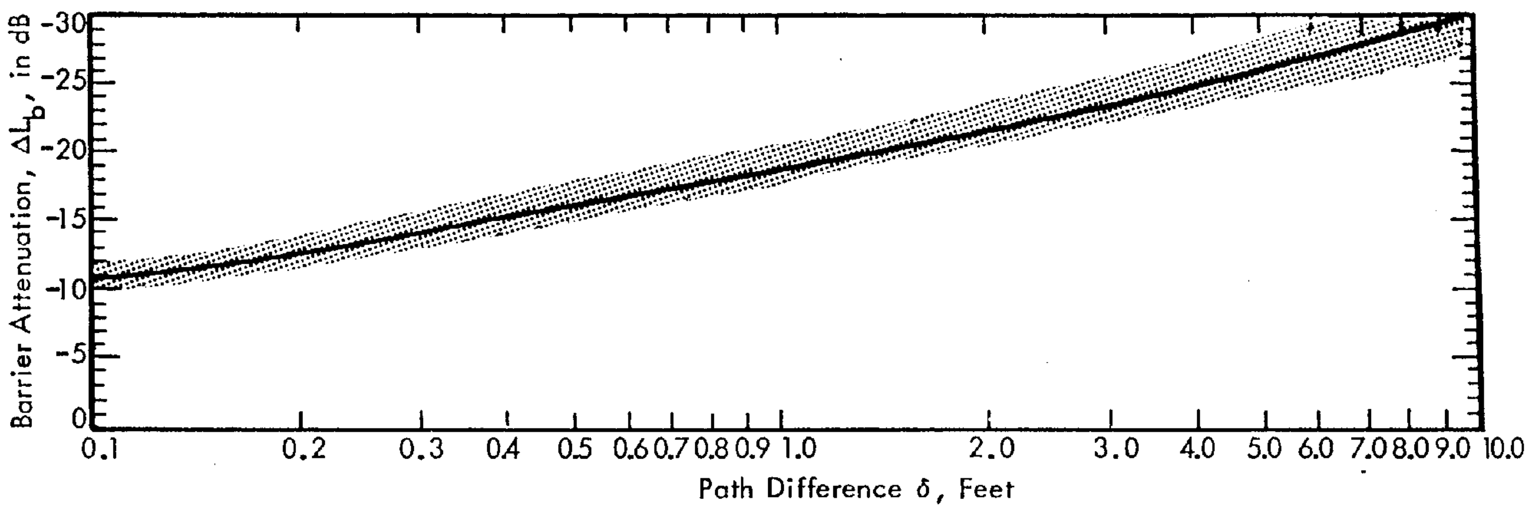


Figure 2-34. Barrier Shielding For Typical Retarder Squeal Spectra.

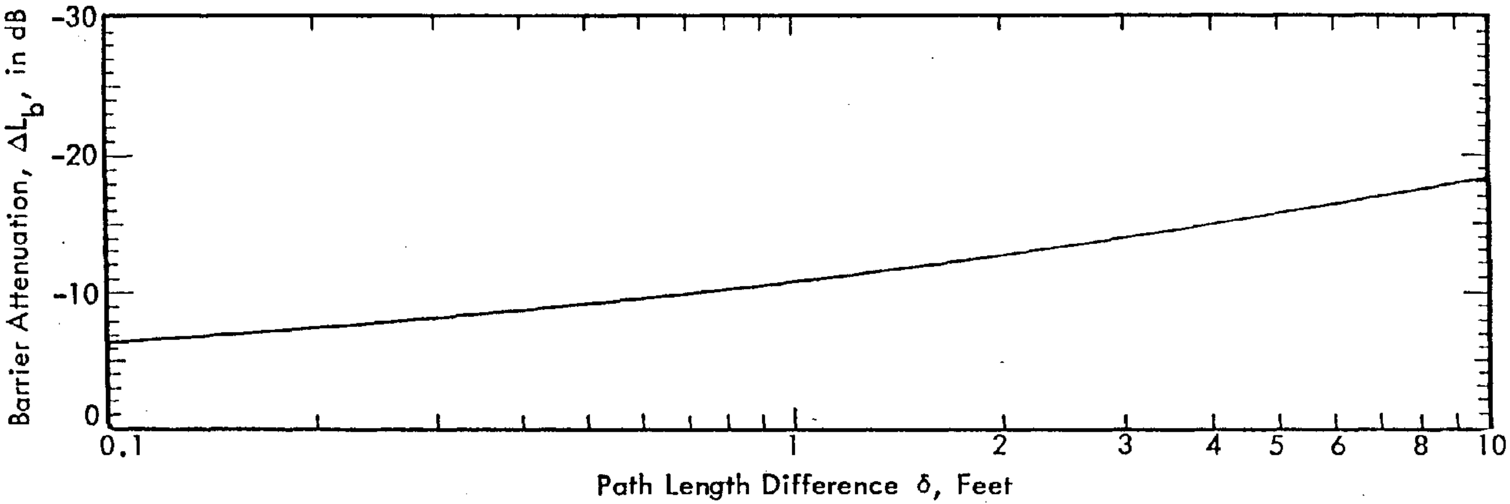


Figure 2-35. Nominal Barrier Shielding For Typical Locomotive Spectra Assuming a Line Source Parallel to the Barrier.

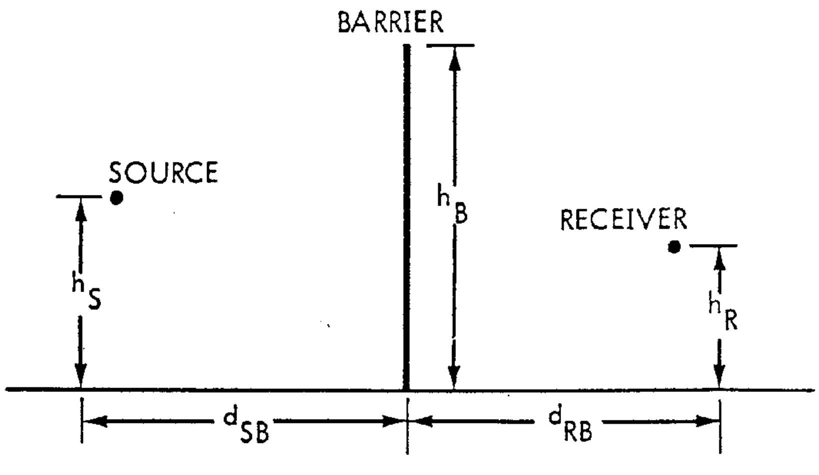


Figure 2-36. Source/Barrier/Receiver Geometry.

Table 2-12

Nominal Heights of Various Railroad Noise Sources

Source	Height,* Feet
Locomotive and Switch Engines	15
Locomotives Undergoing Load Cell Testing	15
Service and Maintenance Areas	**
Refrigerator Cars	6
Retarders	2
Car-Coupling Impacts	3
Wheel-Rail Noise	1
Horns, Bells, Whistles, PA Systems	**

* Height above trackbed. Be sure to take into account any changes in elevation between the trackbed and the ground on which the microphone tripod is situated.

** Use actual height.

Example 2-26:

A 15-foot-high barrier is constructed 20 feet from the retarder described in Example 2-25. In terms of the variables in Equations (2-44), the pertinent dimensions are:

h_B = 15 feet

h_S = 2 feet (from Table 2-12)

h_R = 4 feet (nominal height)

d_{SB} = 20 feet

d_{RB} = 480 feet

Thus from Equations (2-44):

$$A = \left[20^2 + 13^2\right]^{1/2} = 23.854 \text{ ft}$$

$$B = \left[480^2 + 11^2\right]^{1/2} = 480.126 \text{ ft}$$

$$C = \left[500^2 + 2^2\right]^{1/2} = 500.004 \text{ ft}$$

So that:

$$\delta = A + B - C = 3.976 \text{ ft}$$

Since a retarder squeal is considered a point source, Figure 2-34 is entered at this value of δ and the barrier attenuation is found to be:

$$\Delta L_b = -25 \text{ dB}$$

Applying this result along with the parameters in Example 2-25 to Equation (2-42) results in:

$$L_b\,(500 \text{ ft}) = L\,(100 \text{ ft}) + \Delta L_s + \Delta L_a + \Delta L_b$$

$$= 107.0 - 14.0 - 1.4 - 25.0$$

$$= 66.6 \text{ dB}$$

The insertion loss that occurred by building the barrier is the difference between this value and the level, L (500 ft), found in Example 2-25:

$$\Delta L_I = L_b\,(500 \text{ ft}) - L\,(500 \text{ ft})$$

$$= 66.6 - 80.6 = -14 \text{ dB}$$

Note that the insertion loss is 11 dB less than the barrier attenuation, ΔL_b, because of the loss of the ground attenuation.

The key parameter in determining barrier attenuation is the path length difference, δ. For a given source, receiver, and barrier height, both δ and the barrier attenuation are maximized by placing the barrier as close to the source or to the receiver as possible. All else being equal, placing it close to the source is preferable, following the principle of source noise control discussed earlier. For a practical barrier the value of δ should be positive; i.e., the barrier should block the line-of-sight. While some shielding occurs for negative δ, the insertion loss will be much less and the geometry is of a nature that complex interactions will occur.

The acoustical properties of the barrier material are of some importance. Since the performance of a barrier is based on no sound passing through it, the TL of the barrier material should exceed the shielding by a substantial amount. A margin of at least 10 dB is good practice. In most cases, structural considerations will result in barriers massive enough to satisfy this condition. Common building materials (plywood, concrete, etc.) generally can be used. The important considerations are that there be no holes or gaps, and that the TL be satisfactory. Within these constraints, ordinary structural designs may be used. There are commercial noise barriers available which may offer convenience or esthetic benefits. If a commercial barrier system is used, care must be taken that all performance specifications by the manufacturer are understood.

The acoustic absorption of the barrier can also be significant. If the surface facing the source is absorbent, the shielding may be improved. There is some controversy over this, but up to 3 dB improvement has been claimed. Where reflections are a potential problem, such as in the case in which noise-sensitive receivers are on both sides of the source, absorption will help to reduce these. Absorption may be necessary to eliminate reverberant build-up in some cases, such as near a retarder where reverberation can occur between the barrier and the sides of cars. Although weathering is a potential problem for absorbent barriers, some commercial systems have practical designs for weather protection.

2.3.3 Receiver Control

2.3.3.1 Insulation of Buildings

Where affected personnel are inside buildings, control can be achieved by improving the noise insulation of the structure. The basic concept of building noise insulation is to improve the TL of the building structure. Unlike equipment enclosures discussed earlier, building walls are generally not homogeneous: a basic wall has windows, doors, utility pass-throughs, etc. The noise insulation process consists of sequentially improving the weak links. The sequence generally occurs in three stages:

1. Sealing cracks, holes, and other noise leaks. This includes weatherstripping doors and windows.
2. Modifying or replacing low-TL wall elements, generally windows or doors.
3. Major modification of the wall structure to improve its TL.

With all windows and doors closed, the weakest acoustical elements will be gaps, cracks, and vents. Gaps and cracks occur most often in older structures where the weatherstripping is in poor condition, and where cracks have appeared in the wall near window or door frames. Other sound entry paths include chimneys without dampers and most types of vents to the exterior, including window air conditioners and mail slots. The first step of soundproofing involves closing or sealing these leaks, and providing acoustic baffles for the vents. However, for the building to be habitable, a certain minimum air infiltration is necessary, and this must be provided by an acoustically treated air ventilation system of some kind.

Further reduction in the interior noise level beyond this first step requires more care since the weak acoustical paths are now not so obvious and the effort may be wasted on unnecessary items. In most cases, the next step is to modify the windows and doors themselves, since these generally become the dominating paths in terms of noise entry after the gaps and cracks are sealed. A double-window system is required together with a solid core-type door, both of which must include good quality edge seals. The exceptions to these requirements occur on the shielded sides of the building which often require no further treatment beyond the first stage. If a dwelling has a beamed ceiling, then modification of the roof may be necessary, both because of the poor attenuation characteristics of beamed ceilings and because of the large ceiling area involved. These modifications form the second stage of soundproofing.

The final stage of soundproofing, if the two previous stages do not provide adequate noise reduction, is modification of the main wall and roof elements. Two of the simpler modifications are addition of absorbing material to the ceiling, and resilient mounting of the interior wall panels. For walls with single continuous studs, adding absorption to the cavity increases the transmission loss at low frequencies. Medium- and high-frequency sound is transmitted more through the studs than the cavity.

Table 2-13 shows estimates of the increase in TL that can be expected from each of these three stages of modification. Also indicated are estimates of the initial modification cost, the additional ventilation required, and the heating and air-conditioning energy savings that accrue from the modification.

2.3.3.2 Isolation Booths

A specialized case of a noise-insulated structure is a small booth specifically for noise protection. Such a booth can be a shack in a noisy part of the yard, or an office enclosure within a noisy shop area. Exactly the same design considerations apply as previously described. Commercially manufactured isolation booths are available, ranging from components with documented TL curves to complete booths with specified NR. Purchasing such a booth can be less costly than designing one specially. As with any commercial product, the manufacturer's presentation of specifications should be understood, and a performance standard should be required when ordering.

2.3.3.3 Hearing Protectors

When engineering controls of noise are not feasible and workers must work in noisy areas, hearing protectors may be the only protection means available. They should always be worn whenever the OSHA noise criteria are exceeded.

There are two types of protectors available: muffs and plugs. Muffs are hard foam-lined shells which fit over the ears. They generally are connected by a flexible headband, but are also available built onto hard hats, like ear flaps on a winter cap. A soft grommet around the edge of the shell provides a good seal against the

Table 2-13

Relative Aspects of Noise Reduction Modifications to External Walls[19]

Noise Reduction Modification	Increase in TL of Structure	Initial Modification Cost	Additional Ventilation Required	Heating and Air Conditioning Energy Savings
SEAL LEAKS Seal all cracks, openings, and leaks with caulk, tape, or weatherstripping around door, window, and wall joint seams. Provide acoustical baffles for chimneys, ventilators, etc.	Up to 4 dB	Low	High	High
IMPROVE LOW-TL WALL ELEMENTS For windows, doors, air conditioners, and ventilators, install new elements with upgraded TL comparable to that of wall structure.	Up to 10 dB over sealing of cracks; typically, 4 to 7 dB.	Moderate	None	Moderate
WALL AND ROOF STRUCTURE Construction changes to walls and roof, including stud space insulation and resilient mounting of interior surface.	Up to 10 dB over small element modifications; higher for more extensive modifications.	High	None	Moderate to High

head. On better quality muffs, this grommet is liquid filled so as to permit good sealing with very little pressure. Ear plugs fit into the ear canal, and come in several varieties. Fixed-shape plugs are made of rubber-like materials, and resemble those used by swimmers. A number of different designs exist, with some available in a range of sizes. Moldable plugs are lumps of wax-like or cotton-like material which are rolled into balls or cones, then pressed into the ears. They are usually used a few times (sometimes just once), then thrown away. Custom-molded plugs are individually cast for each person. They are made of a material which is molded and inserted like moldable plugs, but which then cures and retains its shape.

Figure 2-37 shows attenuation curves for several hearing protectors. In general, muffs perform better than plugs at low to medium frequencies. The attenuation values are not highly precise, however. Attenuation values are obtained by performing audiograms on subjects with and without the protectors. A standard deviation of 10 dB is common in this type of data.[21] Proper fitting and use are important. Ear plugs must be fitted correctly; this requires trained personnel, especially for the fitting of custom-molded plugs. Personnel must be trained in proper use of protectors. Plugs must be inserted so as to form an airtight seal. Muffs must be worn over the ears, with no interference from hair, eyeglass bows, clothing, etc. Good use instructions are generally available from manufacturers.

The greatest difficulty with hearing protectors is in getting personnel to use them, and to use them properly. A positive educational and enforcement program is necessary. Failure to wear hearing protectors when required can be considered grounds for disciplinary action. Relying solely upon discipline for use is not likely to be completely successful, however, as it places a heavy policing burden on supervisors. It is very difficult to tell if ear plugs are in use without close inspection; even then, they may just be sitting loosely in place. Muffs can be improperly used, without this being apparent from a distance. They must be worn over the ears, not the temples, hat rim, etc.

The major objections to the use of hearing protectors are comfort and the belief that danger signals will not be heard. The comfort objection can be overcome by providing a variety of good-quality protectors. Muffs with liquid-filled seals are more comfortable because they require less pressure. Individuals will also have preferences between muffs and plugs, as well as between different types of plugs. If disposable plugs are used, an adequate supply should be conveniently available. It is also advisable to have spare muffs and a dispenser of disposable plugs in critical areas for use by personnel who have forgotten to bring their own.

Impaired perception of danger signals is a real concern, although not as serious as might be thought. In a steady noise area, such as next to a load cell, any signal which can be heard above the noise can be heard equally well with protectors. This applies to speech communication as well; voices must be raised above the background with or without protectors. Warning devices, such as bells and whistles, are loud enough that they rise above the background and can therefore be heard with protectors. In the case of intermittent noise, however, protectors may block out noises which might otherwise be audible during quiet periods. Muffs are better than plugs in this regard because they are more easily removed and replaced.

2.3.3.4 Scheduling of Personnel

Where noise controls are not feasible, personnel may be scheduled so as to limit their noise exposure. The simplest method is to rotate personnel, dividing the time spent in noisy areas among several employees. The OSHA noise guidelines, Table 2-8, specify how many hours per day are allowed at different levels. This table may be used as the basis for developing a rotation schedule.

2.3.3.5 Masking

When the human ear is exposed to two sounds in the same frequency range, only the louder will be perceived. Individual sounds below the background noise are thus not perceived. If the background noise is very low, sounds which would normally not pose any sort of problem may be quite noticeable. In open-plan offices, privacy of speech communication may be impaired. Some individuals may find it difficult to sleep in a very quiet bedroom because minor sounds will be intrusive. In such cases, it is useful to introduce a controlled background noise, usually broadband random noise although music is sometimes used. Masking noise is of low level, usually no greater than 45 to 50 dB. If louder, it becomes an intrusive problem itself. Masking in no way reduces noise; it always raises the overall level. However, masking noise produces an environment which may be psychologically more desirable because it reduces the information content in the sound heard. While specialized masking noise sources are available, it is very often adequate to turn on a fan, window air conditioner, or radio.

2.3.3.6 Hearing Conservation Programs

Whenever personnel are exposed to high noise levels, a hearing conservation program must be implemented. On 16 January 1980, the U.S. Department of Labor promulgated an amendment to the occupational noise exposure standard (CFR 1910.95) which spells out in considerable detail the requirements that such a hearing conservation program must meet.[3] This amendment applies to all employees experiencing an 8-hour time-weighted average level of 85 dB or greater (or, equivalently, a noise dose of 50 percent or greater).

As of the time of publication of this manual, certain detailed parts of this amendment had been stayed and were under review, while other parts were in force.[3] The general provisions, which contain the elements of a good hearing conservation program, are in force and include:

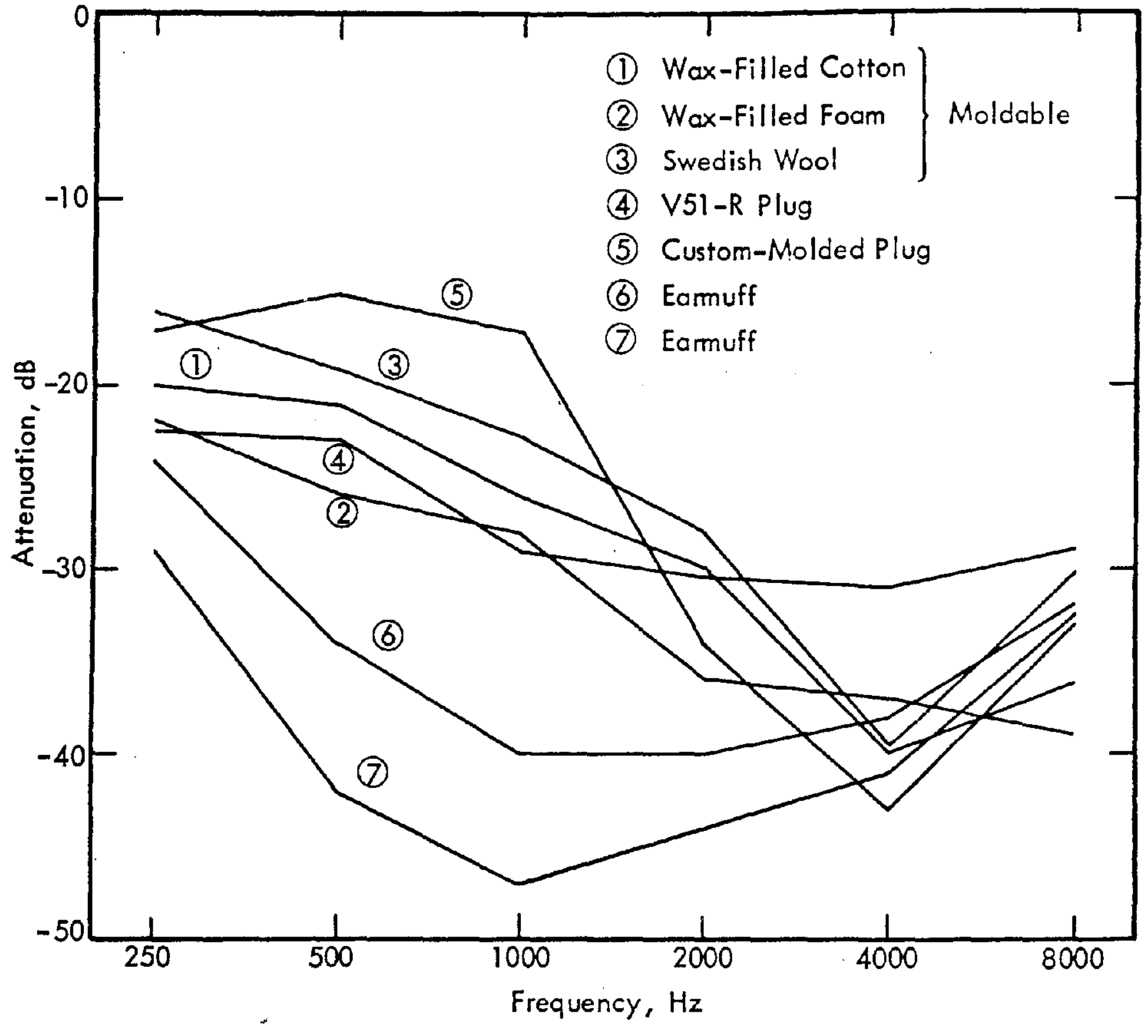


Figure 2-37. Attenuation of Various Hearing Protectors.[20,21]

- identification of affected employees,
- periodic noise exposure monitoring,
- periodic audiometric testing,
- the use of hearing protectors where necessary,
- employee education programs, and
- record keeping and reporting.

Because the detailed requirements for each of these elements may change in the future, they are not presented here. Instead, the general characteristics of each of these elements are described.

Unless all employees are to be included in a hearing conservation program, those exposed to excessive noise must be identified to determine who should be included in the program. An employee's noise exposure can be measured directly by having him wear an audiodosimeter during his workday or it can be estimated from measurements of the sound levels and exposure times for the various noise environments that he experiences using the procedure described in Section 2.1.8. At the time of publication of this handbook, CFR 1910.95 permitted either method provided that all continuous, intermittent, and impulsive sound levels from 80 dB to 130 dB are integrated into the computation. It also required that all such noise exposure monitoring be completed by 22 February 1982.

Both methods provide a reasonable measure of an employee's noise exposure when the noise environments that he experiences are similar from day to day and consist of non-impulsive noise. When the daily noise environment to which a worker is subjected varies, it may be necessary to measure or estimate his noise exposure on several different days in order to determine a range of exposures.

If impulsive noise plays a dominant role in determining an employee's noise exposure, accurate measurement of his dose becomes difficult. Present standards governing audiodosimeters do not specify how impulsive sounds shall be integrated into the noise dose computation. Thus, in an impulsive noise environment, the measured dose may vary considerably from one type of instrument to another. Similarly, no standards exist defining how sound level meter measurements of impulsive noise peaks can be used to estimate a noise dose.

Since an employee's noise exposure will change if any of the noise sources to which he is exposed is changed or if any of his duties is changed, it is wise to occasionally remeasure all employees' noise dose to determine if any should be added to the hearing conservation program or if any can be dropped from the program. Thus periodic noise exposure monitoring should be part of a good hearing conservation program.

Once the employees to be included in a hearing conservation program are identified, each should be given an initial baseline audiogram to determine the present extent of hearing loss, if any. This should be followed by periodic follow-on audiograms to check for any additional hearing loss. At the time of publication of this handbook, CFR 1910.95 required that baseline audiograms be completed by 22 August 1982. Additional follow-on audiograms are required at least annually.

CFR 1910.95 also requires that audiometric tests be performed by a licensed or certified audiologist, otolaryngologist, or other qualified physician, or by a technician who is certified by the Council of Accreditation in Occupational Hearing Conservation, or who has satisfactorily demonstrated competence in administering audiometric examinations, obtaining valid audiograms, and properly using, maintaining, and calibrating audiometers. If a technician performs audiometric tests, he must be responsible to an audiologist, otolaryngologist, or qualified physician.

Annual audiograms are to be compared to the employee's baseline audiogram to determine if a significant threshold shift has occurred. An audiologist, otolaryngologist, or qualified physician must review the audiograms to determine whether or not there is need for further evaluation. If a comparison of the annual audiogram to the baseline audiogram indicates a significant threshold shift, the following steps must be taken:

- Employees not using hearing protectors must be fitted with hearing protectors, trained in their use and care, and required to use them.
- Employees already using hearing protectors must be refitted and retrained in the use of hearing protectors and provided with hearing protectors offering greater attenuation if necessary.
- An employee must be informed, in writing, within 21 days of the determination, of the existence of a significant threshold shift.

Detailed requirements for audiometric measuring instruments, audiometric test procedures, audiometer calibrations, and audiometric test room requirements are presented in CFR 1910.95. These should be reviewed before implementing any hearing conservation program.

An important part of a hearing conservation program, often overlooked, is a coordinated employee education program. Employees cannot generally be counted on to avoid high noise areas and to wear hearing protectors, unless they are informed of the dangers of excessive noise exposure and instructed in the proper use of protective equipment. In addition to initial instruction in these matters, periodic reviews and updates should be provided so that employees are continually reminded of safe practices. Warning signs should also be placed in high noise areas to remind employees of the potential hazard.

Finally, every hearing conservation program should include detailed record keeping. CFR 1910.95 requires that employer records be kept of:

- all employee noise exposure measurements,
- all employee audiograms, and
- background sound level measurements in audiometric test rooms.

Such record keeping protects not only the employee, by allowing the identification of a progressive hearing loss, but also the employer, by certifying those cases where hearing loss did not occur. Many actions of hearing loss against employers are won because records do not exist to show that the noise exposure received at work was within safe limits.

2.3.3.7 Noise-Compatible Land-Use Planning

Although not strictly a receiver control, the application of land-use planning to separate areas of residential development from areas of noisy industrial development is often the most sensible means of reducing residential noise exposure. This technique essentially takes advantage of the relatively short-range propagation of sound by increasing the distance between noise sources and noise-sensitive receivers or by providing less noise-sensitive buffers (such as commercial developments) between them, which then partially act as barriers.

In attempting to reduce noise impact on neighboring communities, source and path controls by a railroad generally either produce insufficient attenuation of sound levels or are prohibitively expensive. Receiver controls within the community are usually not an available technique. What has often proved to be most effective is a combination of source and path control coupled with noise-compatible land-use planning within the local community.

Such a strategy places some of the responsibility for the problem solution on the community as well as the railroad. In that the railroad provides economic benefit to the community, this approach is entirely reasonable.

To successfully implement noise compatibility in the proximity of railroad operations requires the railroads to provide information to the community on noise levels emitted by their operations. Such information is typically developed through environmental impact statements. The community's responsibility is to utilize such information in zoning and rezoning considerations such that residential and other noise-sensitive land uses are buffered from railroad noise sources by less noise-sensitive activities.

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CHAPTER 3

LINE-HAUL OPERATIONS

This chapter discusses two general types of noise source that are present in line-haul operations on railroad systems. These are:

- Moving Locomotives, and
- Moving Railroad Cars.

The following items are described separately for each of these sources:

- Existing federal regulations controlling noise emission from the source;
- The acoustic metric used to quantify this noise emission;
- The measurement site selection;
- The instrumentation and measurement procedure needed to determine the noise emission;
- The existing data base describing noise emission levels from the source; and
- Noise abatement techniques that may be applied to control noise emission from the source.

Where appropriate, typical checklists, data sheets, and analysis worksheets are provided along with examples of their use.

This chapter is arranged in two sections: Section 3.1 describes exterior noise emission into the community from moving locomotives and railroad cars; Section 3.2 describes interior noise exposure within moving locomotives and railroad cars.

3.1 Exterior Noise Emission From Moving Locomotives and Railroad Cars

The noise emissions into the community from moving locomotives and railroad cars are regulated by the United States Code of Federal Regulations – 40 CFR Part 201. In Section 3.1.1, the regulations for each of these two sources are described. In Sections 3.1.2 through 3.1.5, the common acoustic metric, measurement site requirements, instrumentation, and measurement procedures for these sources are discussed. Data bases of current noise levels from each of the two sources are given in Section 3.1.6, while noise abatement techniques for each source are described in Section 3.1.7.

3.1.1 Regulations

3.1.1.1 Moving Locomotives

On January 4, 1980, the Environmental Protection Agency published updated regulations specifying noise emission standards for moving locomotives in line-haul operation. The noise limits set forth in the standard are summarized in Table 3-1.

Table 3-1

Noise Emission Standard For
Moving Locomotives In Line-Haul Service

Date Effective	Date of Manufacture of Locomotive	Type of Locomotive	Maximum Permitted A-Weighted Sound Level(1)	Tolerance(2)
Dec. 31, 1976	On or Before Dec. 31, 1979	Any	96 dB	2 dB
	After Dec. 31, 1979	Any	90 dB	2 dB
Jan. 15, 1984	Any	Switcher(3) Only	90 dB	(4)

(1) When measured at a distance of 100 feet with fast response at any time under any condition of grade, load, acceleration, or deceleration.

(2) Re: FRA Noise Emission Compliance Regulation, 49 CFR Part 210.

(3) Switcher locomotives as defined by the regulation are those locomotives listed in Table 3-2.

(4) Allowed tolerance had not been specified by FRA at the time of publication of this handbook.

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Table 3-2
Switcher Locomotives Defined in 40 CFR Part 201

Type	Engine
General Electric Co.	
44 ton	8-D17000(2)
70 ton	6-CBFWL-6T
95 ton	6-CBFWL-6T
Electromotive Division (GMC)	
SC	8-201A
NC	12-201A
NC1	12-201A
NC2	12-201A
NW	12-201A
NW1	12-201A
NW1A	12-201A
NW2	12-567
NW2	12-567A
NW3	12-567
NW4	12-201A
NW5	12-567B
SW	8-201A/6-567
SW1	6-567A/AC
SW2	6-567
SW3	6-567
SW600	6-567C
SW7	12-567A
SW8	8-567B/BC
SW900	8-567B
SW9	12-567B/BC/C
SW1200	12-567C
SW1000	8-645E
SW1001	8-645E
SW1500	12-645E
MP15	12-645E
MP15AC	12-645E
GMD1	12-567C
RS1325	12-567C
Transfer Switcher Including "Cow and Calf"	
T	12-201A(2)
TR	12-567(2)
TR1	16-567(2)
TR2	12-567A(2)
TR3	12-567(3)
TR4	12-567A(2)
TR5	12-567B(2)
TR6	8-567B(2)

Type	Engine
Baldwin	
VO-660	6-VO
DS-446	6-606NA
DS4475	6-750
S-8	6-606
VO-1000	8-VO
DS-4410	8-608NA
DS-4410	6-606SC
S-12	6-606A
DRS-4410*	6-606SC
DRS-12*	6-606A
Fairbanks Morse	
H-10-44	6-OP
H-12-44	6-OP
H-12-44TS	6-OP
H-12-46*	6-OP
Lima	
750 hp	6-Hamilton
800 hp	6-Hamilton
1000 hp	8-Hamilton
1200 hp	8-Hamilton
LRS*	8-Hamilton
TL*	8-Hamilton(2)
ALCO and MLW	
S1	6-539NA
S2	6-539T
S3	6-539NA
S4	6-539T
S5	6-251
S6	6-251A,B
S7	6-539
S10	6-539
S11	6-539
S12	6-539T
S13	6-251C
RSD-1	6-539
RSC-13	6-539
RSC-24	12-244
RS1	6-539T
RS2*	12-244
RS3*	12-244
RS10*	12-244
RSC-2*	12-244
RS3*	12-244
RSD-4*	12-244
RSD-5*	12-244
T6	6-251B
C-415*	8-251F
M-420TR	12-251

* These models may be found assigned to road service as well as switcher service, but are considered switcher locomotives for the purpose of this regulation.

The final regulation in 40 CFR Part 201 is as follows:

§ 201.12 Standard for locomotive operation under moving condition.

(a) Commencing December 31, 1976, no carrier subject to this regulation may operate any locomotive or combination of locomotives to which this regulation is applicable, and of which manufacture is completed on or before December 31, 1979, which produces A-weighted sound levels in excess of 96 dB when moving at any time or under any condition of grade, load, acceleration, or deceleration, when measured in accordance with the criteria specified in Subpart C of this regulation with fast meter response at 30 meters (100 feet) from the centerline of any section of track having less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2,865 feet)).

(b) No carrier subject to this regulation may operate any locomotive or combination of locomotives to which this regulation is applicable, and of which manufacture is completed after December 31, 1979, which produce A-weighted sound levels in excess of 90 dB when moving at any time or under any condition of grade, load, acceleration, or deceleration, when measured in accordance with the criteria specified in Subpart C of this part with fast meter response at 30 meters (100 feet) from the centerline of any section of track having less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2,865 feet)).

(c) Commencing January 15, 1984, no carrier subject to this regulation may operate any switcher locomotive or a combination of switcher locomotives to which this regulation is applicable, and of which manufacture is completed on or before December 31, 1979, which produce A-weighted sound levels in excess of 90 dB when moving at any time or under any condition of grade, load, acceleration, or deceleration, and when measured in accordance with the criteria in Subpart C of this part with fast meter response at 30 meters (100 feet) from the centerline of any section of track having less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2,865 feet)). All switcher locomotives that operate in a particular railroad facility are deemed to be in compliance with this standard if the A-weighted sound level from stationary switcher locomotives, singly or in combination with other stationary locomotives, does not exceed 65 dB when measured with fast meter response at any receiving property measurement location near that particular railyard facility and when measured in accordance with Subpart C of this regulation.

3.1.1.2 Moving Railroad Cars

On December 31, 1975, the Environmental Protection Agency published regulations specifying noise emission standards for moving railroad cars in line-haul operation. The noise limits set forth in the standard are summarized in Table 3-3.

Table 3-3

Noise Emission Standard For
Moving Railroad Cars In Line-Haul Service
(40 CFR Part 201, § 201.13)

Date Effective	Speed	Maximum Permitted A-Weighted Sound Level (2)	Tolerance(3)
December 31, 1976	45 mph or Lower	88 dB	2 dB
	Above 45 mph	93 dB	2 dB

(1) When speed cannot be determined to an accuracy of ±5 mph, the 93 dB standard shall apply.(3)

(2) When measured at a distance of 100 feet with fast response.

(3) Re: FRA Noise Emission Compliance Regulations, 49 CFR Part 210.

The final regulation in 40 CFR Part 201 is as follows:

§ 201.13 Standard For Rail Operations.

Effective December 31, 1976, no carrier subject to this regulation shall operate any rail car or combination of rail cars which while in motion produce sound levels in excess of (1) 88 dB(A) at rail car speeds up to and including 72 km/hr (45 mph); or (2) 93 dB(A) at rail car speeds greater than 72 km/hr (45 mph); when measured in accordance with the criteria specified in Subpart (C) of this part with fast meter response at 30 meters (100 feet) from the centerline of any section of track which is free of special track work or bridges or trestles and which exhibits less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2,865 feet)).

3.1.2 Acoustic Metric

The metric used in these regulations is summarized in Table 3-4.

Table 3-4

Acoustic Metric For Moving Locomotives
And Railroad Cars Noise Measurements

A-WEIGHTED SOUND LEVEL
"FAST" METER RESPONSE

As stated in § 201.21 of the regulations:

"The quantities to be measured under the test conditions described below, are the A-weighted sound levels for "fast" meter response as defined in the American National Standard S1.4-1971."[1] *

3.1.3 Measurement Site Selection

The location at which the sound measurements are to be conducted must be chosen carefully to ensure that the conditions summarized in Table 3-5 are satisfied.

When carrying out measurements on a stationary locomotive under load, it is often difficult to meet the clear-zone requirements in Figure 3-1. This difficulty occurs when it is necessary to conduct the noise measurements at a locomotive load cell test stand, because the locomotive to be tested cannot be self-loaded. In general, such test stands are located in yard areas near reflecting objects, such as buildings, load cell structures, and other locomotives.

If a site conforming to the clear-zone requirements is not available, it may still be possible to obtain acceptably accurate measurements of locomotive noise at existing load cell test sites. On the basis of the results of a recent study,[2] the clear-zone requirements can be relaxed, as described below, and one should still be able to obtain measurements of locomotive noise within +1 dBA to -0.5 dBA of measurements at a conforming site.

Load Cell Requirements

- The locomotive should be located between the test microphone and load cell with no part of the load cell visible from the test microphone.
- The outlet for cooling air from the load cell should be as low as possible. High chimneys should be avoided.

Site Geometry

- The locomotive should be fully visible from the test microphone, especially the exhaust outlet and radiator cooling fan inlets and outlets.
- A single, large reflecting surface (greater than 6 feet by 6 feet) directly behind the microphone, e.g., such that the microphone is between the locomotive and the reflecting surface, can be as close as 50 feet away from the microphone. This restriction can be relaxed if it can be shown that because of the limited size and orientation of the reflecting surface no paths exist for sound to propagate from the locomotive to the microphone by reflecting off the surface.
- A single, large reflecting surface (greater than 6 feet by 6 feet) to the side of and approximately parallel to a line joining the center of the locomotive and microphone should be 100 feet from that line as the standard requires. This restriction can be relaxed if it can be shown that no paths exist for sound to propagate from the locomotive to the microphone by reflecting off the surface.
- A single, large reflecting surface behind the locomotive, e.g., such that the locomotive is between the microphone and the surface, does not present as severe a problem because of the substantial barrier that the locomotive presents to reflected sound. If sound reflecting off that surface must pass through the locomotive in order to reach the microphone, the surface may be as close as 10 feet from the side of the locomotive.

Weather Conditions

- Requirements on weather conditions specified in the standard should be adhered to. In addition, it is desirable to locate the microphone downwind from the locomotive and to test on days with steady wind rather than on days in which the wind speed fluctuates between calm and the 20 mph wind gust limits allowed in the standard.

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* Superscripts refer to references at end of chapter.

Table 3-5

Measurement Site Requirements For
Moving and Stationary Locomotives,* Railroad Cars, and
Locomotive Load Cell Noise Measurements

TEST SITE

Open space with no large reflecting objects within 100 feet of the source or the measurement position (see Figure 3-1).

SITE ELEVATION

The top of at least one rail must be visible from 4 feet above the ground at the microphone location.

GROUND COVER

At least 80 percent of the rail must be visible from the microphone position with no ground cover (trees, grass, fences, etc.) obstructing the view.

MICROPHONE POSITION

The microphone must be 4 feet above the ground. The ground elevation at the microphone location must be between 10 feet below and 5 feet above the elevation of the top of the rail at position A in the figure.

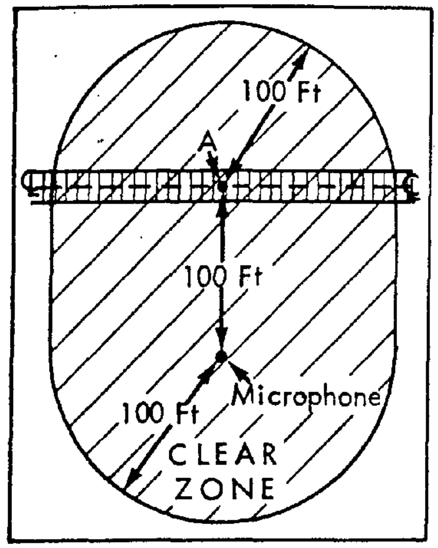


Figure 3-1. Test Site Clear Zone Requirement For Locomotives (Moving and Stationary), Locomotive Load Cell Test Stands, and Moving Railroad Cars.

TRACK CONDITIONS
(Moving Locomotives and Railroad Cars Only)

Less than 2-degree curve or a radius greater than 2,865 feet.

WEATHER CONDITIONS

Measurements should be taken only under these conditions:

- No precipitation (rain, snow, sleet, hail, etc.).
- Wind speed below 12 mph.
- Wind gusts below 20 mph.

BACKGROUND NOISE LEVEL

The maximum A-weighted fast response sound level measured at the test site immediately before and after the source test must be at least 10 dB lower than that of the source being measured.

* Relaxed requirements for carrying out measurements on stationary locomotives under load are discussed in the text.

The measurement site selection conditions as stated in § 201.23 of the regulations are as follows:

(a) The standard test site shall be such that the locomotive or train radiates sound into a free field over the ground plane. This condition may be considered fulfilled if the test site consists of an open space free of large, sound-reflecting objects, such as barriers, hills, signboards, parked vehicles, locomotives or rail cars on adjacent tracks, bridges or buildings within the boundaries described by Figure 1, as well as conforms to the other requirements of this § 201.23.

(b) Within the complete test site, the top of at least one rail upon which the locomotive or train is located shall be visible (line of site) from a position 1.2 meters (4 feet) above the ground at the microphone location, except as provided in paragraph (c) of this section.

(c) Ground cover such as vegetation, fenceposts, small trees, telephone poles, etc., shall be limited within the area in the test site between the vehicle under test and the measuring microphone such that 80 percent of the top of at least one rail along the entire test section of track be visible from a position 1.2 meters (4 feet) above the ground at the microphone location; except that no single obstruction shall account for more than 5 percent of the total allowable obstruction.

(d) The ground elevation at the microphone location shall be within plus 1.5 meters (5 feet) or minus 3.0 meters (10 feet) of the elevation of the top of the rail at the location in-line with the microphone.

(e) Within the test site, the track shall exhibit less than a two (2) degree curve or a radius of curvature greater than 873 meters (2,865 feet). This paragraph shall not apply during a stationary test. The track shall be tie and ballast, free of special track work and bridges or trestles.

(f) Measurements shall not be made during precipitation.

(g) The maximum A-weighted fast response sound level observed at the test site immediately before and after the test shall be at least 10 dB(A) below the level measured during the test. For the locomotive pass-by tests this requirement applies before and after the train containing the rolling stock to be tested has passed. This background sound level measurement shall include the contribution from the operation of the load cell, if any, including load cell contribution during test.

(h) Noise measurements may only be made if the measured wind velocity is 19.3 km/hr (12 mph) or less. Gust wind measurements of up to 33.2 km/hr (20 mph) are allowed.

3.1.4 Instrumentation

The instrumentation recommended to make moving locomotive and railroad car passby noise measurements is shown in Table 3-6.

Table 3-6

Instrumentation For Moving Locomotive and Railroad Car Noise Measurements

SOUND LEVEL METER
MICROPHONE AND WINDSCREEN
TRIPOD
SOUND LEVEL CALIBRATOR
WIND SPEED METER
TRAIN SPEED MEASURING DEVICE
ACCESSORIES

The instrumentation requirements stated in § 201.22 of the regulations are as follows:

(a) A sound level meter or alternate sound level measurement system that meets, as a minimum, all the requirements of American National Standard S1.4-1971[1] for a Type 1 (or S1A) instrument must be used with the "fast" meter response characteristic as specified in Subpart B. To insure Type 1 response, the manufacturer's instructions regarding mounting or orienting of the microphone, and positioning of the observer must be observed. In the event that a Type 1 (or S1A) instrument is not available for determining non-compliance with this regulation, the measurements may be made with a Type 2 (or S2A).

(b) A microphone windscreen and an acoustic calibrator of the coupler type must be used as recommended by: (1) the manufacturer of the sound level meter, or (2) the manufacturer of the microphone. The choice of both devices must be based on ensuring that Type 1 or Type 2 performance, as appropriate, is maintained for frequencies below 10,000 Hz.

In addition, the FRA Compliance Regulations (49 CFR Part 210, § 210.29) require that the following calibration procedures must be utilized:

(1) (i) The sound level measurement system including the microphone must be calibrated and appropriately adjusted at one or more nominal frequencies in the range from 250 through 1000 Hz at the beginning of each series of measurements, at intervals not exceeding 1 (one) hour during continual use, and immediately following a measurement indicating a violation.

(ii) The sound level measurement system must be checked out not less than once each year by its manufacturer, a representative of its manufacturer, or a person of equivalent special competence to verify that its accuracy meets the manufacturer's design criteria.

(2) An acoustical calibrator of the microphone coupler type designed for the sound level measurement system in use shall be used to calibrate the sound level measurement system in accordance with paragraph (1) (i) of this subsection. The calibration must meet or exceed the accuracy requirements specified in § 5.4.1 of the American National Standard Institute Standards, "Method for Measurement of Sound Pressure Levels" (ANSI S1.13-1971),[1] for field method measurements.

3.1.5 Measurement Procedure

The procedure to be followed when conducting moving locomotive and railroad car noise measurements is derived from the EPA noise standard regulation, the FRA compliance regulation, and common measurement practice.

The procedure is made up of four phases. They include:

- Program Planning
- Instrumentation Checkout
- Instrumentation Setup
- Data Collection

A description of these phases as applied to moving locomotive and railroad car noise measurements is presented in the rest of this section. Where appropriate, sample worksheets are included. These may be copied directly or may be used as a basis for designing a more personalized format.

3.1.5.1 Program Planning

The first stage of the measurement program is program planning. It is during this phase that decisions are made concerning such factors as the number of locomotives, locomotive consists, and railroad cars to be tested; specifically which units will be tested, the locations and number of test sites, and the day and time the measurements are to be made. Permission to be allowed access to the measurement locations at the time desired should be obtained from the responsible railroad official. The number of people to carry out the measurements should be determined and specific individuals assigned to the measurement team. Most field measurements involving moving or changing sources require at least two people – one to observe and record the sound level measurements, the other to determine and note other characteristics of the noise source (e.g., type, identification, location, speed, etc.)

It is also at this point that the instrumentation system is specified and acquired. The system used for moving locomotive and railroad car noise measurements will normally consist of a Type 1 or 2 sound level meter with a calibrator, windscreen, and tripod. Other useful equipment include a wind speed-measuring device, a 100-foot tape measure, and a thermometer.

A program planning worksheet is useful in assuring that all of the planning details are carried out. An example of such a worksheet is shown in Figure 3-2.

3.1.5.2 Instrumentation Checkout

Before proceeding to the field for measurements, the instrumentation system should be assembled and thoroughly checked out and the manufacturer's instructions referred to for calibration and operational procedures. The batteries should be tested and all interconnecting cables and mounting hardware should be connected to assure that the correct plugs fit into the proper instruments, and that the overall system operates as required. Accessories such as extra batteries, note pads, adhesive tape, and the like, should be assembled.

PROGRAM PLANNING WORKSHEET

Moving Locomotives and Railroad Cars

Date: ________________ Prepared By: ______________________________

Check When Completed

Test Plan

- _____ Determine the number of units to be tested.
- _____ Determine when the measurements will be made.
- _____ Determine where the measurements will be made.
- _____ Identify the train number and locomotive number of the units to be tested.
- _____ Obtain permission to carry out measurements at desired location.

Instrumentation Checkout

- _____ Specify the instrumentation system required for the measurements.
- _____ Acquire the components of the instrumentation system.
- _____ Check out and calibrate the instrumentation system.
- _____ Complete the instrumentation system inventory worksheet.
- _____ Pack the instrumentation system for shipment to the measurement site.
- _____ Check weather conditions at measurement site; reschedule test if necessary.

Measurement Site Setup

- _____ Check in with person responsible for measurement site property.
- _____ Complete measurement site qualification worksheet.
- _____ Unpack instrumentation system, checking against inventory worksheet.
- _____ Set up the instrumentation system and check components for damage.
- _____ Calibrate the system and report results on the field data log.
- _____ Complete the annotation on the field data log.

Noise Measurements

- _____ Conduct noise measurements.
- _____ Record results on the field data log.
- _____ Check calibration of the system and record results on the field data log.
- _____ Repack system for return shipment, referring to inventory checksheet.

Program Completion

- _____ Unpack instrumentation system; check for damage.
- _____ Document measurement program.

Figure 3-2. Sample Program Planning Worksheet.

An inventory of the necessary equipment and a measurement site qualification worksheet should be prepared and taken to the field. This assures that no details will be forgotten once the measurement program has begun. Samples of inventory and site qualification worksheets are shown in Figures 3-3 and 3-4, respectively. The inventory sheet is meant to be quite general; thus, depending on the situation, it may not be necessary to take all the equipment listed.

3.1.5.3 Instrumentation Setup

Before proceeding to the measurement site, the person in charge of the property on which the measurements are to be taken should be informed of the presence of the measurement team. Once at the site, the instrumentation system should be set up according to the manufacturer's instructions. The inventory worksheet should be referred to at this time. The measurement site qualification should be verified, using the measurement site qualification worksheet.

The sound level meter should be mounted on a tripod with the microphone at a level of 1.2 meters (4 feet) above the ground. A windscreen should always be attached to the microphone. The sound level meter may be tilted to allow ease of reading, and the microphone should be oriented according to manufacturer's instructions. This is critical, since certain microphones (perpendicular incidence) are designed to be pointed directly at the major noise source, other microphones (grazing incidence) are designed to be pointed at right angles to the line between the observer and the noise source, and still others (random incidence) are designed to be oriented in a direction intermediate to these two.

For locomotive pass-by tests, the microphone should be positioned on a line perpendicular to the track at a point 30 meters (100 feet) from the track centerline.

The operator should stand as far away from the meter as possible, consistent with his ability to make the sound level readings easily. He should avoid standing between the microphone and the noise source being measured. When possible, the microphone/preamplifier assembly should be mounted remote from the sound level meter so that there is less chance of the observer affecting the measured data.

Care should be taken to make sure that there is nothing between the microphone position and the sound source which may interfere with the sound propagation. No reflecting objects should be located within 100 feet of either the microphone or the noise source. Refer to Figure 3-1 within Table 3-5 for a sketch of the clear zone requirements.

The sound level meter should be calibrated by adjusting the meter to read the level generated by the calibrator, according to the manufacturer's instructions. This should be done prior to the beginning of measurements, and noted in the field data log. At least once each hour during the measurement period and at the completion of the measurements, the calibration should be checked; the calibrator level at this time should be recorded in the data log. In addition, the calibrator level should be recorded immediately following any source measurement indicating a violation.

Draw a sketch of the measurement area that includes all audible noise sources and their approximate location with respect to the measurement position. The location of all reflecting surfaces, barriers, and other factors that may affect the sound propagation should also be noted on the sketch. An exact scale map is not necessary, but a good representation of the area, with distances to outstanding landmarks indicated, is desirable. If a detailed map of the area is available, the site area should be located on it.

If possible, photographs of the area should be taken to show the noise source. A very effective way to photograph the site is to stand at the microphone position and take a series of pictures which show the full 360^{o} view from that spot. It is also helpful to document the microphone location by stepping behind the microphone and taking a picture which shows the microphone as well as the sound source being measured.

A data log should be completed for the measurement program. A typical data log sheet is shown in Figure 3-5 and should contain the following information:

- Description of measurement location.
- Date of measurements.
- Name of person performing the measurements.
- Types, models, serial numbers, or other identification characteristics for all instrumentation.
- Barometric pressure, temperature, wind velocity, and relative humidity. (This information can be measured directly or, in many cases, can be obtained from local weather radio stations.)
- Results of calibration tests.
- Measured levels and background levels.
- Description of equipment under test.
- Description of secondary noise sources including type and location.

INSTRUMENTATION SYSTEM INVENTORY WORKSHEET

Moving Locomotives and Railroad Cars

Date: ________________ Prepared By: ______________________________

INSTRUMENT	Make	Model	Serial No.	Date of Last Calibration	Check Out	Return
Sound Level Meter (SLM)						
Microphone						
Sound Level Calibrator						
Wind Speed Measuring Device						
Train Speed Measuring Device						

REQUIRED (*) AND RECOMMENDED ACCESSORIES	Checkout	Return
* Microphone Windscreen		
* SLM Calibration Adjustment Tool (Screwdriver)		
* Tripod		
* Tape Measure		
Thermometer		
Hygrometer		
Watch		
Extra Batteries		
Duct Tape		
Connecting Cables		
Flashlight		
Weather Radio		
Camera and Film		
Ground Cloth		
Earphones		
Tools (screwdriver, pliers, etc.)		

Figure 3-3. Sample Instrumentation System Inventory Worksheet.

MEASUREMENT SITE QUALIFICATION WORKSHEET

Moving Locomotives and Railroad Cars

Date: ________________ Prepared By: ______________________________

Location: ____

____

	YES	NO
Have the test area clear-zone requirements been met?	___	___
Have the site ground contour requirements been met?	___	___
Have the track conditions requirements been met?	___	___
Have the site ground cover requirements been met?	___	___
Has the microphone elevation requirement been met?	___	___
Will the ambient weather conditions permit noise emission tests?	___	___
Wind Speed Below 12 mph?	___	___
Wind Gusts Below 20 mph?	___	___
No-precipitation condition met?	___	___
Will the ambient sound level conditions permit noise emission tests?	___	___
Has a sketch been made of the measurement site?	___	___
Have photographs been taken of the measurement site?	___	___

Figure 3-4. Sample Measurement Site Qualification Worksheet.

FIELD DATA LOG

Moving Locomotives and Railroad Cars

(PART A — Use For Each Continuous Measurement Period)

Date: ________________ Prepared By: ______________________________________

Location: ____

____

Time: Start of Measurements: _________ Completion of Measurements: _________

EQUIPMENT:

Instrument	Manufacturer	Model	Serial No.	Date of Last Calibration
Sound Level Meter				
Microphone				
Calibrator				

WEATHER CONDITIONS:

	Time	Wind Speed	Direction	Temperature	Relative Humidity	Barometric Pressure
Pre-Test						
Post-Test						

CALIBRATION: Calibrator Level: _______dB Calibrator Frequency: _______Hz

Time						
Sound Level						

BACKGROUND LEVEL:

Time						
A-Weighted Sound Level						

SKETCH OF SITE GEOMETRY:

↑ N

Figure 3-5. Sample Field Data Log.

FIELD DATA LOG (Continued)

Moving Locomotives and Railroad Cars

(PART B — Use One Sheet For Each Train Passby Measured)

Date: ______________ Prepared By: ____

Location: ____

____

Railroad: _________ Train No. _______ Train Direction: ____ Train Speed: _____

LOCOMOTIVE SOUND LEVELS:

Time	Locomotive Identification		A-Weighted Sound Level, dB	Comments
	Railroad	Number		

RAILROAD CAR SOUND LEVELS:

Time	General Car Type	A-Weighted Sound Level, dB	Comments

OTHER NOISE SOURCES: ____

____

____

REMARKS: ____

____

____

____

Figure 3-5 (Concluded).

Note that the sample data log in Figure 3-5 consists of two parts. Part A is completed for each continuous measurement period at a given location. It is used to identify the measurement equipment and weather conditions, to record the calibration and background sound levels, and to provide a sketch of the measurement site geometry. One Part B form is completed for each train passby at the site. It is used to identify the train and its direction and speed and the sound levels of locomotives, locomotive consists, and railroad cars within the train. It is also used to record sound levels of other nearby sources that may have contributed to the train passby measurements. The "Remarks" section of the Part B form should be used to note any atypical events which may have an effect on the measurements or their interpretation.

3.1.5.4 Data Collection

The noise level of a moving locomotive should be measured as the locomotive approaches and passes by the microphone location. The maximum noise level observed during this period should be recorded on the data log.

The noise level of a moving locomotive consist should be measured as the whole consist approaches and passes the microphone location. The maximum noise level observed during this period should be recorded on the data log.

Locomotives or locomotive consists within a train which are separated by at least ten rail car lengths or 500 feet should be treated as separate units and noise levels for each should be measured and recorded on the data log. Consists of locomotives containing at least one locomotive unit manufactured prior to December 31, 1979, must be evaluated for compliance using the 96 dB standard in Table 3-1. Consists of locomotives composed entirely of locomotive units manufactured after December 31, 1979, must be evaluated for compliance using the 90 dB standard in Table 3-1. If the build dates of all locomotives in a consist cannot be established, evaluation for compliance must be made using the 96 dB standard in Table 3-1.

Railroad car noise measurements can only be made when the locomotives have passed a distance of 500 feet or ten railroad cars beyond the point at the intersection of the track and the line which extends perpendicularly from the track to the microphone location (Point "A" in Figure 3-1), providing any other locomotives are also at least 500 feet or ten railroad car lengths away from the measuring point. The maximum sound level observed in this manner should be recorded on the data log.

The train speed should be determined to within ± 5 mph as the train passes the microphone location. If the speed measurement equipment is not operating at the time of the measurement within the required tolerance, then the measurements must be evaluated using the "Above 45 mph" criterion in Table 3-3.

3.1.6 Data Base

The purpose of this data base is to provide a summary of representative locomotive and railroad car sound levels to which field measurements can be compared. An individual source measurement lying far above the range of values reported here should be cause of some concern, since it may be indication of mechanical problems in the unit. The data presented here are based on measurements made by FRA inspectors during the period from September 1978 to June 1981.

3.1.6.1 Moving Locomotives

On the basis of the results of 379 passby noise tests reported by FRA,[3] A-weighted sound levels from moving diesel-electric locomotive consists at a distance of 100 feet may range from 69 dB to 97 dB with a mean value of 87.8 dB. Table 3-7 shows the range, mean value, and standard deviation of these sound levels as a function of number of units in the consist. It appears that the sound level does not increase with the number of units in the consist, as one might expect. However, it should be noted that many of the variables that affect noise emission, such as the power settings of the units, are unknown in these samples. These uncontrolled variables presumably play a more important role in determining the peak sound level than do the number of units in the consist. Figure 3-6 shows the distribution of the sound levels in the overall FRA data base.

One-third octave band spectra typical of that from moving locomotives are shown in Figures 3-7 and 3-8. The former is for a locomotive moving at 58 mph on level grade; the latter is for a locomotive ascending a 2.2-percent grade at 20 mph. A- and C-weighted levels are also indicated in the figures.

Figure 3-9 shows the relationship between A-weighted sound level and locomotive speed for the FRA data base described above. Also indicated is the corresponding linear regression curve, standard error of estimate, σ, and correlation coefficient, r, for these data. A correlation coefficient of ± 1.00 would indicate that all the data points lie on a straight line; a correlation coefficient of zero would indicate that there is no relation between the sound level and the speed.

Table 3-7

Range, Mean Value, and Standard Deviation of A-Weighted Sound Levels For Moving Locomotive Consists[3]

Number of Units In Consist	Number of Samples	A-Weighted Sound Level At 100 Feet (dB re 20μPa)			
		Min.	Max.	Mean	σ
1	153	70	96	88.1	4.8
2	97	70	96	87.4	6.0
3	82	70	96	88.6	5.7
4	30	69	97	85.9	7.6
5	9	74	94	84.8	7.4
6	8	83	96	87.8	5.7
ANY	379	69	97	87.8	5.7

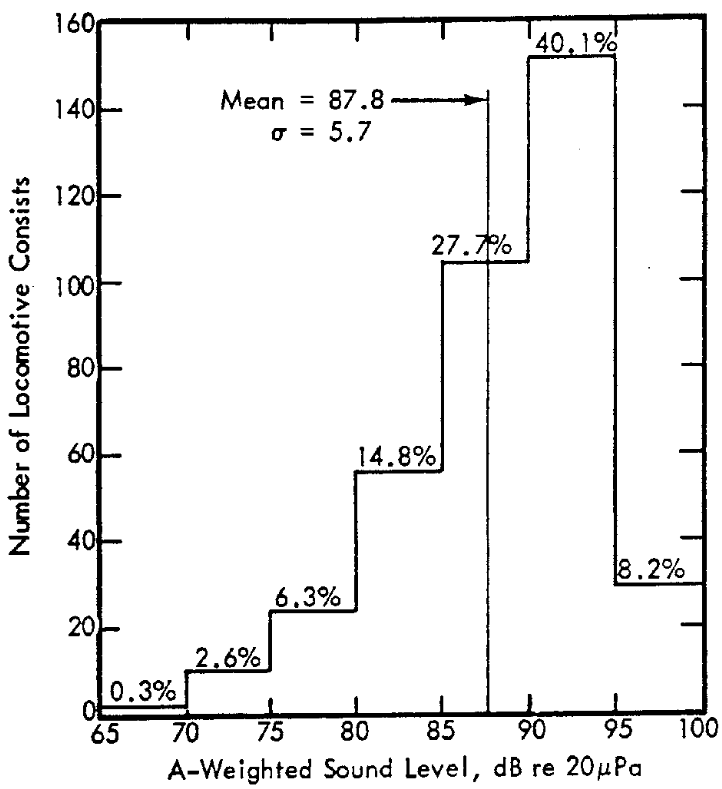


Figure 3-6. Distribution of Sound Levels For Moving Locomotive Consists.[3]

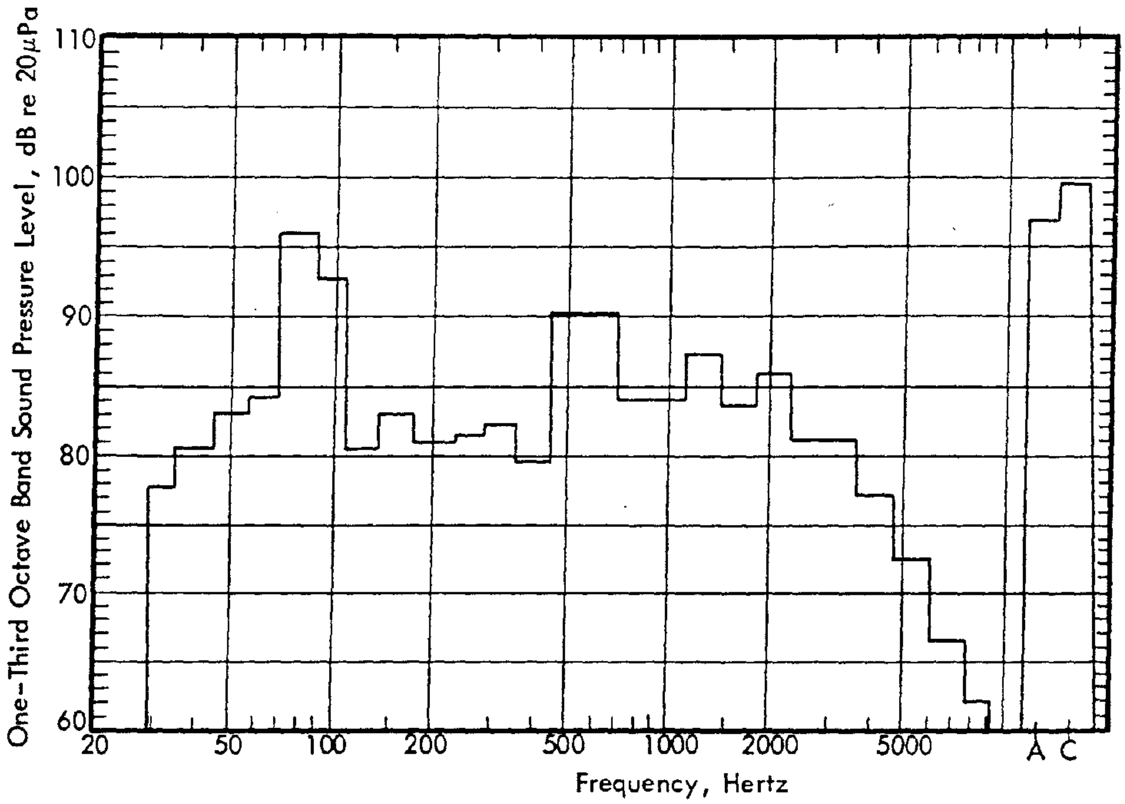


Figure 3-7. Spectrum of Noise Emitted By a Diesel-Electric Locomotive Operating Over Level Grade[4] (0 Percent Grade at 58 mph, Measurements at 50 Feet).

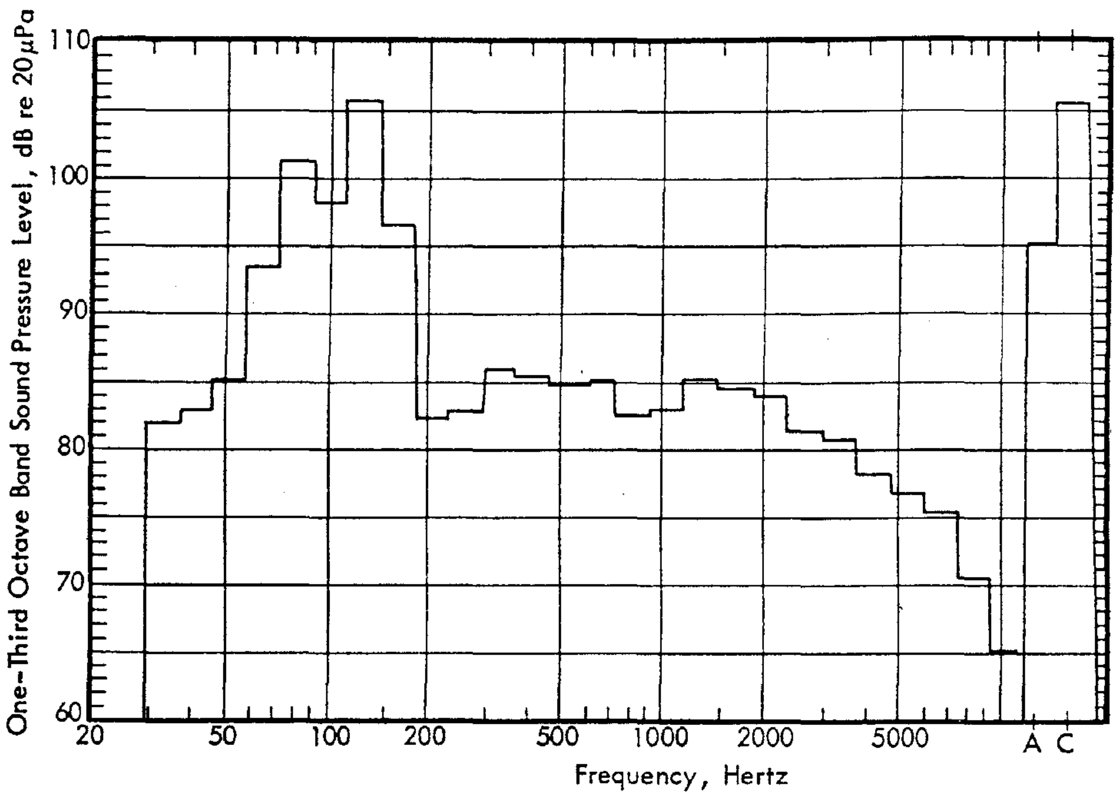


Figure 3-8. Spectrum of Noise Emitted By a Diesel-Electric Locomotive Under Maximum Power Conditions[4] (Ascending 2.2 Percent Grade At 20 mph, Measurements at 50 Feet).

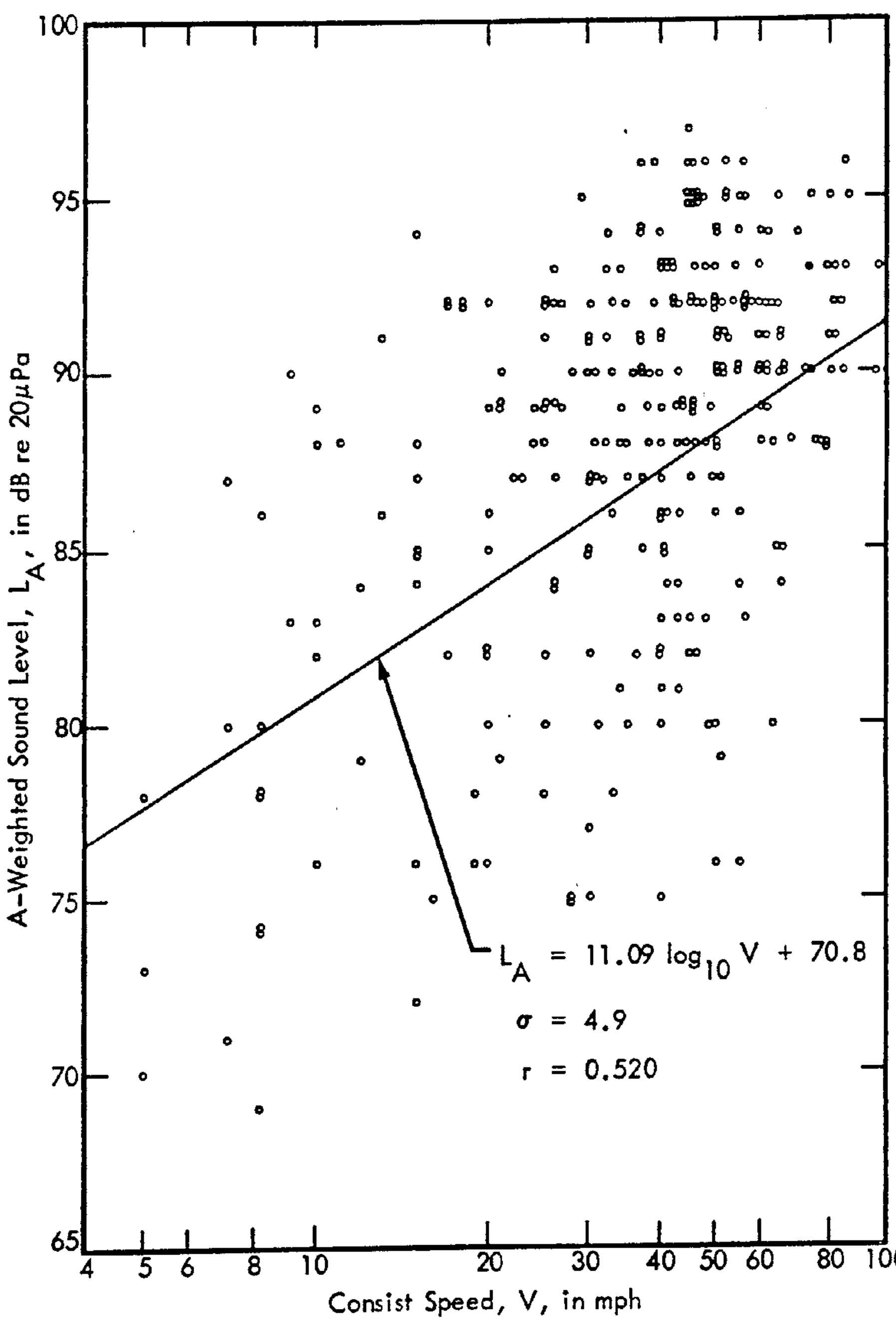


Figure 3-9. A-Weighted Sound Level of Locomotive Consists As a Function of Speed[3] (Measurements at 100 Feet).

3.1.6.2 Moving Railroad Cars

On the basis of the results of 180 low-speed (≤ 45 mph) passby noise tests,[3] A-weighted sound levels of low-speed railroad cars measured at a distance of 100 feet range from 64 dB to 92 dB with a mean value of 80.4 dB. Based on the results of 115 high-speed (> 45 mph) passby noise tests,[3] A-weighted sound levels of high-speed railroad cars measured at this distance range from 74 dB to 94 dB with a mean value of 86.7 dB. Figure 3-10 shows the distributions of these two sets of sound levels. One-third octave band spectra measured from a train operating at 24 and 58 mph are shown in Figure 3-11.

Figure 3-12 shows the relationship between A-weighted sound level and railroad car speed for the FRA data base described above. Also indicated are the corresponding linear regression curve, standard error of estimate, σ, and correlation coefficient, r, for these data.

3.1.7 Noise Abatement Techniques

3.1.7.1 Corrective Actions

The FRA Noise Emission Compliance Regulations (49 CFR Part 210) states the procedure that may be carried out if a rail car or a locomotive is found to exceed the noise emission standards as follows:

> § 210.25 (c) (1) An inspector is authorized to inspect or examine a locomotive, rail car or consist of a locomotive and rail cars operated by a railroad, or to request the railroad to inspect or examine the locomotive, rail car or consist of a locomotive and rail cars, whenever he has reason to believe that it does not conform to the requirements of the Standards.
>
> (2) The request referred to in this paragraph must be in writing, must state the grounds upon which the inspector has reason to believe that the locomotive, rail car or consist of a locomotive and rail cars does not conform to the Standards, and must be presented to an appropriate operating official of the railroad.
>
> (3) The inspection or examination referred to in this paragraph may be conducted only at recognized inspection points or scheduled stopping points.
>
> (4) An inspector may request a railroad to conduct an inspection or examination of a rail car or consist of railcars on the basis of an excessive noise emission level measured by a passby test. If, after such inspection or examination, no mechanical condition that would result in a noise defect can be found, and the inspector verifies that no such mechanical condition exists, the rail car or consist of rail cars may be continued in service.
>
> (5) An inspector may request a railroad to conduct an inspection or examination of a locomotive on the basis of an excessive noise emission level measured by a passive test. If, after such inspection or examination, no mechanical condition that would result in a noise defect can be found, and the inspector verifies that no such mechanical condition exists, the locomotive may be continued in service.

3.1.7.2 Moving Locomotives

Noise emission from locomotives can be reduced by closing all doors, hatches, and panels and making sure that the seals on these devices are in place and in good condition. Loose parts on the locomotive body should be tightened or repaired and proper lubrication and maintenance schedules should be adhered to. Should the noise from a locomotive be substantially louder than that indicated in the data base above, the locomotive should be checked to determine if it is operating within specifications.

Engine exhaust is the dominant source of locomotive noise at high throttle positions. Using oversized specially designed mufflers to control the exhaust noise, reductions in overall A-weighted locomotive noise of 3 to 6 dB have been demonstrated at notch 8. At lower throttle settings much less reduction was obtained. Because of the large size of the mufflers required, this technique of noise quieting is not practical in retrofit applications. New locomotives manufactured after 1980 are equipped with noise abatement features that allow them to meet current regulations.

Cooling fans are also a major source of moving locomotive noise. This noise can be controlled two different ways, both of which require a redesign of the cooling system and are therefore most feasible during the original design and construction of the locomotive. The first method consists of reducing the fan speed; the second requires the removal of all obstructions at the fan inlet. The first approach takes advantage of the dependence of fan noise on the sixth power of fan speed. The second approach reduces turbulence entering the fan, and hence the resulting noise due to the fluctuating pressures on the fan blades as they encounter the turbulent eddies.

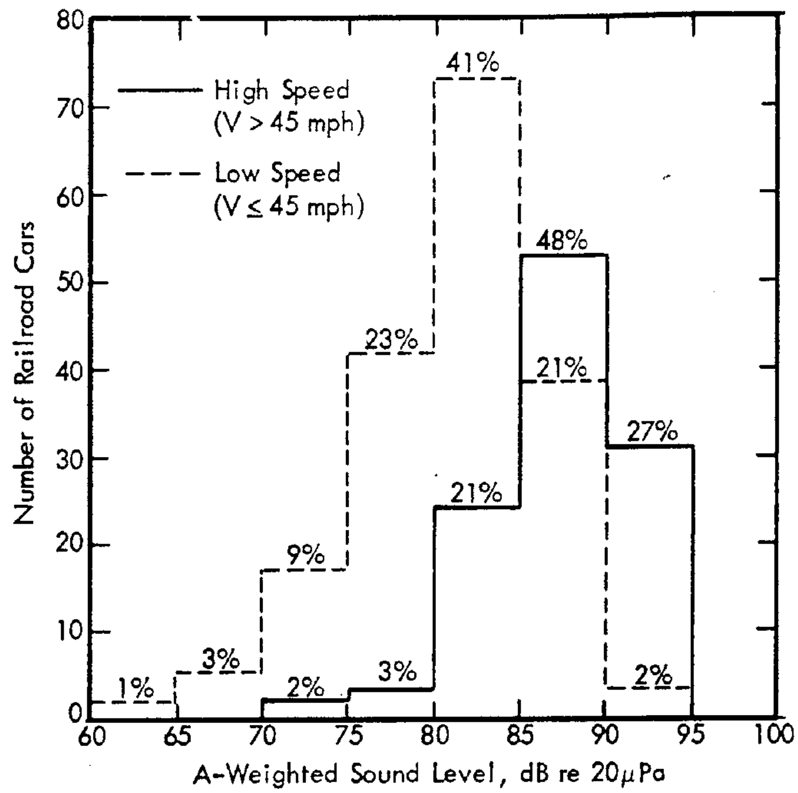


Figure 3-10. Distribution of Sound Levels For Moving Railroad Cars.[3]

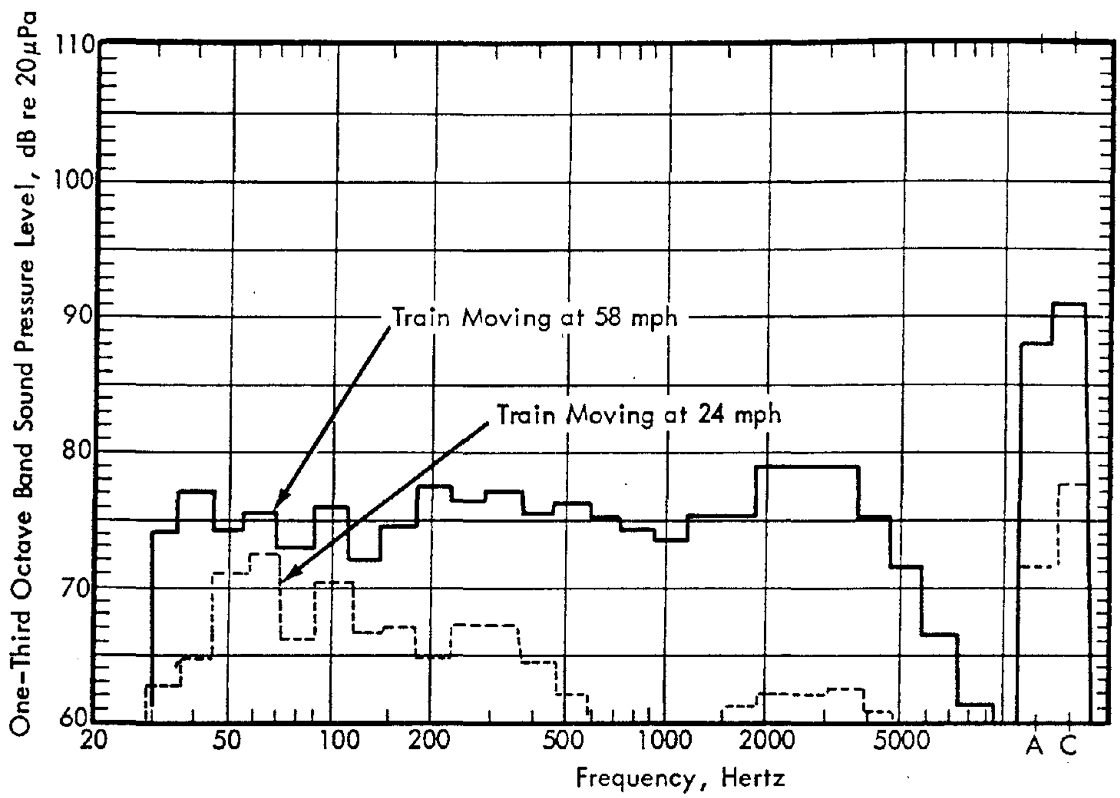


Figure 3-11. Comparison of Car Noise Frequency Spectra at Speeds of 58 and 24 Miles Per Hour[4] (Measurements at 100-Foot Distance To Track).

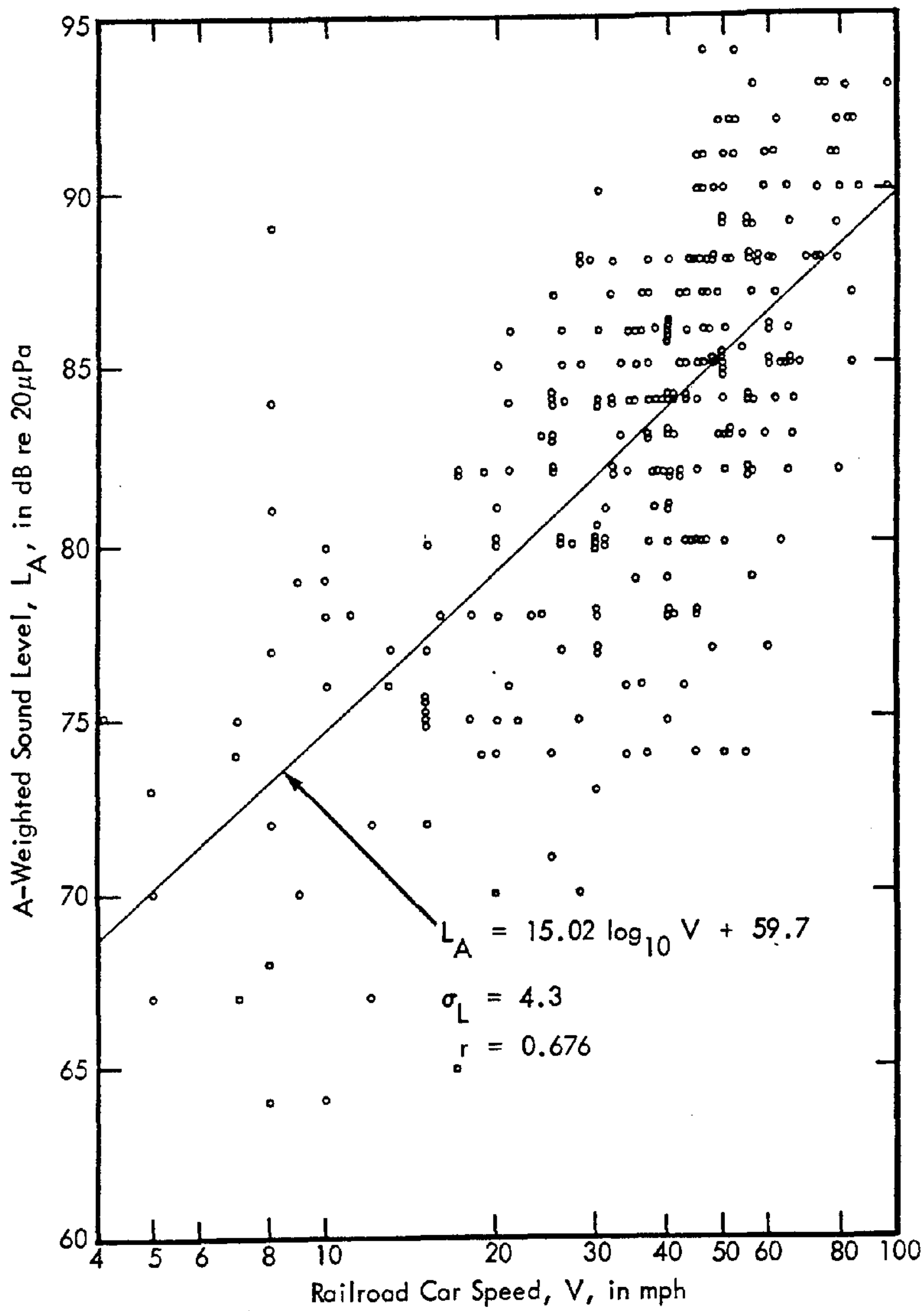


Figure 3-12. A-Weighted Sound Level of Railroad Cars As a Function of Speed[2] (Measurements at 100 Feet).

3.1.7.3 Moving Railroad Cars

The major technique for controlling noise from railroad cars is the use of good operational procedures to secure all loose items, such as doors, hatches, and loads, and good maintenance practices to remove flat spots from wheels and corrugations from the rail, thus reducing the impact component of wheel/rail interaction. In addition, by eliminating tight radius curves where practical, and using lubrication on those curves that cannot be eliminated, the occurrence of wheel squeal can be reduced. More sophisticated techniques for reducing wheel squeal include wheel damping and the use of steerable trucks. The use of such techniques is not generally cost effective or practical. Further reduction of impact noises can be achieved by the use of continuous welded rail.

3.2 Interior Noise Exposure Within Moving Locomotives and Cabooses

The noise exposure within moving locomotive cabs is regulated by the United States Code of Federal Regulations – 49 CFR Part 229. The noise exposure within moving cabooses is not federally regulated. However, the noise environment within a caboose can be studied applying the same techniques used to monitor the interior noise levels of moving locomotives. High noise levels in cabooses may create communications problems, thus preventing the railroad staff from carrying out their tasks efficiently. (For example, see Section 2.1.9.2.) Also, since very high levels in many types of cabooses are not normal, the presence of such levels may suggest the possibility of a mechanical problem which requires attention.

In Section 3.2.1, the regulation for in-cab locomotive noise exposure is described. Sections 3.2.2 through 3.2.5 discuss the acoustic metric, the microphone location, the instrumentation, and the measurement procedures for in-cab locomotive noise measurements. Data bases describing current noise and exposure levels in moving locomotive cabs and in moving cabooses are described in Section 3.2.6, while noise abatement techniques are discussed in Section 3.2.7.

3.2.1 Regulation

On March 31, 1980, the Federal Railroad Administration published Railroad Locomotive Safety Standards which include standards for the locomotive in-cab noise environment. The noise limits set forth in the standard are summarized in Table 3-8.

Table 3-8

Noise Exposure Standard For
Moving Locomotive In-Cab Environment

Date Effective	Maximum Allowed Noise Dose	Maximum Eight-Hour Time-Weighted Average Level	Maximum Instantaneous A-Weighted Sound Level
August 31, 1980	1.00	90 dB	115 dB

The final regulation in 49 CFR Part 229 is as follows:

§ 229.121 Locomotive cab noise.

(a) After August 31, 1980, the permissible exposure to a continuous noise in a locomotive cab shall not exceed an eight-hour time-weighted average of 90 dB(A), with a doubling rate of 5 dB(A) as indicated in the table. Continuous noise is any sound with a rise time of more than 35 milliseconds to peak intensity and a duration of more than 500 milliseconds to the time when the level is 20 dB below the peak.

Duration Permitted (Hours):	Sound Level (dB(A)):
12	87
8	90
6	92
4	95
2	100
1½	102
1	105
½	110
¼ or less	115

(b) When the continuous noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect shall be considered. Exposure to different levels for various periods of time shall be computed according to the following formula:

$$D = T_1 / L_1 + T_2 / L_2 + \dots T_n / L_n$$

where D = noise dose.

T = the duration of exposure (in hours) at a given continuous noise level.

L = the limit (in hours) for the level present during the time T (from the table).

If the value of D exceeds 1, the exposure exceeds permissible levels.

(c) Exposure to continuous noise shall not exceed 115 dB(A).

3.2.2 Choice of Metric

The metrics used in this regulation are summarized in Table 3-9.

Table 3-9

Acoustic Metric For Moving Locomotive
In-Cab Noise Measurements

A-WEIGHTED SOUND LEVEL
"SLOW" METER RESPONSE
NOISE DOSE OR EIGHT-HOUR
TIME-WEIGHTED AVERAGE LEVEL

3.2.3 Microphone Location

The regulation states:

(e) In conducting sound level measurements with a sound level meter, the microphone shall be oriented vertically and positioned approximately 15 centimeters from and on axis with the crew member's ear. Measurements with an audiodosimeter shall be conducted in accordance with manufacturer's procedures as to microphone placement and orientation.

3.2.4 Instrumentation

The instrumentation required to make moving locomotive in-cab noise measurements is shown in Table 3-10.

Table 3-10

Instrumentation For Moving Locomotive
In-Cab Noise Measurements

SOUND LEVEL METER
MICROPHONE AND WINDSCREEN
AUDIODOSIMETER
TRIPOD
SOUND LEVEL CALIBRATOR
ACCESSORIES

The instrumentation requirements stated in the regulation are as follows:

(d) Noise measurements shall be made under typical operating conditions using a sound level meter conforming, at a minimum, to the requirements of ANSI S1.4-1971,[1] Type 2, and set to an A-weighted slow response or with an audiodosimeter of equivalent accuracy and precision.

3.2.5 Measurement Procedure

The procedure to be followed when conducting moving locomotive in-cab noise measurements is derived from the FRA noise standard regulation and common measurement practice.

The procedure is made up of four phases. They include:

- Program Planning
- Instrumentation Checkout
- Instrumentation Setup
- Data Collection

A description of these phases as applied to moving locomotive in-cab noise measurements is presented in the rest of this section. Where appropriate, sample worksheets are included. These may be copied directly or may be used as a basis for designing a more personalized format.

3.2.5.1 Program Planning

The first stage of the measurement program is program planning. It is during this phase that decisions are made concerning such factors as the number of locomotives to be tested, specifically which locomotives will be tested, the locations of the test locomotives, and the date and time period at which the measurements will be made. Permission to be allowed access to the test locomotives at the time desired should be obtained from the responsible railroad official. The number of people to carry out the measurements should be determined and specific individuals assigned to the measurement team.

It is also at this point that the instrumentation system is specified and acquired. The system used for locomotive in-cab noise measurements will normally consists of a Type 1 or 2 sound level meter with a calibrator, windscreen, tripod, and an audiodosimeter. Other useful equipment include a tape measure, a thermometer, and a camera.

A program planning worksheet is shown in Figure 3-13. This is useful in assuring that all of the planning details are carried out.

3.2.5.2 Instrumentation Checkout

Before proceeding to the field for measurements, the instrumentation system should be assembled and thoroughly checked out and the manufacturer's instructions referred to for calibration and operational procedures. The batteries must be tested and all interconnecting cables and mounting hardware should be connected to assure that the correct plugs fit into the proper instruments, and that the overall system works as required. The accessories such as extra batteries, note pads, adhesive tape, and the like, should be assembled.

An inventory of the necessary equipment should be prepared and brought into the field. This assures that no equipment will be forgotten. A sample of an inventory worksheet is shown in Figure 3-14. This inventory is meant to be quite general; thus, depending on the situation, it may not be necessary to take all the equipment listed.

3.2.5.3 Instrumentation Setup

When arriving at the site where the locomotive is to be met, the railroad official in charge should be notified of the presence of the measurement team. Once in the locomotive cab, the instrumentation should be set up according to the manufacturer's instructions. The inventory worksheet should be referred to at this time.

The microphone should be oriented vertically and positioned approximately 5 7/8 inches (15 centimeters) from and on axis with the crew member's ear, as shown in Figure 3-15. The sound level meter and/or audiodosimeter should be calibrated according to the manufacturer's instructions. This should be done prior to the beginning of measurements, and noted in the field data log. After the measurements have been completed, the calibration of each instrument should be checked; the calibrator levels at this time should be recorded in the data log.

A sketch of the microphone position should be drawn, indicating the position of the engineer and/or brakeman and the microphone(s) relative to the locomotive cab. The location of windows, the locomotive horn, the air brake exhaust, and other major noise sources should be indicated on the sketch. If possible, a photograph of the interior of the cab, showing the operators' positions and the microphone location, should be taken.

A data log should be completed for the measurement program. A typical data log sheet is shown in Figure 3-16 and should contain the following information:

- Description of trip.
- Date of measurements.
- Name of person performing the measurements.
- Types, models, serial numbers, or other identification characteristics for all instrumentation.
- Description of locomotive under test.
- Description of major noise sources.
- Results of calibration tests.
- Background levels.
- Measured doses and levels.

A note pad should be taken into the field and used to write extensive notes detailing anything going on which may have a bearing on the measurements or the interpretation of the data. The occurrence of atypical events are examples of the type of information which should be recorded.

PROGRAM PLANNING WORKSHEET

Moving Locomotive In-Cab Noise

Date: ____________________ Prepared By: ______________________________________

Check When Completed

Test Plan

_____ Determine the number of units to be tested.
_____ Determine when the measurements will be made.
_____ Determine where the measurements will be made.
_____ Identify the train number and locomotive number of the units to be tested.
_____ Obtain permission to carry out measurements.

Instrumentation Checkout

_____ Specify the instrumentation system required for the measurements.
_____ Acquire the components of the instrumentation system.
_____ Check out and calibrate the instrumentation system.
_____ Complete the instrumentation system inventory worksheet.
_____ Pack the instrumentation system for shipment to the test location.

Measurement Site Setup

_____ Check in with responsible railroad official.
_____ Unpack instrumentation system, checking against the inventory worksheet.
_____ Set up the instrumentation system and check components for damage.
_____ Calibrate the system and report results on the field data log.
_____ Complete the annotation on the field data log.

Noise Measurements

_____ Conduct noise measurements.
_____ Record results on the field data log.
_____ Check calibration of the system and record results on the field data log.
_____ Repack system for return shipment, referring to inventory checksheet.

Program Completion

_____ Unpack instrumentation system, check for damage.
_____ Process data.
_____ Document measurement program.

Figure 3-13. Sample Program Planning Worksheet.

INSTRUMENTATION SYSTEM INVENTORY WORKSHEET

Moving Locomotive In-Cab Noise

Date: ______________ Prepared By: ____________________________________

INSTRUMENT	Make	Model	Serial No.	Date of Last Calibration	Check Out	Return
Sound Level Meter (SLM)						
Microphone						
Sound Level Calibrator						
Audiodosimeter Monitor						
Audiodosimeter Indicator						

REQUIRED (*) AND RECOMMENDED ACCESSORIES	Checkout	Return
* Microphone Windscreen		
* SLM Calibration Adjustment Tool (Screwdriver)		
* Tripod		
* Tape Measure		
Watch		
Extra Batteries		
Duct Tape		
Connecting Cables		
Flashlight		
Camera and Film		
Earphones		
Tools (screwdriver, pliers, etc.)		

Figure 3-14. Sample Instrumentation System Inventory Worksheet.

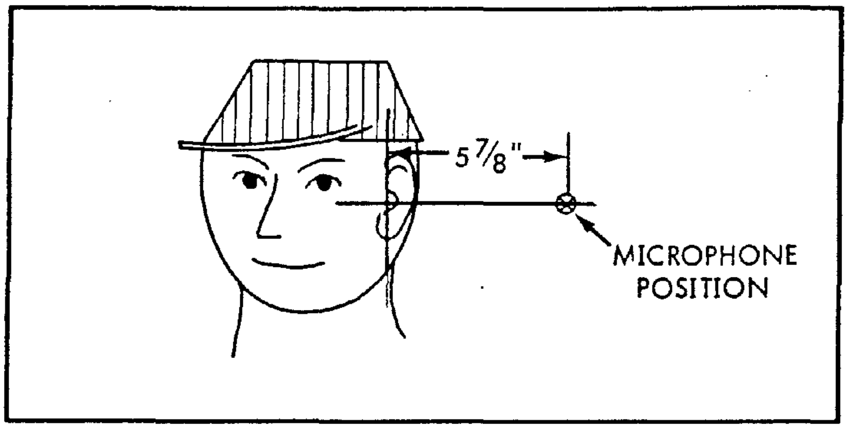


Figure 3-15. Microphone Position for In-Cab Noise Exposure Measurements.

FIELD DATA LOG

Moving Locomotive In-Cab Noise

Date: ____________________ Prepared By: ______________________________

Trip Description: ____

____

EQUIPMENT:

Instrument	Manufacturer	Model	Serial No.	Date of Last Calibration
Sound Level Meter				
Microphone				
Calibrator				
Audiodosimeter Monitor				
Audiodosimeter Indicator				

CALIBRATION:

Sound Level Meter: Calibrator Level: ________ dB; Calibrator Frequency: ________ Hz

Time						
Sound Level						

Audiodosimeter: Calibrator Level: ________ dB; Calibrator Frequency: ________ Hz

Time						
Sound Level						

SKETCH OF MICROPHONE POSITION:

Figure 3-16. Sample Field Data Log.

FIELD DATA LOG (Continued)

Moving Locomotive In-Cab Noise

LOCOMOTIVE PARAMETERS AND LEVELS:

Train Number __________ Railroad ______________________________

Locomotive Number ________ Locomotive Model ____________________

Sound Level Measurements					
Time	Throttle Setting	Speed	A-Weighted Sound Level, dB	Microphone Position(1)	Comments

Dose Measurements						
Time		Duration (T, hours)	Dose (D)	TWA(2) (dB)	Microphone Position(1)	Comments
Start	Stop					

(1) E = Engineer, B = Brakeman

(2) $TWA = 90 + 16.61 \log_{10} (8\,D/T)$

where T = measurement duration in hours

D = fractional dose

TWA = time-weighted average sound level.

REMARKS: ____

Figure 3-16 (Concluded).

3.2.5.4 Data Collection

Sound levels should be measured at various throttle settings, when the horn is sounded, and when pressure in the braking system is released. Dose measurements should only be made at the operator's position for the entire time period in which the operator is present in the locomotive cab.

3.2.6 Data Base

The purpose of this data base is to provide a summary of measured locomotive cab noise levels and noise exposure values. Caution should be used in the application of these data, since the number of measurements in the data base is quite limited.

3.2.6.1 Moving Locomotives

In a recent study conducted by the National Bureau of Standards,[5] A-weighted sound levels were measured in various locomotive cabs during a series of typical revenue-producing, over-the-road trips. Tests were conducted in the cabs of 16 locomotives operating on various routes in the contintental United States. Two of the locomotives made separate trips with two different crews, so that a total of 18 test trips were studied. Acoustic measurements were made at four locations in the locomotive cab – approximately six inches from each ear of the engineer and brakeman.

Figure 3-17 shows the averages over these 18 trips of the A-weighted sound levels of the engine at various throttle settings, the horn, and the pneumatic brake exhaust at the engineer left-side microphone. The error bars indicate one standard deviation for the distribution of levels for each source. For 78 percent of the trips, the locomotive windows were open, thus this data generally represents open-window conditions. The source level of the engine and brake exhaust within the cab is insensitive to whether or not the windows are open, decreasing by approximately 1 dB or less when the windows are closed. The sound level of the horn decreases on the average by about 5 dB when the windows are closed.

Although the levels in the figure are those for only one of the four microphone positions, the study showed that the sound level within the cab was relatively insensitive to position, varying by at most 2 dB between positions. Since this variation is small compared to the trip-to-trip variation as characterized by the error bars in the figure, the sound levels at these positions can be considered approximately the same.

The average fractional noise doses (averaged over the four microphone positions) for the 18 trips ranged from 0.02 to 0.97, with all but one being at or below 0.50. The mean value of these average doses was 0.25 with a standard deviation of 0.22. The change in dose from one microphone position to another for a given trip was quite small, being characterized by a typical standard deviation of 0.04. Since the number of trips in this sample is small, the sample statistics may not be representative of the present population of all locomotive trips.

Figures 3-18 and 3-19 present histograms of average fractional noise doses and eight-hour time-weighted average levels, respectively, for a different sample of 21 locomotive trips recently tabulated by FRA.[3] Again, the parameter is an average over a series of different microphone positions. For this sample, the mean value of the average dose is 0.61 with a standard deviation of 0.80.

3.2.6.2 Moving Cabooses

Little data exist on sound levels within cabooses. A few such measurements have recently been gathered by FRA.[3] These are presented in Table 3-11 as sound level ranges as a function of caboose speed range. Note that this table represents a very small amount of data, so that caution should be applied in its use.

3.2.7 Noise Abatement Techniques

3.2.7.1 Moving Locomotives

The loudest sounds that are heard within moving locomotive cabs are those from the horn and the air brake exhaust. These, however, are brief events which, unless they occur a very large number of times, may not contribute very significantly to the dose. The sounds that occur most often are those from the engine and its components.

Horn noise reduction within the cab can be achieved by proper design and location of the horn. The horn should be located as far from the engineer's and brakeman's positions as possible, consistent with its being heard in front of the locomotive.* The body of the horn should be isolated from the cab structure and acoustic insulation should be provided in the ceiling of the cab. The number of horn soundings and the duration of each sounding should be kept to a minimum, consistent with good safety practices. The cab windows should be left closed as much as possible.

---

* 49 CFR Part 229 also requires that:

> After August 30, 1980, each lead locomotive shall be provided with an audible warning device that produces a minimum sound level of 96 dB(A) at 100 feet forward of the locomotive in its direction of travel.

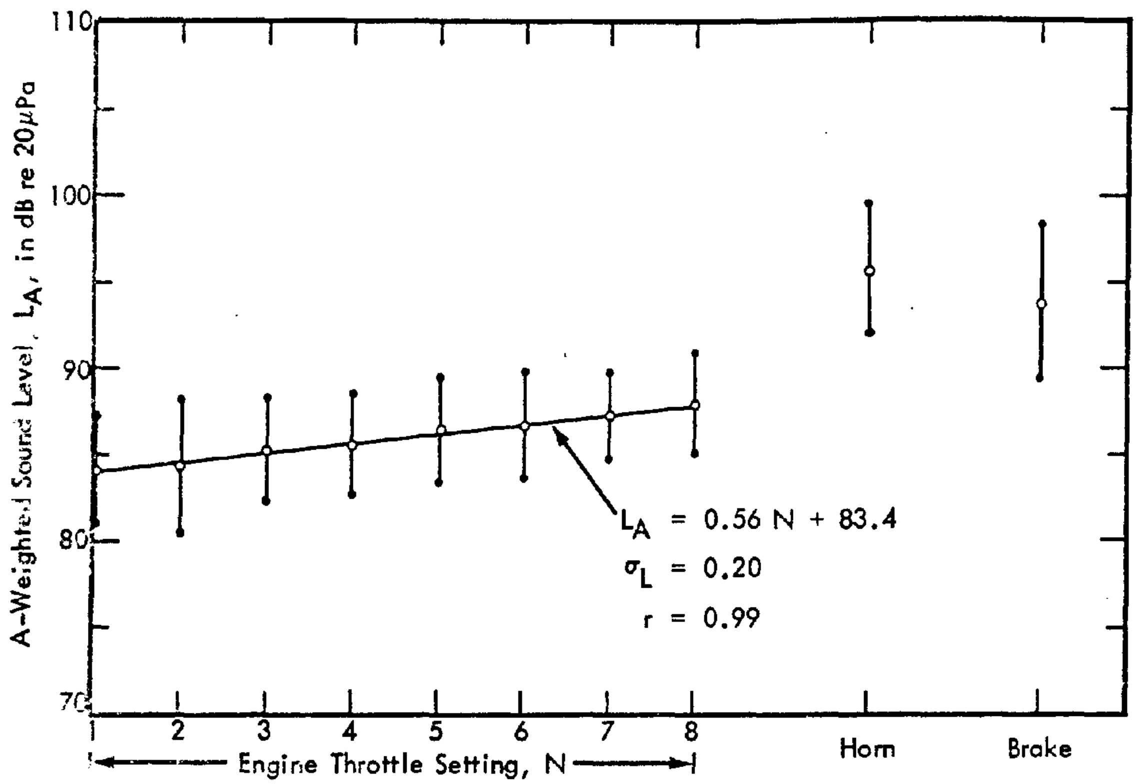


Figure 3-17. In-Cab A-Weighted Sound Levels From Various Locomotive Noise Sources.[5]

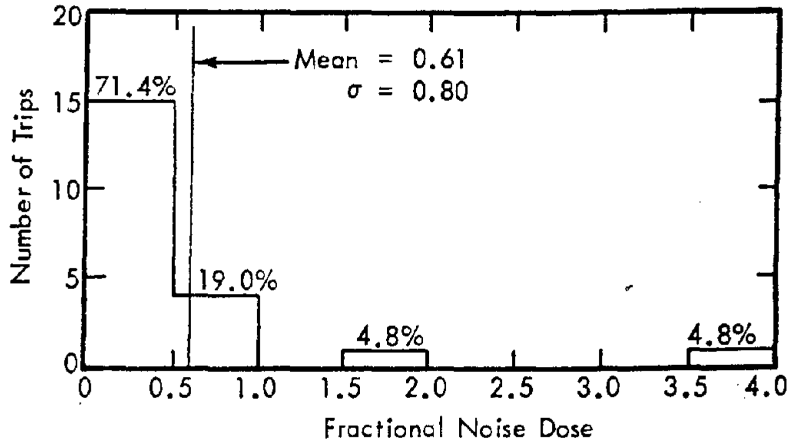


Figure 3-18. Histogram of In-Cab Locomotive Noise Doses.[3]

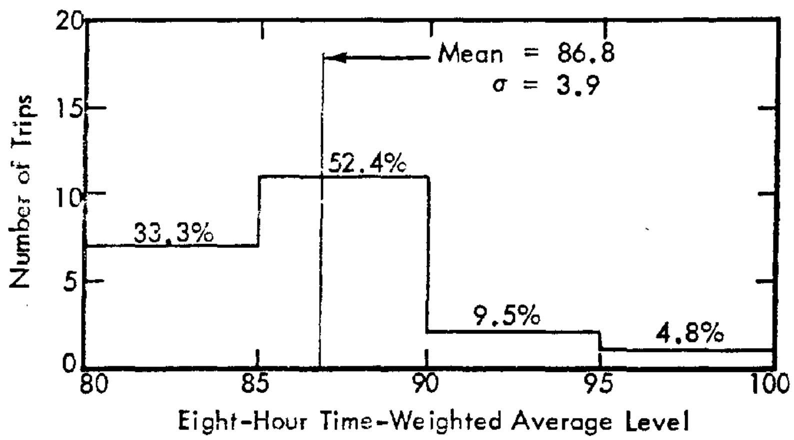


Figure 3-19. Histogram of In-Cab Locomotive Time-Weighted Average Levels.[3]

Air brake exhaust noise can be reduced by venting the braking system outside of the cab. Systems that accomplish this are generally available from the manufacturers of air brake systems.

Engine noise can be minimized by proper maintenance procedures which include: replacing worn seals and gaskets; being sure that doors, hatches, and loose equipment are secured; and adding absorbing material to the interior of the cab to prevent reverberant buildup of the sound field.

3.2.7.2 Moving Cabooses

Noise in cabooses is primarily due to wheel/rail interaction and to vibration of loose items. Making sure that doors, hatches, and loose items are properly secured may reduce much of the noise. Further noise reduction can be accomplished by isolating the car body from the trucks, applying structural damping to the car body, and supplying acoustic absorption within the car.

Table 3-11

Interior A-Weighted Sound Levels As a Function of Car Speed For Four Cabooses[3]

Speed Range (mph)	Sample Number			
	1	2	3	4
0–19	63–78	65–75	70–84	40–81
20–44	77–94	79–87	83–86	73–94
≥45	84–93	—	84–93	87–93

NOTE: This table contains sound levels measured for only four cabooses. Because of the small number of vehicles involved, caution should be applied in the use of these data.

REFERENCES FOR CHAPTER 3

1. Available from the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

2. Remington, P.J., Alakel, M.N., Ernest, J.W., and Dixon, N.R., "The Measurement of Locomotive Noise at Existing Railroad Test Sites," FRA/ORD-79/55, November 1979.

3. Data supplied by Office of Safety, Federal Railroad Administration, 400 Seventh Street, S.W., Washington, D.C. 20590.

4. Swing, J.W., and Pies, D.B., "Assessment of Noise Environments Around Railroad Operations," Wyle Research Report WCR 73-5, July 1973.

5. Kilmer, R.D., "Assessment of Locomotive Crew In-Cab Occupational Noise Exposure," FRA/ORD-80/91, December 1980.

CHAPTER 4

RAILROAD YARD OPERATIONS

Railroad yard operations include the classification of railroad cars, the performance of routine maintenance and simple repair of locomotives and railroad cars, and, in some cases, the carrying out of locomotive load tests to check the performance of locomotives. Large yards also provide more comprehensive maintenance and repair facilities, and, in some cases, dormitory facilities for locomotive crew members. In addition, many yards serve as terminal areas for trailer-on-flatcar and container-on-flatcar (TOFC / COFC) operations.

To support these operations, a yard may contain a variety of noise sources including: stationary idling locomotives, moving locomotives, load test cells, maintenance and repair facilities, and TOFC / COFC loading and unloading facilities. Although railroad car speeds within a yard are sufficiently low that wheel/rail noise is negligible, car-to-car and multiple car impacts in the classification area do generate loud impulsive sounds. Finally, in hump yards, the interaction of wheel, rail, and retarder brake shoes can produce loud squeal-type noise events.

This chapter discusses those of the above noise sources whose noise emissions are currently controlled by federal regulations. These include:

- Locomotives – both idling and moving,
- Locomotive load cell test stands,
- Car-coupling impacts, and
- Retarders.

The following items are described separately for each of those sources:

- The existing federal regulation controlling noise emission from the source,
- The acoustic metric used to quantify this noise emission,
- The measurement site selection,
- The instrumentation and measurement procedure needed to determine the noise emission,
- The existing data base describing noise emission levels from the source, and
- Noise abatement techniques that may be applied to control noise emission from the source.

Where appropriate, typical checklists, data sheets, and analysis worksheets are provided along with examples of their use.

This chapter is arranged in two sections: Section 4.1 discusses stationary and moving locomotives and locomotive load cell test stands, and Section 4.2 discusses car-coupling impacts and retarders.

4.1 Exterior Noise Emission From Locomotives

The most pervasive noise sources found within railroad yards, but not necessarily the loudest, are stationary, idling locomotives and moving locomotives. A stationary locomotive may be found almost anywhere within a yard, depending on where it was last used and where it is anticipated it will next be needed. Groups of stationary locomotives are most often found near fueling and maintenance areas and near repair facilities. A moving locomotive may be found in transit at any point within a yard; however, moving locomotives are generally found for long periods of time at the ends of the classification areas in flat yards and in the hump area in hump yards. In contrast to line-haul operations, where moving locomotives spend most of their time at the highest throttle settings, moving locomotives within railroad yards spend most of their time at lower throttle settings.

Another locomotive-related noise source found in many railroad yards are locomotive load cell test stands. Diesel-electric locomotives use a diesel engine to drive an electric generator which, in turn, provides power to electric motors which turn the wheels of the locomotive. In order to perform stationary tests to determine if the diesel engine is operating properly, it is necessary to provide an electrical load to the generator which simulates the load supplied by the electric motors when the locomotive is in motion. This electrical load is generally supplied by switching the generator across a large bank of resistors. The electricity produced by the generator is then dissipated in the resistors as heat, which is convected away from the resistor bank by cooling fans.

Some types of locomotives, called self-loading, contain onboard resistor banks and cooling fans. These can be load tested anywhere in the yard, although usual practice is to test them either in the maintenance or service area. To test locomotives which are not self-loading, locomotive load cell test stands are used. Such test stands consist of a resistor bank, cooling fans, and connecting cables. These are usually housed in some sort of protective shed. Locomotive load cell test stands are usually located in the maintenance or repair areas of a yard.

The primary source of noise at locomotive load cell test stands is the locomotive under test; although, at low throttle settings, the noise from the test cell cooling fans can also contribute a detectable amount of energy to the total acoustic field.

The noise emissions into the community from stationary, idling locomotives, from moving locomotives, and from locomotive load cell test stands are regulated by the United States Code of Federal Regulations – 40 CFR Part 201. In Sections 4.1.1 and 4.1.2, respectively, the regulations and acoustic metrics for each of these noise sources are described. In Sections 4.1.3 through 4.1.5, the common measurement site requirements, instrumentation, and measurement procedures for these sources are described. The data bases of current noise levels from locomotives and locomotive load cell test stands are given in Section 4.1.6, while noise abatement techniques for these source are discussed in Section 4.1.7.

4.1.1 Regulations

4.1.1.1 Stationary Locomotives

On January 4, 1980, the U.S. Environmental Protection Agency published updated regulations specifying noise emission standards for stationary locomotives in rail yard operation. The noise limits set forth in the standard are summarized in Table 4-1.

Table 4-1

Noise Emission Standard For Stationary Locomotives

Date Effective	Date of Manufacture of Locomotive	Type of Locomotive	Throttle Setting	Maximum Permitted A-Weighted Sound Level, dB (1)	Tolerance, dB(2)
Dec. 31, 1976	On or Before December 31, 1979	Any	Idle	73	2
			Other	93	2
	After Dec. 31, 1979	Any	Idle	70	2
			Other	87	2
Jan. 15, 1984	Any	Switcher(3) Only	Idle	70(4)	(5)
			Other	87(4)	(5)

(1) When measured at a distance of 100 feet using slow response.

(2) The FRA Noise Emission Compliance Regulations, 49 CFR Part 210.

(3) Switcher locomotives are those locomotives listed in Table 4-2.

(4) These locomotives are deemed to be in compliance with this regulation if the L90 from stationary locomotives does not exceed 65 dB when measured with fast meter response at any nearby receiving property. (At the time of the preparation of this handbook, 40 CFR Part 201 specifies slow meter response. This will be modified to fast response by a Technical Amendment soon to be promulgated by the U.S. Environmental Protection Agency.)

(5) Allowed tolerance had not been specified by FRA at the time of publication of this handbook.

The regulation in 40 CFR Part 201 is as follows:

§ 201.11 Standard for locomotive operation under stationary condition.

(a) Commencing December 31, 1976, no carrier subject to this regulation shall operate any locomotive to which this regulation is applicable, and of which manufacture is completed on or before December 31, 1979, which produces A-weighted sound levels in excess of 93 dB at any throttle setting except idle, when operated singly or when connected to a load cell, or in excess of 73 dB at idle when operated singly, and when measured in accordance with the criteria specified in Subpart C of this part with slow meter response at a point 30 meters (100 feet) from the geometric center of the locomotive along a line that is both perpendicular to the centerline of the track and originates at the locomotive geometric center.

(b) No carrier subject to this regulation shall operate any locomotive to which this regulation is applicable, and of which manufacture is completed after December 31, 1979, which produces A-weighted sound levels in excess of 87 dB at any throttle setting except idle, when operated singly

Table 4-2

Switcher Locomotives Defined in 40 CFR Part 201

Type	Engine
General Electric Co.	
44 ton	8-D17000(2)
70 ton	6-CBFWL-6T
95 ton	6-CBFWL-6T
Electromotive Division (GMC)	
SC	8-201A
NC	12-201A
NC1	12-201A
NC2	12-201A
NW	12-201A
NW1	12-201A
NW1A	12-201A
NW2	12-567
NW2	12-567A
NW3	12-567
NW4	12-201A
NW5	12-567B
SW	8-201A/6-567
SW1	6-567A/AC
SW2	6-567
SW3	6-567
SW600	6-567C
SW7	12-567A
SW8	8-567B/BC
SW900	8-567B
SW9	12-567B/BC/C
SW1200	12-567C
SW1000	8-645E
SW1001	8-645E
SW1500	12-645E
MP15	12-645E
MP15AC	12-645E
GMD1	12-567C
RS1325	12-567C
Transfer Switcher Including "Cow and Calf"	
T	12-201A(2)
TR	12-567(2)
TR1	16-567(2)
TR2	12-567A(2)
TR3	12-567(3)
TR4	12-567A(2)
TR5	12-567B(2)
TR6	8-567B(2)

Type	Engine
Baldwin	
VO-660	6-VO
DS-446	6-606NA
DS4475	6-750
S-8	6-606
VO-1000	8-VO
DS-4410	8-608NA
DS-4410	6-606SC
S-12	6-606A
DRS-4410*	6-606SC
DRS-12*	6-606A
Fairbanks Morse	
H-10-44	6-OP
H-12-44	6-OP
H-12-44TS	6-OP
H-12-46*	6-OP
Lima	
750 hp	6-Hamilton
800 hp	6-Hamilton
1000 hp	8-Hamilton
1200 hp	8-Hamilton
LRS*	8-Hamilton
TL*	8-Hamilton(2)
ALCO and MLW	
S1	6-539NA
S2	6-539T
S3	6-539NA
S4	6-539T
S5	6-251
S6	6-251A,B
S7	6-539
S10	6-539
S11	6-539
S12	6-539T
S13	6-251C
RSD-1	6-539
RSC-13	6-539
RSC-24	12-244
RS1	6-539T
RS2*	12-244
RS3*	12-244
RS10*	12-244
RSC-2*	12-244
RS3*	12-244
RSD-4*	12-244
RSD-5*	12-244
T6	6-251B
C-415*	8-251F
M-420TR	12-251

* These models may be found assigned to road service as well as switcher service, but are considered switcher locomotives for the purpose of this regulation.

or when connected to a load cell, or in excess of 70 dB at idle when operated singly, and when measured in accordance with the criteria specified in Subpart C of this part with slow meter response at a point 30 meters (100 feet) from the geometric center of the locomotive along a line that is both perpendicular to the centerline of the track and originates at the locomotive geometric center.

(c) Commencing January 15, 1984, no carrier subject to this regulation may operate any switcher locomotive to which this regulation is applicable, and of which manufacture is completed on or before December 31, 1979, which produces A-weighted sound levels in excess of 87 dB at any throttle setting except idle, when operated singly or when connected to a load cell, or in excess of 70 dB at idle, and when measured in accordance with the criteria specified in Subpart C of this part with slow meter response at a point 30 meters (100 feet) from the geometric center of the locomotive along a line that is both perpendicular to the centerline of the track and originates at the locomotive geometric center. All switcher locomotives that operate in a particular railroad facility are deemed to be in compliance with this standard if the A-weighted sound level from stationary switcher locomotives, singly or in combination with other stationary locomotives, does not exceed 65 dB when measured with slow* meter response at any receiving property measurement location near that particular railyard facility and when measured in accordance with Subpart C of this regulation.

* This will be modified to fast by a Technical Amendment soon to be promulgated by the U.S. Environmental Protection Agency.

4.3.1.2 Moving Locomotives

On January 4, 1980, the Environmental Protection Agency published updated regulations specifying noise emission standards for moving locomotives in rail yard operation. The noise limits set forth in the standard are summarized in Table 4-3:

Table 4-3

Noise Emission Standard For
Moving Locomotives in Rail Yard Service

Date Effective	Date of Manufacture of Locomotive	Type of Locomotive	Maximum Permitted A-Weighted Sound Level, dB(1)	Tolerance, dB(2)
Dec. 31, 1976	On or Before Dec. 31, 1979	Any	96	2
	After Dec. 31, 1979	Any	90	2
[illegible] 5, 1984	Any	Switcher(3) Only	90(4)	(5)

(1) When measured at a distance of 100 feet with fast response at any time under any condition of grade, load, acceleration, or deceleration.

(2) Re: FRA Noise Emission Compliance Regulations, 49 CFR Part 210.

(3) Switcher locomotives are those locomotives listed in Table 4-2.

(4) These locomotives are deemed to be in compliance with this regulation if the L90 from stationary locomotives does not exceed 65 dB when measured with fast meter response at any nearby receiving property.

(5) Allowed tolerance had not been specified by FRA at the time of publication of this handbook.

The regulation in 40 CFR Part 201 is as follows:

§ 201.12 Standard for locomotive operation under moving condition.

(a) Commencing December 31, 1976, no carrier subject to this regulation may operate any locomotive or combination of locomotives to which this regulation is applicable, and of which manufacture is completed on or before December 31, 1979, which produces A-weighted sound levels in excess of 96 dB when moving at any time or under any condition of grade, load, acceleration, or deceleration, when measured in accordance with the criteria specified in Subpart C of this regulation with fast meter response at 30 meters (100 feet) from the centerline of any section of track having less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2,865 feet)).

(b) No carrier subject to this regulation may operate any locomotive or combination of locomotives to which this regulation is applicable, and of which manufacture is completed after December 31, 1979, which produce A-weighted sound levels in excess of 90 dB when moving at any time or under any condition of grade, load, acceleration, or deceleration, when measured in accordance with the criteria specified in Subpart C of this part with fast meter response at 30 meters (100 feet) from the centerline of any section of track having less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2,865 feet)).

(c) Commencing January 15, 1984, no carrier subject to this regulation may operate any switcher locomotive or a combination of switcher locomotives to which this regulation is applicable, and of which manufacture is completed on or before December 31, 1979, which produce A-weighted sound levels in excess of 90 dB when moving at any time or under any condition of grade, load, acceleration, or deceleration, and when measured in accordance with the criteria in Subpart C of this part with fast meter response at 30 meters (100 feet) from the centerline of any section of track having less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2,865 feet)). All switcher locomotives that operate in a particular railroad facility are deemed to be in compliance with this standard if the A-weighted sound level from stationary switcher locomoties, singly or in combination with other stationary locomotives, does not exceed 65 dB when measured with fast meter response at any receiving property measurement location near that particular railyard facility and when measured in accordance with Subpart C of this regulation.

4.1.1.3 Locomotive Load Cell Test Stands

On January 4, 1980, the U.S. Environmental Protection Agency published regulations specifying noise emission standards for locomotive load cell test stands. The noise limits set forth in the standard are summarized in Table 4-4.

Table 4-4

Noise Emission Standard For Locomotive Load Cell Test Stands

Date Effective	Maximum Permitted A-Weighted Sound Level(1)
Jan 15, 1984	78 dB(2)

(1) When measured at a distance of 100 feet with slow response. An allowed tolerance for this measurement had not been specified at the time of publication of this handbook.

(2) If the clear-zone requirement (see Figure 4-1 in Table 4-8) cannot be met at a specific load cell test stand site, that site is deemed to be in compliance if the L_{90} from the load cell does not exceed 65 dB when measured with fast response at any nearby non-railroad receiving property measurement location which is at least 400 feet from the geometric center of the locomotive being tested.

The regulation in 40 CFR Part 201 is as follows:

§ 201.16 Standard For Locomotive Load Cell Test Stands.

(a) Effective January 15, 1984, no carrier subject to this regulation shall operate locomotive load cell test stands that exceed an A-weighted sound level of 78 dB when measured with slow meter response in accordance with Subpart C of this part excluding § 201.23 (b) and (c), at a point 30 meters (100 feet) from the geometric center of the locomotive undergoing test, along a line that is both perpendicular to the centerline of the track and originates at the locomotive geometric center, and in the direction most nearly towards the closest receiving property measurement location. All locomotive load cell test stands in a particular railroad facility are in compliance with this standard if the A-weighted sound level from the load cells does not exceed 65 dB at a receiving property measurement location near that particular railyard facility and when measured with fast meter response in accordance with Subpart C of this regulation.

(b) If the conditions of any part of § 201.23(a) cannot be met at a specific load cell test stand site, then the A-weighted sound level from that specific load cell test stand must not exceed 65 dB when measured with fast meter response at a receiving property measurement location more than 120 meters (400 feet) from the geometric center of the locomotive being tested and in accordance with Subpart C of this regulation.

4.1.2 Acoustic Metrics

4.1.2.1 Stationary Locomotives and Locomotive Load Cell Test Stands

The metric used in these regulations for noise emission from stationary locomotives and from locomotive load cell test stands is summarized in Table 4-5.

Table 4-5

Acoustic Metric For Stationary Locomotives And Locomotive Load Cell Test Stands

A-WEIGHTED SOUND LEVEL
"SLOW" METER RESPONSE

As stated in § 201.21 of the regulations:

The quantities to be measured under the test conditions described below, are the A-weighted sound levels for "slow" meter response as defined in the American National Standard S1.4-1971.[1] *

4.1.2.2 Moving Locomotives

The metric used in these regulations for noise emission from moving locomotives is summarized in Table 4-6.

Table 4-6

Acoustic Metric For Moving Locomotives

A-WEIGHTED SOUND LEVEL
"FAST" METER RESPONSE

As stated in § 201.21 of the regulations:

The quantities to be measured under the test conditions described below, are the A-weighted sound levels for "fast" meter response as defined in the American National Standard S1.4-1971.[1]

4.1.2.3 Receiving Property

The metric used at receiving property measurement locations which acts as a "trigger" to determine if noise levels of individual switcher locomotives or locomotive load cell test stands within a facility need be measured is summarized in Table 4-7.

Table 4-7

Acoustic Metric For Receiving Property Measurement Locations

L_{90}
"FAST" METER RESPONSE

As stated in § 201.27 of the regulations:

(b) Data: (1) When there is evidence that at least one of these two types (locomotive load cell test stand and/or switcher locomotive) of nearly steady state sound sources is affecting the noise environment, the following measurements must be made. The purpose of these measurements is to determine the A-weighted L90 statistical sound level, which is to be used as described in subparagraph (c) below to determine the applicability of the source standards. Before this determination can be made, the measured L90 is to be "validated" by comparing the measured L10 and L99 statistical sound levels. If the difference between these levels is sufficiently small (4 dB or less), the source(s) being measured is considered to be a nearly steady state source.

* Superscripts refer to references at end of chapter.

(2) Data shall be collected by measuring the instantaneous A-weighted sound level (FAST) at a rate of at least once each 10 seconds for a measurement period of at least 15 minutes and until 100 measurements are obtained. The data may be taken manually by direct reading of the indicator at 10-second intervals (±1 second), or by attaching a statistical analyzer, graphic level recorder, or other equivalent device to the sound level meter for a more continuous recording of the instantaneous sound level.

(3) The data shall be analyzed to determine the levels exceeding 99%, 90%, and 10% of the time, i.e., L99, L90, and L10, respectively. The value of L90 is considered a valid measure of the A-weighted sound level for the standards in § 201.16 only if the difference between L10 and L99 has a value of 4 dB or less. If a measured value of L90 is not valid for this purpose, measurements may be taken over a longer period to attempt to improve the certainty of the measurement and to validate L90. If L90 is valid and is less than the level in applicable standards for these source types, the sources are in compliance. If the measured value of L90 is valid and exceeds the initial 65 dB requirement for any of the source types that appear to be affecting the noise environments, the evaluation according to the following subparagraph (c) is required.

4.1.3 Measurement Site Selection

Three different measurement site criteria are applicable to locomotive and to load cell test stand noise measurements. The first, which applies to all locomotive measurements and to load cell test stand measurements, defines a site at a distance of 100 feet from the locomotive. The second, which applies only to switcher locomotives and to certain load cell test stand measurements, defines a site on nearby non-railroad receiving property. This measurement site is used to determine if it is necessary to measure switcher locomotives at the 100-foot position. It is also used for load cell test stand measurements if the required clear-zone (Figure 4-1 of Table 4-8) is not present. The third, which is meant to simulate the acoustic field on non-railroad receiving property, allows measurements to be made by the railroad on its own property.

Table 4-8 defines the measurement site criteria for the 100-foot measurement position. Table 4-9 defines the site criteria for the receiving property "trigger" measurements that are used to determine if switcher locomotive measurements must be carried out.

To determine whether it is probably complying with the locomotive and/or load cell test stand regulations, and therefore whether it should institute noise abatement, a railroad may simulate receiving property measurements by taking measurements on its own property at locations that:

(1) Are between the source and receiving property,

(2) Derive no greater benefit from shielding and other noise reduction features than does the receiving property, and

(3) Otherwise meet the requirements of Table 4-9.

When noise from locomotive load cell test stands is being measured, the 100-foot measurement position should be chosen along a line that is both perpendicular to the centerline of the track and originates at the locomotive geometric center, and in the direction most nearly towards the closest receiving property. If the measurement site clear-zone criteria in Table 4-8 cannot be met at this location, then a measurement must be made at a receiving property measurement location more than 400 feet from the geometric center of the locomotive being tested.

The "100-foot" measurement site selection conditions as stated in § 201.23 of the regulations are as follows:

(a) The standard test site shall be such that the locomotive or train radiates sound into a free field over the ground plane. This condition may be considered fulfilled if the test site consists of an open space free of large, sound-reflecting objects, such as barriers, hills, signboards, parked vehicles, locomotives or rail cars on adjacent tracks, bridges or buildings within the boundaries described by Figure 1, as well as conforms to the other requirements of this § 201.23.

(b) Within the complete test site, the top of at least one rail upon which the locomotive or train is located shall be visible (line of site) from a position 1.2 meters (4 feet) above the ground at the microphone location, except as provided in paragraph (c) of this section.

(c) Ground cover such as vegetation, fenceposts, small trees, telephone poles, etc., shall be limited within the area in the test site between the vehicle under test and the measuring microphone such that 80 percent of the top of at least one rail along the entire test section of track be visible from a position 1.2 meters (4 feet) above the ground at the microphone location; except that no single obstruction shall account for more than 5 percent of the total allowable obstruction.

Table 4-8

Measurement Site Requirements for Moving and Stationary Locomotives,* Railroad Cars, and Locomotive Load Cell Test Stand Noise Measurements

TEST SITE

Open space with no large reflecting objects within 100 feet of the source or the measurement position (see Figure 4-1).

SITE ELEVATION

The top of at least one rail must be visible from 4 feet above the ground at the microphone location.

GROUND COVER

At least 80 percent of the rail must be visible from the microphone position with no ground cover (trees, grass, fences, etc.) obstructing the view.

MICROPHONE POSITION

The microphone must be 4 feet above the ground. The ground elevation at the microphone location must be between 10 feet below and 5 feet above the elevation of the top of the rail at position A in Figure 4-1.

TRACK CONDITIONS
(Moving Locomotives and Railroad Cars Only)

Less than 2-degree curve or a radius greater than 2,865 feet.

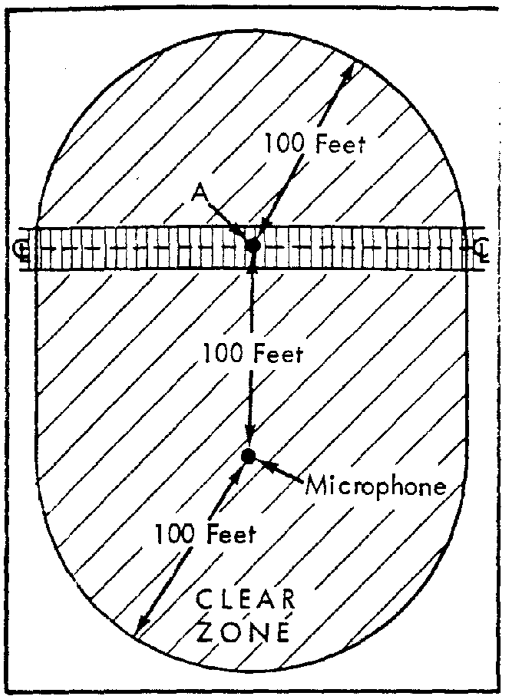


Figure 4-1. Test Site Clearance Requirement For Locomotive and Locomotive Load Cell Test Stand Noise Measurements.

WEATHER CONDITIONS

Measurements should be taken only under these conditions:

- No precipitation (rain, snow, sleet, hail, etc.).
- Wind speed below 12 mph.
- Wind gusts below 20 mph.

BACKGROUND NOISE LEVEL

The maximum A-weighted fast response sound level measured at the test site immediately before and after the source test must be at least 10 dB lower than that of the source being measured.

* Relaxed requirements for carrying out measurements on stationary locomotive under load are discussed in the text.

Table 4-9

Receiving Property* Site Requirements For
Switcher Locomotive and Locomotive Load Cell Test Stand Noise Measurements

<table>
<tr><td>

TEST SITE

Located on receiving property with no vertical plane surfaces exceeding 4 feet in height within 33.3 feet of the microphone position. The following structures are exempt from the above requirement:

- Residential or commercial unit wall located at least 6.6 feet from the microphone position;
- Facility boundary noise barrier.

If the residential structure is a farm home, the microphone must be located between 6.6 feet and 33.3 feet away from the wall.

MICROPHONE POSITION

The microphone must be positioned at a height between 4 feet to 5 feet above the ground.

WEATHER CONDITIONS

Measurements should be taken only under these conditions:

- No precipitation (rain, snow, sleet, hail, etc.).
- Wind speed below 12 mph.
- Wind gusts below 20 mph.

</td></tr>
</table>

* In the context of the regulation, "receiving property" refers to non-railroad property. (See definition of receiving property in Appendix A.)

(d) The ground elevation at the microphone location shall be within plus 1.5 meters (5 feet) or minus 3.0 meters (10 feet) of the elevation of the top of the rail at the location in-line with the microphone.

(e) Within the test site, the track shall exhibit less than a two (2) degree curve or a radius of curvature greater than 873 meters (2,865 feet). This paragraph shall not apply during a stationary test. The track shall be tie and ballast, free of special track work and bridges or trestles.

(f) Measurements shall not be made during precipitation.

(g) The maximum A-weighted fast response sound level observed at the test site immediately before and after the test shall be at least 10 dB(A) below the level measured during the test. For the locomotive pass-by tests this requirement applies before and after the train containing the rolling stock to be tested has passed. This background sound level measurement shall include the contribution from the operation of the load cell, if any, including load cell contribution during test.

(h) Noise measurements may only be made if the measured wind velocity is 19.3 km/hr (12 mph) or less. Gust wind measurements of up to 33.2 km/hr (20 mph) are allowed.

When carrying out "100-foot" measurements on a stationary locomotive under load, it is often difficult to meet the clear-zone requirements in Figure 4-1. This difficulty occurs when it is necessary to conduct the noise measurements at a locomotive load cell test stand, because the locomotive to be tested cannot be self-loaded. In general, such test stands are located in yard areas near reflecting objects, such as buildings, load cell structures, and other locomotives.

If a site conforming to the clear-zone requirements is not available, it may still be possible to obtain acceptably accurate measurements of locomotive noise at existing load cell test sites. Based on the results of a recent study,[2] the clear-zone requirements can be relaxed, as described below, and one should still be able to obtain measurements of locomotive noise within +1 dBA to -0.5 dBA of measurements at a conforming site.

Load Cell Requirements

- The locomotive should be located between the test microphone and load cell with no part of the load cell visible from the test microphone.
- The outlet for cooling air from the load cell should be as low as possible. High chimneys should be avoided.

Site Geometry

- The locomotive should be fully visible from the test microphone, especially the exhaust outlet and radiator cooling fan inlets and outlets.
- A single, large reflecting surface (greater than 6 feet by 6 feet) directly behind the microphone, e.g., such that the microphone is between the locomotive and the reflecting surface, can be as close as 50 feet away from the microphone. This restriction can be relaxed if it can be shown that because of the limited size and orientation of the reflecting surface no paths exist for sound to propagate from the locomotive to the microphone by reflecting off the surface.
- A single, large reflecting surface (greater than 6 feet by 6 feet) to the side of and approximately parallel to a line joining the center of the locomotive and microphone should be 100 feet from that line as the standard requires. This restriction can be relaxed if it can be shown that no paths exist for sound to propagate from the locomotive to the microphone by reflecting off the surface.
- A single, large reflecting surface behind the locomotive, e.g., such that the locomotive is between the microphone and the surface, does not present as severe a problem because of the substantial barrier that the locomotive presents to reflected sound. If sound reflecting off that surface must pass through the locomotive in order to reach the microphone, the surface may be as close as 10 feet from the side of the locomotive.

Weather Conditions

- Requirements on weather conditions specified in the standard should be adhered to. In addition, it is desirable to locate the microphone downwind from the locomotive and to test on days with steady wind rather than on days in which the wind speed fluctuates between calm and the 20 mph wind gust limits allowed in the standard.

The receiving property measurement site selection conditions as stated in § 201.25 of the regulations are as follows:

(a) Measurements must be conducted only at receiving property measurement locations.

(b) Measurement locations on receiving property must be selected such that no substantially vertical plane surface, other than a residential or commercial unit wall or facility boundary noise barrier, that exceeds 1.2 meters (4 feet) in height is located within 10 meters (33.3 feet) of the microphone and that no exterior wall of a residential or commercial structure is located within 2.0 meters (6.6 feet) of the microphone. If the residential structure is a farm home, measurements must be made 2.0 to 10.0 meters (6.6 to 33.3 feet) from any exterior wall.

(c) No measurement may be made when the average wind velocity during the period of measurement exceeds 19.3 km/hr (12 mph) or when the maximum wind gust velocity exceeds 32.2 km/hr (20 mph).

(d) No measurement may be taken when precipitation, e.g., rain, snow, sleet, or hail, is occurring.

4.1.4 Instrumentation

4.1.4.1 "100-Foot" Measurement Position

The instrumentation required to make noise measurements at the 100-foot position is shown in Table 4-10.

Table 4-10

Instrumentation For "100-Foot" Measurements

SOUND LEVEL METER
MICROPHONE AND WINDSCREEN
TRIPOD
SOUND LEVEL CALIBRATOR
WIND SPEED METER
ACCESSORIES

The instrumentation requirements stated in § 201.22 of the regulation are as follows:

(a) A sound level meter or alternate sound level measurement system that meets, as a minimum, all the requirements of American National Standard S1.4-1971[1] for a Type 1 (or S1A) instrument must be used with the "fast" meter response characteristic as specified in Subpart B. To insure Type 1 response, the manufacturer's instructions regarding mounting or orienting of the microphone, and positioning of the observer must be observed. In the event that a Type 1 (or S1A) instrument is not available for determining non-compliance with this regulation, the measurements may be made with a Type 2 (or S2A).

(b) A microphone windscreen and an acoustic calibrator of the coupler type must be used as recommended by: (1) the manufacturer of the sound level meter, or (2) the manufacturer of the microphone. The choice of both devices must be based on ensuring that Type 1 or Type 2 performance, as appropriate, is maintained for frequencies below 10,000 Hz.

In addition, the FRA Compliance Regulations (49 CFR Part 210, § 210.29) require that the following calibration procedures must be utilized:

(1) (i) The sound level measurement system including the microphone must be calibrated and appropriately adjusted at one or more nominal frequencies in the range from 250 through 1000 Hz at the beginning of each series of measurements, at intervals not exceeding 1 (one) hour during continual use, and immediately following a measurement indicating a violation.

(ii) The sound level measurement system must be checked out less than once each year by its manufacturer, a representative of its manufacturer, or a person of equivalent special competence to verify that its accuracy meets the manufacturer's design criteria.

(2) An acoustical calibrator of the microphone coupler type designed for the sound level measurement system in use shall be used to calibrate the sound level measurement system in accordance with paragraph (1) (i) of this subsection. The calibration must meet or exceed the accuracy requirements specified in § 5.4.1 of the American National Standard Institute Standards, "Method for Measurement of Sound Pressure Levels" (ANSI S1.13-1971),[1] for field method measurements.

4.1.4.2 Receiving Property Measurement Position

The instrumentation required to make noise measurements on nearby receiving property is shown in Table 4-11.

Table 4-11

Instrumentation For Receiving Property Measurements

SOUND LEVEL METER
OR
STATISTICAL ANALYZER
OR
GRAPHIC LEVEL RECORDER
MICROPHONE AND WINDSCREEN
TRIPOD
SOUND LEVEL CALIBRATOR
WIND SPEED METER
ACCESSORIES

The instrumentation requirements stated in § 201.27 of the regulations are as follows:

(2) Data shall be collected by measuring the instantaneous A-weighted sound level (FAST) at a rate of at least once each 10 seconds for a measurement period of at least 15 minutes and until 100 measurements are obtained. The data may be taken manually by direct reading of the indicator at 10-second intervals (±1 second), or by attaching a statistical analyzer, graphic level recorder, or other equivalent device to the sound level meter for a more continuous recording of the instantaneous sound level.

4.1.5 Measurement Procedure

The procedure to be followed when conducting locomotive or load cell test stand noise measurements is derived from the EPA noise standard regulation, the FRA compliance regulation, and common measurement practice.

The procedure is made up of five phases. They include:

- Program Planning
- Instrumentation Checkout
- Instrumentation Setup
- Data Collection
- Data Analysis

A description of these phases as applied to locomotive and load cell test stand noise measurements is presented in the rest of this section. Where appropriate, sample worksheets are included. These may be copied directly or may be used as a basis for designing a more personalized format.

4.1.5.1 Program Planning

The first stage of the measurement program is program planning. It is during this phase that decisions are made concerning such factors as whether or not receiving property measurements are to be made, the number of locomotives or load cell test stands to be tested, specifically which locomotives or which test stands will be tested, the locations and number of test sites, and the day and time the measurements are to be made. Permission to be allowed access to the measurement locations at the time desired should be obtained from the responsible railroad official or, if on non-railroad property, from the property owner. The number of people to carry out the measurements should be determined and specific individuals assigned to the measurement team. Most field measurements involving moving or changing sources require at least two people – one to observe and record the sound level measurements, the other to determine and note other characteristics of the noise source (e.g., type, identification, location, speed, etc.).

It is also at this point that the instrumentation system is specified and acquired. The system used for locomotive noise measurements will normally consist of a Type 1 or 2 sound level meter with a calibrator, windscreen, and tripod. Other useful equipment include a wind speed-measuring device, a 100-foot tape measure, and thermometer.

A program planning worksheet is shown in Figure 4-2. This is useful in assuring that all of the planning details are carried out.

4.1.5.2 Instrumentation Checkout

Before proceeding to the field for measurements, the instrumentation system should be put together and thoroughly checked out and the manufacturer's instructions referred to for calibration and operational procedures. The batteries must be tested and all interconnecting cables and mounting hardware should be connected to assure that the correct plugs fit into the proper instruments, and that the overall system works as required. The accessories such as extra batteries, note pads, adhesive tape, and the like, should be assembled.

An inventory of the necessary equipment and a measurement site qualification worksheet should be prepared and brought into the field. This assures that once the measurement program has begun no details will be forgotten. Samples of inventory and site qualification worksheets are shown in Figures 4-3 and 4-4. The inventory sheet is meant to be quite general; thus depending on the situation, it may not be necessary to take all the equipment listed.

4.1.5.3 Instrumentation Setup

Before proceeding to the measurement site, the person in charge of the property on which the measurements are to be taken should be informed of the presence of the measurement team. At the site, the instrumentation system should be set up according to the manufacturer's instructions. The inventory worksheet should be referred to at this time. The measurement site qualification should be verified, using the measurement site qualification worksheet.

The sound level meter should be mounted on a tripod with the microphone at a level of 1.2 meters (4 feet) above the ground. A windscreen should always be attached to the microphone. The sound level meter may be tilted to allow ease of reading, and the microphone should be oriented according to manufacturer's instructions. This is critical, since certain microphones (perpendicular incidence) are designed to be pointed directly at the major noise source, other microphones (grazing incidence) are designed to be pointed at right angles to the line between the observer and the noise source, and still others (random incidence) are designed to be oriented in a direction intermediate to these two.

PROGRAM PLANNING WORKSHEET

Locomotives and Locomotive Load Cell Test Stands

Date: ____________________ Prepared By: ____________________________________

Check When Completed

Test Plan

_____ Decide if receiving property measurements are to be made.

_____ Determine when and where the receiving property measurements will be made.

_____ Determine the number of locomotives or test stands to be tested.

_____ Determine when and where the measurements will be made.

_____ Identify by locomotive number the units to be tested.

_____ For each unit, determine what throttle settings will be used in the test.

_____ Obtain permission to carry out measurements at desired location.

Instrumentation Checkout

_____ Specify the instrumentation system required for the measurements.

_____ Acquire the components of the instrumentation system.

_____ Check out and calibrate the instrumentation system.

_____ Complete the instrumentation system inventory worksheet.

_____ Pack the instrumentation system for shipment to the measurement site.

_____ Check current weather conditions, reschedule test if necessary.

Measurement Site Setup

_____ Check in with person responsible for measurement site property.

_____ Complete measurement site qualification worksheet.

_____ Unpack instrumentation system, checking against inventory worksheet.

_____ Set up the instrumentation system and check components for damage.

_____ Calibrate the system and report results on the field data log.

_____ Complete the annotation on the field data log.

Noise Measurements

_____ Conduct noise measurements.

_____ Record results on the field data log.

_____ Check calibration of the system and record results on the field data log.

_____ Repack system for return shipment, referring to inventory checksheet.

Program Completion

_____ Unpack instrumentation system; check for damage.

_____ Document measurement program.

Figure 4-2. Sample Program Planning Worksheet.

INSTRUMENTATION SYSTEM INVENTORY WORKSHEET

Locomotives and Locomotive Load Cell Test Stands

Date: ____________ Prepared By: ______________________________

Location: ____

INSTRUMENT	Make	Model	Serial No.	Date of Last Calibration	Check Out	Return
Sound Level Meter (SLM)						
Microphone						
Sound Level Calibrator						
Wind Speed Measuring Device						

REQUIRED (*) AND RECOMMENDED ACCESSORIES	Checkout	Return
* Microphone Windscreen		
* SLM Calibration Adjustment Tool (Screwdriver)		
* Tripod		
* Tape Measure		
Thermometer		
Hygrometer		
Watch		
Extra Batteries		
Duct Tape		
Connecting Cables		
Flashlight		
Weather Radio		
Camera and Film		
Ground Cloth		
Earphones		
Tools (screwdriver, pliers, etc.)		

Figure 4-3. Sample Instrumentation System Inventory Worksheet.

MEASUREMENT SITE QUALIFICATION WORKSHEET

Locomotives and Locomotive Load Cell Test Stands

Date: ________________ Prepared By: ______________________________

Location: ____

____

Receiving Property Measurement Site:	YES	NO
Is the measurement site on a receiving property?	___	___
Have the test area clear-zone requirements been met?	___	___
Has the microphone elevation requirement been met?	___	___
Will the ambient weather conditions permit noise emission tests?	___	___
Wind Speed Below 12 mph?	___	___
Wind Gusts Below 20 mph?	___	___
No precipitation condition met?	___	___
Will the ambient sound level conditions permit noise emission tests?	___	___
Has a sketch been made of the measurement site?	___	___
Have photographs been taken of the measurement site?	___	___
Measurement Site 100 Feet From Locomotive:		
Have the test area clear-zone requirements been met?	___	___
Have the site ground contour requirements been met?	___	___
Have the track conditions requirements been met?	___	___
Have the site ground cover requirements been met?	___	___
Has the microphone elevation requirement been met?	___	___
Will the ambient weather conditions permit noise emission tests?	___	___
Wind Speed Below 12 mph?	___	___
Wind Gusts Below 20 mph?	___	___
No precipitation condition met?	___	___
Will the ambient sound level conditions permit noise emission tests?	___	___
Has a sketch been made of the measurement site?	___	___
Have photographs been taken of the measurement site?	___	___

Figure 4-4. Sample Measurement Site Qualification Worksheet.

The operator should stand as far away from the meter as possible, consistent with his ability to make the sound level readings easily. When possible, the microphone/preamplifier assembly should be mounted remote from the sound level meter so that there is less chance of the observer's affecting the measured data.

Care should be taken to make sure that there is nothing between the microphone position and the sound source which may interfere with the sound propagation. Nearby reflecting objects, such as walls behind the microphone, should be avoided. When making source measurements, reflecting surfaces behind and to the sides of the source should be avoided.

The sound level meter should be calibrated by adjusting the meter to read the level generated by the calibrator, according to the manufacturer's instructions. This should be done prior to the beginning of measurements, and noted in the field data log.

A sketch should be drawn of the measurement area, which includes all audible noise sources and their approximate location with respect to the measurement position. The location of all reflecting surfaces, barriers, and other factors that may affect the sound propagation should also be noted on the sketch. An exact scale map is not necessary, but a good representation of the area, with distances to outstanding landmarks indicated, is desirable. If a detailed map of the area is available, the site area should be located on it. If possible, photographs of the area should be taken to show the noise source. A very effective way to photograph the site is to stand at the microphone position and take a series of pictures which show the full 360° view from that spot. It is also helpful to document the microphone location by stepping behind the microphone and taking a picture which shows the microphone as well as the sound source being measured.

A data log should be filled out at the beginning of each measurement. The nature of the data log will depend on whether locomotive or receiving property measurements are to be made.

A typical locomotive data log sheet is shown in Figure 4-5 and should contain the following information:

- Description of measurement location.
- Date of measurements.
- Name of person performing the measurements.
- Types, models, serial numbers, or other identification characteristics for all instrumentation.
- Barometric pressure, temperature, wind velocity, and relative humidity. (This information can be measured directly or, in many cases, can be obtained from local weather radio stations.)
- Results of calibration tests.
- Measured levels and background levels.
- Description of equipment under test.
- Description of secondary noise sources.

A data log sheet which provides the means to sample manually the noise levels at receiving property measurement sites using a sound level meter is shown in Figure 4-6. The use of such a log to determine exceedance percentile sound levels, such as L_{10}, L_{90}, and L_{99}, will be explained in the next section.

A note pad should also be taken into the field and used to write extensive notes detailing anything going on which may have a bearing on the measurements or the interpretation of the data. Such incidents as unusually high railroad traffic or other atypical events are examples of the type of information which should be recorded.

4.1.5.4 Data Collection

Moving Locomotives:

The noise level of a moving locomotive should be measured as the locomotive approaches and passes by the microphone location. The maximum noise level observed during this period should be recorded on the data log.

The noise level of a moving locomotive consist should be measured as the whole consist approaches and passes the microphone location. The maximum noise level observed during this period should be recorded on the data log.

Locomotives or locomotive consists within a train which are separated by at least ten rail car lengths or 500 feet should be treated as separate units and noise levels for each should be measured and recorded on the data log.

FIELD DATA LOG

Locomotives and Locomotive Load Cell Test Stands

(PART A — Use For Each Continuous Measurement Period)

Date: ____________________ Prepared By: ______________________________________

Location: ____

____

EQUIPMENT:

Instrument	Manufacturer	Model	Serial No.	Date of Last Calibration
Sound Level Meter				
Microphone				
Calibrator				

WEATHER CONDITIONS:

	Time	Wind Speed	Direction	Temp.	Rel.Hmdty.	Bar.Pres.
Pre-Test						
Post-Test						

CALIBRATION: Calibration Level: ________ dB; Calibrator Frequency: ________ Hz

Time						
Sound Level						

BACKGROUND LEVEL:

Time						
A-Weighted Sound Level						

Figure 4-5. Sample Locomotive Field Data Log.

FIELD DATA LOG (Continued)

Locomotives and Locomotive Load Cell Test Stands

(PART B — Use One Sheet For Each Source)

SOURCE PARAMETERS AND LEVELS:

______ Single Locomotive   ______ Locomotive Load Cell Test Stand

______ Locomotive Consist (Number of Units: ______)

Time	Locomotive I.D.			Year of Manufacture	Throttle Setting	Speed	A-Weighted Sound Level, dB	Comments
	RR	No.	Type(1)					

(1) R = Road Unit, S = Switcher

Load Cell Test Stand Description: ________________________________

Other Noise Sources: ________________________________

SKETCH OF SITE GEOMETRY:

↑ N

Figure 4-5 (Concluded).

FIELD DATA LOG

Receiving Property Measurements

Date: ____________________ Prepared By: ______________________________________

Location: ____

____

EQUIPMENT:

Instrument	Manufacturer	Model	Serial No.	Date of Last Calibration
Sound Level Meter				
Microphone				
Calibrator				

WEATHER CONDITIONS:

	Time	Wind Speed	Direction	Temperature	Relative Humidity	Barometric Pressure
Pre-Test						
Post-Test						

CALIBRATION:

Calibrator Level: __________ dB Calibrator Frequency: __________ Hz

Time						
Sound Level						

MAJOR NOISE SOURCES: ____

____

____

SKETCH OF SITE GEOMETRY:

↑ N

Figure 4-6. Sample Receiving Property Field Data Log.

FIELD DATA LOG (Continued)

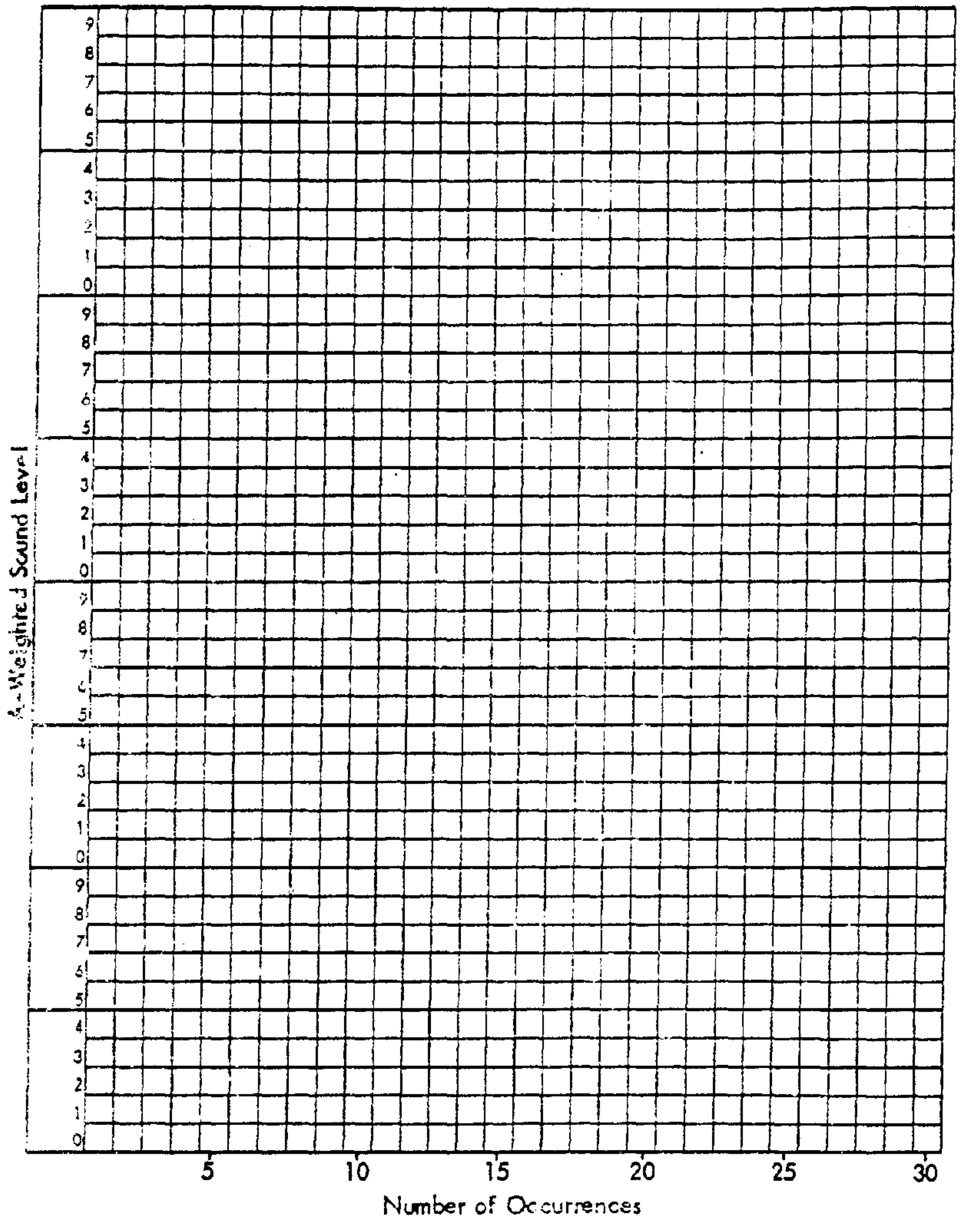
Receiving Property Measurements

Date: ______________ Prepared By: ______________________________

Location: ____

____

Start Time ____________________ Stop Time ____________________



L_{10} = ______

L_{90} = ______

L_{99} = ______

$L_{10} - L_{99}$ = ______

$L_{10} - L_{99} \leq 4$ dB?

☐ YES: L_{90} Validated.

☐ NO: L_{90} Not Validated

Figure 4-6 (Concluded).

Stationary Locomotives:

The following procedures are recommended for performing measurements of stationary locomotives:

- Position the locomotive so that its longitudinal midpoint lies at "A" in Figure 4-1.
- Set the throttle at the desired setting and turn on all cooling fans.
- Observe the A-weighted sound level (slow response) for 30 seconds after the throttle setting has been established. Record the maximum observed sound levels on the data sheet.

Locomotive Load Cell Test Stands:

The following procedures are recommended for performing measurements of locomotive load cell test stands:

- Position the locomotive so that its longitudinal midpoint lies at "A" in Figure 4-1.
- Connect the locomotive to the load cell.
- Set the throttle at the desired setting (notch "8" will generally produce the loudest noise) and turn on all cooling fans.
- Observe the A-weighted sound level (slow response) for 30 seconds after the throttle setting has been established. Record the maximum observed sound level on the data sheet.

Receiving Property Noise Measurements:

The procedures described below are designed for the measurement of L_{90} at receiving property locations using a sound level meter. This level will be used as a "trigger" to determine if individual switcher locomotive or locomotive load cell test stand noise levels must be measured. It must also be used if the "100-foot" measurement site criteria cannot be met for the test stand.

A. For measurement locations where idling switcher locomotives or load cell test stands affect the noise environment, observers should take 100 successive measurements of the A-weighted sound level using the "fast" meter response at 10-second intervals. Record each of these data samples in histogram format as shown in Figure 4-7. Figure 4-6 shows a typical worksheet that can be used for this purpose.

B. Using the histogram developed in Figure 4-7, determine the values of L_{10}, L_{90}, and L_{99}. L_{10} is the sound level exceeded 10 percent of the time and is approximated by the level corresponding to the 10th sample from the top of the histogram. L_{90} is the sound level exceeded 90 percent of the time and is approximated by the level corresponding to the 90th sample from the top of the histogram (or more easily by the 11th sample from the bottom of the histogram). L_{99} is the sound level exceeded 99 percent of the time and is approximated by the level corresponding to the next to last sample in the histogram. Figure 4-8 repeats the example of Figure 4-7, showing the above-indicated samples and their corresponding sound levels.

C. If $L_{10} - L_{99}$ is 4 dB or less, the value of L_{90} is validated and the measurements may be terminated. Note the values of L_{10}, L_{90}, and L_{99}, and go on to Step E.

D. If $L_{10} - L_{99}$ is greater than 4 dB, take an extra 100 measurements as before combining them with the previous data. Since there are now 200 total samples in the histogram, L_{10} is the level corresponding to the 20th sample from the top, L_{90} is the level corresponding to the 21st sample from the bottom, and L_{99} is the level corresponding to the 3rd sample from the bottom. If $L_{10} - L_{99}$ is now 4 dB or less, note the new values of L_{10}, L_{90}, and L_{99}, and go on to Step E. If $L_{10} - L_{99}$ is still greater than 4 dB, more measurements may be taken until the value of L_{90} is validated. If the value of L_{90} cannot be validated, state so on the data sheet, and discontinue measurements at that location.

E. Note the number and location of idling switcher locomotives for each series of measurements. Also try to identify the major source of noise if this is possible. If not, indicate so.

4.1.5.5 Data Analysis

The measurements of A-weighted sound levels from locomotives or load cell test stands require no further processing. They either conform to the regulatory limits (within the 2 dB tolerance allowed by the FRA compliance regulation) or they do not.

The measurement of a valid L_{90} (i.e., one for which $L_{10} - L_{99} \leq 4$ dB) in excess of 65 dB at a receiving property location requires further analysis to determine the applicability of the standard. In such a case, the following steps, as stated in § 201.27 of the regulation, must be carried out:

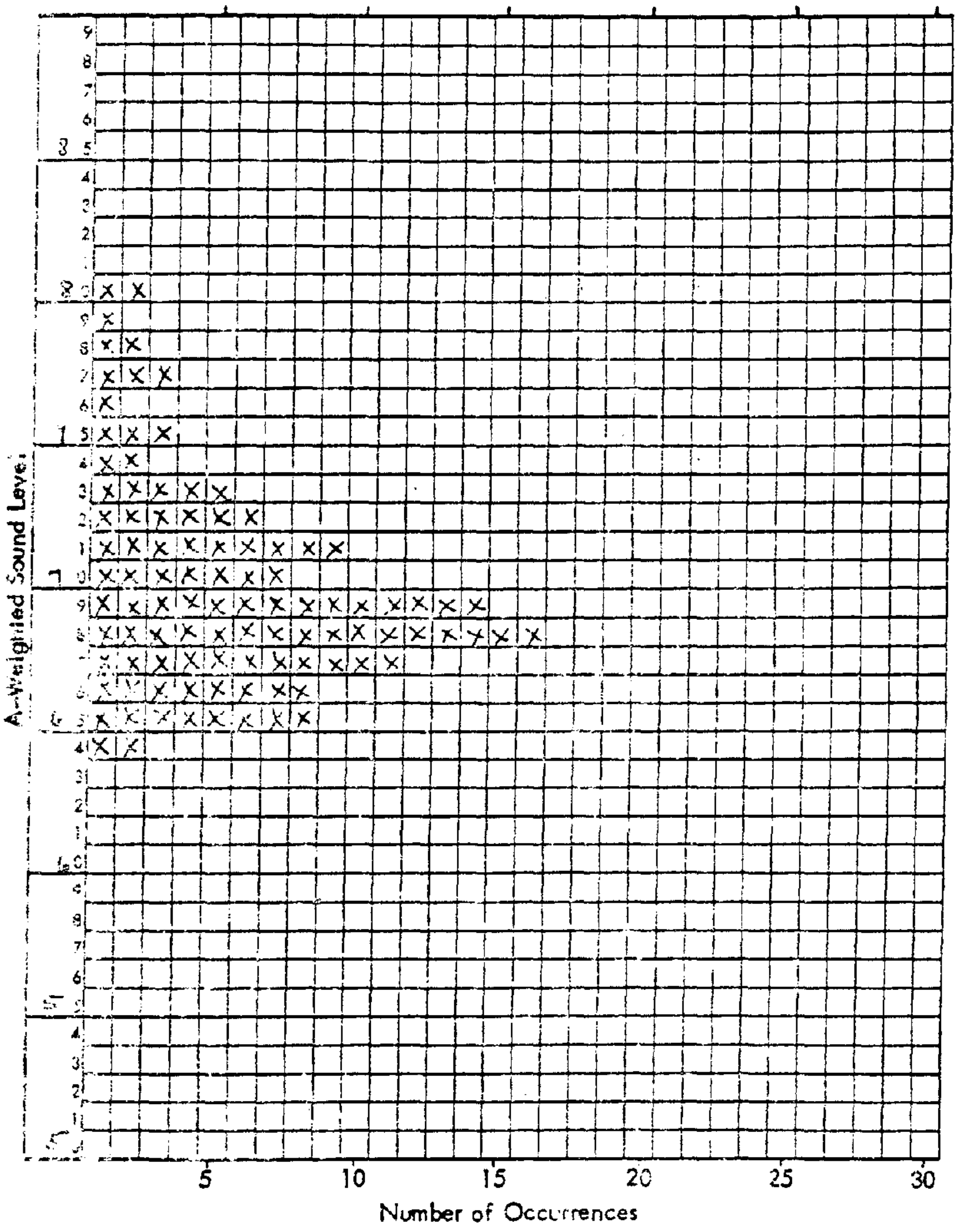
FIELD DATA LOG

Receiving Property Measurements

Date: FEB. 5, 1980 Prepared By: A. W. LEVEL

Location: IN FRONT OF 2130 CONCOURSE RD. - APPROX. 500 FEET ACROSS TWO-LANE SECONDARY ROAD FROM RR PROPERTY.

Start Time 1500 hrs. Stop Time 1517 hrs.



L_{10} = ______

L_{90} = ______

L_{99} = ______

$L_{10} - L_{99}$ = ______

$L_{90} - L_{99} \leq 4$ dB?

☐ YES: L_{90} Validated.

☐ NO: L_{90} Not Validated.

Figure 4-7. Example of Completed Receiving Property Field Data Log.

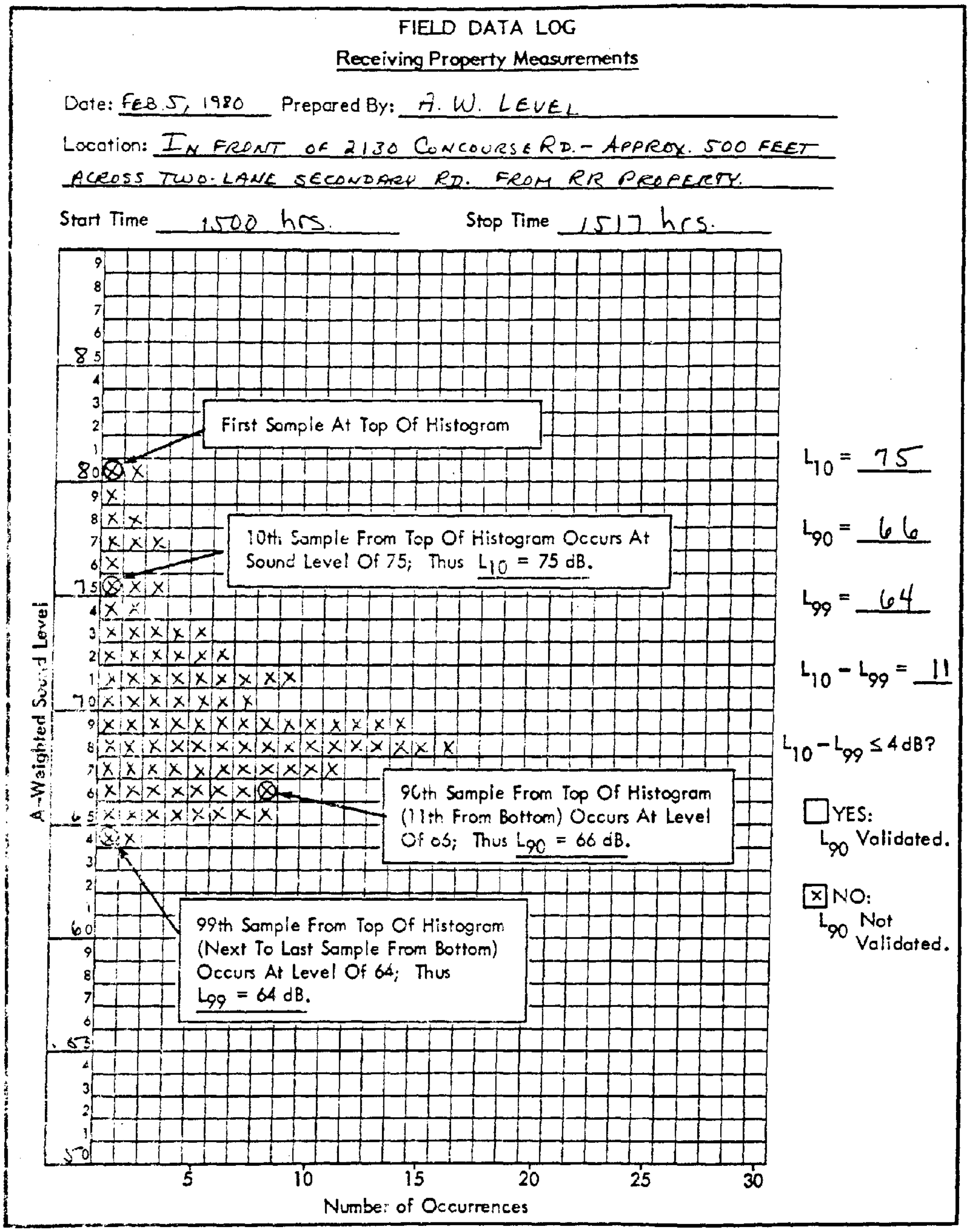


Figure 4-8. Determination of L10, L90, and L99 From Completed Receiving Property Field Data Log.

(1) The principal direction of the nearly steady-state sound at the measurement location must be determined, if possible, by listening to the sound and localizing its apparent source(s). If the observer is clearly convinced by this localization process that the sound emanates only from one or both of these two sources (locomotive load cell test stands and/or stationary switcher locomotives), then:

(i) If only stationary locomotive(s), including at least one switcher locomotive, are present, the value of L_{90} is the value of the A-weighted sound level to be used in determining if the 65 dB requirement is exceeded and compliance with the standards for moving and stationary switcher locomotives is necessary.

(ii) If only a locomotive load cell test stand and the locomotive being tested are present and operating, the value of L_{90} is the value of the A-weighted sound level to be used in determining applicability of the locomotive load cell test stand standard.

(iii) If a locomotive load cell test stand(s) and the locomotive being tested are present and operating with stationary locomotive(s), including at least one switcher locomotive, the value L_{90} minus 3 dB is the value of the A-weighted sound level to be used in determining applicability of the moving and stationary locomotive standards and the load cell test stand standard.

(iv) If a locomotive load cell test stand(s) and the locomotive being tested are present and operating, and a stationary locomotive(s) is present, and if the nearly steady-state sound level is observed to change by 10 dB, coincident with evidence of a change in operation of the locomotive load cell test stand but without apparent change in the location of stationary locomotives, another measurement of L_{90} must be made. If this additional measure of L_{90} is validated and differs from the initial measure of L_{90} by an absolute value of 10 dB or more, then the higher value of L_{90} is the value of the A-weighted sound level to be used in determining applicability of the locomotive load cell test stand standard.

A flow chart describing the individual steps to be carried out in measuring, validating, and assessing the L_{90} for a given measurement location is shown in Figure 4-9.

In addition to the items in (1) above, § 201.27 of the regulation allows for an assessment of the noise from sources other than locomotives or load cell test stands in the following two steps:

(2) If it can be demonstrated that the validated L_{90} is less than 5 dB greater than any L_{90} measured at the same receiving property location when the source types that were operating during the initial measurement(s) are either turned off or moved, such that they can no longer be detected, the initial value(s) of L_{90} must not be used for determining applicability to the standards. This demonstration must be made at a time of day comparable to that of the initial measurements and when all other conditions are acoustically similar.

(3) In order to accomplish the comparison demonstration of (2) above, documentation of noise source information shall be necessary. This will include, but not be limited to, the approximate location of all sources of each source type present and the microphone position on a diagram of the particular railroad facility, and the distances between the microphone location and each of the sources must be estimated and reported. Additionally, if other rail or non-rail noise sources are detected, they must be identified and similarly reported.

4.1.6 Data Base

The purpose of this section is to provide a summary of representative locomotive and load cell test stand sound levels to which field measurements can be compared. Although levels and spectra of other equipment will not be precisely the same as those shown here, they should not be too dissimilar.

4.1.6.1 Stationary Locomotives

On the basis of the results of 84 stationary locomotive noise tests reported in the general literature,[2-8] A-weighted sound levels from stationary, idling locomotives at a distance of 100 feet range from 55 dB to 73 dB with a mean value of 66.1 dB. Figure 4-10 shows the distribution of sound levels. One-third octave band spectra of an idling road engine and an idling switcher locomotive are shown in Figures 4-11 and 4-12, respectively.

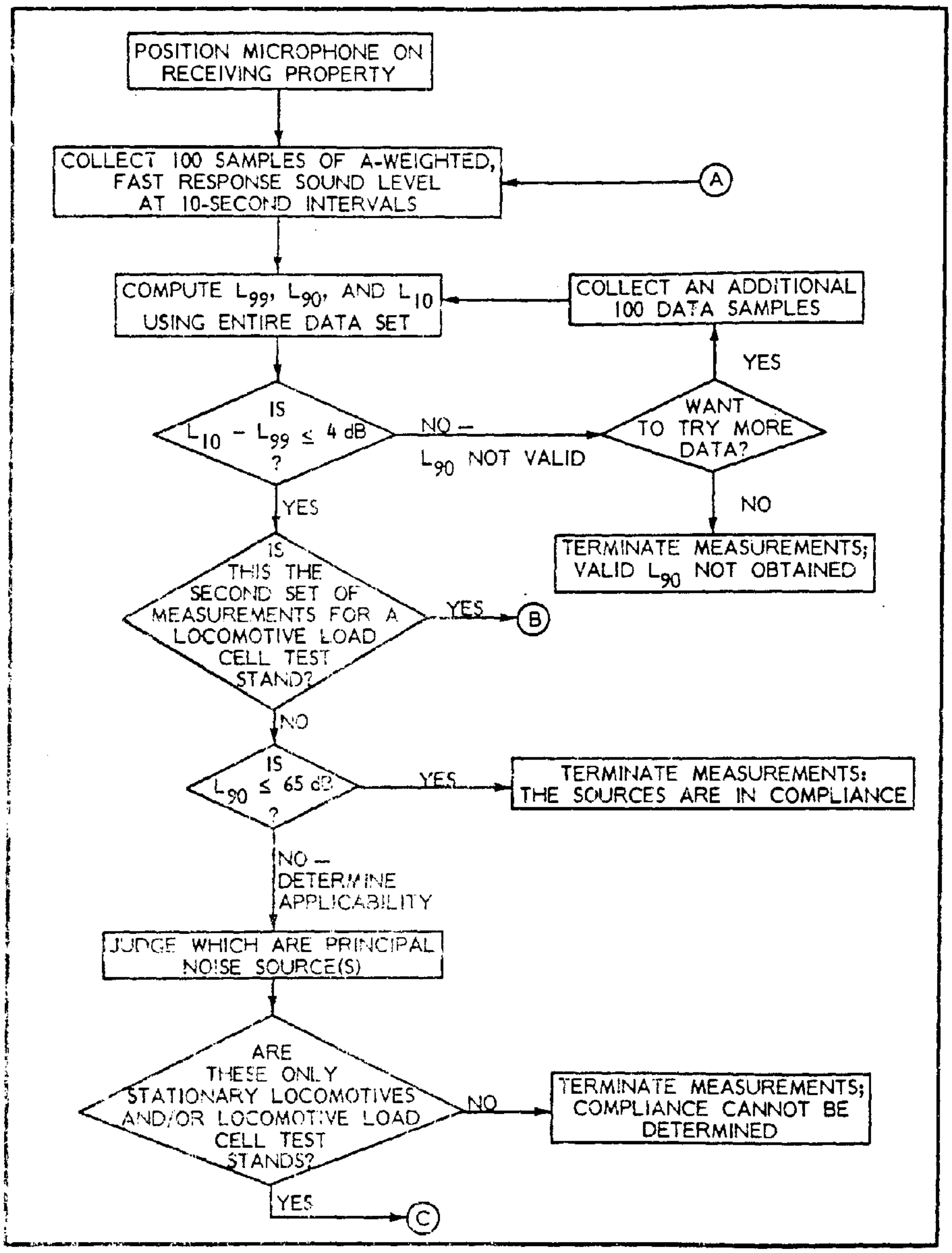


Figure 4-9. Procedure For Determining the Applicability of the Locomotive Load Cell Test Stand Standard and Switcher Locomotive Standard by Noise Measurement on a Receiving Property.

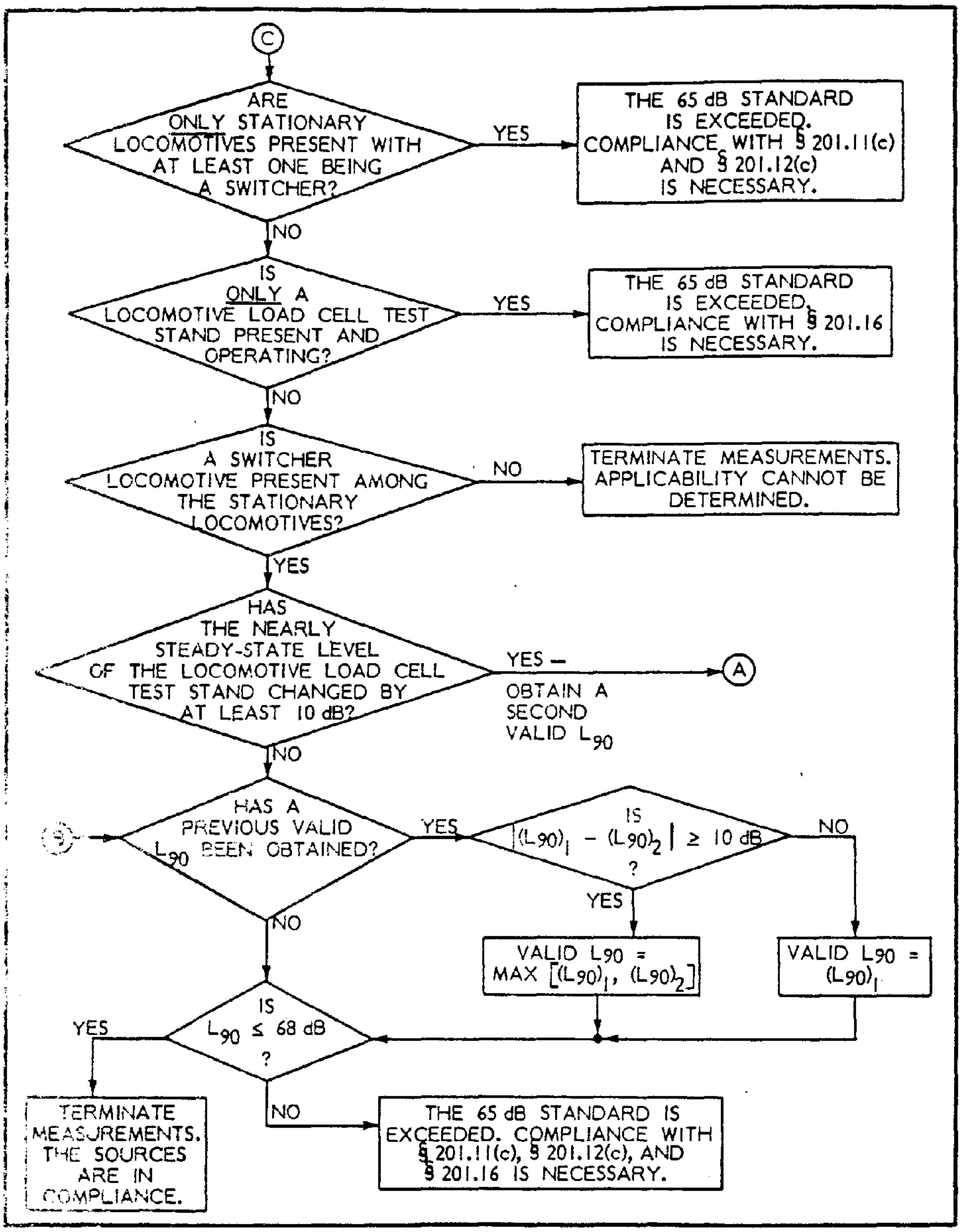


Figure 4-9 (Concluded).

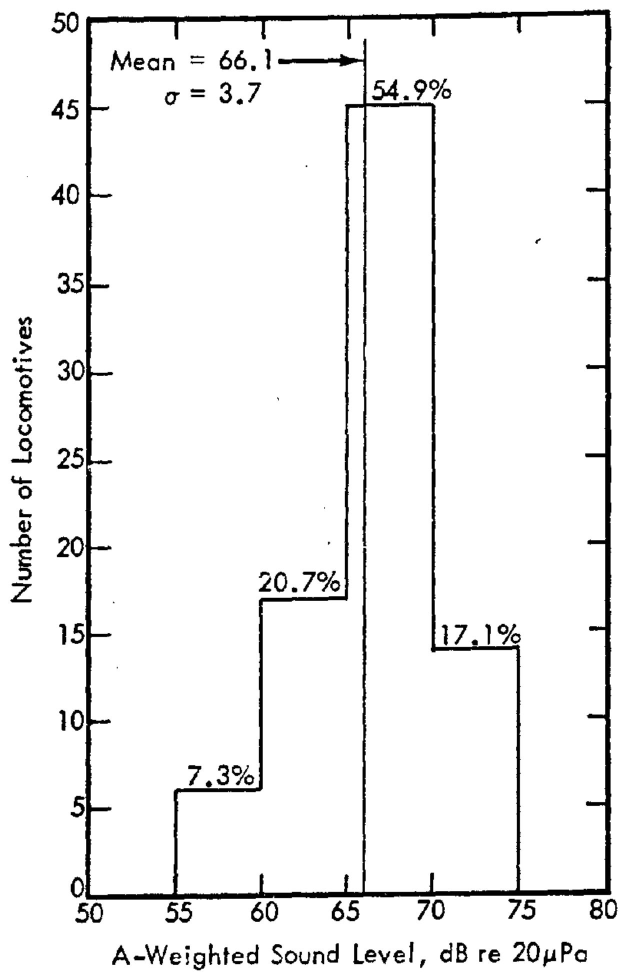


Figure 4-10. Distribution of A-Weighted Sound Levels For Idling Locomotives[2-8] (Measurements at 100 Feet).

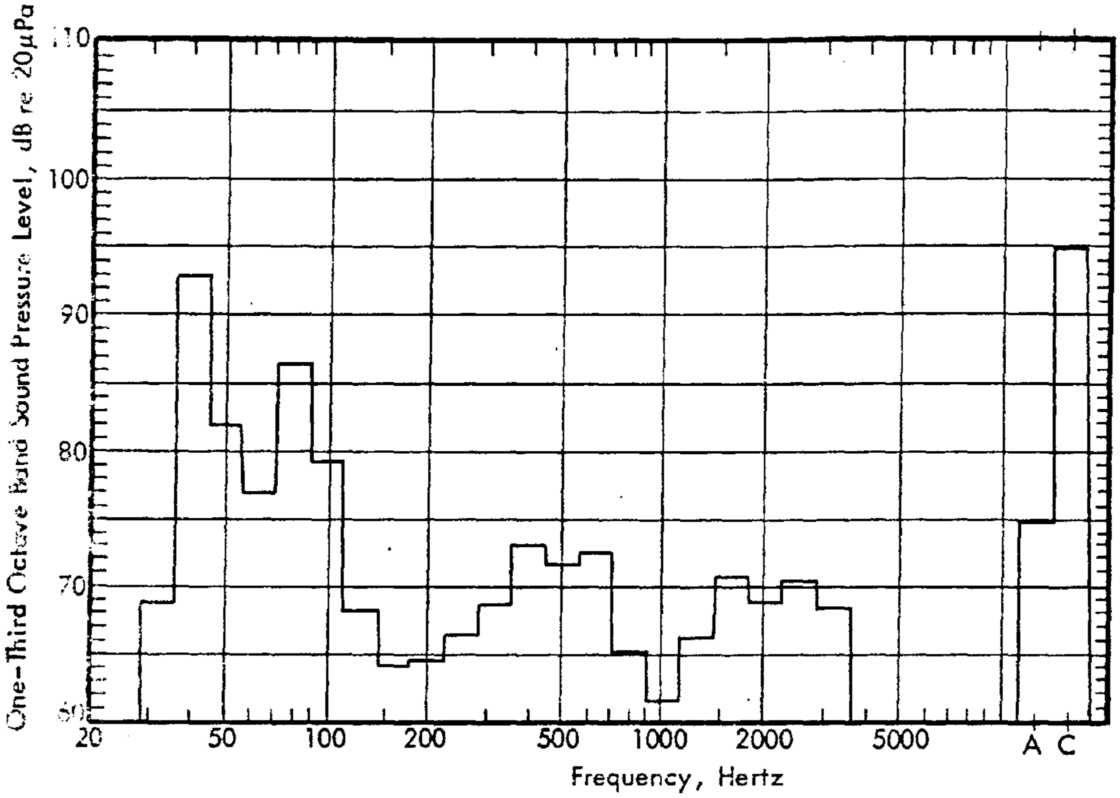


Figure 4-11. Spectrum of Idling Road Engine[3] (Measurements Taken 50 Feet From Track).

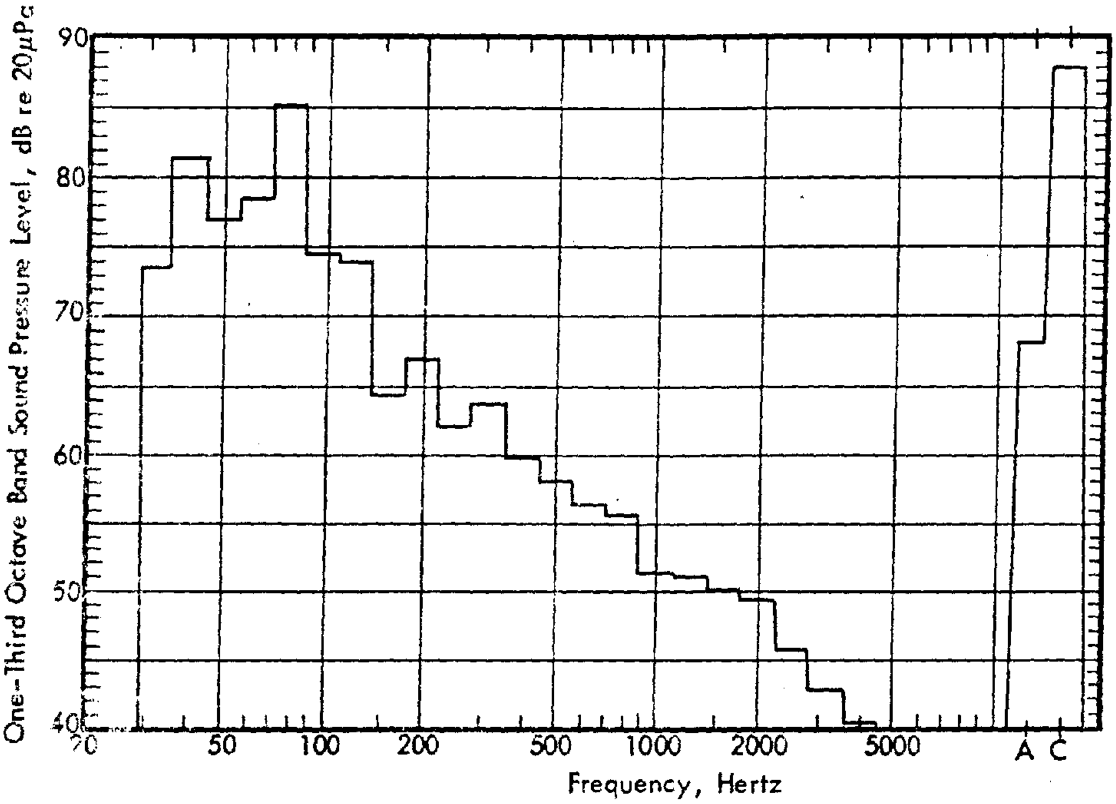


Figure 4-12. Spectrum of Idling Switcher Locomotive[3] (Measurements Taken 50 Feet From Track).

4.1.6.2 Moving Locomotives

On the basis of the results of 59 moving locomotive noise tests, made within railroad yards and reported in the general literature,[3-6] maximum A-weighted sound levels from moving locomotives at a distance of 100 feet range from 67 dB to 94 dB with a mean value of 79.5 dB. Figure 4-13 shows the distribution of sound levels. One-third octave band spectra of a switcher pulling a cut of cars at low speed and a switcher accelerating with a cut of cars are shown in Figures 4-14 and 4-15, respectively.

The time history of the A-weighted sound level during a typical cycle for a flat yard switching operation is shown in Figure 4-16.

4.1.6.3 Locomotive Load Cell Test Stands

Noise emitted from locomotive load cell test stands is primarily from the locomotive under test. This noise is most dependent on the throttle setting of the locomotive. Figure 4-17 shows the relation between A-weighted sound level at 100 feet and the locomotive throttle setting for two populations of locomotive undergoing load tests. The solid circles and the solid line smoothed through them are averages for 16 locomotives representing all available engines; the open circles and the dashed line smoothed through them are averages for a subset of 7 locomotives representing engines having maximum power less than 2500 hp. Figure 4-18 shows the one-third octave band spectra of a 2500 hp locomotive at three different throttle settings.

4.1.7 Noise Abatement Techniques

Noise emission from locomotives can be reduced by closing all doors, hatches, and panels and making sure that the seals on these devices are in place and in good condition. Loose parts on the locomotive should be tightened or repaired and proper lubrication and maintenance schedules should be adhered to. Should the noise from a locomotive be substantially louder than that indicated in the data bases above, the locomotive should be checked to determine if it is operating within specifications.

At idle and low throttle settings, such as those typically found in railroad yards, engine exhaust is the major noise source of diesel-electric locomotives. By installing specialized exhaust mufflers, overall locomotive noise at these throttle settings has been reduced from zero to 1.5 dB. For practical purposes, however, such a small noise reduction cannot be considered a cost-effective control option.

One of the methods of locomotive noise control is to shut down idling locomotives when they are not needed for use in the near future. This procedure is in fact already used in many yards as an energy-conservation measure. It is, however, not feasible in all cases. At low temperatures (below 50°F), the low viscosity of the lubricating oil used in locomotives creates engine-restarting problems. In addition, any time a locomotive is shut down and restarted there is some risk involved. As the engine cools down, the various components may contract at different rates allowing cooling water to leak into the cylinders. Serious damage may occur upon restart of the engine if proper caution is not exercised to drain any water from the cylinders.

An alternative method of locomotive noise control is to locate idling locomotives as far as possible from the noise-sensitive areas of the community. This method is generally most practical when a yard is still in the design stage. In an existing yard, lack of space or labor agreements may make relocation difficult.

Barriers may also be built at the yard boundary to shield noise-sensitive portions of neighboring communities. Because the engine exhaust is generally 15 to 16 feet above the ground, such barriers must generally be quite high (20 to 30 feet) in order to achieve a useful amount of noise reduction. Such barriers can be quite costly. In addition, barriers are sometimes objected to by residents living near them because of their visual intrusion and interference with free air flow.

Local barriers may be built within the yard at places where idling locomotives are normally parked, such as maintenance and repair facilities. Such barriers would reduce the noise propagated into the community by concentrated groups of idling locomotives. Barriers or enclosures may also be built around locomotive load cell test stand areas to reduce the noise propagated into the community from this source. Such an enclosure must be carefully designed to provide sufficient acoustic shielding while at the same time providing enough ventilation that the locomotive within it can be operated at all loads. As a result, an enclosure of this type can be quite costly.

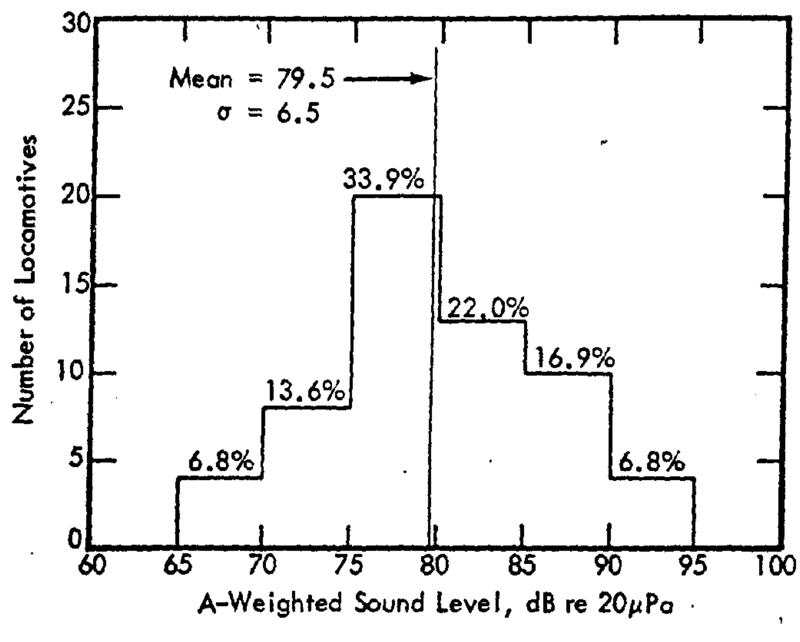


Figure 4-13. Distribution of A-Weighted Sound Levels For Moving Locomotives.[3-6] (Measurements Taken 100 Feet From Track).

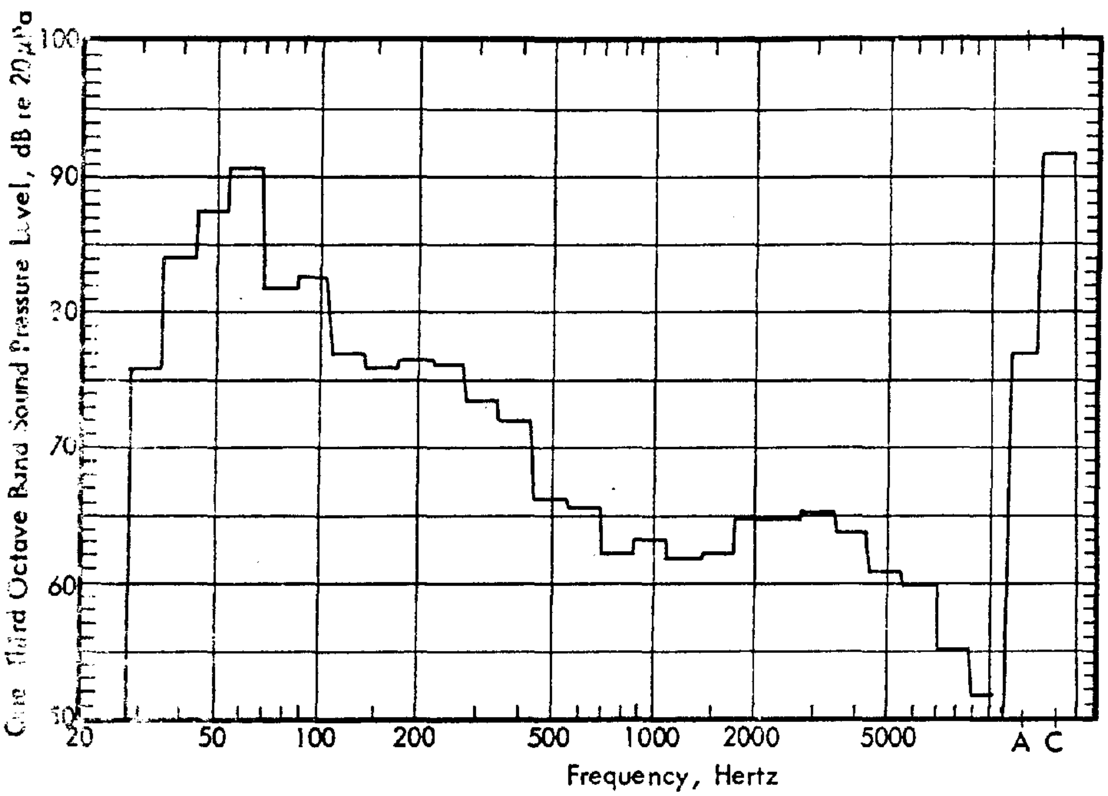


Figure 4-14. Spectrum of Switcher Pulling a Cut of Cars At Low Speed[3]
(Measurements Taken at 90 Feet From Track).

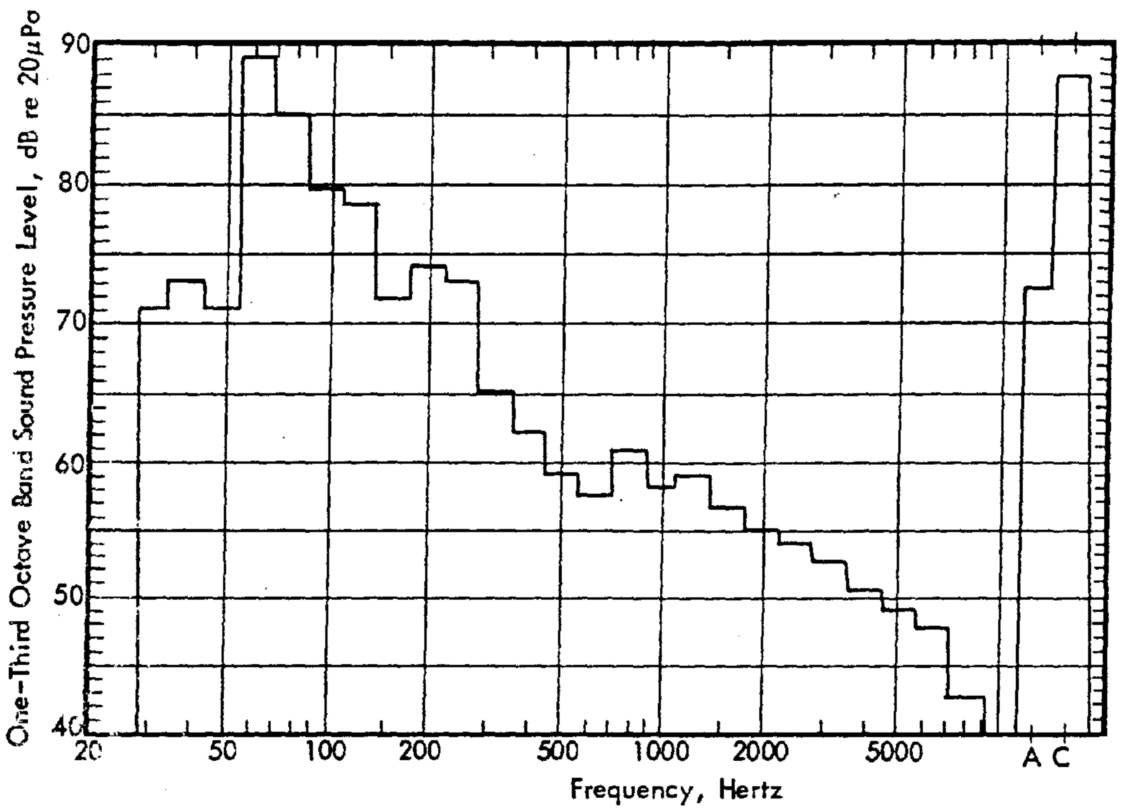
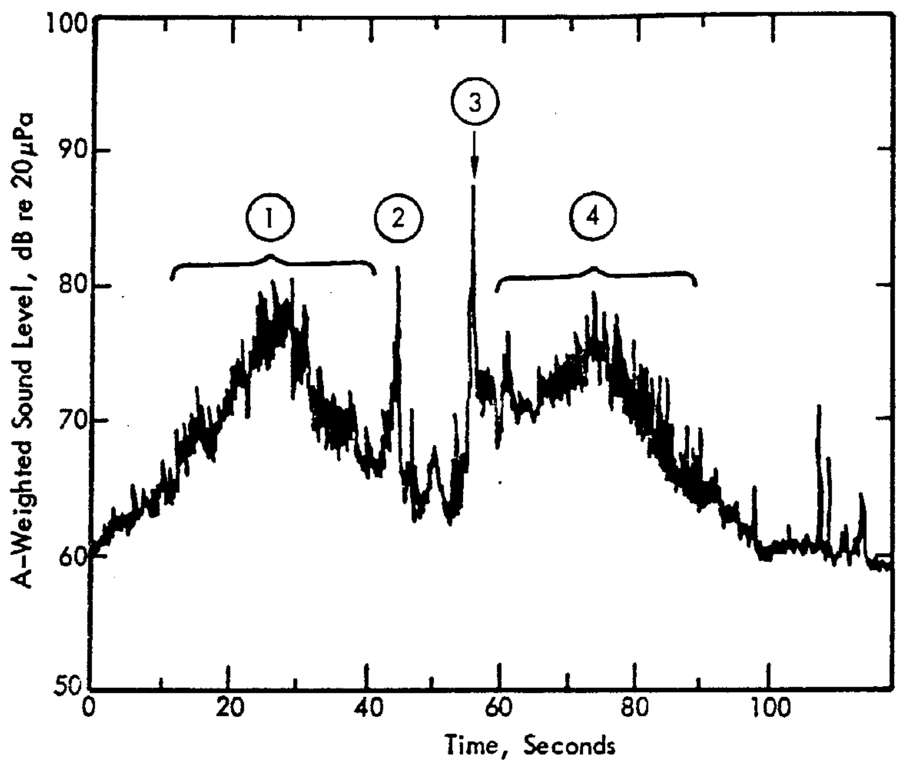


Figure 4-15. Spectrum of Switcher Accelerating With Cut of Cars[3] (Measurements Taken at 100 Feet From Track).



(1) Switcher Approaches With Cut of Cars;

(2) Chain-Reaction Impact Occurs When Switcher Suddenly Stops to Release Cars Being Classified;

(3) Released Car Couples With Stationary Cut In Classification Tracks; and

(4) Switcher Moves Away.

Figure 4-16. A-Weighted Time History of Flat Yard Locomotive Switching Cycle[3] (Measurements Taken 25 Feet From Switching Track).

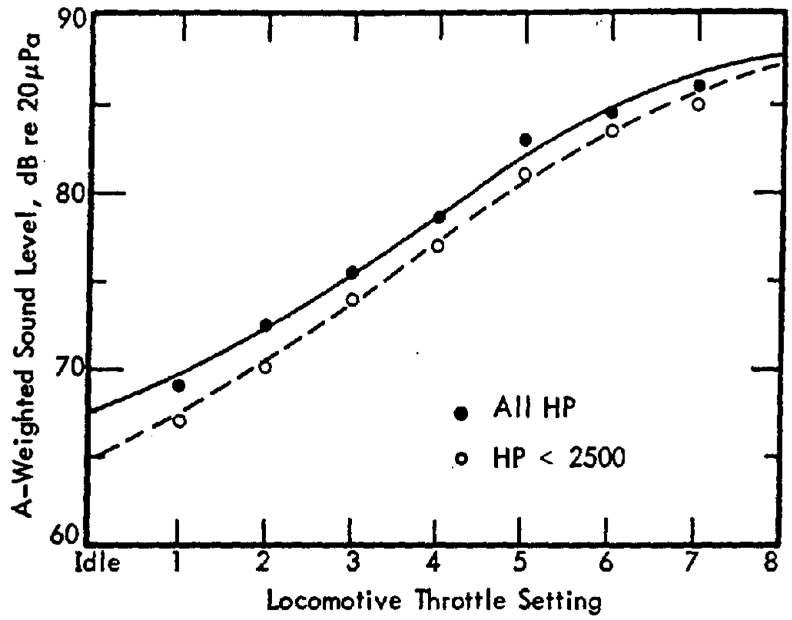


Figure 4-17. A-Weighted Sound Level of Stationary Locomotive As a Function of Locomotive Throttle Setting (Measurements Taken 100 Feet From Track).

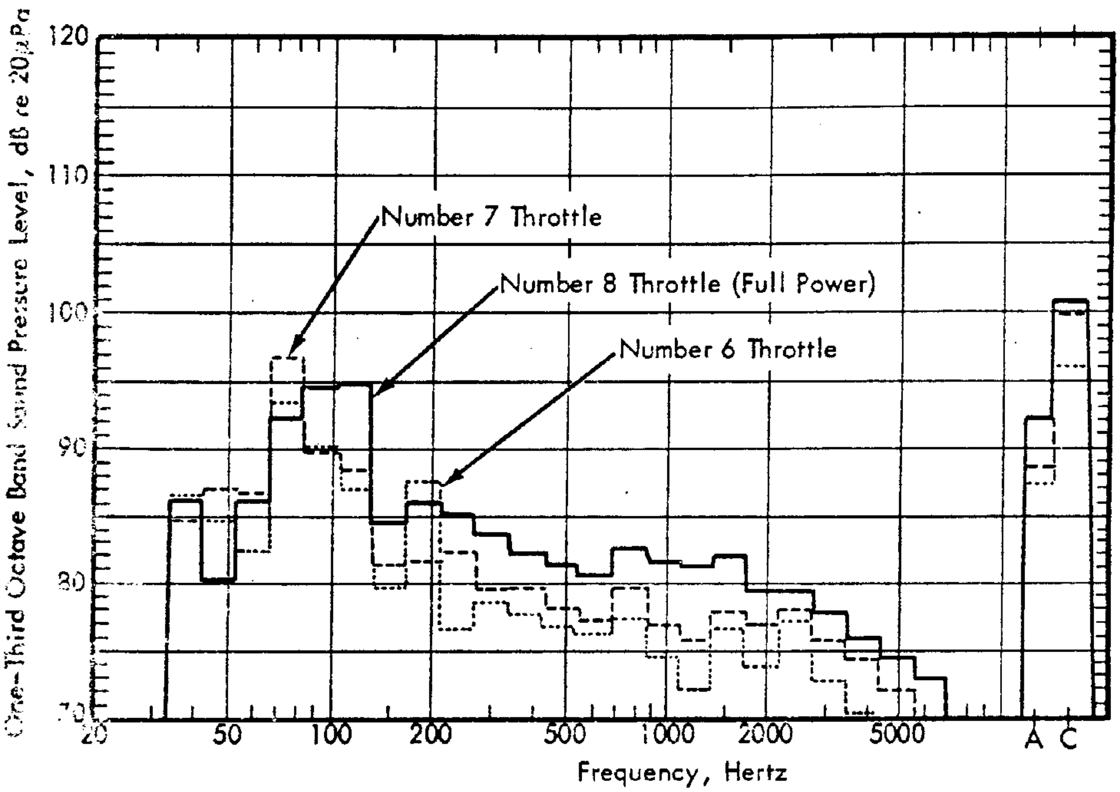


Figure 4-18. Spectrum of Noise Emitted by 1500 HP Locomotive Under Load Test at Throttle Settings 6, 7, and 8[3] (Measurements at 50 Feet).

4.2 Car-Coupling Impacts and Retarders

A major source of noise associated with railroad yards is that emitted from the impact of two or more railroad cars. In such an impact, an impulsive force is transmitted to the car frames and to the car bodies causing them to vibrate and emit sound. There are two types of noise event associated with car-coupling impacts: single acoustic impulses occurring from the impact of two railroad cars and multiple acoustic impulses occurring when one car collides with a cut of stationary cars causing the impact to be transmitted in a chain-reaction to all cars in the cut. The duration of a single car-coupling impulse is on the order of one second or less; a sequence of chain-reaction impulses can last for several seconds. The levels of the impulses following the initial impact in a chain-reaction are generally less than the level of a single car-coupling impulse because energy is absorbed in rolling friction and in the coupler cushions as the impacts propogate through the cut of cars. Chain-reaction impacts can also occur when slack is removed between cars in the start and stop operation of a train.

A major source of noise present in hump yards is railroad car retarders. These devices occasionally emit high-frequency squeals due to a stick-slip process between the car wheel, the rail, and the retarder brake shoes. Retarders operate by having a movable brake shoe press each wheel against a stationary shoe. The resulting frictional forces serve to slow down the rolling car.

In an active retarder, the pressure applied to the wheels by the brake shoes is generally supplied by pneumatic or hydraulic cylinders which are controlled either manually by an operator or automatically by a computer. In an inert retarder, the brake shoes are spring activated by the weight of the railroad car as it passes over the retarder.

The retarders in a hump yard are given different names depending where in the yard they are located. The master retarder, which is an active retarder located a short distance past the crest of the hump, serves as the primary speed control for cars entering the classification area. All cars pass through the master retarder after which they are sent through switches to various groups of tracks.

Before entering a specific track in a group, the car passes through another active retarder called a group retarder where a second speed adjustment can be made. Generally a master retarder will serve up to six or seven group retarders; thus, on the average, only one-sixth or one-seventh of the cars that pass through the master retarder will pass through a given group retarder.

After passing through the group retarder, the car will be directed by a series of switches to a specific track which, in most yards, it will enter uninhibited. In some yards, however, a third set of active retarders exists – one on each individual track. These retarders, which are called tangent point retarders, allow a third opportunity to adjust the car speed.

In most yards an inert retarder is located at the end of each classification track to prevent the first car into the track from rolling out of the classification area. These retarders generally emit noise only when a string of cars is pulled through them for removal from the classification track. Some inert retarders are releasable, in which case they can be locked open so that they do not emit noise when cars are pulled through them.

Figure 4-19 shows a typical layout of the classification area of a hump yard and indicates the location of some of the various types of retarders.

The noise emissions into the community from both car-coupling impacts and retarders are regulated by the United States Code of Federal Regulations – 40 CFR Part 201.

4.2.1 Regulations

4.2.1.1 Car-Coupling Impacts

On January 14, 1980, the Environmental Protection Agency published regulations specifying the noise emission standard for car-coupling operations at railroad yards. The noise limit set forth in the standard is summarized in Table 4-12.

The regulation as published in 40 CFR Part 201 is as follows:

§ 201.15 Standard for car coupling operations.

Effective January 15, 1984, no carrier subject to this regulation shall conduct car coupling operations that exceed an adjusted average maximum A-weighted sound level of 92 dB at the receiving property measurement location, when measured with fast meter response in accordance with Subpart C of this part, except, such coupling will be found in compliance with this standard and the carrier will be considered in compliance, if the railroad demonstrates that the standard is exceeded at the receiving property measurement locations (where the standard was previously exceeded) when cars representative of those found to exceed the standard are coupled at similar locations at coupling speeds of eight miles per hour or less.

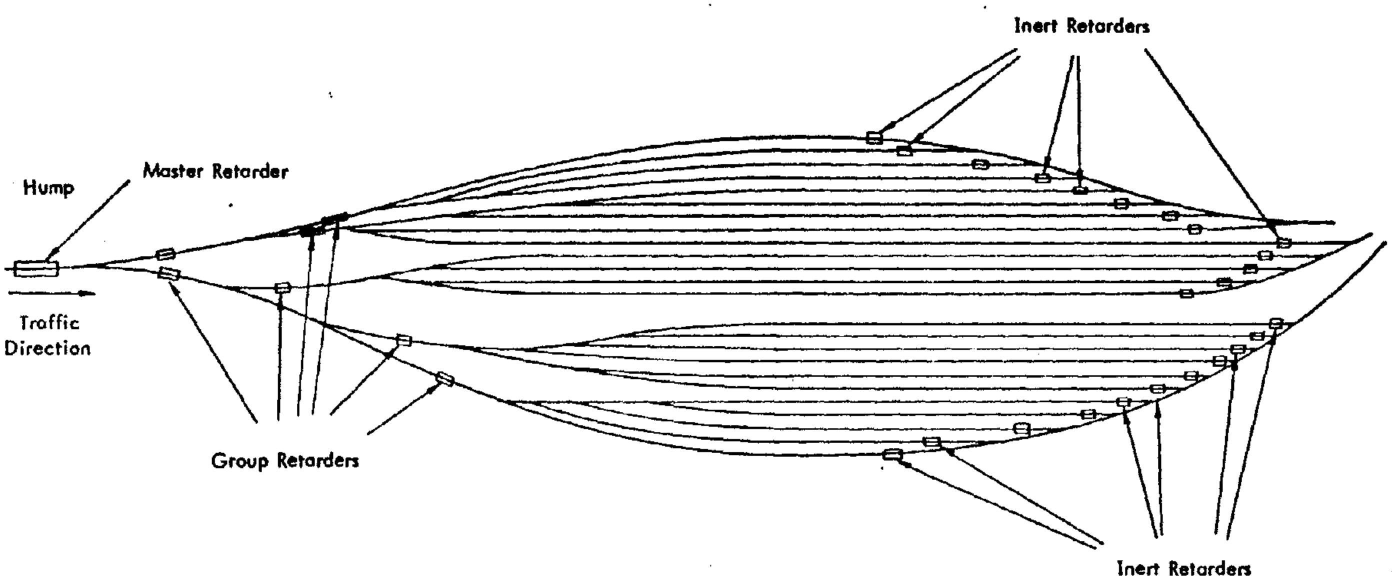


Figure 4-19. Typical Layout of the Classification Area of a Hump Yard.

Table 4-12

Noise Emission Standard For
Rail Car-Coupling Operations

Date Effective	Maximum Permitted Adjusted Average A-Weighted Sound Level(1)	Type 2 Correction
Jan. 15, 1984	92 dB(2)	2 dB(3)

(1) When measured on the receiving property using fast response. Allowed tolerance for this measurement had not been specified by FRA at the time of publication of this handbook.

(2) In instances when the measured noise level is above 92 dB, the car-coupling operations are deemed to be in compliance with this regulation if the car-coupling speed is 8 miles per hour or less.

(3) Subtract from measured levels when ANSI Type 2 (S2A) sound level meter is used in lieu of ANSI Type 1 (S1A).

4.2.1.2 Railroad Car Retarders

On January 14, 1980, the Environmental Protection Agency published regulations specifying the noise emission standard for retarder operations at railroad yards. The noise limit set forth in the standard is summarized in Table 4-13:

Table 4-13

Noise Emission Regulation For Retarder(1) Operations

Date Effective	Maximum Permitted Adjusted Average A-Weighted Sound Level(2)	Type 2 Correction
Jan. 15, 1984	83 dB	4 dB(3)

(1) Only active retarders are covered by this regulation; inert retarders are excluded.

(2) When measured on non-railroad receiving property using fast response. Allowed tolerance for this measurement had not been specified by FRA at the time of publication of this handbook.

(3) Subtract from measured levels when ANSI Type 2 (S2A) sound level meter is used in lieu of ANSI Type 1 (S1A).

The regulation as published in 40 CFR Part 201 is as follows:

§ 201.14 Standard for retarders.

Effective January 15, 1984, no carrier subject to this regulation shall operate retarders that exceed an adjusted average maximum A-weighted sound level of 83 dB at a receiving property measurement location, when measured with fast meter response in accordance with Subpart C of this part.

Retarders are defined in § 201.1 of the regulation as:

(y) "Retarder (Active)" means a device or system for decelerating rolling rail cars and controlling the degree of deceleration on a car-by-car basis.

4.2.2 Acoustic Metric

The metric used in these regulations for noise emission from car-coupling impacts and retarders is summarized in Table 4-14.

Table 4-14

Acoustic Metric For Car-Coupling Impacts and Retarders

ADJUSTED AVERAGE MAXIMUM A-WEIGHTED SOUND LEVEL "FAST" METER RESPONSE

The "adjusted average" level, $L_{adj\ ave\ max}$, is defined as the energy average of at least 30 consecutive maximum noise event source levels, $L_{ave\ max}$, with a correction factor, C, applied to account for the rate at which the events occur:

$$L_{adj\ ave\ max} = L_{ave\ max} + C$$

The correction factor is determined from Table 4-15.

Table 4-15

Adjustment to $L_{ave\ max}$ To Obtain $L_{adj\ ave\ max}$ For Car-Coupling Impacts and Retarders

N / T *	Adjustment Factor, C (dB)	N / T *	Adjustment Factor, C (dB)
0.111 to 0.141	-9	0.709 to 0.891	-1
0.142 to 0.178	-8	0.892 to 1.122	0
0.179 to 0.224	-7	1.123 to 1.413	+1
0.225 to 0.282	-6	1.414 to 1.778	+2
0.283 to 0.355	-5	1.779 to 2.239	+3
0.356 to 0.447	-4	2.240 to 2.818	+4
0.448 to 0.562	-3	2.819 to 3.548	+5
0.563 to 0.708	-2	3.549 to 4.467	+6

* N is the number of measurements in time period T (in minutes).

Values in this table are calculated from the relation:

$$C = 10 \log_{10} (N/T)$$

where N is the number of measurements in the time period T (in minutes). Intervals in the table are selected to round values of C to the nearest whole decibel. The table may be extended or interpolated to finer interval graduations by using this defining equation.

The noise events to be included in the energy-average for car-coupling impacts are defined in § 201.1 of the regulation as:

> (b) "Car Coupling Sound" means a sound which is heard and identified by the observer as that of car coupling impact, and that causes a sound level meter indicator (FAST) to register an increase of at least ten decibels above the level observed immediately before hearing the sound.

Those to be included in the average for retarders are defined in § 201.1 of the regulation as:

> (z) "Retarder Sound" means a sound which is heard and identified by the observer as that of a retarder, and that causes a sound level meter indicator at fast meter response § 201.1(l) to register an increase of at least ten decibels above the level observed immediately before hearing the sound.

4.2.3 Measurement Site Selection

The location at which the sound measurements are to be conducted must be chosen carefully to ensure that the conditions summarized in Table 4-16 are satisfied. If the measurement is being conducted by enforcement personnel to determine compliance with the standards, the measurement site must be on non-railroad receiving property. If the measurement is being conducted by the railroad to determine whether it is probably complying with the regulation, and therefore whether it should institute noise abatement, a railroad may take measurements on its own property at locations that:

(1) are between the source and receiving property,

(2) Derive no greater benefit from shielding and other noise reduction features than does the receiving property, and

(3) otherwise meet the requirements of Table 4-16.

Table 4-16

Receiving Property Site Requirements
For Car-Coupling Impacts and Retarders

<u>TEST SITE</u>

Located on receiving property with no vertical plane surfaces exceeding 4 feet in height within 33.3 feet of the microphone position. The following structures are exempt from the above requirement:

- Residential or commercial unit wall located at least 6.6 feet from the microphone position;
- Facility boundary noise barrier.

If the residential structure is a farm home, the microphone must be located between 6.6 feet and 33.3 feet away from the wall.

<u>MICROPHONE POSITION</u>

The microphone must be positioned at a height between 4 feet to 5 feet above the ground.

<u>WEATHER CONDITIONS</u>

Measurements should be taken only under these conditions:

- No precipitation (rain, snow, sleet, hail, etc.).
- Wind speed below 12 mph.
- Wind gusts below 20 mph.

<u>BACKGROUND NOISE LEVEL</u>

The A-weighted, fast response sound level measured immediately before the noise event should be at least 10 dB lower than that of the event.

The measurement site selection conditions as stated in § 201.25 of the regulations are as follows:

(a) Measurements must be conducted only at receiving property measurement locations.

(b) Measurement locations on receiving property must be selected such that no substantially vertical plane surface, other than a residential or commercial unit wall or facility boundary noise barrier, that exceeds 1.2 meters (4 feet) in height is located within 10 meters (33.3 feet) of the microphone and that no exterior wall of a residential or commercial structure is located within 2.0 meters (6.6 feet) of the microphone. If the residential structure is a farm home, measurements must be made 2.0 to 10.0 meters (6.6 to 33.3 feet) from any exterior wall.

(c) No measurement may be made when the average wind velocity during the period of measurement exceeds 19.3 km/hr (12 mph) or when the maximum wind gust velocity exceeds 32.2 km/hr (20 mph).

(d) No measurement may be taken when precipitation, e.g., rain, snow, sleet, or hail, is occurring.

4.2.4 **Instrumentation**

The instrumentation required to make car-coupling and retarder operations noise measurements is shown in Table 4-17.

Table 4-17

Instrumentation for Car-Coupling and Retarder Noise Measurements

SOUND LEVEL METER
MICROPHONE AND WINDSCREEN
TRIPOD
SOUND LEVEL CALIBRATOR
WIND SPEED METER
ACCESSORIES

The instrumentation requirements stated in § 201.22 of the regulations are as follows:

(a) A sound level meter or alternate sound level measurement system that meets, as a minimum, all the requirements of American National Standard S1.4-1971[1] for a Type I (or S1A) instrument must be used with the "fast" meter response characteristic as specified in Subpart B. To insure Type I response, the manufacturer's instructions regarding mounting or orienting of the microphone, and positioning of the observer must be observed. In the event that a Type I (or S1A) instrument is not available for determining non-compliance with this regulation, the measurements may be made with a Type 2 (or S2A), but with the measured levels reduced by the following amount to account for possible measurement instrument errors pertaining to specific measurements and sources:

Sound Level Corrections When Using
A Type 2 (or S2A) Instrument

Measurement Section	Source	Decibels*
201.26	Retarder	4
	Car Coupling	2

* Amount of correction to be subtracted from measured level (dB).

(b) A microphone windscreen and an acoustic calibrator of the coupler type must be used as recommended by: (1) the manufacturer of the sound level meter, or (2) the manufacturer of the microphone. The choice of both devices must be based on ensuring that Type I or Type 2 performance, as appropriate, is maintained for frequencies below 10,000 Hz.

In addition, although not presently required, it is wise to follow the FRA Compliance Regulations (49 CFR Part 210, § 210.29) which define the following calibration procedures:

(1) (i) The sound level measurement system including the microphone must be calibrated and appropriately adjusted at one or more nominal frequencies in the range from 250 through 1000 Hz at the beginning of each series of measurements, at intervals not exceeding 1 (one) hour during continual use, and immediately following a measurement indicating a violation.

(ii) The sound level measurement system must be checked out not less than once each year by its manufacturer, a representative of its manufacturer, or a person of equivalent special competence to verify that its accuracy meets the manufacturer's design criteria.

(2) An acoustical calibrator of the microphone coupler type designed for the sound level measurement system in use shall be used to calibrate the sound level measurement system in accordance with paragraph (1) (i) of this subsection. The calibration must meet or exceed the accuracy requirements specified in § 5.4.1 of the American National Standard Institute Standards, "Method for Measurement of Sound Pressure Levels" (ANSI S1.13-1971),[1] for field method measurements.

4.2.5 Measurement Procedure

The procedure to be followed when conducting rail-car coupling operations noise measurements is derived from the EPA noise standard regulation, and common measurement practice.

The procedure is made up of five phases. They include:

- Program Planning
- Instrumentation Checkout
- Instrumentation Setup
- Data Collection
- Data Reduction

A description of these phases as applied to car-coupling impact and retarder noise measurements is presented in the rest of this section. Where appropriate, sample worksheets are included. These may be copied directly or may be used as a basis for designing a more personalized format.

4.2.5.1 Program Planning

The first stage of the measurement program is program planning. It is during this phase that decisions are made concerning such factors as the number of locations to be tested, specifically which locations will be used, and the day and time the measurements are to be made. Permission to be allowed access to the measurement locations at the time desired should be obtained from the responsible railroad official or, if on non-railroad property, from the property owner. The number of people to carry out the measurements should be determined and specific individuals assigned to the measurement team. Most field measurements involving moving or changing sources require at least two people – one to observe and record the sound level measurements, the other to determine and note other characteristics of the noise source (e.g. type, identification, location, speed, etc.).

It is also at this point that the instrumentation system is specified and acquired. The system used for car-coupling and retarder operations noise measurements will normally consist of a Type 1 or 2 sound level meter with a calibrator, windscreen, and tripod. If car-coupling noise measurements are to be made for the purpose of demonstrating that the standard is exceeded when cars couple at less than 8 miles per hour, a speed-measuring device should be included. Other useful equipment include a wind speed-measuring device, a 100-foot tape measure, and thermometer.

A program planning worksheet is shown in Figure 4-20. This is useful in assuring that all of the planning details are carried out.

4.2.5.2 Instrumentation Checkout

Before proceeding to the field for measurements, the instrumentation system should be put together and thoroughly checked out and the manufacturer's instructions referred to for calibration and operational procedures. The batteries must be tested and all interconnecting cables and mounting hardware should be connected to assure that the correct plugs fit into the proper instruments, and that the overall system works as required. The accessories such as extra batteries, note pads, adhesive tape, and the like, should be assembled.

An inventory of the necessary equipment and a measurement site qualification worksheet should be prepared and brought into the field. This assures that once the measurement program has begun no details will be forgotten. Samples of inventory and site qualification worksheets are shown in Figures 4-21 and 4-22. The inventory sheet is meant to be quite general; thus depending on the purpose of the measurement, it may not be necessary to take all the equipment listed.

4.2.5.3 Instrumentation Setup

Before proceeding to the measurement site, the person in charge of the property on which the measurements are to be taken should be informed of the presence of the measurement team. At the site, the instrumentation system should be set up according to the manufacturer's instructions. The inventory worksheet should be referred to at this time. The measurement site qualification should be verified, using the measurement site qualification worksheet.

The sound level meter should be mounted on a tripod with the microphone at a level of 1.2 meters (4 feet) above the ground. A windscreen should always be attached to the microphone. The sound level meter may be tilted to allow ease of reading, and the microphone should be oriented according to manufacturer's instructions. This is critical, since certain microphones (perpendicular incidence) are designed to be pointed directly at the major noise source, other microphones (grazing incidence) are designed to be pointed at right angles to the line between the observer and the noise source, and still others (random incidence) are designed to be oriented in a direction intermediate to these two.

PROGRAM PLANNING WORKSHEET

Car-Coupling and Retarder Operations

Date: ____________ Prepared By: ____________

Check When Completed

Test Plan

____ Determine where the measurements will be made.
____ Determine when the measurements will be made.
____ Obtain permission to carry out measurements at desired location.

Instrumentation Checkout

____ Specify the instrumentation system required for the measurements.
____ Acquire the components of the instrumentation system.
____ Check out and calibrate the instrumentation system.
____ Complete the instrumentation system inventory worksheet.
____ Pack up the instrumentation system for shipment to the measurement site.
____ Check current weather conditions, reschedule test if necessary.

Measurement Site Setup

____ Check in with person responsible for measurement site property.
____ Complete measurement site qualification worksheet.
____ Unpack instrumentation system, checking against inventory worksheet.
____ Set up the instrumentation system and check components for damage.
____ Calibrate the system and report results on the field data log.
____ Complete the annotation on the field data log.

Noise Measurements

____ Conduct noise measurements.
____ Record results on the field data log.
____ Check calibration of the system and record results on the field data log.
____ Repack system for return shipment, referring to inventory checksheet.

Program Completion

____ Unpack instrumentation system, checking for damage.
____ Process data.
____ Document measurement program.

Figure 4-20. Sample Program Planning Worksheet.

INSTRUMENTATION SYSTEM INVENTORY WORKSHEET

Car-Coupling and Retarder Operations

Date: ________________ Prepared By: ______________________________

Location: ____

____

INSTRUMENT	Make	Model	Serial No.	Date of Last Calibration	Check Out	Return
Sound Level Meter (SLM)						
Microphone						
Sound Level Calibrator						
Wind Speed Measuring Device						
Railroad Car Speed Measuring Device (For Car-Coupling Only)						

REQUIRED (*) AND RECOMMENDED ACCESSORIES	Checkout	Return
* Microphone Windscreen		
* SLM Calibration Adjustment Tool (Screwdriver)		
* Tripod		
* Tape Measure		
Thermometer		
Hygrometer		
Watch		
Extra Batteries		
Duct Tape		
Connecting Cables		
Flash Light		
Weather Radio		
Camera and Film		
Ground Cloth		
Earphones		
Tools (screwdriver, pliers, etc.)		

Figure 4-21. Sample Instrumentation System Inventory Worksheet.

MEASUREMENT SITE QUALIFICATION WORKSHEET

Car-Coupling and Retarder Operations

Date: ____________________ Prepared By: ____________________________________

Location: ____

____

	YES	NO
Is the measurement site on a receiving property?	___	___
Have the test area clear-zone requirements been met?	___	___
Has the microphone position requirement been met?	___	___
Will the ambient weather conditions permit noise emission tests?	___	___
Wind Speed Below 12 mph?	___	___
Wind Gusts Below 20 mph?	___	___
No precipitation condition met?	___	___
Has a sketch been made of the measurement site?	___	___
Have photographs been taken of the measurement site?	___	___

Figure 4-22. Sample Measurement Site Qualification Worksheet.

For car-coupling operations noise tests, the microphone should be positioned in a receiving property, on a line perpendicular to the nearest track on which car-coupling occurs at a point at least 30 meters (100 feet) from the track centerline. If this is not possible, all sounds resulting from car-coupling impacts on closer tracks are to be disregarded.

The operator should stand as far away from the meter as possible, consistent with his ability to make the sound level readings easily. When possible, the microphone/preamplifier assembly should be mounted remote from the sound level meter so that there is less chance of the observer's affecting the measured data.

Care should be taken to make sure that there is nothing between the microphone position and the sound source, with the exception of a facility boundary noise barrier, which may interfere with the sound propagation. Nearby reflecting objects, such as walls behind the microphone, should be avoided. It is, however, permissible to take measurements at a location where residential or commercial structures are located at least 6.6 feet away from the microphone position.

The sound level meter should be calibrated by adjusting the meter to read the level generated by the calibrator, according to the manufacturer's instructions. This should be done prior to the beginning of measurements, and noted in the field data log.

Draw a sketch of the measurement area that includes all audible noise sources and their approximate location with respect to the measurement position. The location of all reflecting surfaces, barriers, and other factors that may affect the sound propagation should also be noted on the sketch. An exact scale map is not necessary, but a good representation of the area, with distances to outstanding landmarks indicated, is desirable. If a detailed map of the area is available, the site area should be located on it. If possible, photographs of the area should be taken to show the noise source. A very effective way to photograph the site is to stand at the microphone position and take a series of pictures which show the full 360° view from that spot. It is also helpful to document the microphone location by stepping behind the microphone and taking a picture which shows the microphone as well as the sound source being measured.

A data log should be filled out at the beginning of each measurement. A typical data log sheet is shown in Figure 4-23 and should contain the following information:

- Description of measurement location.
- Date of measurements.
- Name of person performing the measurements.
- Types, models, serial numbers, or other identification characteristics for all instrumentation.
- Barometric pressure, temperature, wind velocity, and humidity. (This information can be measured directly or, in many cases, can be obtained from local weather radio stations.)
- Results of calibration tests.
- Measured levels and background levels.
- Description of equipment under test.
- Description of secondary noise sources.

A note pad should also be taken into the field and used to write extensive notes detailing anything going on which may have a bearing on the measurements or the interpretation of the data. Such incidents as unusually high railroad traffic or other atypical events are examples of the type of information which should be recorded.

4.2.5.4 Data Collection

Using fast meter response, measure and record the maximum A-weighted sound level during each car-coupling impact or retarder squeal event and the background levels immediately before and after the event. At least 30 valid measurements must be recorded. A valid measurement is one for which the maximum level during the event is at least 10 dB greater than the background level immediately before the event. The measurement period must be at least 60 minutes and not more than 240 minutes and it must be reported.

4.2.5.5 Data Reduction

Figure 4-24 presents a sample data reduction worksheet that may be used to determine the adjusted average maximum A-weighted sound level of the collected sample of noise events. Figure 4-25 and the discussion below illustrate the use of this worksheet.

STEP 1:

- Divide by 10 each measured noise event sound level which is at least 10 dB above the background before the event, and take the antilogarithm of the resultant number. For example, if the sound level is 90 dB, dividing by 10 gives 9.0, and taking the antilog gives $10^{9.0}$ = 1,000,000,000.

FIELD DATA LOG

Car-Coupling and Retarder Operations

Date: ____________________ Prepared By: ______________________________________

Location: ____

____

EQUIPMENT:

Instrument	Manufacturer	Model	Serial No.	Date of Last Calibration
Sound Level Meter				
Microphone				
Calibrator				

WEATHER CONDITIONS:

	Time	Wind Speed	Direction	Temperature	Relative Humidity	Barometric Pressure
Pre-Test						
Post-Test						

CALIBRATION: Calibrator Level: __________ dB Calibrator Frequency: ________ Hz

Time						
Sound Level						

MAJOR NOISE SOURCES: ____

____

____

SKETCH OF SITE GEOMETRY:

N

Figure 4-23. Sample Car-Coupling and Retarder Operation Field Data Log.

FIELD DATA LOG (Continued)

Car-Coupling and Retarder Operations

Date: ____________________ Prepared By: ____

Location: ____

____

Start Time: ______________ NOTE: Minimum Sample Time = 1 hour

Stop Time: ______________ Maximum Sample Time = 4 hours

A-WEIGHTED SOUND LEVELS ("FAST" RESPONSE)

Pre-Event Level	Max. During Event	Post-Event Level	VALID*	Source	Pre-Event Level	Max. During Event	Post-Event Level	VALID*	Source

* Check (✓) those measurements which are valid. A valid measurement is one for which the maximum level during the event exceeds the pre-event level by at least 10 dB. Thirty valid measurements are required.

Figure 4-23 (Concluded).

ADJUSTED AVERAGE MAXIMUM A-WEIGHTED SOUND LEVEL WORKSHEET

Car-Coupling and Retarder Operations

Date: ____________ Prepared By: ____________________

Location: ______________________________

NOISE SOURCE: ☐ Retarder ☐ Car-Coupling

Event No.	Maximum Level, L_i *	$10^{L_i/10}$
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
Sum: $S = \sum 10^{L_i/10} =$		

* Only valid measurements, for which L is 10 dB or more above the level just prior to the event, are to be included. At least 30 valid measurements are required.

Sum: S = ____________

No. Samples: N = ____________

Average: $A = S/N =$ ____________

Energy-Average Maximum Level: $L_E = 10 \log_{10}(A) =$ dB

Correction For Sound Level Meter

☐ Type 1: B = 0 dB

☐ Type 2: ☐ Retarders: B = 4 dB ☐ Car-Coupling: B = 2 dB

Corrected Energy-Average Maximum Level

$L'_E = L_E - B =$ dB

Stop Time: ____ (h) ____ (m)

Start Time: ____ (h) ____ (m)

Duration: T = (h) (m) = min.

Event Rate: N/T =

Adjustment: $C = 10 \log_{10}(N/T) =$ dB

Adjusted Average Maximum Level: $L'_E + C =$ dB

Figure 4-24. Sample Adjusted Average Maximum A-Weighted Sound Level Worksheet.

ADJUSTED AVERAGE MAXIMUM A-WEIGHTED SOUND LEVEL WORKSHEET

Car-Coupling and Retarder Operations

Date: FEB. 5, 1980 Prepared By: A. W. Level

Location: S.E. Corner of Sixth St. and Concourse Rd. - Approximately 2,000 Feet from Master Retarder

NOISE SOURCE: [X] Retarder [ ] Car-Coupling

Event No.	Maximum Level, L_i *	$10^{L_i/10}$
1	85	316,227,766
2	90	1,000,000,000
3	75	31,622,777
4	80	100,000,000
5	70	10,000,000
6	88	630,957,344
7	82	158,489,319
8	77	50,118,723
9	80	100,000,000
10	81	125,892,541
11	89	794,328,235
12	72	15,848,932
13	74	25,118,864
14	83	199,526,232
15	80	100,000,000
16	76	39,810,717
17	79	79,432,823
18	82	158,489,319
19	74	25,118,864
20	81	125,892,541
21	77	50,118,723
22	85	316,227,766
23	70	10,000,000
24	73	63,095,734
25	82	158,489,319
26	75	31,622,777
27	71	12,589,254
28	80	100,000,000
29	73	19,952,623
30	77	50,118,723
Sum: $S = \sum 10^{L_i/10}$ = 4,899,089,915		

* Only valid measurements, for which L_i is 10 dB or more above the level just prior to the event, are to be included. At least 30 valid measurements are required.

Sum: S = 4,899,089,915

No. Samples: N = 30

Average: $A = S/N$ = 163,302,997

Energy-Average Maximum Level: $L_E = 10 \log_{10}(A)$ = 82 dB

Correction For Sound Level Meter

[ ] Type 1: B = 0 dB

[X] Type 2: [X] Retarders: B = 4 dB; [ ] Car-Coupling: B = 2 dB

Corrected Energy-Average Maximum Level

$L'_E = L_E - B$ = 82 − 4 = 78 dB

Stop Time: 14 (h) 40 (m)

Start Time: 13 (h) 10 (m)

Duration: T = 1 (h) 30 (m) = 90 min.

Event Rate: N/T = 30/90 = 0.333

Adjustment: $C = 10 \log_{10}(N/T)$ = −5 dB

Adjusted Average Maximum Level: $L'_E + C$ = 78 − 5 = 73 dB

Figure 4-24. Example of Completed Worksheet.

- Sum the resultant antilogarithms for all the measured sound levels and divide by the number of measurements. It is not necessary to record the individual antilogarithms if a calculator with a cumulative memory is being used to sum them.
- Take the logarithm and multiply by 10 to obtain the energy-average maximum sound level.

STEP 2: If a Type 2 (or S2A) sound level meter was used for the measurements, subtract 2 dB from the energy-average maximum sound level (Step 1) if car-coupling impacts are being measured and subtract 4 dB from the energy-average maximum sound level if retarder squeals are being measured.

STEP 3: Determine the correction factor either by using Table 4-15 or by calculating the factor by the following method: divide the number of valid car-coupling measurements by the measurement time period in minutes, take the logarithm and multiply the resultant number by 10. Add this figure to the energy-average sound level calculated in Step 1, corrected if necessary as in Step 2.

4.2.6 Data Base

4.2.6.1 Car-Coupling Impacts

On the basis of the results of 94 car-coupling impact noise measurements,[4,6,10] the maximum A-weighted sound levels from these noise events at a distance of 100 feet range from 69 dB to 113 dB with a mean value of 86.3 dB. Figure 4-26 shows a distribution of these sound levels. Figure 4-27 shows a typical time history of the A-weighted sound level of car-coupling impacts in a flat yard. One-third octave band spectra of a single car-coupling impact and of a series of chain-reaction impacts are shown in Figures 4-28 and 4-29, respectively.

The maximum level of the noise emitted in a single car-coupling impact depends most directly on the relative speed with which the two cars collide. Figure 4-30 shows the relationship between maximum A-weighted sound level (fast meter response) at 100 feet and relative car-coupling speed. Also indicated is the corresponding linear regression curve, standard error of estimate, σ, and correlation coefficient, r, for these data.

4.2.6.2 Retarder Squeals

On the basis of the results of 750 retarder squeal noise measurements,[4,6,7,10] the maximum A-weighted sound levels from these noise events at a distance of 100 feet range from 70 dB to 130 dB with a mean value of 97.5 dB. Figure 4-31 shows a distribution of these sound levels. Figure 4-32 shows a typical time history of the A-weighted sound level emitted by a master retarder. One-third octave band spectra of sound emitted from a master retarder and from an inert retarder are shown in Figures 4-33 and 4-34, respectively.

The maximum sound level of a retarder squeal and, indeed, whether or not a car passing through a retarder will squeal, are thought to depend on a large number of parameters such as: car weight, applied retarding force, surface characteristics of wheel and brake shoe, temperature, and relative humidity. Few controlled experiments, in which all but one of these variables are held constant, have been performed; thus little is known about the functional dependance of the emitted sound level on each of these parameters.

4.2.7 Noise Control Techniques

4.2.7.1 Car-Coupling Impacts

As seen in Figure 4-30, the maximum sound level emitted in a car-coupling impact is proportional to the relative speed with which the cars come together. Thus the primary method of impact noise control is to minimize the coupling speed, subject to the requirement, of course, that the cars do couple. If the speed is set too low so that a car coupling does not occur, a locomotive would have to be sent down the track to couple the two cars together. This would not only reduce the efficiency of the classification operation but also would emit more noise into the community due to the additional motion of the locomotive.

Other types of coupling procedures have been proposed, such as shove-to-rest or the use of specially cushioned couplers, but these in general have not been found to be either technically or economically feasible.

4.2.7.2 Retarder Squeals

Retarder noise is generated from slip-stick mechanism between the wheel, rail, and retarder brake shoe which sets each component into vibration. The level of the squeal and whether or not a squeal will occur seems to depend on the weight of the car, the retardation force, the frictional characteristics of the wheel, brakeshoe, and rail, and the weather conditions.

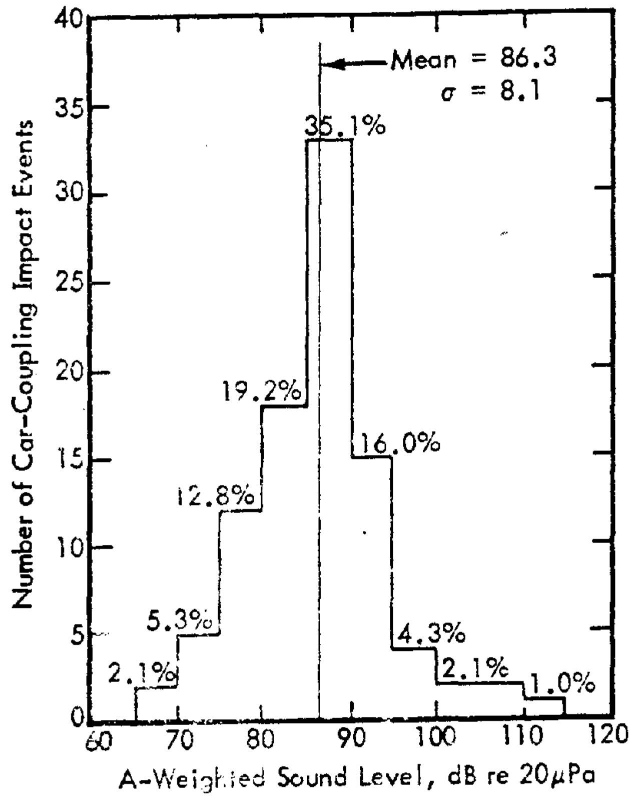


Figure 4-26. Distribution of Maximum A-Weighted Sound Levels For Car-Coupling Impacts[4,6,10] (Measurements Taken 100 Feet From Track).

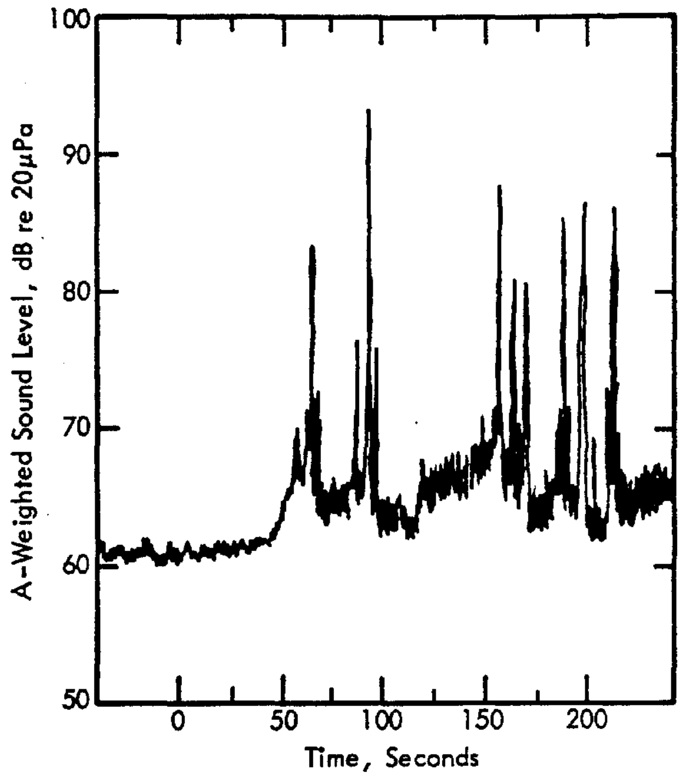


Figure 4-27. Time History of A-Weighted Sound Levels of Car-Coupling Inputs In Flat Yard[3] (Measurement Taken 80 Feet From Switching Track).

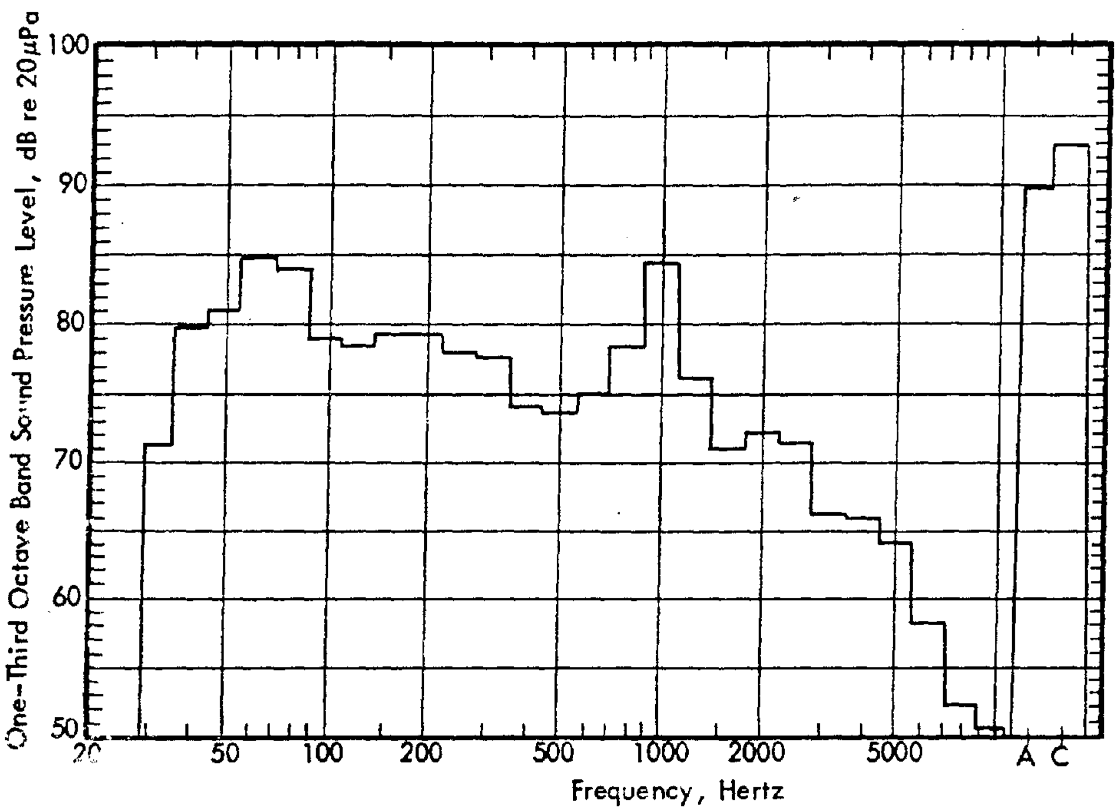


Figure 4-28. Spectrum of Sound Emitted From a Car-Coupling Impact 3 (Measurements Taken 100 Feet From Track).

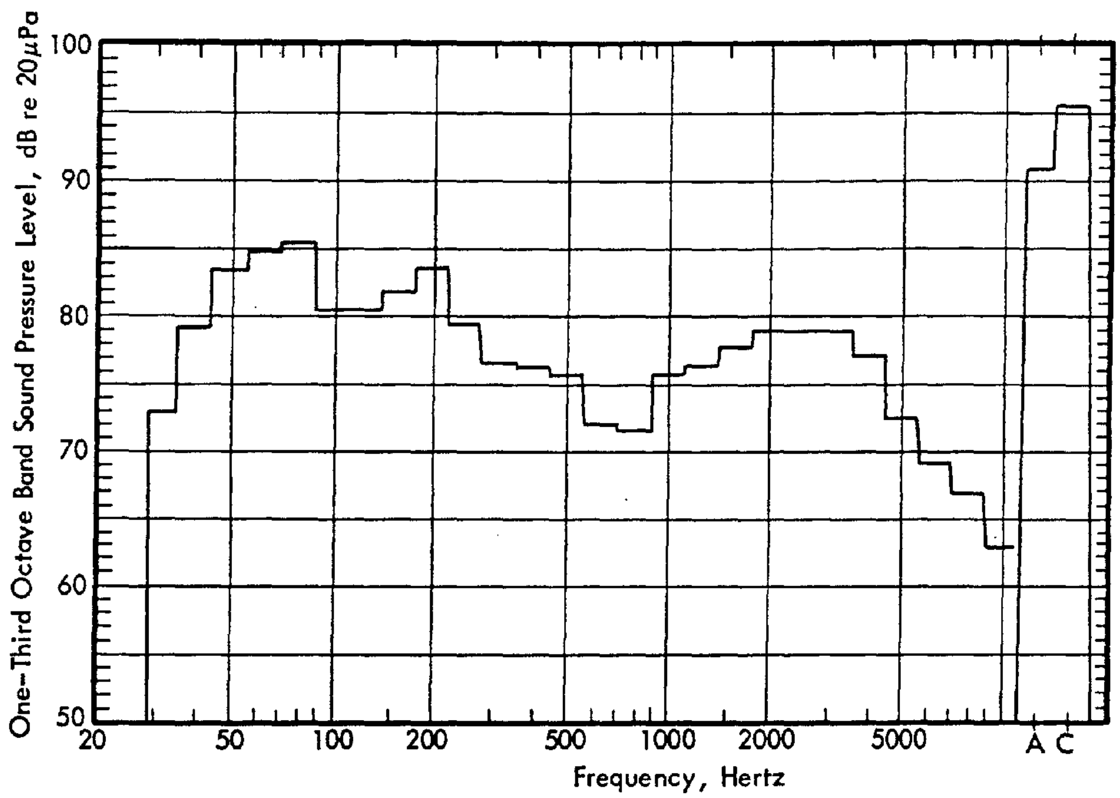


Figure 4-29. Spectrum of Sound Emitted From a Series of Chain Reaction Impacts[3] (Measurements Taken 100 Feet From Track).

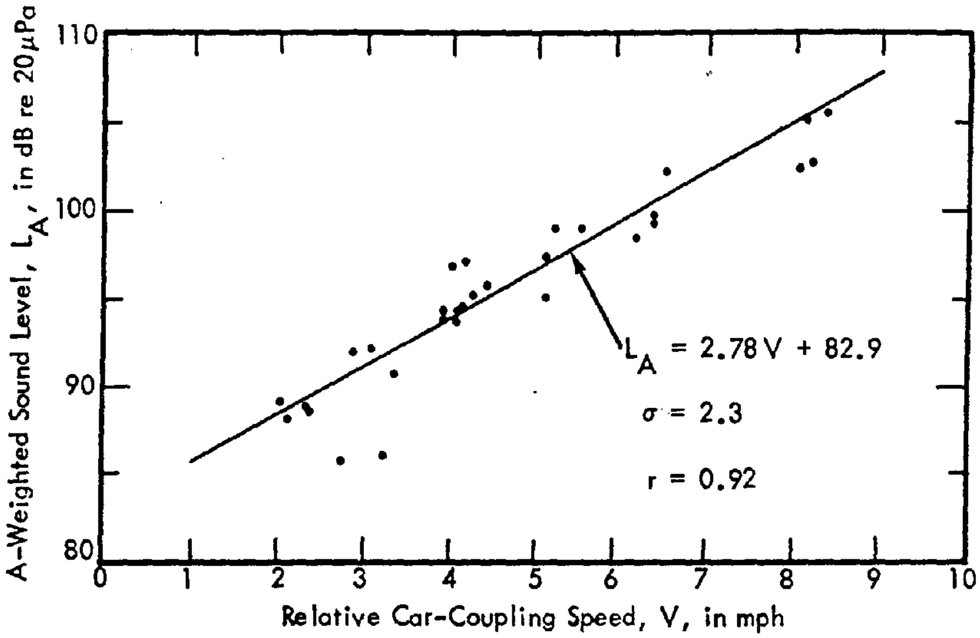


Figure 4-30. Maximum A-Weighted Sound Level (Fast Response) As a Function of Relative Car-Coupling Speed[11] (Measurements Taken 100 Feet From Track).

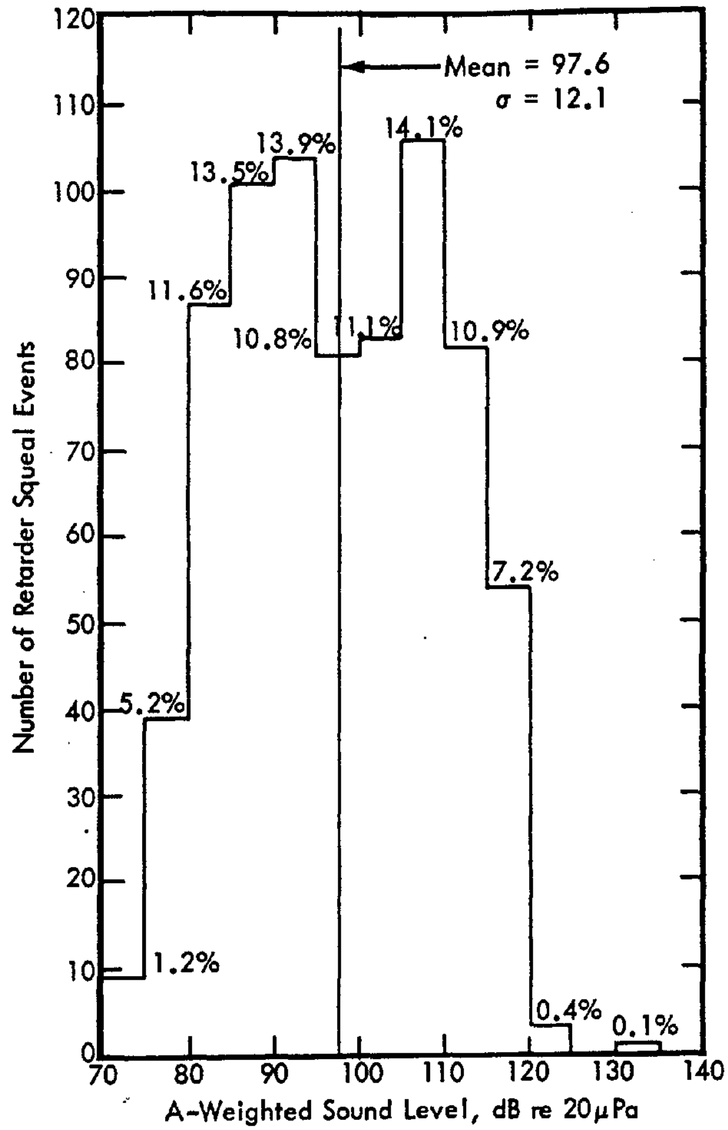


Figure 4-31. Distribution of Maximum A-Weighted Sound Levels For Retarder Squeals[4,6,7,10] (Measurements Taken 100 Feet From Retarder).

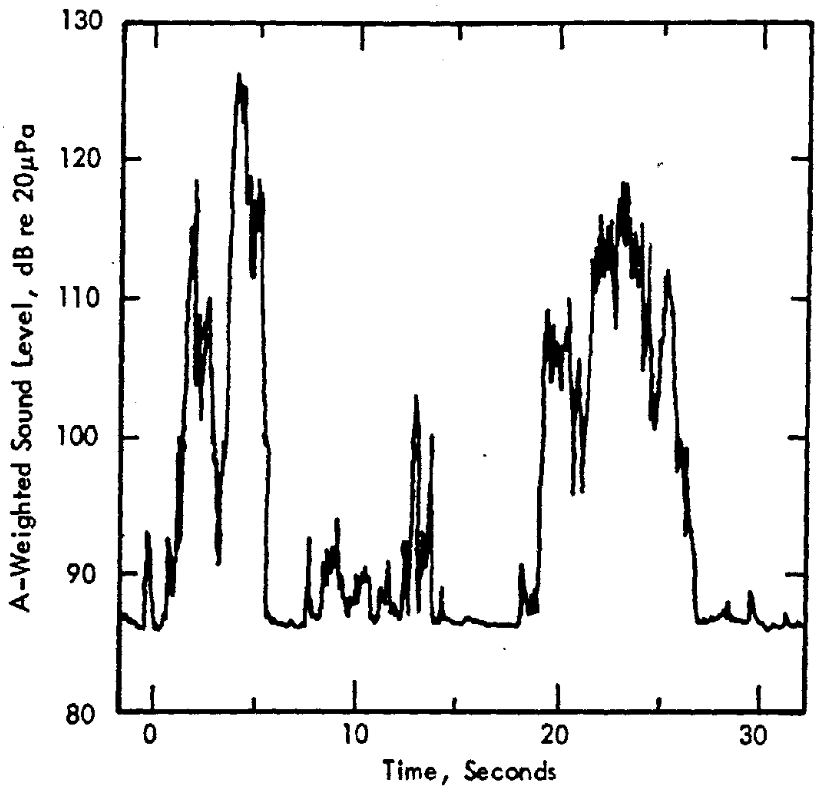


Figure 4-32. Time History of A-Weighted Sound Level Emitted by Master Retarder[3] (Measurements Taken 25 Feet From Retarder).

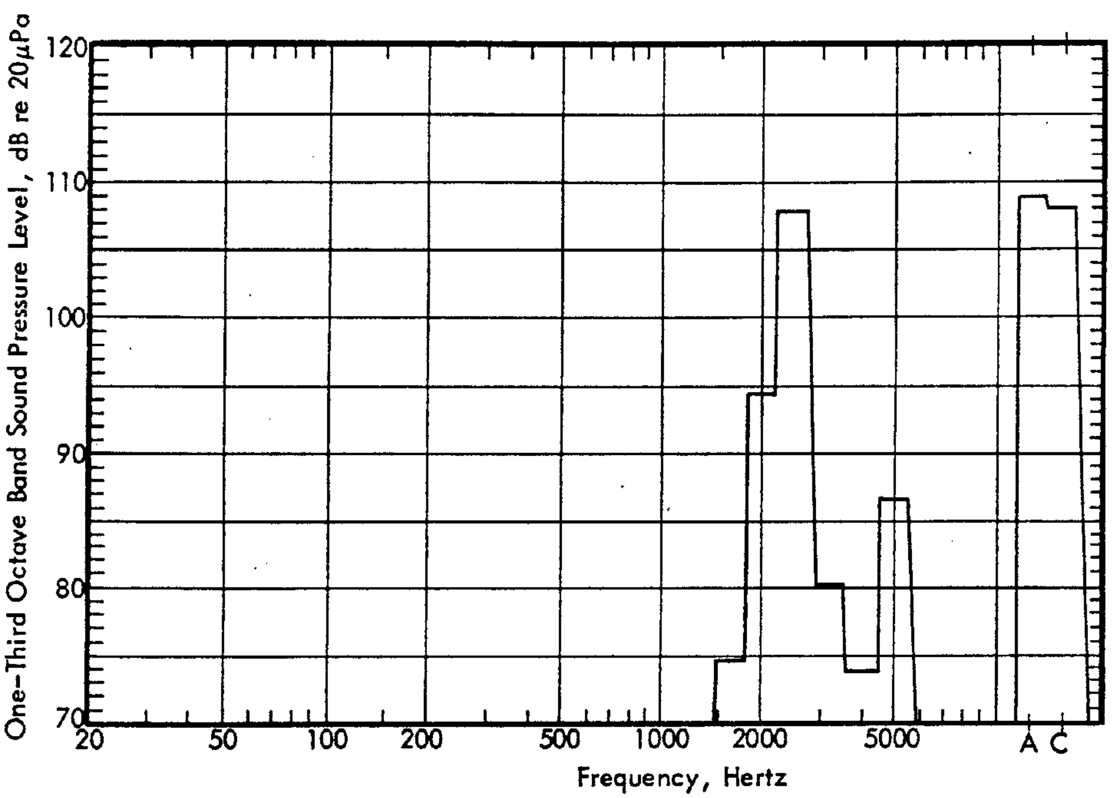


Figure 4-33. Spectrum of Sound Emitted From Master Retarder[3] (Measurements Taken 100 Feet From Retarder). Spectra For Group Retarders Are Similar.

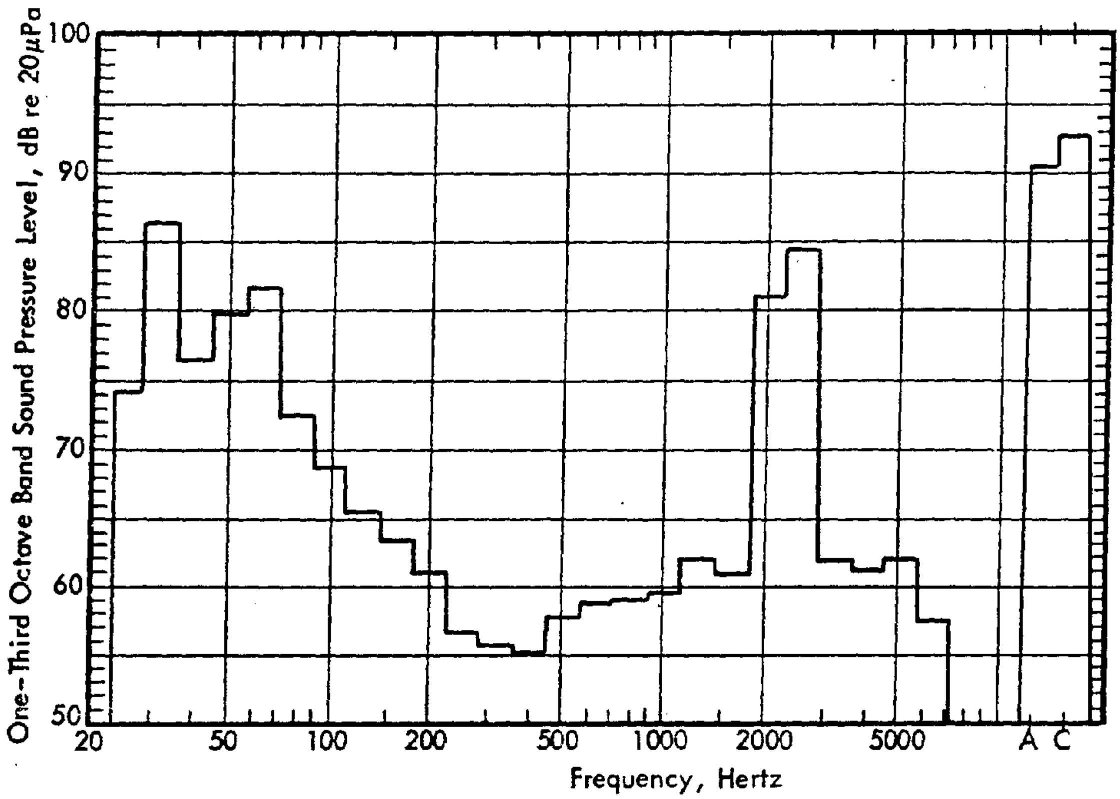


Figure 4-34. Spectrum of Sound Emitted From Inert Retarder[3] (Measurements Taken 100 Feet From Track).

Numerous techniques of retarder noise reduction have been proposed; however, the following three approaches are being implemented at some hump yards:

- Barriers
- Lubrication system
- "Low noise" brake shoes

Barriers have been installed at the Madison Yard in St. Louis, the Burlington Northern Yard in Kansas City, the Northtown Yard in Fridley, Minnesota, and at the Calder Yard in Edmonton, Alberta. These devices are located parallel to the retarders and are lined with absorptive material. Since the source of the noise is close to the ground and the spectral content of the noise is predominantly high frequency, absorptive barriers have been shown to be quite effective in reducing noise propagating in directions perpendicular to the retarder. The insertion loss of a 12-foot-high barrier is shown in Figure 4-35.

A major problem with the barriers is that they restrict the visibility of the hump operator, thus making it difficult to monitor the movement of cars through the retarders. In order to improve visibility, the operator may have to be relocated. For example, at Madison Yard, the hump control operator was relocated to the top level of the tower building in order to improve his visibilty of the hump. This move required major alterations of communications, controls, and other related facilities.

Another problem with barriers is that they restrict access to the retarders, so that repair and maintenance work become more difficult and thus more expensive. In addition, derailments near retarders usually cause damage to the barriers, thus requiring extensive cleanup, reconstruction of the barriers, and down-time of the operation of the retarder.

At Northtown Yard in Fridley, Minnesota, lubrication systems have been used to spray small amounts of oil onto car wheels before entering the retarder. The lubrication system consists of a series of nozzles on a header pipe located at both sides of each rail with a concrete trough below the rail to collect the residue. A water-soluble oil solution of less than two percent oil is employed. In winter, ethylene glycol is added to the mixture to keep the water from freezing. The lubricant is collected in a retrieval system and cleaned for reuse.

This system has been effective in changing the frictional characteristics of the wheel and brake shoe sufficiently to eliminate wheel squeal. There is, however, the danger that too much oil will be deposited so that the car will not be sufficiently slowed by the retarder. Another problem with the lubricant system is that the excess oil can drop onto the ground and eventually contaminate ground water.

Recently, several manufacturers have introduced "low noise" brake shoes for use in reducing the occurrence of retarder squeal. These designs employ both new metallic compositions and new surface designs to constrain the coefficient of friction between wheel and brake shoe in a range that will minimize the probability of exciting the system. Although in the past, ductile iron brake shoes did reduce the incidence of squeal at the cost of highly accelerated brake shoe wear, the new compositions and designs appear to wear as well as conventional brake shoes.

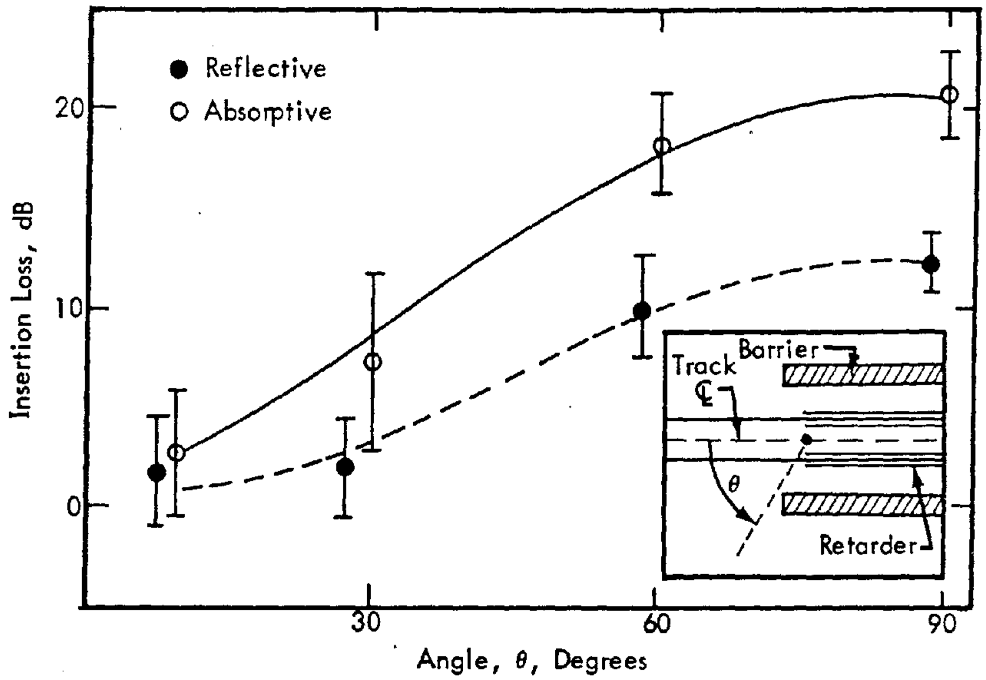


Figure 4-35. Insertion Loss of 12-Foot Barriers, As a Function of Angular Position[12] (100-Foot Equivalent Distance).

REFERENCES FOR CHAPTER 4

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2. Remington, P.J., Alakel, M.N., Ernest, J.W., and Dixon, N.R., "The Measurement of Locomotive Noise at Existing Railroad Test Sites," FRA/ORD-79/55, January 1980, PB 80-137 334.*

3. Swing, J.W., and Pies, D.B., "Assessment of Noise Environments Around Railroad Operations," Wyle Research Report WCR 73-5, July 1973.

4. Bender, E.K., Ely, R.A., Remington, P.J., and Rudd, M.J., "Railroad Environmental Noise: A State-of-the-Art Assessment," BBN Report No. 2709, January 1974.

5. "Background Document for Railroad Noise Emission Standards," EPA-550/9-76-005, U.S. Environmental Protection Agency, December 1975.

6. Pies, D.B., "Data Collection at California Railroad Yard Sites," Wyle Research Technical Note 75-10, December 1975.

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9. Data provided by the Office of Noise Abatement and Control, U.S. Environmental Protection Agency, and available at the EPA Public Information Center, 401 M St., S.W., Washington, D.C. 20460.

10. Based on data provided by Research and Test Department, Association of American Railroads, 1920 L St., N.W., Washington, D.C. 20036.

11. "Background Document for Final Interstate Rail Carrier Noise Emission Regulation: Source Standards," EPA-550/9-79-210, December 1979.

12. Morgan, J.A., and Ingard, U., "Railroad Retarder Noise Reduction: Study of Acoustical Barrier Configurations," DOT-TSC-NHTSA-79-35, May 1979.

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* NOTE: "PB" numbers refer to NTIS documents.

CHAPTER 5

MISCELLANEOUS REGULATIONS

In addition to the noise emission from the sources discussed in Chapters 3 and 4, two additional railroad-associated acoustic environments are controlled by federal regulations:

1. The energy-average sound level within railroad employee sleeping quarters is required to be below a defined standard; and
2. The A-weighted sound level from audible warning devices on locomotives is required to be above a defined level.

This chapter discusses the following items for each of these two standards:

- The existing federal regulation controlling the acoustic environment,
- The acoustic metric used to quantify this acoustic environment,
- The measurement site selection,
- The instrumentation and measurement procedure needed to determine the characteristics of the acoustic environment,
- The existing data base describing the acoustic environment, and
- Techniques for meeting the acoustic standard.

The chapter is arranged in two sections: Section 5.1 discusses railroad employee sleeping quarters, and Section 5.2 discusses audible warning devices on locomotives.

5.1 Interior Noise Levels Within Railroad Employee Sleeping Quarters

On July 19, 1978, the Federal Railroad Administration of the U.S. Department of Transportation published final rules under which it will consider whether proposed sites for the construction or reconstruction of sleeping quarters for railroad employees subject to the Hours of Service Act are "within or in the immediate vicinity of any area where railroad switching or humping operations are performed." The Hours of Service Act, as amended by the Federal Railway Safety Act of 1976, prohibits the construction or reconstruction of quarters for such employees within or in the immediate vicinity of switching and humping.

In the FRA rules, one factor to be evaluated when considering a petition for approval of the construction or reconstruction of sleeping quarters for railroad employees is the interior noise level in the facility.

5.1.1 Regulation

The noise limit set forth in the FRA rules is shown in Table 5-1.

Table 5-1

Noise Exposure Standard For Railroad Employee Sleeping Quarters

Date Effective	Maximum Permitted A-Weighted 8-Hour Equivalent Sound Level, $L_{eq(8)}$	Measurement Tolerance *
July 8, 1984	55 dB	2 dB

* Re: FRA "Railroad Noise Enforcement Manual"[1] **

** Superscripts refer to references at end of chapter.

The portion of the FRA rules pertaining to the acoustic environment, as published in 43 FR 31006 (1978), is as follows:

(b) In considering a petition for approval filed under this subpart, the Railroad Safety Board evaluates the material factors bearing on –

(1) The safety of employees utilizing the proposed facility in the event of a hazardous materials accident/incident and in light of other relevant safety factors; and

(2) Interior noise levels in the facility.

(c) The Railroad Safety Board will not approve an application submitted under this subpart if it appears from the available information that the proposed sleeping quarters will be so situated and constructed as to permit interior noise levels due to noise under the control of the railroad to exceed an $L_{eq(8)}$ value of 55 dB(A). If individual air conditioning and heating systems are to be utilized, projections may relate to noise levels with such units turned off.

5.1.2 Acoustic Metric

The metric used in these rules is summarized in Table 5-2.

Table 5-2

Acoustic Metric for Interior Noise Levels Within Railroad Employee Sleeping Quarters

A-WEIGHTED EIGHT-HOUR EQUIVALENT SOUND LEVEL, $L_{eq(8)}$
A-WEIGHTED SOUND LEVEL "SLOW" RESPONSE

The metric used to check compliance with the standard is the A-weighted 8-hour equivalent sound level, $L_{eq(8)}$. Equivalent sound level (L_{eq}) is the level of the constant sound which, in a given time period, would transmit the same sound energy as did the actual time-varying sound.

5.1.3 Measurement Site Selection

The purpose of this regulation is to assure that the railroad employees are provided sleeping quarters which afford them the opportunity for rest, free from interruptions caused by noise from switching and humping operations under the control of the railroad. The measurements therefore should be made in "high noise" dormitory rooms. The choice of such rooms is based on such factors as proximity to predominant or intense railroad noise sources such as retarder squeal and car impacts, employee interviews, or preliminary "walk-through" sampling with a sound level meter.

Within each room, the microphone should be positioned where it can best capture the sounds which may cause sleep interference. A position near the head side of a bed, for example, would be appropriate. If time and availability of equipment permits, the sound level in more than one room in the dormitory should be measured. Unoccupied rooms are preferred in order to avoid measurement of internally generated noise associated with human activities. The objective is to measure external noise levels that may potentially disrupt occupants at rest.

The regulation requires that any individual heating or air-conditioning units present in the room should be turned off during the measurement period. Central heating and air-conditioning systems may remain in operation.

5.1.4 Instrumentation

The instrumentation required to conduct railroad employee sleeping quarters noise measurements is shown in Table 5-3.

Table 5-3

Instrumentation For Interior Noise Levels Within Railroad Employee Sleeping Quarters

INTEGRATING SOUND LEVEL METER *
SOUND LEVEL METER
MICROPHONE AND WINDSCREEN
TRIPOD
SOUND LEVEL CALIBRATOR
ACCESSORIES

* A noise dosimeter with a 3 dB exchange rate may be used.

Calibration procedures for this measurement are specified in Reference 1. Calibration and adjustment of the measurement instrumentation according to manufacturer's instructions are required before the measurement and a recheck of the calibration is required after the measurement has been completed. In addition, the measurement instrumentation should be checked by the manufacturer or an authorized representative at least once each year. A dated sticker attesting to this inspection should be attached to the instrument.

5.1.5 Measurement Procedure

The procedure to be followed when conducting railroad employee sleeping quarters noise measurements is derived from the FRA noise standard regulation and common measurement practice.

The procedure is made up of four phases. They include:

- Program Planning
- Instrumentation Checkout
- Instrumentation Setup
- Data Collection

A description of these phases as applied to sleeping quarters noise measurements is presented in the rest of this section. Where appropriate, sample worksheets are included. These may be copied directly or may be used as a basis for designing a more personalized format.

5.1.5.1 Program Planning

The first stage of the measurement program is program planning. It is during this phase that decisions are made concerning such factors as the number of dormitories to be tested, specifically which dormitories will be tested, the number and locations of the rooms to be tested in each facility, and the day and time the measurements are to be made. Permission to be allowed access to the measurement locations at the time desired should be obtained from the responsible railroad official.

It is also at this point that the instrumentation system is specified and acquired. The system used for sleeping quarters noise measurements will normally consist of a Type 1 or 2 integrating sound level meter, a sound level meter, a calibrator, windscreen, and tripod. Other useful equipment include a tape measure and a camera.

A program planning worksheet is shown in Figure 5-1. This is useful in assuring that all of the planning details are carried out.

5.1.5.2 Instrumentation Checkout

Before proceeding to the field for measurements, the instrumentation system should be put together and thoroughly checked out and the manufacturer's instructions referred to for calibration and operational procedures. The batteries must be tested and all interconnecting cables and mounting hardware should be connected to assure that the correct plugs fit into the proper instruments, and that the overall system works as required. The accessories such as extra batteries, note pads, adhesive tape, and the like, should be assembled.

PROGRAM PLANNING WORKSHEET

Railroad Employee Sleeping Quarters

Date: ____________________ Prepared By: ______________________________

Check When Completed

Test Plan

_____ Determine the number of dormitories and dormitory rooms to be tested.

_____ Determine the location of each dormitory to be tested.

_____ Determine when the measurements will be made.

_____ Obtain permission to carry out measurements on railroad property.

Instrumentation Checkout

_____ Specify the instrumentation system required for the measurements.

_____ Acquire the instrumentation system.

_____ Check out and calibrate the instrumentation system.

_____ Complete the instrumentation system inventory worksheet.

_____ Pack the instrumentation system for shipment to the measurement site.

Measurement Site Setup

_____ Check in with responsible railroad official.

_____ Unpack instrumentation system, checking against worksheet.

_____ Set up the instrumentation system and check components for damage.

_____ Calibrate the system and report results on the field data log.

_____ Complete the annotation on the field data log.

Noise Measurements

_____ Conduct noise measurements.

_____ Record results on the field data log.

_____ Check calibration of the system and record results on the field data log.

_____ Repack system for return shipment, referring to inventory checksheet.

Program Completion

_____ Unpack instrumentation system, check for damage.

_____ Document measurement program.

Figure 5-1. Sample Program Planning Worksheet.

An inventory of the necessary equipment should be prepared and brought into the field. This assures that once the measurement program has begun no details will be forgotten. A sample of an inventory worksheet is shown in Figure 5-2.

5.1.5.3 Instrumentation Setup

Before proceeding to the railroad employee sleeping quarters, notify the railroad official responsible for the facility of the presence of the measurement personnel. Once in the sleeping quarters, the instrumentation should be set up according to the manufacturer's instructions. The inventory worksheet should be referred to at this time.

The integrating sound level meter should be placed at a representative location in a "high noise" room of the sleeping quarters. The choice of such a room should be based on such factors as:

- Proximity to predominant or intense noise sources,
- Employee interviews, or
- A preliminary survey of A-weighted sound levels in the sleeping quarters building.

The microphone should not be placed near any local noise sources. Radios, record players, etc., should be turned off. An unoccupied room should be used, if possible. Initial sound level measurements should be made to assure that railroad operations are the predominant source detected by the microphone.

The sound level meter should be calibrated according to the manufacturer's instructions. This should be done prior to the beginning of measurements, and noted in the field data log. After the measurements have been completed, the calibration of each instrument should be checked; the calibrator levels at this time should be recorded in the data log.

A sketch of the microphone position should be drawn, indicating the position of the microphone relative to the beds in the sleeping quarters. The location of doors, windows, window air conditioners, and other major noise sources should be indicated on the sketch. If possible, a photograph of the interior of the room, showing the microphone location, should be taken.

A data log should be completed for the measurement program. A typical data log sheet is shown in Figure 5-3 and should contain the following information:

- Date of measurements.
- Name of person performing the measurements.
- Location of dormitory facilities.
- Types, models, serial numbers, or other identification characteristics for all instrumentation.
- Results of calibration tests.
- Background levels.
- Dormitory and room identification.
- Measured equivalent sound levels.

A note pad should be taken into the field and used to write extensive notes detailing anything going on which may have a bearing on the measurements or the interpretation of the data. The occurrence of atypical events are examples of the type of information which should be recorded.

5.1.5.4 Data Collection

Before beginning the integrating sound level meter measurements, measurements of the instantaneous sound level at the microphone position due to commonly occurring noises should be measured and recorded on the data log. The following examples illustrate the type of source levels that should be noted:

- Air-conditioning systems.
- Ambient sound level (no identifiable source).
- Noise in adjacent rooms, if present.
- Idling locomotive(s), if present.
- Car-coupling impacts.
- Retarder squeals.
- Identifiable non-railroad sounds (e.g., automobile and truck passbys, aircraft flyovers, etc.)

INSTRUMENTATION SYSTEM INVENTORY WORKSHEET

Railroad Employee Sleeping Quarters

Date: ____________________ Prepared By: ________________________________

INSTRUMENT	Make	Model	Serial No.	Date of Last Calibration	Check Out	Return
Integrating Sound Level Meter (SLM)						
Sound Level Meter						
Microphone						
Sound Level Calibrator						

REQUIRED (*) AND RECOMMENDED ACCESSORIES	Checkout	Return
* SLM Calibration Adjustment Tool (Screwdriver)		
* Tripod		
Microphone Windscreen		
Thermometer		
Hygrometer		
Tape Measure		
Watch		
Extra Batteries		
Duct Tape		
Connecting Cables		
Flashlight		
Camera and Film		
Earphones		
Tools (screwdriver, pliers, etc.)		

Figure 5-2. Sample Instrumentation System Inventory Worksheet.

FIELD DATA LOG

Railroad Employee Sleeping Quarters

Date: ____________________ Prepared By: ________________________________

Location: ____

____

EQUIPMENT:

Instrument	Manufacturer	Model	Serial No.	Date of Last Calibration
Integrating Sound Level Meter				
Sound Level Meter				
Microphone				
Calibrator				

CALIBRATION: Calibrator Level: _______ dB; Calibrator Frequency: _______ Hz

Time						
Sound Level						

REPRESENTATIVE LEVELS: (WHERE SPECIFIC SOURCES CAN BE IDENTIFIED)

Time						
Level						
Source						

Figure 5-3. Sample Field Data Log.

FIELD DATA LOG (Continued)

Railroad Employee Sleeping Quarters

Date: ____________ Prepared By: ______________________

DORMITORY PARAMETERS AND LEVELS:

Dormitory ________________ Room Number* ________

Time		Total Duration	Energy-Equivalent Sound Level, dB	Comments
Start	Stop			

REMARKS: ______________________________________

____

____

* Sketch Building If Not Numbered:

SKETCH OF SITE GEOMETRY:

↑ N

Figure 5-3 (Concluded).

The integrating sound level meter should be started according to manufacturer's instructions and left undisturbed for the entire measurement period. This will normally be eight hours,* although it can be shorter if either of the following criteria are met:

(a) The acoustic environment is known to be essentially constant or

(b) The distribution of sound levels measured during the measurement period can be considered to be representative of the distribution of sound levels that would have been measured in eight hours.

These conditions can be tested by measuring equivalent sound levels for a series of short time periods. If the resultant L_{eq} values are essentially equal, then the measured sound levels are representative of the acoustic environment that would occur in eight hours. Thus, for example, if the $L_{eq}(0.5)$ values measured within three successive half-hour periods are within a few decibels of each other and if it is known that the railroad operations that occurred in these time periods were representative of those operations that occur throughout the eight-hour period, then the arithmetic average of the L_{eq} values is a reasonable approximation to the $L_{eq}(8)$ value that would be obtained from a full eight-hour measurement.

Occupants of the dormitory should be instructed to behave as they normally would (when other occupants are resting) while the sound level measurements are being made. Whistling, shouting, and loud radio playing should be avoided. Room occupants should be instructed not to touch the instrumentation. If possible, unoccupied rooms should be used for the measurements. Individual room air-conditioning or heating systems should be turned off during the measurement period.

At the end of each measurement period, the equivalent sound level should be read out and recorded on the data log. Any unusual occurrences reported by the room occupants should be noted on the data log.

The following manual sampling procedure** using a sound level meter is used by the FRA as a backup to integrating sound level meter measurements to estimate the $L_{eq}(0.5)$ sound level of railroad noise sources:

- Observe the sound level meter during the first 10 seconds of each 30-second period for 30 minutes.
- Record the maximum*** sound level in each 10-second period. If this maximum is identified as emanating from a non-railroad source, it is not "valid" and should not be used in the subsequent L_{eq} calculation. If the maximum is identified as emanating from a railroad source or if the source is not identifiable, then it is valid and should be included in the L_{eq} calculation.
- Continue this sampling procedure until 60 valid measurements are obtained.
- Compute the energy-average of the resultant 60 measurements.

The data sheet in Figure 5-4 may be used for these manual samples; the resultant estimated $L_{eq}(0.5)$ can then be copied onto the data sheet in Figure 5-3. The manual sampling data sheets used for each $L_{eq}(0.5)$ estimate should be attached to the field data log to form a complete package. An example is given in Figure 5-5.

5.1.6 Data Base

On the basis of the results of 75 noise measurements made in railroad employee sleeping quarters and reported by FRA,[2] the values of $L_{eq}(8)$ range from 35 dB to 60 dB with a mean value of 46.0 dB. Figure 5-6 shows the distribution of these levels. The peak in this distribution at 35 to 40 dB represents a large number of reported 35 dB measurements. This level may represent the electrical noise floor of the instrumentation used to collect the data.

---

* FRA inspectors are required to conduct three consecutive 8-hour L_{eq} measurements with an integrating sound level meter (or dosimeter) and two valid 30-minute sound level meter measurements using the following manual sampling procedure in each room. Local inspectors or railroad personnel may rely on abbreviated techniques as long as the data collected are informational and not used for citations.

** Adapted from SAE Recommended Practice J1075, "Measurement Procedure for Determining a Representative Sound Level at a Construction Site Boundary Location."

*** Note that this procedure overestimates the equivalent sound level. A more accurate estimate would be obtained by recording the sound level at the end of each 10-second period as discussed in Section 2.2.2.8. The procedure here ensures that if the overestimated equivalent sound level is below the standard, then the true equivalent sound level will also be below the standard.

MANUAL $L_{eq(0.5)}$ ESTIMATE WORKSHEET

Date: ____________________ Prepared By: ____________________________________

DORMITORY PARAMETERS AND A-WEIGHTED SOUND LEVELS:

Dormitory____________ Room Number____________

Start Time____________ Stop Time____________

Level, L_i (dB)	Source	No.,* i	Level, L_i (dB)	Source	No.,* i	Level L_i (dB)	Source	No.,* i

* Number only valid measurements (those for which the source is either not identifiable or identifiable as a railroad source). Sixty valid measurements are required.

$$L_{eq(0.5)} = 10 \log_{10} \left[\frac{1}{60} \left(\sum_{i=1}^{60} 10^{L_i/10} \right) \right] = \boxed{}$$

Figure 5-4. Sample Worksheet for Manual Sampling.

MANUAL $L_{eq(0.5)}$ ESTIMATE WORKSHEET

Date: Dec. 10, 1981 Prepared By: J.S. WING

DORMITORY PARAMETERS AND A-WEIGHTED SOUND LEVELS:

Dormitory #2 Room Number 212

Start Time 14:10 Stop Time 14:46

Level, L_i (dB)	Source	No.,* i	Level, L_i (dB)	Source	No.,* i	Level L_i (dB)	Source	No.,* i
52	AMBIENT	1	50	AMBIENT	25	64	A/C	—
54	AMBIENT	2	51	"	26	60	A/C	—
60	LOCOMOTIVE	3	47	"	27	49	AMBIENT	51
64	LOCOMOTIVE	4	53	"	28	50	"	52
64	LOCOMOTIVE	5	55	"	29	52	"	53
60	LOCOMOTIVE	6	62	LOCOMOTIVE	30	55	"	54
54	AMBIENT	7	60	LOCOMOTIVE	31	62	RETARDER	55
58	AUTO	—	66	RETARDER	32	64	RETARDER	56
62	TRUCK	—	62	RETARDER	33	58	LOCOMOTIVE	57
50	AMBIENT	8	60	LOCOMOTIVE	34	57	LOCOMOTIVE	58
48	"	9	64	LOCOMOTIVE	35	52	AMBIENT	59
48	"	10	60	RETARDER	36	54	"	60
56	RETARDER	11	54	AMBIENT	37			
64	RETARDER	12	52	"	38			
68	RETARDER	13	50	"	39			
60	RETARDER	14	48	"	40			
50	AMBIENT	15	48	"	41			
46	"	16	49	"	42			
62	AUTO	—	59	AUTO	—			
60	AUTO	—	64	TRUCK	—			
52	AMBIENT	17	62	TRUCK	—			
54	"	18	60	AUTO	—			
50	"	19	52	AMBIENT	43			
50	"	20	55	"	44			
58	LOCOMOTIVE	21	50	"	45			
62	LOCOMOTIVE	22	50	"	46			
66	A/C	—	47	"	47			
64	A/C	—	55	"	48			
60	LOCOMOTIVE	23	62	LOCOMOTIVE	49			
56	LOCOMOTIVE	24	62	LOCOMOTIVE	50			

* Number only valid measurements (those for which the source is either not identifiable or identifiable as a railroad source). Sixty valid measurements are required.

$$L_{eq(0.5)} = 10 \log_{10} \left[\frac{1}{60} \left(\sum_{i=1}^{60} 10^{L_i/10} \right) \right] = 59$$

Figure 5-5. Example of Completed Worksheet for Manual Sampling.

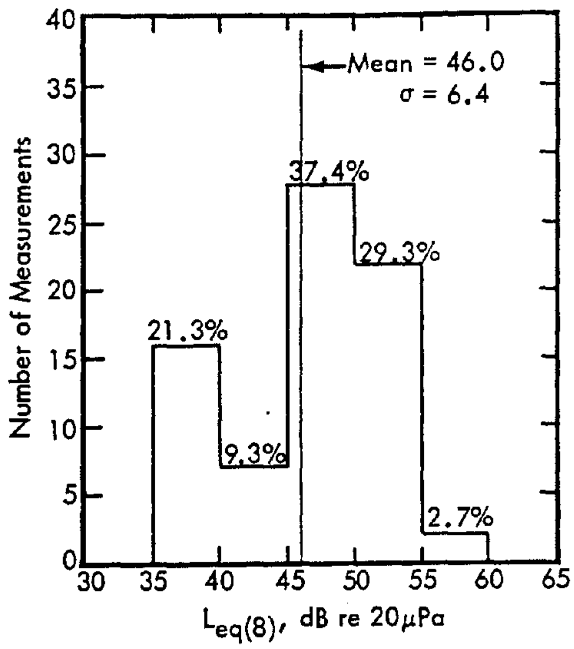

Figure 5-6. Distribution of Railroad Employee Sleeping Quarters Sound Measurements.[2]

5.1.7 Noise Abatement Techniques

To reduce the exterior noise transmitted into railroad employee sleeping quarters, the procedures discussed in Sections 2.3.2 and 2.3.3 above should be utilized. These include, in order of cost effectiveness:

- Closing windows, provided adequate ventilation can be provided by other means;
- Sealing cracks, holes, and other noise leaks;
- Weatherstripping doors and windows;
- Modifying or replacing low sound-attenuating elements, such as windows and doors;
- Modifying wall structure to improve its transmission loss;
- Using barriers to shield sleeping quarters; and
- Relocating sleeping quarters further from noise sources.

5.2 Sound From Audible Warning Devices on Locomotives

Although the conditions under which audible warning devices or locomotives are to be used are determined by railroad operating rules as allowed by state and local ordinances, the minimum sound level of each warning device is governed by federal regulation. Railroad locomotive safety standards are defined by the United States Code of Federal Regulations – 49 CFR Part 229. As part of these safety standards, the sound level of audible warning devices on locomotives is required to be above a defined minimum value.

5.2.1 Regulation

On March 31, 1980, the Federal Railroad Administration published final rules on Railroad Locomotive Safety Standards which, in part, require that the sound level from an audible warning device on a lead locomotive be above the level shown in Table 5-4.

Table 5-4

Sound Emission Standard For
Audible Warning Devices on Locomotives

Date Effective	Minimum A-Weighted Sound Level*	Measurement Tolerance
August 31, 1980	96 dB	4 dB

* When measured at a distance of 100 feet forward of the locomotive in its direction of travel using slow response.

The final regulation in 49 CFR Part 229 is as follows:

§ 229.129 Audible warning device.

(a) After August 31, 1980, each lead locomotive shall be provided with an audible warning device that produces a minimum sound level of 96 dB(A) at 100 feet forward of the locomotive in its direction of travel. The device shall be arranged so that it can be conveniently operated from the engineer's normal position in the cab.

(c) A 4 dB(A) measurement tolerance is allowable for a given measurement.

5.2.2 Choice of Metric

The metric used in this regulation is summarized in Table 5-5.

Table 5-5

Acoustic Metric For Audible Warning Devices on Locomotives

A-WEIGHTED SOUND LEVEL "SLOW" RESPONSE

5.2.3 Microphone Location

The regulation states that the sound level shall be measured "at 100 feet forward of the locomotive in its direction of travel." Bi-directional locomotives with dual controls normally travel with either end forward. These locomotives should be measured at two positions, 100 feet from each end of the locomotive (Positions A and B in Figure 5-7). For single-direction locomotives (i.e., single control), measurements are usually made only at Position A.

In addition, the regulation states:

"While the locomotive is on level tangent track, the microphone shall be positioned 4 feet above the ground at the center line of the track, and shall be oriented with respect to the sound source in accordance with the manufacturers recommendations."

Although not stated explicitly in the regulation, good measurement practice requires that there be no large reflecting objects near the locomotive or the measurement position, that measurements not be taken in adverse weather conditions, and that the background level just before and just after the horn sounding be at least 10 dB below the source level. The presence of sound-reflecting objects and high winds may yield incorrect measurements of the warning device's acoustic output.

The requirements above are summarized in Table 5-6.

Table 5-6

Measurement Site Requirements For Tests of
Audible Warning Devices on Locomotives

TEST SITE *

Open space with no large reflecting objects within 100 feet of the source or the measurement position. Locomotive on level tangent track.

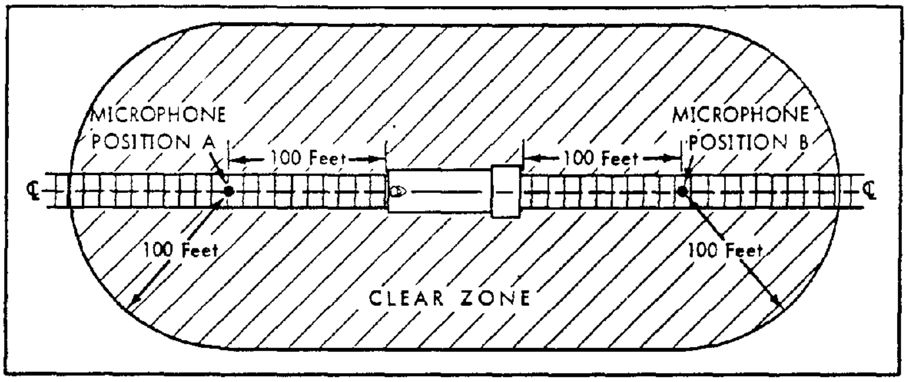

Figure 5-7. Recommended Test Site Clearance Zone (Locomotive Stationary).
(Bi-directional locomotive illustrated.)

MICROPHONE POSITION

The microphone must be located 4 feet above the ground along the centerline of the track at a distance of 100 feet forward of the locomotive in its direction of travel (see Figure 5-7).

WEATHER CONDITIONS *

Measurements should be taken only under these conditions:

- No precipitation (rain, snow, sleet, hail, etc.).
- Wind speed below 12 mph.
- Wind gusts below 20 mph.

BACKGROUND NOISE LEVEL *

The A-weighted, slow response sound level measured just before and just after the source test should be at least 10 dB lower than that of the source being measured.

* Recommended Standard Practice.

5.2.4 Instrumentation

The instrumentation required to make the noise measurements is shown in Table 5-7.

Table 5-7

Instrumentation For Audible Warning Device Sound Measurements

SOUND LEVEL METER
MICROPHONE AND WINDSCREEN
TRIPOD
SOUND LEVEL CALIBRATOR
WIND SPEED METER
ACCESSORIES

5.2.5 Measurement Procedure

The procedure to be followed when conducting audible warning device noise measurements is derived from common FRA measurement practice.

The procedure is made up of four phases. They include:

- Program Planning
- Instrumentation Checkout
- Instrumentation Setup
- Data Collection

A description of these phases as applied to audible warning device noise measurements is presented in the rest of this section. Where appropriate, sample worksheets are included. These may be copied directly or may be used as a basis for designing a more personalized format.

5.2.5.1 Program Planning

The first stage of the measurement program is program planning. It is during this phase that decisions are made concerning the number of locomotives to be tested, specifically which locomotives will be tested, the locations of the locomotives, and the day and time the measurements are to be made. Permission to perform the tests at the desired place and time should be obtained from the responsible railroad official.

It is also at this point that the instrumentation system is specified and acquired. The system used for audible warning device sound measurements will normally consists of a Type 1 or 2 sound level meter with a calibrator, windscreen, and tripod. Other useful equipment include a wind speed-measuring device, a 100-foot tape measure, and thermometer.

A program planning worksheet is shown in Figure 5-8. This is useful in assuring that all of the planning details are carried out.

5.2.5.2 Instrumentation Checkout

Before proceeding to the field for measurements, the instrumentation system should be put together and thoroughly checked out and the manufacturer's instructions referred to for calibration and operational procedures. The batteries must be tested and all interconnecting cables and mounting hardware should be connected to assure that the correct plugs fit into the proper instruments, and that the overall system works as required. The accessories such as extra batteries, note pads, adhesive tape, and the like, should be assembled.

An inventory of the necessary equipment and a measurement site qualification worksheet should be prepared and brought into the field. This assures that once the measurement program has begun no details will be forgotten. Samples of inventory and site qualification worksheets are shown in Figures 5-9 and 5-10. The inventory sheet is meant to be quite general; thus depending on the situation, it may not be necessary to take all the equipment listed.

PROGRAM PLANNING WORKSHEET

Audible Warning Devices on Locomotives

Date: ____________________ Prepared By: ____________________________________

Check When Completed	Test Plan
____	Determine the number of locomotives to be tested.
____	Determine when and where the measurements will be made.
____	Identify by locomotive number the units to be tested.
____	Obtain permission to carry out measurements from responsible railroad official.
	Instrumentation Checkout
____	Specify the instrumentation system required for the measurements.
____	Acquire the components of the instrumentation system.
____	Check out and calibrate the instrumentation system.
____	Complete the instrumentation system inventory worksheet.
____	Pack the instrumentation system for shipment to the measurement site.
____	Check current weather conditions, reschedule test if necessary.
	Test Site Setup
____	Check in with railroad official in charge of facility.
____	Complete measurement site qualification worksheet.
____	Unpack instrumentation system, checking against inventory worksheet.
____	Set up the instrumentation system and check components for damage.
____	Calibrate the system and report results on the field data log.
____	Complete the annotation on the field data log.
	Noise Measurements
____	Conduct noise measurements.
____	Record results on the field data log.
____	Check calibration of the system and record results on the field data log.
____	Repack system for return shipment, referring to inventory checksheet.
	Program Completion
____	Unpack instrumentation system; check for damage.
____	Document measurement program.

Figure 5-8. Sample Program Planning Worksheet.

INSTRUMENTATION SYSTEM INVENTORY WORKSHEET

Audible Warning Devices on Locomotives

Date: ________________ Prepared By: ______________________________

Location: ____

INSTRUMENT	Make	Model	Serial No.	Date of Last Calibration	Check Out	Return
Sound Level Meter (SLM)						
Microphone						
Sound Level Calibrator						
Wind Speed Measuring Device						

REQUIRED (*) AND RECOMMENDED ACCESSORIES	Checkout	Return
* Microphone Windscreen		
* SLM Calibration Adjustment Tool (Screwdriver)		
* Tripod		
* Tape Measure		
Thermometer		
Hygrometer		
Watch		
Extra Batteries		
Duct Tape		
Connecting Cables		
Flashlight		
Weather Radio		
Camera and Film		
Ground Cloth		
Earphones		
Tools (screwdriver, pliers, etc.)		

Figure 5-9. Sample Instrumentation System Inventory Worksheet.

MEASUREMENT SITE QUALIFICATION WORKSHEET

Audible Warning Devices on Locomotives

Date: ________________ Prepared By: ______________________________

Location: ____

____

	YES	NO
Have the test area clear-zone recommendations been met?	___	___
Has the microphone elevation requirement been met?	___	___
Will the ambient weather conditions permit noise emission tests?	___	___
Wind Speed Below 12 mph?	___	___
Wind Gusts Below 20 mph?	___	___
No precipitation condition met?	___	___
Will the ambient sound level conditions permit noise emission tests?	___	___
Has a sketch been made of the measurement site?	___	___
Have photographs been taken of the measurement site?	___	___

Figure 5-10. Sample Measurement Site Qualification Worksheet.

5.2.5.3 Instrumentation Setup

Upon arrival at the facility at which the testing is to be done, the railroad official in charge should be informed of the presence of the measurement personnel. Once at the test site, the instrumentation system should be set up according to the manufacturer's instructions. The inventory worksheet should be referred to at this time. The measurement site qualification should be verified, using the measurement site qualification worksheet.

The sound level meter should be mounted on a tripod with the microphone at a level of 4 feet (1.2 meters) above the ground. A windscreen should always be attached to the microphone. The sound level meter may be tilted to allow ease of reading, and the microphone should be oriented according to manufacturer's instructions. This is critical, since certain microphones (perpendicular incidence) are designed to be pointed directly at the major noise source, other microphones (grazing incidence) are designed to be pointed at right angles to the line between the observer and the noise source, and still others (random incidence) are designed to be oriented in a direction intermediate to these two.

The operator should stand as far away from the meter as possible, consistent with his ability to make the sound level readings easily. When possible, the microphone/preamplifier assembly should be mounted remote from the sound level meter so that there is less chance of the observer's affecting the measured data.

Care should be taken to make sure that there is nothing between the microphone position and the sound source which may interfere with the sound propagation. Nearby reflecting objects should be avoided. When making source measurements, reflecting surfaces behind and to the sides of the source should be avoided.

The sound level meter should be calibrated by adjusting the meter to read the level generated by the calibrator, according to the manufacturer's instructions. This should be done prior to the beginning of measurements, and noted in the field data log.

A sketch should be drawn of the measurement area, which includes all audible noise sources and their approximate location with respect to the measurement position. The location of all reflecting surfaces, barriers, and other factors that may affect the sound propagation, including wind direction, should also be noted on the sketch. An exact scale map is not necessary, but a good representation of the area, with distances to outstanding landmarks indicated, is desirable. If a detailed map of the area is available, the site area should be located on it. If possible, photographs of the area should be taken to show the noise source. A very effective way to photograph the site is to stand at the microphone position and take a series of pictures which show the full 360° view from that spot. It is also helpful to document the microphone location by stepping behind the microphone and taking a picture which shows the microphone as well as the sound source being measured.

A data log should be filled out at the beginning of each measurement.

A typical audible warning device data log sheet is shown in Figure 5-11 and should contain the following information:

- Description of measurement location.
- Date of measurements.
- Name of person performing the measurements.
- Types, models, serial numbers, or other identification characteristics for all instrumentation.
- Barometric pressure, temperature, wind velocity, and relative humidity. (This information can be measured directly or, in many cases, can be obtained from local weather radio stations.)
- Results of calibration tests.
- Measured levels and background levels.
- Description of equipment under test.
- Description of secondary noise sources.

A note pad should also be taken into the field and used to write extensive notes detailing anything going on which may have a bearing on the measurements or the interpretation of the data. Such incidents as loud competing noise sources or other atypical events are examples of the type of information which should be recorded.

5.2.5.4 Data Collection

The maximum noise level of the audible warning device should be measured when it is sounded using normal operating procedures. That is, the pressure, for a pneumatic device, or the voltage, for an electrical device, should be adjusted to the value required by the operating procedures of the railroad. At least three soundings of the device should be measured at each of the two measurement positions (forward and behind) and the results recorded on the data log.

The background level at each position before and after each measurement sequence should also be measured and the results recorded in the log.

FIELD DATA LOG

Audible Warning Devices on Locomotives

Date: ____________________ Prepared By: ____

Location: ____

____

EQUIPMENT:

Instrument	Manufacturer	Model	Serial No.	Date of Last Calibration
Sound Level Meter				
Microphone				
Calibrator				

WEATHER CONDITIONS:

	Time	Wind Speed	Direction	Temp.	Rel.Hmdty.	Bar.Pres.
Pre-Test						
Post-Test						

CALIBRATION: Calibrator Level: _______ dB; Calibrator Frequency: _______ Hz

Time						
Sound Level						

BACKGROUND LEVEL:

Time						
A-Weighted Sound Level						

Figure 5-11. Sample Field Data Log.

FIELD DATA LOG (Continued)

Audible Warning Devices on Locomotives

AUDIBLE WARNING DEVICE PARAMETERS AND LEVELS:

Time	Locomotive		Warning Device		Sound Level		Comments
	RR	No.	Manufacturer	Model	Forward	Behind*	

* For Bi-Directional Locomotives.

OTHER NOISE SOURCES: ____

____

____

____

REMARKS: ____

____

____

SKETCH OF SITE GEOMETRY:

↑ N

Figure 5-11 (Concluded).

5.2.6 Data Base

At present there is no published data base of sound levels from audible warning devices on locomotives.

5.2.7 Noise Augmentation Procedures

If the measured sound level is below the minimum requirement, the audible warning device should be checked to ensure that nothing is blocking the path of the emitted sound. If it is a pneumatic device, the pressure and volume of drive air should be checked to ensure that they meet manufacturer's standards. If these are within the proper range, the diaphragms of the individual chimes should be inspected for damage. If the device is electrical, the voltage and current draw should be measured and compared to the manufacturer's specifications. If these are within the proper range, the transducing element which produces the sound should be inspected for damage.

REFERENCES FOR CHAPTER 5

1. "Railroad Noise Enforcement Manual," U.S. Department of Transportation, Federal Railroad Administration, August 1978.

2. Data supplied by the Office of Safety, Federal Railroad Administration, 400 Seventh Street, S.W., Washington, D.C. 20590.

APPENDIX A

Glossary

This appendix contains brief definitions of the technical terms contained in present federal railroad noise standards and regulations. Both acoustic and non-acoustic terms are included. For the acoustic terms, the numbers of the sections in the text in which the concept is more fully explained are included in parentheses at the end of each definition. For the non-acoustic terms, a reference to the appropriate page number in the Federal Register is provided.

A-Weighted Sound Level (L_A): A weighted decibel summation of all of the frequency components in the spectrum of the sound, the weighting functions being chosen to simulate the sensitivity of the human ear to each frequency. (2.1.7.)

Adjusted Average Maximum A-Weighted Sound Level ($L_{adj.ave.max.}$): The acoustic metric for car-coupling impacts and car retarders. (4.2.2.)

Ambient Sound Level: The sound level attributable to all non-distinguishable sources in the absence of identifiable intrusive sounds – approximated by L_{90}. (2.2.2.7.)

Audible Warning Device: A sound-emitting device used to alert and warn people of the presence of railroad equipment. (45 FR 1264.)

Background Sound Level: As used in these regulations shall mean: The instantaneous A-weighted sound level observed prior to and following a measured railroad noise event. (45 FR 1263.)

Car Coupling Sound: A sound which is heard and identified by the observer as that of car coupling impact, and that causes a sound level meter indicator having fast dynamic response characteristics to register an increase of at least ten decibels above the level observed immediately before hearing the sound. (45 FR 1263.)

Carrier: A common carrier by railroad, or partly by railroad and partly by water, within the continental United States, subject to the Interstate Commerce Act, as amended, excluding street, suburban, and interurban electric railways unless operated as a part of a general railroad system of transportation. (45 FR 1263.)

Commercial Property: Any property that is normally accessible to the public and that is used for any of the purposes described in the following standard land-use codes (reference Standard Land-Use Coding Manual, U.S. DOT/FHWA, Washington, D.C., reprinted March 1977) –

- 53–59: Retail Trade;
- 61–64: Finance, Insurance, Real Estate, Personal, Business, and Repair Services;
- 652–659: Legal and other professional services;
- 671, 672, and 673: Government Services;
- 692 and 699: Welfare, Charitable, and Other Miscellaneous Services;
- 712 and 719: Nature Exhibitions and Other Cultural Activities;
- 721, 723, and 729: Entertainment, Public, and Other Public Assembly; and
- 74–79: Recreational, Resort, Park, and Other Cultural Activities.

(45 FR 1263.)

Continuous Noise: Any sound with a rise time of more than 35 milliseconds to peak intensity and a duration of more than 500 milliseconds to the time when the level is 20 dB below the peak. (45 FR 21117.)

dB(A): An abbreviation meaning A-weighted sound level in decibels, referenced to 20 micropascals. (2.1.7.)

Day-Night Sound Level (L_{dn}): The 24-hour time-of-day weighted equivalent sound level, in decibels, for any continuous 24-hour period, obtained after addition of ten decibels to sound levels produced in the hours from 10 p.m. to 7 a.m. (2.1.8.3.)

Decibel (dB): The unit measure of sound level calculated by taking ten times the common logarithm of the ratio of the squared-pressure of the particular sound to the squared-pressure of a standard reference sound. Usually a reference sound having a sound pressure of 20 micropascals is used. (2.1.3.)

Dose: See "Noise Dose."

Dose-Equivalent Level: The level of the constant sound that would, in a given time period, contribute to the environment the same noise dose as did the actual time-varying sound. (2.1.8.4.)

Eight-Hour Time Weighted Average (TWA) Level: An alternate terminology for "dose-equivalent level." (45 FR 21117.)

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Energy-Average Level: Ten times the common logarithm of the arithmetic average of the antilogarithms of one-tenth of each of the levels being averaged. (2.1.8.2.)

Energy-Equivalent Sound Level (L_{eq}): The level of the constant sound that would, in a given time period, contribute to the environment the same A-weighted acoustic energy as did the actual time-varying sound. It is equal to the energy-average level of the sound levels occurring in the time period. (2.1.8.2.)

Equivalent Steady-State Sound Level: See "Equivalent Sound Level."

Equivalent Sound Level: A term generally used to mean energy-equivalent sound level.

Exceedance Percentile Sound Level (L_x): The A-weighted sound level in decibels that is exceeded for a stated percentage (x) of the duration of the measurement period (i.e., L_{10}, L_{90}). (2.1.8.1.)

Fast Meter Response: Sound level meter dynamic characteristics which comply with Paragraph 5.3 of the American National Standard Specification for Sound Level Meters ANSI S1.4-1971. (2.1.2.)

Idle: That condition where all engines capable of providing motive power to the locomotive are set at the lowest operating throttle position; and where all auxiliary non-motive power engines are not operating. (45 FR 1264.)

Load Cell: A device external to the locomotive, of high electrical resistance, used in locomotive testing to simulate engine loading while the locomotive is stationary. Electrical energy produced by the diesel generator is dissipated in the load cell resistors instead of the traction motors. (4.1.)

Locomotive: A self-propelled vehicle designed for and used on railroad tracks in the transport or rail cars, including self-propelled rail passenger vehicles. (45 FR 1264.)

Locomotive Consist: Two or more locomotives coupled together.

Locomotive Load Cell Test Stand: The load cell and associated structure, equipment, trackage, and locomotive being tested. (45 FR 1264.)

Maximum Sound Level (L_{max}): The greatest A-weighted sound level in decibels measured during the designated time interval or during the event. (45 FR 1264.)

Measurement Period: A continuous period of time during which noise of railroad yard operations is assessed, the beginning and finishing times of which may be selected after completion of the measurements. (45 FR 1264.)

Noise Dose: A measure of the noise exposure received in a given acoustic environment. It is defined as the summation of the ratios of the actual time spent at each A-weighted sound level to the allowed time at that level. (2.1.8.4.)

Rail Car: A non-self-propelled vehicle designed for and used on railroad tracks. (45 FR 1264.)

Railroad: All the roads in use by any common carrier operating a railroad, whether owned or operated under a contract, agreement, or lease. (45 FR 1264.)

Receiving Property Measurement Location: A location on receiving property that is on or beyond the railroad facility boundary and that meets the receiving property measurement location criteria. (45 FR 1264.)

Receiving Property: Any residential or commercial property that receives the sound from railroad facility operations, but that is not owned or operated by a railroad; except that occupied residences located on property owned or controlled by the railroad are included in the definition of "receiving property". For purposes of this definition railroad crew sleeping quarters located on property owned or controlled by the railroad are not considered as residences. (45 FR 1264.)

Residential Property: Any property that is used for any of the purposes described in the following standard land-use codes (reference Standard Land-Use Coding Manual, U.S. DOT/FHWA, Washington, D.C., reprinted March 1977) –

- 1: Residential;
- 651: Medical and Other Health Services;
- 691: Religious Activities; and
- 711: Cultural Activities.

(45 FR 1264.)

Retarder (Active): A device or system for decelerating rolling rail cars and controlling the degree of deceleration on a car-by-car basis. (45 FR 1263.)

Retarder (Inert): A device for holding rail cars in place along classification tracks in which the brake shoes are spring activated by the weight of the rail car. (4.2.)

Retarder Sound: A sound which is heard and identified by the observer as that of a retarder, and that causes a sound level meter indicator having fast dynamic response characteristics to register an increase of at least ten decibels above the level observed immediately before hearing the sound. (45 FR 1263.)

Slow Meter Response: Sound level meter dynamic characteristics which comply with Paragraph 5.4 of the American National Standard Specification for Sound Level Meters ANSI S1.4-1971. (2.1.2.)

Sound Exposure Level: The energy-equivalent sound level corresponding to the sound levels measured over a given time period. (45 FR 1264.)

Sound Pressure Level (L): Ten times the common logarithm of the ratio of the squared-pressure of the particular sound to the squared-pressure of a standard reference sound. The standard reference pressure is generally 20 micropascals. (2.1.3.)

Special Purpose Equipment: Maintenance-of-way equipment which may be located on or operated from rail cars including: Ballast cribbing machines, ballast regulators, conditioners and scarifiers, bolt machines, brush cutters, compactors, concrete mixers, cranes and derricks, earth-boring machines, electric welding machines, grinders, grouters, pile drivers, rail heaters, rail layers, sandblasters, and other types of such maintenance-of-way equipment. (45 FR 1263.)

Special Track Work: Track other than normal tie and ballast bolted or welded rail or containing devices such as retarders or switching mechanisms. (45 FR 1263.)

Statistical Sound Level (L_x): See "Exceedance Percentile Sound Level."

Switcher Locomotive: Any locomotive designated as a switcher by the builder or reported to the ICC as a switcher by the operator-owning railroad and including, but not limited to, all locomotives of the builder/model designations listed in Tables 3-2 or 4-2 in the text. (3.1.1.1, 4.1.1.1.)

Time-Weighted Average (TWA): See "Eight-Hour Time-Weighted Average Level."

APPENDIX B

Software For Programmable Calculators

This appendix contains three programs, written for portable programmable calculators, which perform various operations described in Section 2. Each program is presented in two versions:

- Reverse Polish Notation (RPN) such as is used in Hewlett-Packard (HP) calculators, and
- Algebraic Notation such as is used in Texas Instrument (TI) calculators.

The programs below are written in languages specific to the HP-25 and TI 58/59 programmable calculator models. They can easily be adapted for all other programmable calculator models of these and other manufacturers. In these programs, O stands for the letter "O" while Ø stands for the numeral zero.

Decibel Addition and Subtraction

The sum of two levels, L_1 and L_2, is given by:

$$L_{sum} = 10 \log_{10} \left[10^{L_1/10} + 10^{L_2/10}\right]$$

and the difference, with $L_1 > L_2$, is given by:

$$L_{dif} = 10 \log_{10} \left[10^{L_1/10} - 10^{L_2/10}\right]$$

Programs to accomplish these operations are:

Reverse Polish Notation (HP-25)

1. ENTER
2. 1
3. Ø
4. STO Ø
5. ÷
6. 1Ø^x
7. R/S
8. RCL Ø
9. ÷
10. 1Ø^x
11. { + for sum / - for difference
12. LOG
13. RCL Ø
14. x
15. R/S

Algebraic Notation (TI 58/59)

0. ÷
1. 1
2. Ø
3. =
4. INV
5. LOG
6. { + for sum / - for difference
7. (
8. R/S
9. ÷
10. 1
11. Ø
12.)
13. INV
14. LOG
15. =
16. LOG
17. x
18. 1
19. Ø
20. =
21. R/S

OPERATION:

- Reset calculator to start of program.
- Key in L_1 and press R/S .
- When calculator completes its initial calculation, key in L_2 and press R/S .
- Final display is L_{sum} or L_{dif}.

Energy-Equivalent Sound Level

The energy-equivalent sound level corresponding to a set of N instantaneous sound levels $(L_1, L_2, \ldots, L_N)$ is given by:

$$L_{eq} = 10 \log_{10}\left[\frac{1}{N}\left(10^{L_1/10} + 10^{L_2/10} + \ldots + 10^{L_N/10}\right)\right]$$

In the programs below, sound levels are continuously entered until a negative number is encountered, at which time the value of L_{eq} is displayed.

Reverse Polish Notation (HP-25)

1. CLEAR REG	11. ÷
2. 1	12. 10^x
3. 0	13. Σ+
4. ENTER	14. GTO 07
5. STO 0	15. $\bar{x}$
6. −	16. LOG
7. R/S	17. RCL 0
8. x < 0	18. x
9. GTO 15	19. R/S
10. RCL 0	

Algebraic Notation (TI 58/59)

0. ÷	10. 02	20. RCL
1. 10	11. RCL	21. 02
2. =	12. 02	22. =
3. INV	13. R/S	23. LOG
4. LOG	14. RST	24. X
5. SUM	15. LBL	25. 10
6. 01	16. E	26. =
7. CLR	17. RCL	27. R/S
8. 1	18. 01	
9. SUM	19. ÷	

OPERATION:

HP-25

- Reset calculator to start of program.
- Press R/S .
- When 0 is displayed, enter first level and press R/S .
- When 1 is displayed, enter second level and press R/S .
- When 2 is displayed, enter third level and press R/S .
- Continue entering levels until all N have been entered.
- When N is displayed, enter -1 and press R/S .
- Final display is L_{eq} .

TI 58/59

- Reset calculator to start of program.
- Clear memories (CMs).
- When 0 is displayed, enter first level and press R/S .
- When 1 is displayed, enter second level and press R/S .
- When 2 is displayed, enter third level and press R/S .
- Continue entering levels until all N have been entered.
- When N is displayed, press E .
- Final display is L_{eq} .

Day-Night Sound Level

The day-night sound level is given by:

$$L_{dn} = 10 \log_{10} \left\{ \left[15/24 \times 10^{L_d/10} \right] + \left[9/24 \times 10^{(L_n + 10)/10} \right] \right\}$$

where L_d is the energy-equivalent daytime (0700–2200) sound level, and

L_n is the energy-equivalent nighttime (2200–0700) sound level.

Reverse Polish Notation (HP-25)

1. 1	14. +
2. Ø	15. RCL Ø
3. STO Ø	16. ÷
4. 1	17. $1Ø^x$
5. 5	18. x
6. R/S	19. +
7. RCL Ø	20. 2
8. ÷	21. 4
9. $1Ø^x$	22. ÷
10. x	23. LOG
11. 9	24. RCL Ø
12. R/S	25. x
13. RCL Ø	26. R/S

Algebraic Notation (TI SR59)

0. (	14. +	28.)
1. (	15. (	29. INV
2. 1	16. 9	30. LOG
3. 5	17. x	31.)
4. x	18. (	32.)
5. (	19. (	33. ÷
6. R/S	20. R/S	34. 2
7. ÷	21. +	35. 4
8. 1	22. 1	36. =
9. Ø	23. Ø	37. LOG
10.)	24.)	38. x
11. INV	25. ÷	39. 1
12. LOG	26. 1	40. Ø
13.)	27. Ø	41. =
		42. R/S

OPERATION:

- Reset calculator to start of program.
- Press R/S .
- When number "15" is displayed, key in L_d and press R/S .
- When number "9" is displayed, key in L_n and press R/S .
- Final display is L_{dn}.

APPENDIX C

Railroad Noise Regulations in the Federal Register

This appendix contains reproductions from the Federal Register of the railroad noise regulations discussed in the text along with the introductory preambles for each final rule.

The first reproduction is of CFR Part 210 – Railroad Noise Emission Compliance Regulations as issued by the Federal Railroad Administration on August 27, 1977 (42 FR 42343) in response to the locomotive and railroad noise emission regulation issued by the Environmental Protection Agency on December 31, 1976 (41 FR 2184). These compliance regulations should be updated by FRA in the near future to reflect the interstate rail carrier noise emission standards issued by the EPA on January 4, 1980 (45 FR 1252).

The second reproduction is of the noise control portion of CFR Part 228 – Hours of Service of Railroad Employees as issued by the FRA on July 18, 1978, and July 19, 1978 (43 FR 30803 and 43 FR 31006).

The third reproduction is of CFR Part 201 – Noise Emission Standards For Transportation Equipment; Interstate Rail Carriers as issued by the EPA on January 4, 1980 (45 FR 1252).

The final reproduction is of the noise control portions of CFR Part 229 – Railroad Locomotive Safety Standards as issued by the FRA on March 31, 1980 (45 FR 21092).

Title 49—Transportation

CHAPTER II—FEDERAL RAILROAD ADMINISTRATION, DEPARTMENT OF TRANSPORTATION

[Docket RNE-1 Notice 2]

PART 210—RAILROAD NOISE EMISSION COMPLIANCE REGULATIONS

AGENCY: Federal Railroad Administration, DOT.

ACTION: Final rule.

SUMMARY: This rule sets forth procedures to insure compliance with the noise emission standards prescribed by the Environmental Protection Agency (EPA) for locomotives and rail cars (40 CFR 201).

EFFECTIVE DATE: October 1, 1977.

FOR FURTHER INFORMATION CONTACT:

Principal Program Person: Philip J. Brannigan, Office of Safety, 202-426-8686.

Principal Attorney: Anne-Marie Hyland, Office of the Chief Counsel, 202-426-8836.

Examination of written comments: All written comments received in this proceeding are available for examination, in the public docket RNE-1, during regular business hours in Room 5101, Nassif Building, 400 Seventh Street SW., Washington, D.C.

SUPPLEMENTARY INFORMATION: On November 8, 1976, FRA published a notice of proposed rulemaking (NPRM, 41 FR 49183) setting forth proposed procedures to assure compliance with the EPA Railroad Noise Emission Standards ("EPA standards", 40 CFR 201). As stated in the proposed rule, the EPA standards were published by the EPA on January 14, 1976 (41 FR 2184). They became effective on December 31, 1976. Both the Standards and these compliance regulations are issued pursuant to section 17 of the Noise Control Act of 1972 "(Noise Control Act)" (86 Stat. 1248, 42 U.S.C. 4916). In the development of this final rule, consultations were conducted with EPA as required by section 17(b) of the Noise Control Act.

FRA has received ten comments on the proposed rule, each of which urged significant changes. As a result of these comments, a number of changes have been made. A summary of the comments and FRA's responses follows.

Discussion of Major Comments

Preliminary Issues

Time to Comment. Two commenters stated that the comment period was too short to complete detailed analysis of certain provisions and noted that they reserved the right to comment further. FRA provided the 45 day comment period which is established by Department of Transportation policy as the minimum time for comment on an NPRM. Because of the effective date of the EPA standards, FRA was unable to provide a more lengthly comment period. Two comments that were received after the close of the comment period were reviewed and have been considered fully. FRA's general rules of practice provide procedures for petitions for reconsideration as well as petitions for waiver or amendment of any rule issued by FRA (See 49 CFR 211, 41 FR 54181 (Dec. 13, 1976)). These additional procedures provide any interested party with the opportunity to express views as to the appropriateness of any FRA regulation, or the need for amendment or revision of any such regulation.

Inflationary Impact and Regulatory Analysis. Two commenters contended that FRA was required to issue an inflationary impact statement for the proposed rule under Executive Order 11821, Office of Management and Budget Circular No. A-107, and DOT Order 2050.4. The NPRM (at 41 FR 49185) stated that the inflationary impact had been considered pursuant to Executive Order 11821. It was determined that the additional impact resulting from the proposed procedures would not be so costly as to reach the $50 million threshold that determines what actions are to be considered "major proposals" requiring inflationary impact evaluation. The major complaint raised by these commenters concerned testing for compliance with the stationary locomotive noise emission standard by use of a load cell as prescribed in the EPA standards (40 CFR 201.11 and Subpart C to 40 CFR 201). The requirement that locomotives be capable of operating within the prescribed decibel limits when connected to a load cell, and the measurement instrumentation, acoustical environment, and procedures which are to be used in determining such compliance have been established by the EPA. The FRA does not have the authority to alter any of these requirements. Several of the commenters have raised issues related to their ability to comply with the measurement criteria for conducting the load cell test. It was noted that many carriers do not presently have load cell facilities, and that the location of the majority of the load cells on those carriers that do have such facilities will not permit noise measurement in accordance with the measurement criteria established by EPA. These comments have raised several difficult issues which FRA has reviewed and considered in detail. Although this agency does not have the authority to alter any provisions of the EPA standards, in developing this final rule we have attempted to define a regulation which will insure compliance with the EPA standards without placing unreasonable or costly additional burdens on railroads. If existing load cell sites will not permit testing for compliance with the requirements prescribed by the EPA without substantial and costly modification, that issue should be addressed to EPA. FRA will provide the appropriate official of that agency with copies of the relevant comments submitted in this proceeding.

One commenter also contended that a regulatory analysis was required under the policy statement of the Secretary of Transportation published April 16, 1976 (41 FR 16200). Since the issuance of this rule is specifically required by section 17 of the Noise Control Act, the comprehensive regulatory impact evaluation normally required of all proposed rulemaking actions undertaken by agencies comprising the Department of Transportation is not required by the Secretary's policies in this case.

Nevertheless, FRA feels that an appropriate application of the Secretary's policies in this case is to assess the relative costs of alternative means of achieving the results contemplated by the statute in an effort to develop an effective and reasonable implementing regulation. FRA believes that, as a result of changes made in response to the comments received in this proceeding, the final rule issued herein will ensure effective enforcement of the EPA standards without imposing on the railroad industry unreasonable costs in excess of the minimum costs necessary to comply with the statutory intent.

Environmental Impact. One commenter also contended that an environmental impact statement is required under the National Environmental Policy Act (NEPA), 42 USC 4332(2)(c). NEPA requires environmental impact statements on all proposals for "major Federal actions significantly affecting the human environment". The Administrator has determined that this rule making is not a major Federal action since the rule only prescribes additional compliance procedures to assure compliance with the substantive requirements of the EPA standards. In the issuance of those standards, the EPA has considered the environmental impacts of the overall railroad noise emission program.

EPA Standards. EPA suggested that the preamble of the final rule should clearly state that the EPA standards do not require that locomotive consists be composed entirely of locomotives manufactured either before 1980 or after 1979. EPA also suggested that the preamble should state clearly that the EPA standards do not apply to warning devices when operated for the purpose of safety. FRA believes that the wording of section 210.3(b)(3) adequately addresses this issue.

SECTION BY SECTION ANALYSIS

§ 210.3

Some question appears to have arisen as to the scope of applicability of these noise compliance rules. These rules are intended to be coextensive with the EPA standards and the Act. The scope of the EPA standards encompasses all common carriers by railroad, or partly by railroad and partly by water, within the continental United States, that are subject to the Interstate Commerce Act. Locomotives and rail cars used in industrial railroad operations that are conducted solely within an industrial complex would not be subject to these rules. The FRA does not have the authority to limit the applicability of the EPA standards, and cannot except any operations that are common carrier operations subject to the Interstate Commerce Act. Section 210.3 has been amended to reflect the statutory scope of applicability of the EPA standards.

§ 210.7

Who should be responsible for compliance? Three commenters recommended that an industrial railroad not be required to repair or remove from service noise defective equipment belonging to another railroad. The commenters operate and maintain some equipment of their own, but they do not have the capacity or capability to repair and maintain the comparatively large number of cars involved in their interchange operations. A similar problem—lack of capability or adequate capacity to perform repairs on potentially large numbers of cars—exists with many short line railroads. In holding the operator, rather than the owner, responsible for compliance with the EPA standards, it was the intent of FRA to utilize present railroad industry practices concerning the repair of defective equipment.

Currently, when defects are found under the Freight Car Safety Standards or other safety regulations, repairs usually are made by the operating railroad. The car owner is then billed for the repair of defects that are not "handling line caused". In those cases in which correction of the defect would involve extensive repairs to the rail car, alternative procedures can be used to return the equipment to its "home shop" for repairs.

This system recognizes the nature of the rail car fleet which operates on the principle of free interchange of railroad cars among carriers. In addition, it assures the efficient freight car utilization which would be impossible if defective equipment had to be returned to its owner each time even minor repairs are required. The FRA believes that the use of this system for the repair and handling of noise defective equipment is the only practical approach to the enforcement of the EPA standards. Some relief may be provided by the procedures established under § 210.9 for the movement of noise defective equipment. If a car is discovered to be defective while being operated by an industrial railroad or short line carrier that does not have the repair facilities necessary to correct the defect, the car may be moved to the next forward location where the noise can be eliminated.

Must noise defective equipment be stopped en route for inspection? One commenter suggested clarification of whether the rule would require immediate stopping for inspection whenever the railroad has notice that a passby test has shown a noise emission in excess of the EPA standards. Stopping trains en route entails an unreasonable interference with interstate commerce and also could result in safety problems that FRA believes would be more serious than the continued excessive noise emission until the train reaches the next point where it is inspected in the normal course of operations. Section 210.25(c)(3) of the final rule provides that inspections on the basis of a passby test are to be performed at the next recognized inspection point, which would include an initial terminal, terminal, interchange, 500-mile, or crew change inspection point.

§ 210.9(a)

Where must noise defective equipment be repaired? Five commenters objected to the proposed restriction allowing noise defective equipment to be moved only to the nearest location where the noise defect can be eliminated, contending that it was unduly burdensome and unclear.

They noted that the procedure for moving cars with safety defects under the Freight Car Safety Standards is less restrictive.

FRA believes that it is reasonable to allow noise defective equipment to be moved in a defective condition to the next forward facility where repairs can be made. The authority for such movement is similar to that adopted when a highly visible rear end marking device becomes inoperative (see 49 CFR 221.17 (a), 42 FR 2321, January 11 1977) and to that included in a recent notice of proposed rulemaking governing movement of a locomotive with an inoperative wheel slip/slide indicator (see 42 FR 2994, January 14, 1977). This provision assures that movement of railroad equipment will not be impeded by a requirement to set out defective cars so as to move them to a closer repair point in the opposite direction. Nevertheless, since the rule prescribes the maximum distance defective equipment may be moved, a carrier also would have the option of moving the defective equipment to a closer facility to the rear. As adopted, the authority for movement of noise defective equipment is somewhat more restrictive than the authority for movement of defective equipment under the Freight Car Safety Standards (49 CFR 215). Under those standards a defective car could be tagged and sent to its "home shop for repairs". The more restrictive limitation in this rule is needed to minimize the noise impact after a violation of the EPA standards is found. We wish to point out that, consistent with the safety rules, movement to the home shop would be allowed after correction of the noise defect. Since equipment maintained in accordance with the Freight Car Safety Standards or the Locomotive Inspection rules also should comply with the noise standards, FRA believes that very few noise defects which are not also safety defects will be found. Accordingly, this rule generally is not expected to impose a significant added burden upon even very small repair facilities.

Should noise defective equipment be inspected before movement for repairs? Two commenters objected to the proposed requirement for an equipment inspection before the noise defective equipment is moved to the repair site. They stated that the requirement could seriously disrupt railroad operations because movement could not be made until after the inspection of each piece of equipment suspected of being noise defective.

One of the commenters contended that it is illegal for FRA to require any inspection under this part on the basis of safety considerations. The commenter argued that in fact there is no connection between noise and safety defects, that Congress intended by its reference to the safety statutes in section 17 of the Noise Control Act solely to provide for the use of available machinery to enforce compliance, and that EPA did not contemplate that compliance with its standards would cause any additional maintenance burden. Both commenters contended that an inspection requirement is unnecessary. The first contended that noise often comes from conditions with no safety consequence, and if there is in fact a safety defect it would have been found and corrected under the equipment safety rules, 49 CFR 215 and 230. The second stated that its current practices would assure safety. The commenter instructs its employees to observe passing trains and report anything unusual, and it requires car inspections at each terminal and interchange.

The requirement for an inspection prescribed in this section is within the authority of FRA, based on the need to avoid exposure to possible safety problems as well as unlawful noise emissions. We disagree with the assertion that a noise violation does not imply existence of a safety problem. Certainly, there are a number of possible nonsafety-related causes for a sound level measurement above those prescribed in the EPA standards. However, the EPA standards were established after consideration of noise emission levels emitted by properly maintained equipment. Therefore, a measurement showing a noise emission in excess of the EPA standard indicates a possible safety problem may be present also. Even if equipment is maintained in accordance with the safety rules, there is no certainty that the previous inspection uncovered every problem or that a safety defect did not develop after the inspection. FRA believes that this inspection is necessary in the interests of railroad safety and the safety of the operating crew. In addition, the inspection is also intended to identify the sources of excess noise emissions for corrective action. A prompt, systematic, thorough inspection is necessary for that purpose alone.

Who should perform the inspection on noise defective equipment? Two other commenters argued that a person designated to inspect and test for noise defects is not the appropriate person to perform the inspection required under section 210.9 since the primary purpose of that inspection is to assure the safety of movement to the repair site.

The FRA agrees with these commenters, and has eliminated the reference to a person designated to inspect for noise defects. The railroad's duty under this provision is to determine that the equipment is safe to move to the repair point. Such a determination may be made by any railroad personnel available at the location where the railroad receives notice of the noise defect. It should be noted, however, that, if such an inspection involving equipment covered by the Freight Car Safety Standards (49 CFR 215) results in the identification of a defective component as defined in those standards, further movement of that equipment will also be governed by § 215.9 of title 49 of the Code of Federal Regulations.

§ 210.15

Section 210.15 of the proposed rule required each railroad that operates equipment to which the EPA standards apply to designate persons qualified to inspect and test locomotives and rail cars for noise defects. The primary purpose for this designation was the need to identify those railroad employees who were to perform the inspection required under § 210.9 above and the load cell test required under § 210.31(g) of the NPRM. As stated earlier, on reconsideration, FRA has determined that the designation of specific railroad personnel under 210.9, to perform the inspection prior to movement of noise defective equipment, is unnecessary. In addition, as a result of the comments submitted concerning the present load cell facilities, and their inappropriate locations for conducting noise tests as specified in the EPA standards, FRA has decided to eliminate the requirement that a locomotive be subjected to a noise test each time it is subjected to a load cell test for whatever reason. Furthermore, it is the responsibility of the railroad to assure that equipment that it is operating is maintained in a manner which will assure compliance with the EPA standards. Similar noise compliance regulations issued under parallel provisions of the Act governing motor carrier operations (section 18 of the Act) do not require the designation of specialized "noise control" personnel (see 49 CFR 325). DOT has not experienced enforcement problems due to any lack of such a designation in the motor carrier area, and does not expect the experience to differ significantly in the railroad area. Therefore, the requirement for the designation of qualified railroad persons under section 210.15 of the NPRM has been eliminated from this final rule.

§ 210.17

Section 210.17 of the proposed rule required that State agencies wishing to participate in the enforcement of the EPA standards must designate qualified personnel who must be approved by FRA prior to the commencement of enforcement activities. This provision remains in the final regulation with slight modifications.

The purpose of such a provision is to encourage States to participate in the Federal railroad noise control program and thus minimize interference with the flow of interstate commerce. State and local governments may, under section 17(c)(1) of the Noise Control Act, enact and enforce their own standards identical to the Federal standards. DOT, however, encourages them to instead enforce the Federal standards by availing themselves of the provisions of § 210.17 of this regulaton. To the extent State and local governments choose to enforce the Federal standards, enforcement of noise standards on rail cars and locomotives will be limited to certain designated and qualified State or local governments officials, all of whom will follow the same rules contained in these regulations.

To further insure against unreasonable interferences with interstate commerce, § 210.25(c)(3) has been revised in this final rule to provide specifically that government inspectors enforcing the Federal standard may perform, or request the railroad to perform, inspections and/or tests prescribed in this part only at recognized inspection points or scheduled stopping points. Train movements may not, under these regulations, be required to stop at other locations en route on the basis of an excessive noise emission noted in a random passby test.

How does State participation in noise enforcement differ from the FRA State Participation Program? From several comments submitted in response to the NPRM it appears that there is some confusion between State participation in the enforcement of the EPA standards and in the FRA "State Participation Program" under section 206 of the Federal Railroad Safety Act of 1970 (84 Stat. 972, 45 U.S.C. 435) and the regulations contained in 49 CFR 212.

The Federal Railroad Safety Act provides for a program of State participation in the investigative and surveillance activities prescribed by the Administrator for the enforcement of railroad safety regulations issued under that Act. Federal grants for up to 50 percent of the State's costs for such activities are also provided. The rules established in this part are issued under the Noise Control Act and the Secretary's authority under the Safety Appliance Acts, the Interstate Commerce Act and the Department of Transportation Act as provided in section 17 of the Noise Control Act. Therefore, the rules and regulations governing the State Participation Program for railroad safety do not apply to noise enforcement activities undertaken by a State under this part. In order to avoid further confusion of the two programs, § 210.17 has been redrafted to eliminate language referring to "participation". In addition, the scope of applicability of the section has been expanded to include not only State but also local jurisdictions that wish to enforce the Federal Railroad Noise Emission Standards.

How should State (local) inspectors be identified? One commenter stated that approved State inspectors should be required to carry appropriate credentials so that access to railroad property may not be denied on the basis of the lack of State authority. This commenter suggested that the FRA issue appropriate credentials to all approved State inspectors. As a result of these comments, FRA has reviewed the entire concept of prior FRA approval of each State or local noise compliance inspector and has determined that the administrative burden and additional paper work involved in such an approval process is unnecessary to accomplish the intent of this provision. As stated above that intent was twofold—to require qualified personnel and to identify such personnel for the railroads that are to be subject to their authority. FRA believes this can be accomplished by requiring the State or local jurisdiction to designate the personnel authorized to enforce the Federal standards, to certify that they are qualified to inspect and test locomotives and rail cars, that is that they have the knowledge and ability to detect the cause of noise defects, and to provide such persons with appropriate credentials to attest to their authority. FRA will continue to require the State or local jurisdiction to notify FRA that it is going to enforce the Federal standards so that we can accurately assess what the overall enforcement effort is at any given time. Section 210.17 of this final rule has been redrafted accordingly.

Should the regulation prescribe a level of effort to assure adequate State (local) effort? One commenter stated that, if State involvement would result in decreased Federal enforcement, the regulation should provide for a specified level of effort to assure that State involvement is adequate for effective enforcement. This comment apparently results from a confusion with the procedures of the State Participation Program as discussed above. Under that Program, once a State's inspection program is fully certified, the State effort replaces the routine Federal inspection effort in that State. Therefore, FRA has prescribed a specific level of State effort necessary before a program for a particular safety standard can be certified. This procedure does not apply to State or local involvement in enforcement of the EPA standards. State noise enforcement is not intended to substitute for, nor is it expected to reduce, the FRA efforts. Therefore, a prescribed level of State or local effort is not necessary.

Should inspectors be required to be qualified to inspect and test both locomotives and rail cars? Section 210.17(a) of the NPRM required the State to designate persons qualified to inspect and test locomotives or rail cars. One commenter suggested that the final rule should make it clear that any designated State inspector is authorized to inspect and test both locomotives and rail cars. The use of the word "or" rather than the word "and" in the proposed rule was purposeful. FRA does not agree that each State or local inspector enforcing the Federal standards must be qualified to inspect and test both locomotives and rail cars. The experience and knowledge necessary to adequately inspect a locomotive is substantially different from that necessary to perform a similar function with respect to rail cars because of the basic mechanical differences in the railroad equipment. FRA believes that an efficient and effective enforcement program must recognize these differences and provide the greatest degree of flexibility. Accordingly, while an individual inspector may be authorized to inspect and test both locomotives and rail cars if he is qualified to do so, the State or local jurisdiction is not limited to individuals with such dual qualifications.

§ 210.19

Two commenters recommended that the waiver provisions be eliminated or clarified. According to one, FRA's proposed rule contains no provision that is unduly burdensome, and all of the provisions are necessary for effective enforcement of the EPA standards. Therefore, any waiver would improperly interfere with enforcement. As an alternative the commenter stated that, if the provision is retained, FRA should amend the regulation to clarify that all of the provisions of 49 CFR 211 apply, including those providing interested parties an opportunity to receive notice of, and to comment on, all waiver applications. The other commenter stated that the regulation should be clarified to state that FRA may not waive, directly or indirectly, any requirement prescribed in the EPA standards.

The suggested changes have not been adopted. First, despite FRA's endeavors to structure a reasonable rule of general applicability, the railroad industry is characterized by such diversity that differing individual circumstances may justify the waiver of some provisions of this rule. The term "waiver" as used here, and throughout FRA safety regulations, does not necessarily mean a total relaxation or exemption from compliance with the prescribed rule. The waiver procedure allows FRA to impose alternative requirements to accomplish the intended purpose of the regulation in those cases in which the general rule may not be appropriate. Second, the proposed rule makes it clear that all of the provisions of part 211 apply to waiver proceedings and that FRA may not, either directly or indirectly, waive a requirement of the EPA standards. FRA will notify the EPA whenever a petition for waiver is filed under this section and will consult with that agency prior to a final determination on such a petition.

One commenter stated that § 210.19 should specify both the period within which the Administrator must make a decision on an application for waiver and the period for which a waiver may be effective.

FRA has not adopted a time limit within which the Administrator must act upon any petition for waiver under this part because the complexity of the issues raised and the time between the filing dates and proposed effective dates will vary. However, to the extent practicable we will comply with the nine-month time limit applicable to waiver proceedings under the Federal Railroad Safety Act of 1970 (See 49 CFR 211.1, 211.41 (41 FR 54181, December 13, 1976)).

With respect to the period for which a waiver may be effective, FRA does not believe it is appropriate to specify a maximum duration for a waiver. A waiver may be temporary or permanent. Each petition is considered individually, on its own merits and conditions that will assure the accomplishment of the intent of the general rule are tailored to the circumstances of each case.

§ 210.21

One commenter contended that the proposed penalty provision is inadequate because penalties would be provided only for knowing violations. The commenter stated that the EPA standards prohibit operation of any car or locomotive that violates the standards, and that only if money penalties are established for all violations will the railroads have the incentive to establish testing and maintenance programs that will eliminate excessive noise. The commenter contended that FRA has the authority under the various acts to establish the penalties.

FRA has considered the Noise Control Act, its legislative history, and the related statutes. We believe that Congress intended to set forth in section 11 all of the penalties applicable to violators of the EPA standards themselves. The criminal penalties (fines and imprisonment) may be assessed against willful or knowing violators of these regulations or the EPA standards.

Another commenter stated that the criminal penalty provision was unacceptable because it was unclear when a railroad would be liable because of a violation on equipment owned by someone else.

The EPA standards prohibit operation of noise defective equipment. In addition, as stated in the discussion of § 210.7, this rule imposes the responsibility for inspection and repair of noise defective equipment on the operating railroad rather than on the owner of the equipment because that is the only practical way to enforce the EPA standards. FRA cannot alter the criminal penalty provisions prescribed in the Noise Control Act. It should be noted, however, that the mere existence of a noise defect on operated equipment is not sufficient in itself to establish criminal liability since the penalties apply only for willful or knowing violations. The words "known or has notice" are included in § 210.7 to indicate that some evidence of willfulness or knowledge is necessary before a criminal action for enforcement of the EPA standards can be initiated under the Noise Control Act.

§ 210.25

Should railroads perform the tests? Some commenters stated that the FRA or State inspectors should conduct any noise emission tests since many railroads do not have instrumentation, trained personnel, or suitable test sites. Section 210.25 (b) of the final rule provides that the railroad carrier can be required to conduct the noise tests itself only if it has the capability to do so.

Should periodic noise inspections be required? Another commenter recommended that the section be strengthened to require the railroad to make periodic inspections of all cars and locomotives for noise violations and keep records of the results available for inspection. Since frequent, thorough inspections are required under 49 CFR Parts 215 and 230, and cars and locomotives maintained in accordance with those parts are expected to meet the EPA standards, FRA does not believe that an additional inspection requirement is warranted.

Should inspectors be empowered to conduct or request inspections or testing at random? The thrust of the other comments was that the FRA and State inspectors' authority to inspect, test, or require a railroad to test or inspect locomotives or rail cars should be limited to avoid undue burdens on interstate commerce. One commenter estimated that an average passby test of a rail car would cost a railroad approximately $1,000 in equipment time, crew time, fuel consumption, and interference with other activities. It recommended amending the proposed rule to include guidelines authorizing an inspector to require a locomotive or rail car to be submitted for inspection or testing only if there are reasonable grounds to suspect a noise defect, if the request is in writing, and if the time and place are reasonable.

In light of the comments, the rule has been redrafted to authorize an inspector to request the railroad to test, inspect or examine for noise defects only when there are reasonable grounds to believe that a noise defect is present. Such grounds could be established by a passby noise emission reading in excess of the standards for locomotives or railroad cars or by numerous public complaints about excessive noise from an identified piece of equipment or specific train operation. On the basis of such evidence, an inspector could make, or request a railroad to make, an inspection of the train at the next recognized inspection point or scheduled stopping point. If a railroad has the capability to perform the appropriate tests for noise emissions as prescribed by EPA, testing requested by an inspector must be performed as soon as practicable. If the railroad does not have the capability, the inspector may request that the railroad make the rolling stock and appropriate personnel available at a reasonable time and location for the inspector to obtain the required sound measurements. However, a railroad is not required to test or submit its rolling stock for testing if a readily identifiable noise producing condition is corrected and the correction is verified by an inspector.

Should the requests be in writing? The section also includes the added requirement that the inspector's request that the railroad make a noise inspection or test be in writing, stating his grounds for suspecting a noise defect. This requirement will provide a basis for the railroads to determine why the inspectors are requesting them to make noise inspections. The written record also will serve as evidence that a railroad has been given notice of the existence of noise defective equipment and will serve to establish the "willful" or "knowing" violation necessary to support a criminal action under the Noise Control Act.

Should the rule allow testing during movement pursuant to § 210.9? The same commenter also recomended that an inspector be precluded from testing or demanding a test when cars are moving pursuant to § 210.9 or when the cause of a noise defect has been noted and there is reasonable evidence to show that it has been eliminated. The suggested amendment to preclude testing during movement to § 210.9 has not been adopted because FRA believes it would constitute too broad an exception. While conducting a passby test to determine whether a train was operating in compliance with the EPA standards, an inspector might not be aware that the train included equipment being moved under § 210.9. Under the rule as written a railroad cited for violating the standards must be prepared to show that the noise emissions above the standards could have resulted from the movement of noise defective equipment in accordance with § 210.9. To preserve its defense in that situation, the railroad will have to retain records of the movement in accordance with § 210.9 for enough time to allow for delays between measuring violations and issuing citations.

§ 210.27(b)(1)

One commenter objected to measuring the noise emissions from a consist of locomotives manufactured both before 1980 and after 1979 against the higher noise emission standard for pre-1980 locomotives. The commenter contended that the provision has the effect of changing the substance of the standard for post-1979 locomotives. This commenter recommended that a procedure be established either to differentiate the noise emitted from different locomotives in a mixed consist, or to require the railroad to test each unit in a mixed consist when the consist violates the lower standard for post-1979 locomotives.

The changes recommended by the commenter have been rejected as infeasible. First, the rule does not prescribe a procedure to distinguish the noise emitted by different locomotives in the same consist during a passby test, because such a procedure is technically impossible given the present state of the art in noise measurement unless such locomotives are separated within the consist by at least 10 rail car lengths or 500 feet. Second, a requirement to test individually each unit in a mixed consist that violates the post-1979 standard probably would force individual retesting of each of the units whenever there is a passby test of a mixed consist. To avoid that retesting burden, a railroad would have to operate only unmixed locomotive consists. Such a severe restriction on the use of motive power would impose an undue burden on interstate commerce by railroad.

§ 210.27(b)(3)

One commenter stated that if the built dates of locomotives are not known to the inspector at the time of a passby test, the railroad should have the burden to supply them or have the lower post-1979 noise emission standards applied. FRA does not agree. In most cases, the inspector will not know the built dates of the locomotive units in a consist at the time of a passby test. He will, therefore, be required to identify the units in the locomotive consist by number when the test is made. The built dates for the specific units in a consist can then be determined by reference to carrier records. If the inspector fails to record the locomotive unit numbers, and the built dates cannot be established, the higher pre-1980 standard will apply since all locomotives, regardless of age, must operate below that noise level.

§ 210.27(c)

One commenter objected to applying the standard for movement at more than 45 miles per hour when the inspector's measuring equipment is not operating within an accuracy of 5 mph. The commenter stated that it is the inspector's duty to maintain properly calibrated measuring devices, and the enforcement regulation should not dilute the EPA standard in anticipation of his failure to do his job properly.

FRA agrees that it is the inspector's duty to maintain his equipment properly. However, if a failure does occur, prosecution for violation of the lower standard is not possible without proof that the train's speed was 45 mph or less.

§ 210.29(b)(1)(i)

One commenter stated that it is unclear whether the noise measurement device must be calibrated to actual frequencies. The section has been amended to make it clear that calibration to nominal frequencies satisfies the requirement. A sufficient degree of accuracy in noise measurements is assured as long as the calibrator frequency is accurate within a range, for example plus or minus three percent.

Another commenter stated that hourly calibrations are not necessary during a series of measurements, stating that calibration at the beginning of each series would assure accurate measurements.

FRA disagrees. The sound level meters are battery powered. Accordingly, frequent calibration during continuous use is important to assure that the inspector is aware as soon as the battery's voltage output drops close to the minimum operating voltage level of the sound level meter.

§ 210.29(c)

One commenter suggested increasing the measurement tolerance to at least 3dB(A), stating that the factors enumerated may realistically justify up to 5dB(A). The 2dB(A) measurement tolerance has been retained because it is the tolerance level generally accepted in the technical noise measurement community for field measurement purposes. (See, e.g., Society of Automotive Engineers Standard J952b, September 1971; SAE Technical Report J192, December 1970.)

In response to another commenter, paragraph (6) of the NPRM, which included an interpretation factor among those taken into account in determining the 2dB(A) tolerance, has been eliminated in this final rule. FRA agrees that the interpretation of the other factors is not properly listed as a separate item in the series and has included this consideration in the general explanation as to the purpose of the 2dB(A) tolerance.

§ 210.31(a)

One commenter opposed requiring that each locomotive manufactured after 1979 be tested for stationary noise emissions before it is placed in service initially. In response to the comment, type certification based on sample testing of each locomotive model will be required on all new locomotives built after 1979. The certification may be based on either load cell or passby testing. For reasons of clarity and rational organization of the final rule, the provisions for new locomotive certification for locomotives built after December 31, 1979 have been placed in a separate section § 210.33.

§ 210.31(g)

Six commenters addressed the proposed requirement for stationary noise testing whenever a locomotive is load cell tested for any reason. All six were opposed. They stated that the requirement would be ineffective in enforcing the noise emission standards, and compliance would be totally impractical. According to the commenters, many railroads do not have load cell facilities at all. One survey that included all of the major railroads plus a number of switching railroads showed that they have only approximately 176 load cell facilities. Furthermore, the typical locations of load cells is in or adjacent to locomotive repair shops. These locations often are unsuitable for noise testing in accordance with the EPA standards because they do not present the large open area, and the isolation from other noise sources that is required by the EPA definition of an acceptable test site. Also, some existing load cells depend upon high voltage direct current. Relocating the load cells at a distance from the shops would require the use of expensive transmission cables, and line losses of electric current during transmission from the power source to the remote load cell would reduce the efficiency of the devices for their primary purpose, i.e., testing the power output of the locomotive engines. The survey cited above showed that only seven existing load cell facilities in the country are suitable for noise testing under the site requirements prescribed in the EPA standards. One commenter that has two locomotive repair shops with load cells estimated that it would need to spend approximately $360,000 on modification of facilities and equipment before it could carry out stationary noise testing in accordance with the EPA standards at those shops. The commenters were also very concerned about the potential delays in returning recently repaired locomotives to service should a load cell noise test be required each time the locomotive is submitted to load cell testing for any purpose, because load cell noise emission tests cannot be performed during precipitation or when the measured wind velocity is over 12 mph. One commenter stated that the ability to take full advantage of its functioning motive power is critical for a small, financially weak railroad. Another concern was utilization of personnel. One commenter asserted that large numbers of new personnel would be needed, especially since the remote locations and random times for the required tests would reduce their efficiency. Finally, a commenter stated that additional problems might arise because of annoyance to the general public and employees who are not now subjected to load cell test noise. That commenter estimated that the proposed regulation would require approximately 47,000 stationary noise tests annually.

Two arguments were made about the effectiveness of the regulation in enforcing the standards. First, the commenters stated that load cell testing normally is done just after overhauls, repairs, or maintenance. That is the time a locomotive is most likely to be in compliance. To provide a more effective enforcement program, the commenters felt that required noise measurements should be taken on equipment with a higher probability of violations. Second, the commenters stated that the proposed rule would in effect exempt certain locomotives from any requirement for stationary noise testing. For example, there are many new locomotives that are equipped with a feature that permits load testing without connecting the unit to wayside load cell testing equipment. Also, locomotives owned by railroads that do not have load cell test facilities would not be subject to the requirement. A commenter that favored more frequent testing stated that the proposed rule needs to be strengthened because railroads do not conduct load cell tests regularly and there is no requirement for them to do so.

As a result of our review of the comments and further analysis, FRA believes it is not reasonable to require periodic load cell testing by the railroads. Many railroads apparently could not perform the tests without a substantial investment in facilities and equipment, and it is not sensible to require such an investment when the EPA has not identified locomotives as a major noise source. However, FRA is not at liberty to exempt locomotives entirely from load cell testing because EPA clearly did not intend the standards for stationary and moving locomotives to be alternatives. The preamble to the EPA standards states in part that—

> The EPA strongly believes that a stationary as well as a moving standard is necessary in order to account for the varying nature of locomotive noise (41 FR 2187).

An inspector could still request a railroad that has the capability to conduct a load cell test to do so if a locomotive is suspected of having a noise defect (§ 210.25(b)(1)). In addition, locomotives manufactured after December 31, 1979, must be certified for noise emission compliance before being placed in service initially. This certification may be based upon a load cell test.

§ 210.31(h)

One commenter stated that no test of a noise defective locotmotive should be required if the cause of the noise defect was readily identifiable and corrected.

The FRA recognizes that the retesting requirement for locomotives under proposed § 210.31(h) will constitute somewhat of a burden on railroads. This is true because the present location of locomotive repair facilities within or directly adjacent to congested yard areas will not ordinarily present an acceptable test site in terms of the criteria established by EPA in Subpart C of 40 CFR 201. In addition, as stated earlier, very few of the existing load cell facilities are located in areas that present acceptable test sites.

FRA believes that the source of excessive locomotive noise will often be readily identifiable as a result of recognized inspection and maintenance procedures. The retesting requirement, is not necessary in such cases in order to accomplish the intended purpose of the EPA standards. Therefore, in those situations in which the excessive noise emission is readily identifiable as related to a particular defective component, and that component can be replaced or there is an accepted repair procedure, FRA believes that retesting before returning the locomotive to service should not be required. Where no such defective component can be readily identified, retesting is necessary to assure elimination of the noise defect and will be required. Paragraph (c) of this section has been redrafted accordingly.

EMPLOYEE SAFETY AND HEALTH

One commenter criticized the EPA standards themselves, stating that they are too high to protect employees from noise related injury. The commenter also stated that there are many sources of railroad noise that might affect an employee's health that are not covered by the EPA standards. The commenters requested that FRA promulgate noise emission standards to protect employees.

The commenter's request is not within the scope of this proceeding. Further related rule making could be undertaken in the future, depending upon the nature of any evidence that particular noise emissions are a serious safety problem.

In accordance with the foregoing, Title 49 of the Code of Federal Regulations is amended by adding a new part 210 to read as set forth below. These rules shall become effective on October 1, 1977.

Issued in Washington, D.C. on August 17, 1977.

JOHN M. SULLIVAN,
Administrator.

AUTHORITY: Sec. 17, Pub. L. 92-574, 86 Stat. 1234 (42 U.S.C. 4916); § 1.49(p) of the regulations of the Office of the Secretary of Transportation, 49 CFR 1.49(p).

Subpart A—General Provisions

§ 210.1 Scope of part.

This part prescribes minimum compliance regulations for enforcement of the Railroad Noise Emission Standards established by the Environmental Protection Agency in 40 CFR Part 201.

§ 210.3 Applicability.

(a) The provisions of this part apply to the total sound emitted by rail cars and locomotives operated by a common carrier as defined in 45 U.S.C. 22 under the conditions prescribed herein and in 40 CFR Part 201, including the sound produced by refrigeration and air conditioning units which are an integral element of such equipment, except:

(b) The provisions of this part do not apply to:

(1) Steam locomotives;

(2) Street, suburban or interurban electric railways unless operated as a part of the general railroad system of transportation;

(3) Sound emitted by a warning device, such as a horn, whistle or bell when operated for the purpose of safety;

(4) Special purpose equipment which may be located on or operated from rail cars; and

(5) As prescribed in 40 CFR 201.10, the provisions of 40 CFR 201.11 (a) and (b) do not apply to gas turbine-powered locomotives or any locomotive type which cannot be connected by any standard method to a load cell.

§ 210.5 Definitions.

(a) *Statutory definitions.* All terms used in this part and defined in the Noise Control Act of 1972 (Pub. L. 92-574, 86 Stat. 1234) have the definitions set forth in that Act.

(b) *Definitions in standards.* All terms used in this part and defined in § 201.1 of the Railroad Noise Emission Standards, 40 CFR 201.1, have the definition set forth in that section.

(c) *Additional definitions:* As used in this part:

(1) "FRA" means the Federal Railroad Administration.

(2) "Administrator" means the Federal Railroad Administrator, the Deputy Administrator, or any official of the FRA to whom the Administrator has delegated authority to enforce the Act.

(3) "Consist of a locomotive and rail cars" means one or more locomotives coupled to a rail car or rail cars.

(4) "Noise defective" means the condition in which a locomotive, rail car or consist of a locomotive and rail cars is found to exceed the Railroad Noise Emission Standards, 40 CFR Part 201.

(5) "Standards" means the Railroad Noise Emission Standards, 40 CFR Part 201.

(6) "Inspector" means FRA regional Motive Power & Equipment Specialists, FRA Motive Power & Equipment Inspectors and State or local noise compliance inspectors designated and certified under § 210.17.

§ 210.7 Responsibility for noise defective locomotives or rail cars.

Any railroad that knows or has notice that a locomotive, rail car or a consist of a locomotive and rail cars that it is operating or testing is noise defective according to the criteria established in this part and in the Standards is responsible for compliance with this part. Subject to § 210.9, such railroad shall:

(a) Correct the noise defect; or

(b) Remove the noise defective locomotive or rail car from service.

§ 210.9 Movement of a noise defective locomotive, rail car or consist of a locomotive and rail cars.

A locomotive, rail cars or consist of a locomotive and rail cars that is noise defective may be moved no further than the nearest forward facility where the noise defective condition can be eliminated only after the locomotive, rail car or consist of a locomotive and rail cars has been inspected and been determined to be safe to move.

§ 210.17 State or local enforcement of the standards—qualified noise compliance inspectors.

(a) Any State or local jurisdiction that desires to enforce the Standards must so notify the FRA, and shall designate persons qualified to inspect and test locomotives or rail cars for defects prescribed by this part. Each person designated must be certified by the State or local jurisdiction and must carry official credentials stating his or her authority to conduct inspections and tests as prescribed in this part.

§ 210.19 Waivers.

(a) Any person may petition the Administrator for a waiver of compliance with any requirement in this part. A waiver of compliance with any requirement prescribed in the Standards, may not be granted under this provision.

(b) Each petition for a waiver under this section must be filed in the manner and contain the information required by 49 CFR Part 211.

(c) If the Administrator finds that a waiver of compliance applied for under paragraph (a) of this section is in the public interest and is consistent with railroad noise abatement and safety, he may grant a waiver subject to any conditions he deems necessary. Notice of each waiver granted, including a statement of the reasons therefor, will be published in the FEDERAL REGISTER.

§ 210.21 Penalty.

Any person who willfully or knowingly operates a locomotive or rail car in violation of the requirements of this part or of the Standards is liable to a penalty as prescribed in section 11 of the Noise Control Act of 1972 (Pub. L. 92-574, 86 Stat 1242).

Subpart B—Inspection and Testing

§ 210.23 Scope of subpart.

This subpart prescribes the compliance criteria concerning the requirements for inspection and testing of a locomotive, a rail car or a consist of a locomotive and rail cars.

§ 210.25 Noise inspection and testing.

(a) An inspector is authorized to perform a passby noise emission test as prescribed in the Standards, and in the procedures of this part, at any time, at any appropriate location, and without prior notice to the railroad for the purpose of determining whether a locomotive, rail car, or consist of a locomotive and rail cars is in compliance with the Standards.

(b) (1) An inspector is authorized to request that a locomotive, rail car or consist of a locomotive and rail cars together with appropriate railroad personnel be made available for a passby or stationary noise emission test as prescribed in the Standards, and in the precedures of this part, and to conduct such test, at a reasonable time and location, for the purpose of determining whether the locomotive, rail car or consist of a locomotive and rail cars is in compliance with the Standards.

(2) If the railroad has the capability to perform an appropriate noise emission test as prescribed in the Standards, and in the procedures of this part, an inspector is authorized to request the railroad to test the locomotives or rail cars. The railroad must perform the appropriate test as soon as practicable.

(3) The requests referred to in this paragraph must be in writing, must state the grounds upon which the inspector has reason to believe that the locomotive, rail car or consist of a locomotive and rail cars does not conform to the Standards, and must be presented to an appropriate operating official of the railroad.

(4) Testing or submission for testing is not required if the cause of the noise defect is readily apparent and the inspector verifies that it is corrected by the replacement of defective components or by instituting a normal maintenance or repair procedure.

(c) (1) An inspector is authorized to inspect or examine a locomotive, rail car or consist of a locomotive and rail cars operated by a railroad, or to request the railroad to inspect or examine the locomotive, rail car or consist of a locomotive and rail cars, whenever he has reason to believe that it does not conform to the requirements of the Standards.

(2) The request referred to in this paragraph must be in writing, must state the grounds upon which the inspector has reason to believe that the locomotive, rail car or consist of a locomotive and rail cars does not conform to the Standards, and must be presented to an appropriate operating official of the railroad.

(3) The inspection or examination referred to in this paragraph may be conducted only at recognized inspection points or scheduled stopping points.

(4) An inspector may request a railroad to conduct an inspection or examination of a rail car or consist of rail cars on the basis of an excessive noise emission level measured by a passby test. If, after such inspection or examination, no mechanical condition that would result in a noise defect can be found, and the inspector verifies that no such mechanical condition exists, the rail car or consist of rail cars may be continued in service.

(5) An inspector may request a railroad to conduct an inspection or examination of a locomotive on the basis of an excessive noise emission level measured by a passby test. If, after such inspection or examination, no mechanical condition that would result in a noise defect can be found, and the inspector verifies that no such mechanical condition exists, the locomotive may be continued in service.

§ 210.27 Operation standards.

The operation standards for the noise emission levels of a locomotive, rail car or consist of a locomotive and rail cars are prescribed in the Standards.

(a) Noise emission standards for locomotive operating under stationary conditions are contained in § 201.11 of the Standards.

(b) Noise emission standards for locomitives operating under moving conditions are contained in § 201.12 of the Standards. Measurements for compliance with the standards prescribed in § 201.12 of the Standards shall be made in compliance with the provisions of Subpart C of the Standards and the following:

(1) Consists of locomotives containing at least one locomotive unit manufactured prior to December 31, 1979, shall be evaluated for compliance in accordance with § 201.12(a) of the Standards, unless a locomotive within the consist is separated by at least 10 rail car lengths or 500 feet from other locomotives in the consist, in which case such separated locomotives may be evaluated for compliance according to their respective built dates.

(2) Consists of locomotives composed entirely of locomotive units manufactured after December 31, 1979, shall be evaluated for compliance in accordance with § 201.12(b) of the Standards.

(3) If the inspector cannot establish the built dates of all locomotives in a consist of locomotives measured under moving conditions, evaluation for compliance shall be made in accordance with § 201.12(a) of the Standards.

(c) Noise emission standards for rail cars operating under moving conditions are contained in section 201.13 of the Standards. If speed measurement equipment used by the inspector at the time of the measurement is not operating within an accuracy of 5 miles per hour, evaluation for compliance shall be made in accordance with § 201.13(2) of the Standards.

§ 210.29 Measurement criteria and procedures.

The parameters and procedures for the measurement of the noise emission levels are prescribed in the Standards.

(a) Quantities measured are defined in § 201.21 of the Standards.

(b) Requirements for measurement instrumentation are prescribed in § 201.22 of the Standards. In addition, the following calibration procedures must be utilized:

(1) (i) The sound level measurement system including the microphone must be calibrated and appropriately adjusted at one or more nominal frequencies in the range from 250 through 1000 Hz at the beginning of each series of measurements, at intervals not exceeding 1 (one) hour during continual use, and immediately following a measurement indicating a violation.

(ii) The sound level measurement system must be checked not less than once each year by its manufacturer, a representative of its manufacturer, or a person of equivalent special competence to verify that its accuracy meets the manufacturer's design criteria.

(2) An acoustical calibrator of the microphone coupler type designed for the sound level measurement system in use shall be used to calibrate the sound level measurement system in accordance with paragraph (1) (i) of this subsection. The calibration must meet or exceed the accuracy requirements specified in § 5.4.1 of the American National Standard Institute Standards, "Method for Measurement of Sound Pressure Levels," (ANSI S1.13-1971) for field method measurements.

(c) Acoustical environment, weather conditions and background noise requirements are prescribed in § 201.23 of the Standards; and in addition, measurement tolerances not to exceed 2dB(A) for a given measurement will be allowed to take into account the effects of the factors listed below and the interpretation of these effects by enforcement personnel:

(1) The common practice of reporting field sound level measurements to the nearest whole decibel; (2) Variations resulting from commercial instrument tolerances; (3) Variations resulting from the topography of the noise measurement site; (4) Variations resulting from atmospheric conditions such as wind, ambient temperature, and atmospheric pressure; and (5) Variations resulting from reflected sound from small objects allowed within the test site.

(d) Procedures for the measurement of locomotive and rail car noise are prescribed in § 201.24 of the Standards; and

(1) Accurate determination to within plus or minus 5 miles per hour of train speed (which may change during a passby) must be made as the train passes the microphone location, as defined in § 201.24 of the Standards, to determine the rail car compliance level specified in § 201.13(1) or (2) of the Standards.

(2) Locomotives and rail cars tested pursuant to the procedures prescribed

in this part and in the Standards shall be considered in noncompliance whenever the test measurement, minus the appropriate tolerance, exceeds the noise emission levels prescribed in §§ 201.11, 201.12, or 201.13 of the Standards, as appropriate.

§ 210.31 Locomotive tests.

(a) For load cell tests: (1) Each noise emission test shall begin after the engine of the locomotive has attained the normal cooling water operating temperature as prescribed by the locomotive manufacturer.

(2) Noise emission testing in idle or maximum throttle setting shall start after a 40 second stabilization period in the throttle setting selected for the test.

(3) After the stabilization period as prescribed in paragraph (2) of this subsection, the A-weighted sound level reading in decibels shall be observed for an additional 30 second period in the throttle setting selected for the test.

(4) The maximum A-weighted sound level reading in decibels that is observed during the 30 second period of time prescribed in paragraph (3) of this subsection shall be used for compliance purposes.

(b) The following data determined by any locomotive noise emission test conducted after December 31, 1976 shall be recorded in the "Remarks" section on the reverse side of Form FRA F 6180.49: (1) Location of the test; (2) Type of test; (3) Date and location of the test; and (4) The A-weighted sound level reading in decibels obtained during the passby test, or the readings obtained at idle throttle setting and maximum throttle setting during a load cell test.

(c) Any locomotive subject to this part that is found not to be in compliance with the Standards as a result of a passby test shall be subjected to a load cell test or another passby test prior to return to service, except that no such retest shall be required if the cause of the noise defect is readily apparent and is corrected by the replacement of defective components or by a normal maintenance or repair procedure.

(d) The last entry recorded on Form FRA F 6180.49 as required by paragraph (b) of this section shall be transcribed to a new Form FRA F 6180.49 when it is posted in the locomotive cab.

§ 210.33 New locomotive certification.

(a) A railroad shall not operate a locomotive built after December 31, 1979 unless the locomotive has been certified to be in compliance with the Standards.

(b) The certification prescribed in this section shall be determined for each locomotive model, by either: (1) Load cell testing in accordance with the criteria prescribed in the Standards; or (2) Passby testing in accordance with the criteria prescribed in the Standards.

(c) If passby testing is used under paragraph (b)(2) of this section, it shall be conducted with the locomotive operating at maximum rated horsepower output.

(d) Each new locomotove certified under this section shall be identified by a permanent badge or tag attached in the cab of the locomotive near the location of the Inspection Form F 6180.49. The badge or tag must state: (1) Whether a load cell or passby test was used; (2) The date and location of the test; and (3) The A-weighted sound level reading in decibels obtained during the passby test, or the readings obtained at idle throttle setting and maximum throttle setting during a load cell test.

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DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
WASHINGTON, D.C. 20590

Office of Associate Administrator for Safety

[4910-06]

Title 49—Transportation

CHAPTER II—FEDERAL RAILROAD ADMINISTRATION, DEPARTMENT OF TRANSPORTATION

[Docket No. HS-4, Notice No. 8]

PART 228—HOURS OF SERVICE OF RAILROAD EMPLOYEES

Noise Levels in Railroad Employee Sleeping Quarters; Guideline

AGENCY: Federal Railroad Administration (FRA), Department of Transportation.

ACTION: Issuance of interpretive guideline; statement of policy.

SUMMARY: This document issues an interpretive guideline which FRA will employ in administering and enforcing section 2(a)(3) of the Hours of Service Act, as amended (45 U.S.C. 62(a)(3)), which was enacted by Pub. L. 94-348, approved July 8, 1976. The statutory provision makes it unlawful for any common carrier "to provide sleeping quarters for employees (including crew quarters, camp or bunk cars, and trailers) which do not afford such employees an opportunity for rest, free from interruptions caused by noise under the control of the railroad, in clean, safe, and sanitary quarters". In order to facilitate compliance with the Hours of Service Act and to give notice concerning the policy of FRA in enforcing this provision of law, FRA is amending appendix A to part 228 by adding a description of the noise level resulting from noise sources within the control of the railroad which will be regarded by FRA as the maximum level permitting "an opportunity for rest" within the meaning of the statute. The standard adopted is an $L_{eq}(8)$ value of 55dB(A).

EFFECTIVE DATE: July 18, 1978.

FOR FURTHER INFORMATION CONTACT:

Stephen Urman (RRS-24), Office of Safety, Federal Railroad Administration, 2100 Second Street SW., Washington, D.C. 20590, 202-426-9178.

SUPPLEMENTARY INFORMATION: Elsewhere in this FEDERAL REGISTER FRA amends part 228 by adopting final rules relating to the construction or reconstruction of railroad employee sleeping quarters in areas close to switching or humping operations. Section 228.107(c) of those rules states that FRA will utilize a standard of 55dB(A) L_{eq} measured over any 8-hour period. The preamble to the rules discusses the public comment received and the basis for FRA action in adopting the aforementioned criterion. That discussion is incorporated herein by reference. See material in Docket No. HS-2, Notice No. 6, in this portion of today's FEDERAL REGISTER.

In light of experience gained through FRA field activities related to the enforcement of the Hours of Service Act since July 8, 1976, and in consideration of the comments received in Docket No. HS-2, FRA has decided to utilize as a guideline in its enforcement of section 2(a)(3) of the Hours of Service Act (45 U.S.C. 62(a)(3)) a maximum equivalent steady state sound level in eight hours ($L_{eq}(8)$) of 55dB(A). That is, any sleeping quarters provided for employees covered by the Hours of Service Act which cannot meet an $L_{eq}(8)$ noise level standard of 55dB(A) as a result of the noise generated by sources within the control of the carrier will be deemed in violation of the Act.

In consideration of the foregoing, appendix A to part 228 (42 FR 27594, 27598; May 31, 1977) is amended by adding immediately after the existing paragraph designated "Sleeping Quarters" under the major heading of "General Provisions" the following new text:

"Sleeping quarters are not considered to be 'free from interruptions caused by noise under the control of the railroad' if noise levels attributable to noise sources under the control of the railroad exceed an $L_{eq}(8)$ value of 55dB(A)."

The principal program draftsman of this document was Stephen Urman of the Office of Safety. The principal legal draftsman was Grady Cothen, Jr., of the Office of Chief Counsel.

Issued in Washington, D.C. on July 11, 1978.

JOHN M. SULLIVAN,
Administrator.

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DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
WASHINGTON, D.C. 20590

Office of Associate Administrator for Safety

[4910-06]

Title 49—Transportation

CHAPTER II—FEDERAL RAILROAD ADMINISTRATION, DEPARTMENT OF TRANSPORTATION

[Docket No. HS-2, Notice No. 6]

PART 228—HOURS OF SERVICE OF RAILROAD EMPLOYEES

Construction of Railroad Employee Sleeping Quarters; Final Rules

AGENCY: Federal Railroad Administration (FRA), Department of Transportation.

ACTION: Final rule.

SUMMARY: This document issues final rules under which the Federal Railroad Administration (FRA) will consider whether proposed sites for the construction or reconstruction of sleeping quarters for railroad employees subject to the Hours of Service Act are "within or in the immediate vicinity * * * of any area where railroad switching or humping operations are performed." The rules are responsive to section 2(a)(4) of the Hours of Service Act (hereafter act), as amended by section 4(a) of the Federal Railroad Safety Act of 1976, which prohibits the construction or reconstruction of quarters for such employees within the immediate vicinity of switching and humping. The rules establish which prospective sites are subject to FRA approval, outline the information required with requests for site approvals, and indicate the general policy considerations which FRA applies in ruling on requests for such approvals.

EFFECTIVE DATE: These rules shall become effective August 18, 1978. However, carriers which have filed petitions for approval pursuant to the interim rules (41 FR 53028 (1976)) may elect to proceed wholly under the interim rules or these permanent rules.

FOR FURTHER INFORMATION CONTACT:

Lawrence I. Wagner, Office of Chief Counsel (RCC-30), Federal Railroad Administration, 400 Seventh Street SW., Washington, D.C. 20590, 202-426-8836.

SUPPLEMENTARY INFORMATION: Section 2(a)(4) of the Hours of Service Act, as amended (45 U.S.C. 62(a)(4)), prohibits the construction or reconstruction of railroad employee sleeping quarters "within or in the immediate vicinity (as determined in accordance with rules prescribed by the Secretary of Transportation) of any area where switching or humping operations are performed." This provision of law became effective on July 8, 1976. (See 94-348, 90 Stat. 818.) FRA administers and enforces the Hours of Service Act under section 6(f)(3)(A) of the Department of Transportation Act (45 U.S.C. 1655(f)(3)(A)) and a delegation from the Secretary of Transportation (49 CFR 1.49(d)).

On December 3, 1976, FRA published in the FEDERAL REGISTER interim rules for making the required determinations (41 FR 53028). A minor amendment to the interim rules was published on June 1, 1977 (42 FR 27895). A notice of proposed rulemaking (NPRM) with respect to permanent rules was also issued on December 3, 1976 (41 FR 53070). The extended deadline for written comments was February 17, 1977 (42 FR 2994; January 14, 1977). A public hearing was convened on March 1, 1977, to receive additional oral and written comments (see 42 FR 5387; January 28, 1977).

All comments, both written and oral, have now been evaluated by FRA. In addition, FRA has acquired considerable experience through the application of the interim rules, which closely parallel those set forth in the NPRM. FRA has now decided to issue final rules responsive to the mandate of the Hours of Service Act which adopt an approach essentially similar to the proposed rules but which have been refined in certain significant respects.

DISCUSSION OF MAJOR COMMENTS AND MODIFICATIONS OF PROPOSED RULES

PRELIMINARY DISCUSSION

One commenter objected to FRA's determination that this rulemaking does not require an evaluation of the regulatory impact of the proposed rules in accordance with the policies of the Department of Transportation as stated in the FEDERAL REGISTER (41 FR 16200; April 16, 1976), since the issuance of these regulations is required by statute. The same commenter also questioned the apparent absence of consideration of environmental impact required by section 102(2)(C) of the National Environmental Policy Act of 1969 (42 U.S.C. 4332(2)(C)). Two commenters objected to the conclusion that the economic consequences of this rule are limited and therefore, do not require an economic impact statement.

The basic position stated by th commenter with respect to the Secr tary's regulatory impact policies that, notwithstanding the exemptic of regulations expressly mandated t statute, the only instance in which statutorily mandated rulemaking pr ceeding is exempt from the impact evaluation procedure required by the Secretary's policies is where the agency has no discretion in issuing the rules.

The FRA does not agree entirely with this narrow interpretation of the policies established by the Secretary. The purpose of the regulatory impact evaluation required by the Secretary's policies is to assure that all of the potential costs and benefits of a proposed rulemaking action are adequately assessed and considered by the agency in an effort to improve the effectiveness of the proposed regulation and minimize unnecessary burdens on affected parties. Where a statute requires the issuance of a rule on a particular matter, the Secretary does not have the discretion to withhold rulemaking action even if it were shown that the possible benefits of the rule would not outweigh its potential costs. The result or impact of the rulemaking at hand is, in effect, prescribed by law, while FRA is granted discretion only as to how the prescribed result of the rule might be most reasonably achieved through regulation. Neither FRA nor any commenter has been able to identify any approach to fulfilling the mandate of the statute which would be less burdensome than the approach embodied in these rules. The statute requires the Secretary to implement a direct prohibition rather than to fashion means of achieving a more general goal. Accordingly, FRA has attempted to examine the potential alternate means of fulfilling the statutory mandate and has opted for an administrative mechanism which will facilitate the implementation of the statutory prohibition at the least possible cost to the industry. As reflected in the preamble to the NPRM and in this preamble, FRA has considered and rejected other approaches to distance limitation as well as different noise levels and descriptors. A more complete analysis of the kind which would be undertaken in the absence of a specific statutory mandate is not appropriate in this context.

With respect to consideration of the environmental impact of the proposed regulations, the FRA has performed a general environmental assessment of the potential effects of safety regulatory actions and has determined that, as a class, they do not constitute major Federal actions significantly affecting the quality of the human environment. Furthermore, the FRA does not believe that the particular rules included in this document, as distinguished from the statutory mandate itself, will have a foreseeably significant impact upon the quality of the human environment. The commenter suggests that increased waste disposal requirements might arise in sparsely populated areas and that this effect of the rules should be taken into consideration. This commenter does not offer any evidence that this possible impact exists under the interim rules or would exist under permanent rules to such an extent that the quality of the human environment will be significantly impacted. Nor does the substantive law here implemented permit FRA to waive the statutory prohibition based on environmental considerations.

The commenter also criticized the FRA for not having evaluated the economic impact of this regulation. DOT order 2050.4 defines what actions are to be considered major proposals for purposes of determining whether an inflationary impact analysis must be undertaken pursuant to Executive Order 11821. For purposes of regulations which impact upon a single industry, the threshold level at which a particular action is to be considered "major" is an action which will result in increased expenses of $50 million in 1 year, or $75 million in any 2 consecutive years. The commenter stated that the additional cost to the railroads due to these regulations will exceed the threshold due to the increased use of commercial facilities, purchase price of land, and transportation costs necessitated by these regulations.

Again, the regulations merely implement the congressional mandate. Since the regulations do not go beyond the congressional mandate, and since no device has been proposed for fulfilling that mandate which would be faithful to the law and yet be less costly, it cannot be fairly asserted that the issuance of those rules will result in any economic impact.

The final rule permits the approval of sites under certain special conditions similar to those raised by the commenter. Through these provisions, FRA believes that the rules provide the broadest degree of flexibility which is possible within the meaning and intent of the statutory requirement. This flexibility should alleviate the more burdensome or costly impacts.

SECTION-BY-SECTION ANALYSIS

Section 228.101(a). One commenter suggests that all sleeping quarters now in use be removed a "safe distance" from areas where switching or humping operations are preformed. The only possible basis for requiring the relocation of existing facilities would be section 2(a)(3) of the Hours of Service Act (45 U.S.C. 62(a)(3)), which prohibits any carrier from providing sleeping quarters for employees which do not afford such employees "an opportunity for rest, free from interruptions caused by noise under the control of the railroad, in clean, safe, and sanitary quarters". Nothing in the legislative history of this provision suggests a congressional intent to require a wholesale relocation of existing facilities, nor would known safety considerations support that result.

Since the Decatur accident of July 19, 1974 (discussed below) and another major explosion in a Houston, Tex. yard 2 months later, measures have been instituted by FRA, the Department of Transportation and the railroads which have already had a significant beneficial effect. See FRA Emergency Order No. 5, 39 FR 38230 (1974); Specifications for Pressure Tank Cars, 42 FR 46306 (September 15, 1977). Indeed, since those two incidents there has not been a single inadvertent release of flammable compressed gas from a railroad tank car during a switching operation. While absolute safety is not possible in any field of endeavor, FRA does not believe that it was the intent of Congress to require that existing sleeping quarters be moved based on existing risks related to the switching of hazardous materials. Further, FRA site visits to existing facilities since publication of the NPRM in this docket have disclosed that noise levels can often be kept within acceptable limits by use of proper construction techniques and/or insulating materials even where quarters are quite close to railroad operations. FRA will continue to monitor conditions in existing facilities to insure that they comply with the law.

Another commenter argued that sleeping quarters for employees engaged in the communication of train orders, such as operators and train dispatchers, should not be included under the coverage of the rules. This contention was based on a belief that employees covered by section 3 of the act are not subject to section 2(a) as it applies to "employees" defined in sections 1 and 3A. It is clear that the "operator, train dispatcher, or other employee" referred to in section 3 of the act (45 U.S.C. 63) is an "employee" for purposes of the statute generally, although some of the subject matter of section 1 is not applicable to such an employee. The provisions of section 2(a) (3) and (4) purport to apply to employees covered by the law generally, and there is no basis in the legislative history for inferring a more limited interpretation.

Section 228.101(b) defines "immediate vicinity" to mean the area within one-half mile of switching or humping, except as determined otherwise by FRA under these rules. One commenter claimed that Congress did not intend for FRA to place any specific distance limitation on the location of facilities. This contention was based on the House committee report on the 1976 legislation, which does not specify a mileage limitation on the location of sleeping quarters and states an intent to give the railroads "some "flexibility" when constructing lodgings. H.R. Rep. No. 1166, 94th Cong., 2d. Sess. 11 (1976). The commenter suggested that "immediate vicinity" be defined to denote any area where an explosion occurring during switching or humping operations would cause death or injury to employees inside sleeping quarters. The railroads would then furnish the FRA the basis for their conclusion that their facilities are located in accordance with these principles. It is difficult to understand how this approach differs from the application process outlined in § 228.103, unless it is intended that FRA should accept without active review the conclusions of the carrier. Certainly FRA, as the administering agency, is responsible for making the judgment called for by the statute.

Another commenter suggested that FRA adopt an additional rule limiting "immediate vicinity" to no farther from tracks on which switching or humping operations are conducted than the closest home, business, school, or other frequently occupied community facility. FRA is not oblivious to the irony that the policy of the statute appears to require railroad employee sleeping quarters to be at a greater distance from switching operations than some homes and schools. However, accepting the evident congressional judgment that the level of risk from hazardous materials incidents is sufficient to warrant the location of newly-constructed quarters outside the zone of danger from a major open-air detonation or similar event, FRA has no practical alternative.

Distances of one-third mile, 2,000 feet, and 1 mile were offered as alternative definitions of "immediate vicinity" by different commenters. However, none of the commenters offered any evidence to support their recommendations. FRA believes that the proposed standard of one-half mile is fully warranted by available information concerning the major occurrences in railroad yards during the current decade.

One commenter disputed the vapor cloud phenomenon discussion in the NPRM and its applicability to the Decatur, Ill. accident on the basis that none of the fatalities occurred to persons who were inside the dormitory. However, the National Transportation Safety Board report states that most of the seriously injured employees were either in the dormitory or adjacent to it. Report No. NTSB-RAR-75-4 (1974). The fact that 316 persons other than railroad employees suffered "burns, lacerations, contusions, anxiety, eye injuries, and concussions" is also significant with respect to the level of hazard to persons at some distance from the point of ignition. The NTSB report goes on to say that "the location of the dormitory subjected those employees to known hazards". Most likely, the existence of the quarters in that particular location contributed to the congregation of persons and the increased exposed population. Many of the severe injuries suffered by the 230 residents of East St. Louis and 235 residents of Houston (similar vapor cloud detonation occurrences in 1972 and 1974, respectively) resulted from structural damage and heat effects at some distance from the point of ignition. Since vapor clouds may spread for hundreds of feet before encountering a source of ignition, any potential sleeping quarters site within one-half mile could be affected, depending on the overall circumstances.

In support of an absolute 1-mile limitation, one commenter urged that the nearly 5 percent of large fragments that fall between one-half and 1 mile in a major explosion or detonation present an unacceptable risk to a person sleeping in that area. See NPRM, 41 FR 53071. FRA does not believe that the gain in real safety at this distance adequately justifies such a determination. Nor would the legislative history of the provision appear to provide any support for the proposition that Congress anticipated a rule of such rigidity.

Section 228.101(c) (1), (2). Subparagraphs (1) and (2) of § 228.101(c) define the terms "construction" and "reconstruction". Since the actions prohibited by the statute are integrally related to the types of facilities covered, comments addressing both issures are discussed here.

One commenter suggested that a new section be added to the regulation which would prohibit the railroads from locating any movable sleeping quarters within an unsafe distance of railroad yards. The commenter amplified this suggestion to include not only trailers and rolling stock, but also hotels and motels selected by the railroads for use by their employees. FRA did not intend placement of mobile sleeping quarters such as trailers, camp cars, or modular units to be outside the scope of these regulation. Potential hazards to employees in these facilities are no less serious than those imposed on employees housed in permanent facilities. To clarify this intent, the definition of "construction" in § 228.101(c)(1) has been expanded to include the placement of mobile or modular units. In addition, the acquisition of an existing structure for use as sleeping quarters is listed as an event clearly within the purview of the statute and these regulations.

However, the regulation of places of public accommodation such as commercial hotels and motels is beyond the scope of FRA authority under the Hours of Service Act. It is clear from the language of the act read in light of the legislative history that quarters provided in places of public accommodation under an ordinary arms-length transaction are not governed by section 2(a) (3) and (4). See H.R. Rep. No. 1166, 94th Cong., 2d Sess. 11 (1976). Of course, if a railroad acquired ownership or control of a commercial hotel or motel for the purpose of housing employees, the fact that the facility or some portion thereof was open to the public would not avoid the applicability of the Hours of Service Act and the prohibition of section 2(a)(4). In such a case, the emloyer-employee relationship would clearly be more relevant than the innkeeper-guest relationship when viewed in the light of the statute.

Concern was expressed by one commenter whether these rules would apply only to sleeping quarters constructed or reconstructed by a railroad or its agent and owned by the railroad, and not to sleeping quarters owned by others and rented by the railroad. Again, FRA does not believe that the legal or equitable ownership of newly constructed sleeping quarters is relevant to railroad employee safety. The act makes it unlawful for a carrier "to begin construction or reconstruction" of sleeping quarters which are to be provided for covered employees. It makes no difference that the carrier may act through an intermediary or that the quarters may be constructed on the property of others, so long as the carrier is acting to provide sleeping quarters. These rules are coextensive with the statute with respect to their coverage.

One commenter suggested that reconstruction be redefined to include all activity involving an expenditure of 50 percent or more of the original cost of a facility as adjusted to account for inflation. FRA believes that the replacement cost is a more realistic criterion and capable of surer application over a long period of time, since building costs do not follow overall price trends and original cost may not be available. Additionally, newer facilities may use different design and material specifications which make them not readily comparable to the original construction.

Indeed, FRA has noted in its administration of the interim rules that the phrase "more than 50 percent of the replacement cost of such facility" (Rule 1(c)(2); 41 FR 53030) is susceptible to two constructions. Specifically, "replacement cost" could be read to refer either to (1) the cost of replicating an existing structure by use of the original design and materials specifications or (2) the cost of replacing the old structure with a contemporary structure of the same capacity built according to contemporary methods with materials customarily used fo such a facility at the time the expenditures are commenced. FRA intended the second meaning; but it is recognized that the interim rule could be read either way. The final rule clarifies this issue by stating that the replacement cost is to be estimated on the basis of contemporary construction methods and materials and use of the existing site.

Concern was also expressed by a commenter that, under the proposed definition, a carrier could possibly stagger its expenditures over a period greater than 18 months and eventually reconstruct a new facility without FRA approval of the site. FRA agrees that the proposed definition does open an unwarranted avenue for evasion of the statutory prohibition. Accordingly, the final rule has been modified to include any work involving the expenditure of the specified amount irregardless of a fixed time period. Routine maintenance would still be excluded from the computation.

Section 228.101(c)(3) defines the term "switching or humping operations". (Since "humping" is really a method by which cars are switched, a separate definition is not provided in the regulations.) This definition provoked the greatest number and variety of comments of any provision in the proposed regulations. FRA's basic approach to defining this term has been to identify substantially all of those circumstances in which there is a potential for the occurrence of high speed impacts of cars which might result in the release of dangerous hazardous materials. Since this potential exists in many situations other than the classification yard (the area of highest risk), FRA has attempted to construct a reasonably inclusive definition.

A number of commenters remarked that the proposed definition of switching operations (§ 228.101(c)(3)) was too broad because movement of non-hazardous material cars was included. This contention was based on the belief that the act was not meant to bar construction of sleeping quarters near areas where only non-hazardous commodities are handled, assuming the criteria of section 2(a)(3) are met.

FRA agrees that primary impetus behind the enactment of section 2(a)(4) was the accident that occurred at Decatur, Ill. on July 19, 1974. As a result of an accidental release and resultant explosion of a product which occurred during the switching of hazardous materials, seven employees were killed and another 33 were injured. According to the National Transportation Safety Board: "Most of the injured employees were either in the dormitory or adjacent to it. All of those who were fatally burned were outside of the dormitory." Report No. NTSB-RAR-75-4 (July 19, 1974).

Since the commenters generally agreed that the proposed definition of switching operations was unnecessarily broad, the final rule has been modified to include only the switching of cars required to be placarded in accordance with the Department of Transportation Hazardous Materials Regulations (49 CFR 172.504). In determining whether hazardous materials cars are switched or humped within the distance for which approvals are required, the rule requires the carriers to ascertain whether such cars have been switched on the given trackage within the past 365 days. In this way, traffic is surveyed over an entire seasonal cycle. In addition, a carrier seeking to determine whether a petition should be filed must consider its plans for future use of the trackage.

FRA is aware that this approach to defining "switching operations" will mean that most operations considered "switching" under the proposed definition will also be considered "switching" under this definition. However, given the strong language of the statute it appears that little latitude exists. The Secretary is required to determine the area of significant risk around switching and humping operations. Acting under a delegation from the Secretary (49 CFR 1.49(d)), FRA has decided that enlightened determinations can be made only by examining concrete circumstances in the light of the statute's intent. Within the area of presumed risk (one-half mile), the rules requires that specific approval be sought.

The approach of the final rule goes beyond the suggestions of two commenters concerning the categories of hazardous materials which should be comprehended by the definition of "switching".

One commenter would have included only the switching of cars requiring special handling under Federal regulations. Another would have included most placarded cars, but would have excepted those containing substances such as corrosives, irritating materials, combustible liquids, class C explosives, radioactive materials, etc. FRA believes that the safety of employees would be best served by a careful examination of any situation in which placarded cars are switched within one-half mile.

However, the commenters seem correct in challenging whether the stringent requirements of the proposed § 228.105 are necessary with respect to sites within one-third mile of areas where some types of placarded cars are handled.

FRA recognizes that there may be locations where some local or industrial switching is conducted but where the most volatile—or dangerous materials are not switched. Therefore, in order to assure appropriate flexibility, §§ 228.103 and 228.105 have been restructed. Section 228.103 now specifies basic requirements for petitions relating to all sites within one-half mile of switching or humping operations involving any cars required to be placarded by the Department's hazardous materials regulations. Section 228.105 now specifies additional, more stringent requirements for those proposed sites which are within one-third mile of switching which involves cars requiring special handling under the hazardous materials regulations (49 CFR 174.83(b)) or FRA emergency order No. 5 (39 FR 38230 (1974)). This refinement eliminates any unnecessarily harsh effect of the proposed one-third mile rule by assuring that the more strict features of that proposed provision will apply only where they are clearly required.

Other suggestions which would reduce the reach of the definition have been rejected. One commenter suggested that the definition include only the classification of cars by humping or flat switching and the making up of cars into trains by a yard crew for train movements, but that it not include changing the position of cars for purposes of loading, unloading, or weighing and the placing of locomotives and cars for repair. It was also suggested that the qualifying words "while enroute to the train's destination" be deleted from the exemption on movement of cars by a road locomotive.

FRA does not entirely agree with these suggestions. As stated above, assurance of safety requires that all operations which occur in a railroad yard or similar facility that have a potential for excessive speed impact or other accident involving hazardous materials be included. Yard movements of hazardous materials cars for repair or for loading, unloading, or weighing satisfy this criterion.

The definition of switching operations excludes "placing locomotives or cars in a train or removing them from a train by a road locomotive while en route to the train's destination." The purpose of the exclusion as used in this context was to except incidental picking up or setting off of cars by a train on the line of haul. As used in these rules, the exclusion is not intended to except the assembling of trains or reblocking of trains by road locomotive at a yard where switching locomotives are not available or where, for whatever reasons road power is used for switching functions. Switching operations performed by a road locomotive are not sufficiently distinct from those performed by a yard locomotive to justify their exclusion. In either situation, the potential for overspeed impacts exists. Accordingly, this language has been retained in the definition.

Another commenter suggested that the definition should include the repair of locomotives to ensure that sleeping quarters are not placed near potential fire hazards and sources of noise. The proposed rule did include the placement of locomotives for repair within the difinition of switching. However, the central intent of the act and of these rules is to minimize the hazard to railroad employees from movements of cars containing hazardous materials and to afford employees an opportunity for uninterrupted rest. FRA has no data at this time indicating that locomotive shops and engine houses as a whole present hazards of an equivalent magnitude. In any event, in virtually every situation where a proposed site is close to such structures there will also be some operation defined as switching conducted within one-half mile of the site. FRA can then consider special circumstances related to locomotive repair in association with other relevant factors. (See revision to § 228.107(b)). Noise due to locomotive repair operations is more appropriately addressed under § 228.107, which requires an evaluation of projected noise levels from all noise sources under the control of the railroad. Any noise component resulting from repair activities would be reflected in that calculation.

Section 228.101(c)(3) has been revised to emphasize the fact that proposed sites may fall within the statute and rules by virtue of proximity to the operations of other railroads, as well as those of the carrier which proposes to undertake construction of sleeping quarters.

Section 228.101(c)(4) defines "placarded car" to mean a car required to be placarded by the Department's Hazardous Materials Regulations (49 CFR 172.504).

Section 228.101(c)(5) defines the technical noise descriptor "L_{eq} (8)". See discussion of § 228.107, below.

Section 228.103 outlines the information required to be submitted to FRA in connection with a petition for approval of any site located within one-half mile of switching or humping operations. A new paragraph (b) has been added to the section clarifying the effect of the new definition of switching operations (§ 228.101(c)(3)) on the requirement of FRA approval. In the absence of carrier records concerning traffic switched within one-half mile of the site, the rule creates a presumption that some hazardous materials are switched at the facility and that, therefore, a petition must be filed. The presumption is fully warranted by common traffic patterns in the industry. Indeed, relatively few locations exist where hazardous materials are not handled at all.

Section 228.103(c) now provides that petitions shall be filed with the Secretary of FRA's Railroad Safety Board instead of the docket clerk. This change conforms these rules to FRA's procedural rule on special approvals (49 CFR 211.55). The only other departure from the NPRM in this paragraph is a revision to subparagraph (7), which requires that the carrier's estimate of hazardous materials cars be based on a full seasonal cycle of 365 days. The rule does not specify any particular sampling technique; however, a representative sample is intended.

One commenter criticized the certification requirement (§ 228.103(c)(8)) for apparently requiring representations concerning planned utilization of trackage or construction of trackage by both the applying carrier and any other railroad with nearby property or trackage. FRA intends that a carrier be required to certify only its existing plans for utilization of trackage or the construction of new trackage. Obviously, it would be impossible for a carrier to certify information concerning the present intent of another railroad. (However, it is expected that the existence of railroad employee sleeping quarters should be an important determinant of future track location plans by a railroad.) The provision has been modified accordingly to better express this intent.

Section 228.103(d) requires that the carrier serve a copy of the petition on employee representatives and so indicate to FRA. The purpose of this provision is to assure timely comment by the principal parties who would be affected by any FRA action on the petition. (As a matter of administrative routine, FRA will notify any other interested person who wishes to be kept informed of the filing of such petitions and FRA action thereon.) One commenter suggested that more formal procedures for employee participation should be adopted. FRA will, of course, receive and consider any written protest to a petition and will provide opportunities for oral presentations in appropriate instances. However, FRA believes that the general rules of practice (49 CFR Part 211; 41 FR 54181 (1976)) provide an adequate framework for administering these approval procedures.

Section 228.105, as restructured for final issuance, specifies additional information which must be submitted and additional conditions precedent to FRA consideration of a petition for approval of a site located within one-third mile of switching or humping operations involving hazardous materials cars which require special handling. Unlike the proposed rule and interim rule, the additional requirements of this section would not apply to sites within one-third mile of trackage on which the enumerated types of traffic are not switched. This relaxation of requirements may provide additional flexibility with respect to crew change points on certain branch lines and locations where only local switching is conducted. However, no detriment to safety will result. Assuming some hazardous materials traffic is switched within one-half mile of the proposed site, FRA will still review the concrete circumstances involved under § 228.103 and may approve or disapprove the site.

Three commenters suggested that the approval procedures for construction within one-third mile be entirely deleted, arguing that the information required under § 228.103 is sufficient for evaluation purposes. FRA does not agree. Appropriate combinations of additional precautions and physical restrictions identified under § 228.105 (favorable topography, existence of barriers, soundproof construction) should be present for approval of sites which are quite close to areas of potential hazard. Moreover, under the policy of the statute a carrier should be required to exhaust all potentially feasible alternatives before proposing construction on a site within one-third mile of switching which may involve the possibility of a major hazardous materials accident. The rule as adopted addresses these concerns.

A number of commenters objected to the requirement of the proposed rule that no feasible alternate site be available "at any cost" before FRA is requested to approve a site within one-third mile. FRA is inclined to agree that commercial feasibility offers a more realistic test of the efforts of the carrier to locate the planned sleeping quarters beyond one-third mile. Therefore, the final rule has been revised accordingly (§ 228.105(a)(1)). Problems with alternate sites similar to those suggested by the commenters involving factors such as unavailability of land, isolation of facilities, limited water and sanitation capacity, etc., will be evaluated on a case-by-case basis, in conjunction with a thorough review of safety protection at the proposed site.

Two commenters claimed that the existence of adequate natural or artificial barriers by itself obviates the need for establishment of unavailability of an alternate site or for the submission of additional data. The FRA does not agree with this contention. Reliance on the existence of a barrier as the sole criterion in judging the safety of a potential construction location is not prudent. To prevent the diffusion of a toxic or flammable gas into crew quarters and to allow for unanticipated ignition sources under all conceivable circumstances, a completely effective barrier would have to enclose completely the switching operations or the quarters. Obviously, it will be necessary for the carrier and FRA to evaluate a number of other factors before reaching an informed decision.

One commenter suggested that the section on approval procedures for construction within one-third mile be expanded to include additional precautions for insuring employee safety from explosions and the escape of poisonous gases. Additionally, requirements concerning respiratory protection and minimum strength and construction of barriers would be specified under the commenter's approach.

FRA agrees that additional precautions may be appropriate in individual circumstances and that FRA should evaluate the adequacy of barriers and the need for further safeguards. However, it appears from the wide variety of circumstances encountered by FRA in administering the interim rules that such concerns are best evaluated in the context of individual petitions. The final rules indicate that it is the carrier's responsibility to consider additional safeguards prior to filing a petition (§ 228.105(a)(4)). Under § 228.107, FRA will independently review the carrier's plans and may impose specific conditions on approval of the petition.

With the restructure of §§ 228.103 and 228.105, a further editorial change has been made in § 228.105. Subparagraph (b)(4) of the proposed § 228.105 has been deleted as redundant, since §§ 228.103(c)(1) and 228.107(c) of the final rules adequately address the question of projected noise levels.

A new paragraph (b) has been added to § 228.105 stating that, in the absence of records establishing the absence of certain hazardous materials activity on the nearby trackage or adequate plans to divert such traffic from the nearby trackage in the future, approval of the site shall be subject to the additional requirements of § 228.105.

Section 225.107 covers the procedures and fundamental criteria for FRA action on petitions filed under § 228.103. In reading the final rules as a whole and this section, in particular, it should be appreciated that FRA action on any petition is, in the final analysis, discretionary. That is, compliance with the rules by a petitioning carrier will not, by itself, entitle a petitioning carrier to favorable action. If the myriad circumstances bearing on individual situations were capable of automatic quantification and application, an approval procedure would not be necessary.

The two general criteria for FRA action are set forth in paragraph (b) of § 228.107. In weighing the "material factors" which impact on those criteria (employee safety and projected interior noise), FRA will consider the information provided by the carrier, information developed by an FRA field investigation, and any information provided by other interested parties.

Subparagraph (b)(1) of § 228.107 has been amended in its final form to reflect the fact that, once a site becomes subject to FRA scrutiny under these rules, FRA must consider all factors bearing on the safety of the facility. That is, FRA cannot divorce its responsibilities under section 2(a)(3) of the act (45 U.S.C. 62(a)(3)), relating to the safety of all sleeping quarters, from its responsibility under section 2(a)(4), relating to construction or reconstruction of such quarters.

Paragraph (c) of § 228.107 addresses the issue of maximum noise levels. Two commenters claimed that FRA lacks jurisdiction to promulgate noise regulations under section 2(a) of the Hours of Service Act. The purpose of addressing maximum noise levels in these regulations is to assure that FRA will not approve construction of a facility under these rules and then be forced to seek remedial action under section 2(a)(3) of the act because noise levels are excessive. Therefore, to the extent possible FRA will seek to ascertain that carriers have made proper allowances in building design to assure that noise levels will be within limits permitting uninterrupted rest.

The purpose of specifying an objective standard which FRA will utilize in evaluating potential noise levels is to assure fairness and to encourage intelligent carrier planning. FRA recognizes that a single objective standard will fall short of producing perfect rest conditions in all settings. However, an objective maximum level for noise within the control of the carrier is necessary as a tool for administration of the act and as a benchmark for the industry.

Another commenter suggested that the noise levels should apply to all new and old sleeping quarters, not just those new quarters constructed within one-half mile of switching or humping. While that specific suggestion is beyond the scope of this rulemaking, FRA agrees that action should be taken to declare what basic standard FRA will employ in administering section 2(a)(3) of the act. Therefore, in a separate document also issued on this date, FRA declares that the standard adopted herein for new or reconstructed facilities shall be employed by FRA as a guideline in administering section 2(a)(3) of the act.

Through the NPRM, comments were solicited on the ability of the industry to meet the Department of Housing and Urban Development (HUD) noise criteria specified in the proposed § 228.107 and on whether upper limits should be set on intermittent noises exceeding the proposed 45 dB(A) standard (41 FR53 072 (1976)). The commenters took issue both with the proposed noise levels and the descriptors used to calculate given levels over time.

The Environmental Protection Agency (EPA), disagreed with FRA's use of the HUD descriptors set forth in HUD Circular 1390.2. EPA's recommendation was that FRA employ an equivalent steady state sound level (L_{eq}) as the descriptor, with an 8-hour criteria level of 45 dB(A). EPA pointed out that the HUD standards were not to designed to accommodate sounds of the character found in railroad operations.

FRA agrees with EPA that the L_{eq} descriptor is more appropriate for the railroad environment. The HUD criteria limit noise levels from exceeding 55 dB(A) for more than 60 minutes in any 24-period (L_4) or 45 dB(A) for more than 30 minutes in any 8 hour period (L_7). However, the HUD criteria make use of only the quietest (93 or 96 percent) of the total exposure. There is no limitation on the maximum single event levels which make up the noisiest seven or four percent of the time. These periods potentially have the greatest influence on sleep disturbance. "L_{eq}", which is a time weighted energy mean descriptor gives proper and significant weighting to high intensity short-lived noises which might not be adequately accounted for in the L_7 or L_4 scheme.

In support of the decision, it may be noted that L_{eq} is now being widely used in the acoustical community. In particular, the Department of Defense has officially adopted the descriptor in its program to control noise at military airfields. The Federal Aviation Administration has accepted L_{eq} as one of the descriptors for evaluation of civilian airport noise impact. The Federal Highway Administration has accepted L_{eq} as an alternative descriptor in its regulation on planning and design of new highway projects.

However, FRA believes that, with the implementation of the L_{eq} descriptor, a 55 dB(A) level is more appropriate than the 45 dB(A) HUD level. Because railroads generally operate on a 24-hour "around the clock" basis, this design goal should be met during an 8 hour period.

A number of commenters believed that the HUD 45 dB(A) level was too stringent and was not necessarily indicative of a poor sleeping environment. Concern was also expressed that the establishment of a 45 dB(A) level would prohibit the use of individual air conditioning and heating units. All of the commenters, with the exception of EPA, agreed by the time of the public hearing that a 55 dB(A) level would be more appropriate to the railroad environment and would provide an adequate measure of the conditions necessary to permit uninterrupted rest. In developing these standards FRA has attempted to strike a balance between that which is most desirable and that which is feasible. The final determinant has been the ability of railroad employees to obtain uninter rupted rest. FRA agrees with those commenters who suggest that 55 dB(A) provides an acceptable measure.

One commenter suggested that an upper limit of 60 dB(A) be specified for intermittent noises which were permitted to exceed the 45 dB(A) standard for less than 30 minutes in an 8 hour day under the NPRM. Unfortunately, at this time, there are serious questions concerning adequacy of current sleep disturbance data that would support the selection of specific single-event maximum. FRA will be closely monitoring the utility of the adopted criteria in evaluating the effect of particular noise events on the sleeping environment near railroad operations. The L_{eq} descriptor will, of course, mitigate the effects of loud single-event intrusions by including all single-event maxima in the energy calculation.

The unanimous opinion of the commenters on the inclusion of background noise from air conditioning and heating systems in noise calculations was that individual units, under the control of the individual employee, should not be considered. FRA concurs that the inclusion of background noise from these units in noise evaluations would be inappropriate. The rule has been changed accordingly.

The subject of noise generated by airports and traffic over highways was also raised in comment. One commenter cited the congressional committee report on the act and its statement that a railroad is responsibile only for the noise its operations are creating. H.R. Rep. No. 1166, 94th Cong., 2d Sess. 11 (1976). FRA agrees that Congress focused on noise created directly by the railroad in fashioning section 2(a)(3), which applies to existing and future sleeping quarters. Certainly a carrier does exercise a degree of control over environmental noise by virtue of its choice of site for lodging facilities. To the extent possible, FRA urges carriers, in their site selection plans, to consider such high noise sources and their effect on uninterrupted sleep for employees. However, given the unanimous view of the commenters on this issue, FRA will not consider noise which is not generated by railroad operations and associated railroad activities in making determinations under these rules. It should be noted that noises generated by railroad repair facilities, carrier public address systems, and central heating and cooling plants are "within the control of the railroad" and, thus, subject to the act.

These amendments are issued under authority of section 2(a)(4) of the Hours of Service Act (45 U.S.C. 62(a)(4)), as amended by section 4, Pub. L. No. 94-348, 90 Stat. 818, and § 1.49(d) of the regulations of the Office of the Secretary of Transportation (49 CFR 1.49(d)).

The principal program draftsman of this document was Stephen Urman of the Office of Safety. The principal legal draftsman was Grady Cothen, Jr., of the Office of Chief Counsel.

In consideration of the foregoing, part 228 is amended as follows:

1. By dividing Part 228 into three subparts and revising the table of contents to read as follows:

Subpart A—General

AUTHORITY: Sec. 2(a)(4) of the Hours of Service Act (45 U.S.C. 62 (a)(4)), as amended by sec. 4, Pub. L. No. 94-348, 90 Stat. 818; § 1.49(d) of the regulations of the Office of the Secretary of Transportation (49 CFR 1.49(d)).

Subpart A—General

2. By inserting "Subpart A—General" as a centerhead immediately above § 228.1 and by revising § 228.1 to read as follows:

§ 228.1 Scope.

This part—

(a) Prescribes reporting and record keeping requirements with respect to the hours of service of certain railroad employees, and

(b) Establishes standards and procedures concerning the construction or reconstruction of employee sleeping quarters.

Subpart B—Records and Reporting

* * * * *

3. By inserting "Subpart B—Records and Reporting" as a centerhead immediately above § 228.7 and by adding the following new subpart:

Subpart C—Construction of Employee Sleeping Quarters

§ 228.101 Distance requirement; definitions.

(a) The Hours of Service Act, as amended (45 U.S.C. 61–64b), makes it unlawful for any common carrier engaged in interstate or foreign commerce by railroad to begin, on or after July 8, 1976, the construction or reconstruction of sleeping quarters for employees who perform duties covered by the act "within or in the immediate vicinity (as determined in accordance with rules prescribed by the Secretary of Transportation) of any area where railroad switching or humping operations are performed." 45 U.S.C. 62(a)(4). This subpart sets forth (1) a general definition of "immediate vicinity" (§ 228.101(b)), (2) procedures under which a carrier may request a determination by the Federal Railroad Administration that a particular proposed site is not within the "immediate vicinity" of railroad switching or humping operations (§§ 228.103 and 228.105), and (3) the basic criteria utilized in evaluating proposed sites (§ 228.107).

(b) Except as determined in accordance with the provisions of this subpart, "The immediate vicinity" shall mean the area within one-half mile (2,640 feet) (804 meters) of switching or humping operations as measured from the nearest rail of the nearest trackage where switching or humping operations are performed to the point on the site where the carrier proposes to construct or reconstruct the exterior wall of the structure, or portion of such wall, which is closest to such operations.

(c) As used in this subpart—

(1) "Construction" shall refer to the—

(i) Creation of a new facility;

(ii) Expansion of an existing facility;

(iii) Placement of a mobile or modular facility; or

(iv) Acquisition and use of an existing building.

(2) "Reconstruction" shall refer to the—

(i) Replacement of an existing facility with a new facility on the same site; or

(ii) Rehabilitation or improvement of an existing facility (normal periodic maintenance excepted) involving the expenditure of an amount representing more than 50 percent of the cost of replacing such facility on the same site at the time the work of rehabilitation or improvement began, the replacement cost to be estimated on the basis of contemporary construction methods and materials.

(3) "Switching or humping operations" includes the classification of placarded railroad cars according to commodity or destination, assembling

of placarded cars for train movements, changing the position of placarded cars for purposes of loading, unloading, or weighing, and the placing of placarded cars for repair. However, the term does not include the moving of rail equipment in connection with work service, the moving of a train or part of a train within yard limits by a road locomotive or placing locomotives or cars in a train or removing them from a train by a road locomotive while en route to the train's destination. The term does include operations within this definition which are conducted by any railroad; it is not limited to the operations of the carrier contemplating construction or reconstruction of railroad employee sleeping quarters.

(4) "Placarded car" shall mean a railroad car required to be placarded by the Department of Transportation hazardous materials regulations (49 CFR 172.504).

(5) The term "L_{eq} (8)" shall mean the equivalent steady state sound level which in 8 hours would contain the same acoustic energy as the time-varying sound level during the same time period.

§ 228.103 Approval procedure: construction within one-half mile (2,640 feet) (804 meters).

(a) A common carrier that has developed plans for the construction or reconstruction of sleeping quarters subject to this subpart and which is considering a site less than one-half mile (2,640 feet) (804 meters) from any area where switching or humping operations are performed, measured from the nearest rail of the nearest trackage utilized on a regular or intermittent basis for switching or humping operations to the point on the site where the carrier proposes to construct or reconstruct the exterior wall of the structure, or portion of such wall, which is closest to such operations, must obtain the approval of the Federal Railroad Administration before commencing construction or reconstruction on that site. Approval may be requested by filing a petition conforming to the requirements of this subpart.

(b) A carrier is deemed to have conducted switching or humping operations on particular trackage within the meaning of this subpart if placarded cars are subjected to the operations described in § 228.101(c)(3) within the 365-day period immediately preceding the date construction or reconstruction is commenced or if such operations are to be permitted on such trackage after such date. If the carrier does not have reliable records concerning the traffic handled on the trackage within the specified period, it shall be presumed that switching of placarded cars is conducted at the location and construction or reconstruction of sleeping quarters within one-half mile shall be subject to the approval procedures of this subpart.

(c) A petition shall be filed in triplicate with the Secretary, Railroad Safety Board, Federal Railroad Administration, Washington, D.C. 20590 and shall contain the following:

(1) A brief description of the type of construction planned, including materials to be employed, means of egress from the quarters, and actual and projected exterior noise levels and projected interior noise levels;

(2) The number of employees expected to utilize the quarters at full capacity;

(3) A brief description of the site, including:

(i) Distance from trackage where switching or humping operations are performed, specifying distances from particular functions such as classification, repair, assembling of trains from large groups of cars, etc. cetera;

(ii) Topography within a general area consisting of the site and all of the rail facilities close to the site;

(iii) Location of other physical improvements situated between the site and areas where railroad operations are conducted;

(4) A blueprint or other drawing showing the relationship of the site to trackage and other planned and existing facilities;

(5) The proposed or estimated date for commencement of construction;

(6) A description of the average number and variety of rail operations in the areas within one-half mile (2,640 feet) (804 meters) of the site (e.g., number of cars classified in 24-hour period; number of train movements);

(7) An estimate of the average daily number of placarded rail cars transporting hazardous materials through the railroad facility (where practicable, based on a 365-day period sample, that period not having ended more than 120 days prior to the date of filing the petition), specifying the—

(i) Number of such cars transporting class A explosives and poison gases; and

(ii) Number of DOT Specification 112A and 114A tank cars transporting flammable gas subject to FRA emergency order No. 5;

(8) A statement certified by a corporate officer of the carrier possessing authority over the subject matter explaining any plans of that carrier for utilization of existing trackage, or for the construction of new trackage, which may impact on the location of switching or humping operations within one-half mile of the proposed site (if there are no plans, the carrier official must so certify); and

(9) Any further information which is necessary for evaluation of the site.

(d) A petition filed under this se[ction must contain a statement th]at the petition has been served on th[e] recognized representatives of the rai[l]road employees who will be utilizin[g] the proposed sleeping quarters, t[o]gether with a list of the employee re[p]resentatives served.

§ 228.105 Additional requirements: co[n]struction within one-third mile (1,76[0] feet) (536 meters) of certain switchin[g]

(a) In addition to providing the i[n]formation specified by § 228.103, a ca[r]rier seeking approval of a site locate[d] within one-third mile (1,760 feet) (53[6] meters) of any area where railroa[d] switching or humping operations a[re] performed involving any cars require[d] to be placarded "EXPLOSIVES A" [or] "POISON GAS" or any DOT Specif[i]cation 112A or 114A tank cars tran[s]porting flammable gas subject to FR[A] emergency order No. 5 shall establis[h] by a supplementary statement cer[ti]fied by a corporate officer possessin[g] authority over the subject matte[r] that—

(1) No feasible alternate site locate[d] at or beyond one-third mile fro[m] switching or humping operations [is] either presently available to the ra[il]road or is obtainable within 3 mile[s] (15,840 feet) (4,827 meters) of the re[]porting point for the employees wh[o] are to be housed in the sleeping qua[r]ters;

(2) Natural or other barriers exist o[r] will be created prior to occupancy o[f] the proposed facility between the pr[o]posed site and any areas in whic[h] switching or humping operations a[re] performed which will be adequate t[o] shield the facility from the direct an[d] severe effects of a hazardous materia[l] accident/incident arising in an area o[f] switching or humping operations;

(3) The topography of the propert[y] is such as most likely to cause any ha[z]ardous materials unintentionally re[]leased during switching or humping t[o] flow away from the proposed site; an[d]

(4) Precautions for ensuring employ[]ee safety from toxic gases or explo[]sions such as employee training an[d] evacuation plans, availability of appro[]priate respiratory protection, an[d] measures for fire protection, hav[e] been considered.

(b) In the absence of reliable record[s] concerning traffic handled on trackag[e] within the one-third mile area, it sha[ll] be presumed that the types of car[s] enumerated in paragraph (a) of th[is] section are switched on that trackag[e] and the additional requirements o[f] this section shall be met by the pet[i]tioning carrier, unless the carrier e[s]tablishes that the switching of th[e] enumerated cars will be effectivel[y] barred from the trackage if the pet[i]tion is approved.

§ 228.107 Action on petition.

(a) Each petition for approval file[d] under § 228.103 is referred to the Rai[l] road Safety Board for action in accordance with the provisions of part 211, Title 49, Code of Federal Regulations, concerning the processing of requests for special approvals.

(b) In considering a petition for approval filed under this subpart, the Railroad Safety Board evaluates the material factors bearing on—

(1) The safety of employees utilizing the proposed facility in the event of a hazardous materials accident/incident and in light of other relevant safety factors; and

(2) Interior noise levels in the facility.

(c) The Railroad Safety Board will not approve an application submitted under this subpart if it appears from the available information that the proposed sleeping quarters will be so situated and constructed as to permit interior noise levels due to noise under the control of the railroad to exceed an $L_{eq}(8)$ value of 55dB(A). If individual air conditioning and heating systems are to be utilized, projections may relate to noise levels with such units turned off.

(d) Approval of a petition filed under this subpart may be withdrawn or modified at any time if it is ascertained, after opportunity for a hearing, that any representation of fact or intent made by a carrier in materials submitted in support of a petition was not accurate or truthful at the time such representation was made.

Issued in Washington, D.C., on July 11, 1978.

JOHN M. SULLIVAN,
Administrator.

[FR Doc. 78-19903 Filed 7-18-78; 8:45 am]

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 201

[FRL 1361-3]

Noise Emission Standards for Transportation Equipment; Interstate Rail Carriers

AGENCY: U.S. Environmental Protection Agency.

ACTION: Final rule.

SUMMARY: On April 17, 1979, the Environmental Protection Agency published in the Federal Register (44 FR 22960) proposed noise emission limits for facilities and equipment of interstate rail carriers.

The purpose of this notice is to establish final noise emission standards for four railyard noise sources. This final rulemaking is promulgated pursuant to Section 17 of the Noise Control Act of 1972, 42 U.S.C. 4916.

We have chosen to regulate only specific major railyard noise sources in this rulemaking. Additional study and assessment necessary to address the complex issues associated with the proposed property line noise standard will be completed by the Agency prior to final promulgation of that standard. The Agency is reopening the formal comment period for the previously proposed property line noise standards in order to facilitate this analysis. (Sections 201.17 and 201.30–201.33)

DATES: The effective date of this rule is January 15, 1984. Comments regarding the previously proposed property line noise standard will be accepted until 4:30 PM, April 4, 1980

ADDRESS: Written comments on the proposed property line standard should be addressed to: Rail Carrier Docket ONAC 80–01, Standards and Regulations Division (ANR–490), U.S. Environmental Protection Agency, Washington, D.C. 20460.

FOR FURTHER INFORMATION CONTACT: Mr. Robert Rose, Standards and Regulations Division (ANR–490), U.S. Environmental Protection Agency, Washington, D.C. 20460, Phone: (202) 557–7666.

SUPPLEMENTARY INFORMATION:

1.0 Background Information

The U.S. Environmenal Protection Agency issued, on December 31, 1975, a noise emission regulation for locomotives and railcars operated by interstate rail carriers (41 FR 2184). In developing that regulation EPA considered broadening the scope of the regulation to include facilities and additional equipment. Because of the wide disparity in perceived severity of noise problems found at differing rail facilities, we decided that railroad facility and equipment noise, other than that produced by locomotives and railcars, was best controlled by measures which did not require national uniformity of treatment. Further, we believed that the health and welfare of the Nation's population being jeopardized by railroad facility and equipment noise, other than locomotive and railcars, was best served by specific controls at the state and local level and not by federal regulations, which would have to address railroad noise on a national, and therefore on a more general, basis. Where the federal government establishes standards for railroad facilities and equipment, state and local noise control ordinances ordinarily are preempted unless they are identical to the federal standards. For this reasons, we decided that is was best to leave state and local authorities free to address site-specific problems on a case-by-case basis, without unnecessary federal hindrance.

The Association of American Railroads (AAR) challenged the regulation on the ground that it did not include sufficiently comprehensive standards for railroad equipment and facilities under Section 17 of the Noise Control Act of 1972. It did not, therefore, provide the rail carriers with adequate federal preemption of potentially conflicting state and local noise ordinances as intended by the Act. The U.S. Court of Appeals for the District of Columbia Circuit ruled that EPA must substantially broaden the scope of its regulation affecting rail carrier facilities and equipment. Association of American Railroads v. Costle, 562 F. 2d 131 (D.C. Cir. 1977). On April 17, 1979, EPA proposed additional rules in response to this court order (44 FR 22960). The proposed standards were developed in terms of typical or average situations. Consequently, the uniform national standards proposed were a compromise, only partially controlling railroad facility and equipment noise throughout the country. The primary factor limiting more effective federal noise control is the very substantial cost incurred when more stringent noise levels are applied on a nationwide basis to all railyards and equipment. Our health and welfare analysis indicated that there would be an appreciable number of people in the nation who would still suffer significant adverse effects of railroad noise even after such a rule was in effect. Further, because of the preemptive nature of the federal regulation, states and localities would find it difficult to provide further relief to their citizens in most of these cases.

The notice of proposed rulemaking (NPRM) was published on April 17, 1979, with a public comment period of 45 days. EPA extended the comment period by an additional 30 days, to July 2, 1979. Our review and analysis of the comments received, especially those regarding the availability of technology, costs associated with the property line standard, and the L_{dn} noise descriptor, have led us to divide our final regulation into two parts, each to be issued separately.

The first part, and the subject of this rulemaking, concerns the immediate promulgation of noise emission limits for four railyard sources. These include two equipment sources, active retarders and locomotive load cell test stands, and one railyard operation, car coupling, as well as switcher locomotive noise, which is covered by amending section 201.11 and 201.12 of the Rail Carrier Noise Emission Regulation (40 CFR Part 201).

The second part, the property line standard, will establish federal regulations limiting other noise emitted from railyard facilities which are not covered by the source standards. This two-phased approach will allow EPA to satisfy the first part of the court order, which requires promulgation of a source standard final rule by January 23, 1980. This two phase approach allows more time to resolve the complex issues raised by the public comments concerning the property line standard.

2.0 Regulation

2.1 Introduction

Specific source standards for locomotive load cell test stands and switcher locomotives were not proposed by the Agency in the notice of proposed rulemaking. Both of these sources were, however, identified as specific sources contributing to the property line noise level of railyards, and specific technologies and attendant costs were identified for controlling these sources in order to obtain the level of noise control necessary to meet the proposed rule. Comments were received relative to the specific technologies and costs estimated by the Agency to bring these sources into compliance with the proposed rule. These comments have been fully considered in developing the recommendation for a final specific source standard for each of these pieces of railroad equipment.

The amended portion of the Rail Carrier Noise Emission Regulation establishes noise standards for stationary and moving switcher locomotives. Switcher locomotives are in compliance with §§ 201.11(c) and 201.12(c) in a particular railyard facility, if the A-weighted sound level from stationary switcher locomotives or any combination of stationary switcher locomotives and other locomotives does not exceed 65 dB at a residential or commercial receiving property. If this level is exceeded, all switcher locomotives in the railyard facility must meet the noise standards specified in §§ 201.11 and 201.12 of this regulation. Similarly, where the A-weighted sound level at the receiving property is 65 dB or less the locomotive load cell test stand is deemed to be in compliance. If the sound level from the locomotive load cell test stand exceeds 65 dB at the receiving property then that locomotive load cell test stand shall not exceed 78 dB measured at 30 meters (100 feet).

The remaining two noise standards apply to the respective source emissions as measured on receiving property. The latter is defined [1] to include only residential or commercial property. The proposed regulation required the railyards to apply noise reduction technologies and techniques to all types of land use classifications except undeveloped land. "Land use" as used in this regulation is not considered to be synonymous with "zoning" and should not be considered to be zoning.

These regulations reflect the degree of noise reduction achievable through the application of best available technology on a national basis taking into account the cost of compliance and the time provided for compliance. For this reason, the maximum allowable sound levels specified for each source standard are not uniform and vary according to the availability and cost of abatement technologies or techniques for the given source. For the purpose of determining the availability of technologies or techniques and costs of applying those technologies or techniques used in developing the final source regulations, the Agency considered the following: the use of local absorptive noise barriers around sources, reflective walls at the facility boundary, exhaust silencers on switcher locomotives, and for car coupling, controlling the operation of rolling stock or its location relative to adjacent receiving property. For example, noise barriers can be constructed in close proximity to the source, or at the railroad facility boundary, or both in combination, as appropriate to the situation. Additionally, barriers used to abate noise at one source would likely reduce the noise not only from that source, but also from other railroad sources, including locomotives and trains. Because these are performance, not design standards, the railroads have total flexibility to apply whatever noise control approaches are most attractive in terms of cost or other considerations, as long as the required noise levels are met.

The noise measurements required by the regulation to determine compliance with the noise levels can be accomplished in most instances by a single individual with the use of a direct reading sound level meter and a wristwatch.

To determine compliance with the retarder and car coupling standards, the measurements are to be made on receiving property. The quantity to be determined for intermittent single-event sounds (retarder and car coupling noises) is the energy-averaged maximum sound level.

For the nearly steady-state sounds, locomotive load cell test stands and switcher locomotives, the quantity to be determined is the level of the specific source sound level observed as separately identifiable from other noise sources.

By amending § 201.11 the Agency is no longer requiring locomotives to be connected to load cells when undergoing stationary tests in the idle throttle setting. This is a technical clarification of the Agency's original intent. The noise from a locomotive in the idle mode can be measured more conveniently and accurately without being connected to a load cell. The Agency further amends § 201.11 (a), (b) and (c) to require "slow" meter instrument response characteristic rather than "fast" for determining compliance with the noise emission standards of § 201.11. Because locomotives operate at steady-state conditions during compliance testing with the stationary locomotive standard in section 201.11, noise measurements made with an instrument on "slow" meter response are essentially equivalent to measurements made on "fast" meter response. An exception to this equivalence is a limited number of apparently highly random peak readings of 1 to 2 dB above the steady-state sound level which occur when using "fast" meter response and do not occur when using "slow" meter response. On further review, the Agency has determined that the random peak noise values are of such a random nature, and are sufficiently infrequent as not to constitute a reason for deterring use of the "slow" meter response characteristic which is procedurally easier to use for compliance testing.

All limits established in this rulemaking are effective January 15, 1984 (approximately 48 months after final promulgation) with the exception of the technical clarification amendments of § 201.11 which are effective upon promulgation of this regulation. Prior to that date state and local ordinances applicable to these railroad equipment and facilities are not federally preempted. The proposed regulation provided for three years (36 months) from final promulgation for the industry to comply with the noise standards. However, legislative amendments in the Congressional process at the time of the drafting of this final rule require that no final regulation issued under this Section be made effective earlier than 4 years (48 months) after publication. The Congressional intent is to provide this additional 12 months' compliance period for Congressional review of the final rule. Thus, the Congress would have the opportunity to act to change the EPA rule during that first 12 months of the four-year period, prior to the industry's having to undertake compliance actions that would involve financial expenditures. The four-year lead time also allows the railroad industry the flexibility of not having to commit financial resources for compliance until after the property line standard is promulgated in January 1981. Although specific sources may be in compliance with the source standards, it may be necessary to apply additional abatement technologies or techniques for compliance with the forthcoming comprehensive property line standard.

If land use changes occur around a railyard after promulgation of this rule, requiring noise abatement application in order to meet the requirements of this regulation, a four-year compliance period is provided from the time of the land use change.

[1] "Receiving property" means any residential or commercial property that receives the sound from railroad facility operations that is used for any of the purposes described in the following standard land use codes (ref. *Standard Land Use Coding Manual*. U.S. DOT/FHWA, reprinted March 1977): for residential land use, 1, Residential; 651, Medical and other Health Services; 68, Educational Services; 691, Religious Activities; and 711, Cultural Activities; for Commercial land use: 53–59, Retail Trade; 61–64, Finance, Insurance, Real Estate, Personal, Business and Repair Services; 652–659, Legal and other professional services; 671, 672 and 673, Governmental Services; 692 and 699, Welfare, Charitable and Other Miscellaneous Services; 712 and 719, Nature exhibitions and other Cultural Activities; 721, 723, and 729, Entertainment, Public, and Other Public Assembly; and 74–79, Recreational, Resort, Park and other Cultural Activities.

2.2 Standards

A. Nearly Steady-State Noise Standards

The noise sources included in these standards are locomotive load cell test stands and switcher locomotives measured at 30 meters (100 feet) from the respective source. However, these standards need be met only if the A-weighted sound level from either of these sources at a specific railyard facility is greater than 65 dB measured at a receiving property location. Thus, the standard requires abatement only where people are benefited.

1. Locomotive Load Cell Test Stands

The Agency has identified locomotive load cell test stands as a major contributor to excessive noise emission from rail facilities. Testing of engines by connecting them to load cell test stands, simulating up to full engine load, is required periodically to assure satisfactory engine performance. During these tests, locomotive engines are run continuously at high throttle settings resulting in noise levels often in excess of 90 dB at 30 meters (100 feet).

The abatement of locomotive load cell test stand noise was described by the Agency as a necessary part of the receiving property line standard in the proposed regulation. EPA believed that the noise from such operations could be dealt with reasonably by relocating locomotive load cell testing away from noise sensitive receiving areas close to the railroad facility boundary, or by enclosure of the test facility from which the noise was emitted. The Agency feels it appropriate to include locomotive load cell test stands in the final rule as a specific source standard because they are important sources of railyard facility noise and abatement technology is available at a reasonable cost for reducing their noise level.

After reviewing comments on the proposed rule, available abatement technologies and techniques, and cost data, the Agency has modified its technology and costing assessment approach to reducing noise from locomotive load cell test operations. EPA cost and benefit studies show that total enclosure of test stands is generally less attractive than the use of 150 foot (length) by 25 foot (height) absorptive barrier walls around the facility and the locomotive being tested. Thus, EPA believes that the standard for locomotive load cell test stands may be met with an absorbing barrier designed to typically give 15 dB noise reduction at 30 meters (100 feet).

The Agency does not intend that railyards apply noise reduction technologies or techniques to control noise emitted from locomotive load cell test stands except where noise reduction is deemed necessary to protect receiving property. Therefore, EPA has instituted a two part compliance procedure. The standard will limit locomotive load cell test stand noise to an A-weighted sound level of 78 dB when measured at 30 meters (100 feet) perpendicular to the centerline of the locomotive load cell track, and centered on the geometric center of the locomotive under test. If the noise level from this source measured at any receiving property measurement location does not exceed 65 dB, then the locomotive load cell test stand is deemed to be in compliance. If the measurement exceeds 65 dB, then that locomotive load cell test stand must meet the prescribed standard, which limits locomotive load cell test stand noise to an A-weighted sound level of 78 dB at 30 meters (100 feet) when measured as prescribed in Subpart C of this part (See Table 2.1).

Certain locomotive load cell test stands may not be able to comply with the measurement conditions specified in § 201.23(a) in that measurement at 30 meters (100 feet) is impossible. In these situations, the A-weighted sound level from the locomotive load cell test stand must not exceed 65 dB when measured at a receiving property measurement location more than 120 meters (400 feet) from the geometric center of the locomotive being tested and in accordance with Subpart C of the regulation.

The 65 dB standard at 120 meters (400 feet) is consistent with the 78 dB standard at 30 meters (100 feet). If the (validated L_{90}) A-weighted sound level at 120 meters (400 feet) exceeds 65 dB at 30 meters (100 feet), the maximum A-weighted sound level would be greater than 78 dB, because of two factors:

(1) There is a minimum change in level of 12 dB between the 30 and 120 meter (100 and 400 feet) locations, due to the inverse-square propagation loss (6 dB per distance doubling) that occurs for all point sources and other air and ground absorption propagation losses, and

(2) There is an additional difference of at least 1 dB between the L_{90} (specified as the noise level to be measured at receiving property locations) and the L_{max} (specified as the noise level to be measured at the 30 meter (100 feet) distance).

Subpart C identifies the measurement procedure for steady state noise levels of a locomotive load cell test stand at receiving property and at 30 meters (100 feet). If ambient noises are not constant, the locomotive load cell test stand steady state level can be determined, but if ambient levels are a constant steady state level above that of the locomotive load cell test stand, then the noise level of that locomotive load cell test stand may not be measurable at the receiving property, but it would be measurable at 30 meters (100 feet) or more than 120 meters (400 feet).

Table 2.1.—*Locomotive Load Cell Test Stand Standard*

Effective date	Standard, L_A
Jan. 15, 1984	78 dB at 30 meters (100 feet).

2. Switcher Locomotive Noise

Switcher locomotive noise is one of the most prominent forms of railyard noise. This locomotive noise is of two types: moving point source noise as the locomotive is involved in switching operations, and stationary point source noise as the locomotive is parked but is allowed to remain idling and not involved in any active operation.

In the proposed regulation switcher locomotives were considered a significant noise source contributing to the noise crossing the property line. Abatement of the noise they produced was included in the Agency's derivation of the overall property line standard as proposed. Because the switcher locomotive is one of the most important sources of railyard facility noise and since there is technology available to reduce its noise level at a reasonable cost the Agency has chosen to address switcher locomotives with a separate source standard and has regulated this source by an amendment to the Rail Carrier Noise Emission Regulation.

An available technology for meeting the switcher locomotive noise emission limits is exhaust silencing of the engine noise. The Agency's original proposal (39 FR 24580) required the retrofit of that part of the entire locomotive (road haul and switcher) fleet used in railyards. The Agency has chosen to include only the switcher locomotives at this time because of arguments by the industry that the retrofit costs for all locomotives used at any time in a railyard would be excessive and that it would be difficult to isolate those road locomotives used in railyard duty.

The Agency does not intend that switcher locomotives, as defined, be retrofitted except in those railyards where noise reduction is deemed necessary. Rather, the compliance procedure the Agency has developed involves taking initial measurements at receiving property locations to determine whether abatement is necessary. If the adjusted average A-weighted sound level of the stationary switcher locomotives or combination of stationary switcher locomotives and other locomotives does not exceed 65 dB, switcher locomotives are deemed to be in compliance with the regulation. If the level exceeds 65 dB, then every switcher locomotive in that railyard must meet the standard. This standard, by amending §§ 201.11 and 201.12, requires that switcher locomotives manufactured prior to December 31, 1979 to emit no more than an A-weighted sound level of 87 dB at any throttle setting except idle, when operated singly connected to a load cell, and no more than an A-weighted sound level of 70 dB at idle when measured at a point 30 meters (100 feet) from the geometric center of the locomotive along a line that is both perpendicular to the centerline of the track and originates at the locomotive geometric center. For switcher locomotives manufactured prior to December 31, 1979, the standard will limit noise emissions of these locomotives to 90 dB when moving at any time or under any condition of grade, load, acceleration or deceleration, measured at 30 meters (100 feet) from the centerline of any section of track which exhibits less than a two degree curve (or a radius of curvature greater than 873 meters) (See Table 2.2). Sections 201.11 and 201.12 promulgated on December 31, 1975 already require all locomotives manufactured after December 31, 1979 to meet these same limits. All measurements must be made as prescribed in Subpart C of this part. EPA studies indicate that no switcher locomotive retrofit at all will be required for many railyards.

Table 2.2.—*Switcher Locomotive Standard*

Effective date	Standard, L_A
	Stationary switcher locomotive
Jan. 15, 1984	87 dB at any throttle setting except idle, at 30 meters (100 feet).
Jan. 15, 1984	70 dB at idle, at 30 meters (100 feet).
	Moving switcher locomotive
Jan. 15, 1984	90 dB at 30 meters (100 feet).

B. Short Duration Noise Source Standards

The noise sources included in these standards are active retarders and car coupling operations. The standards promulgated for these noise sources are adjusted average maximum A-weighted sound levels of 83 dB for retarders and 92 dB for car coupling operations, as measured at any receiving property measurement location.

1. Retarders

The Agency's analysis indicates that retarders are one of the major sources of extremely annoying noise emissions from hump type railyards. After January 15, 1984, the noise from active retarders will be limited to an adjusted average maximum A-weighted sound level of 83 dB, measured as prescribed in Subpart C of this part at any receiving property measurement location (see Table 2.3).

Technology is available at reasonable cost for reducing the noise from retarders. For purposes of identifying available technology which could be applied by rail carriers for abatement of retarder noise, the Agency believes that the application of absorptive noise barriers on both sides of the master retarders where noise adversely affects residential or commercial land use, and reflective barriers at the facility boundary line where it is necessary to reduce retarder noise, will permit compliance with the standard at reasonable costs. For example, a master retarder barrier parallel to the track and extending at least 12 feet above the retarder and 75 feet to each side from the geometric center of the retarder, and containing appropriate absorptive material appears in the majority of instances to permit the standard to be met. A facility boundary barrier placed in the general vicinity of the facility boundary, located for maximum benefit on receiving property, 15 feet high and long enough to prevent line-of-sight between any receiving property measurement location and any retarder, should in most cases provide sufficient abatement to meet the retarder noise standard. An additional option available to the railyard is the use of barriers around the group retarders, either individually or collectively, in various configurations and at various angles to the group retarders, to meet the receiving property standard. The Agency expects about 3 out of 4 humpyards will need to take noise control actions to meet the standard for retarders.

Table 2.3.—*Retarder Noise Standard*

Effective date	Standard, L_A
Jan. 15, 1984	83 dB at receiving property.

2. Car Coupling

The Agency has identified car coupling impacts as a major contributor to noise from rail facilities. This noise is particularly annoying to people, because it is an impulsive noise involving extremely high sound levels occurring at random intervals.

The proposed car coupling standard was 95 dB measured 30 meters (100 feet) from the coupling incident, with an exception provision for those couplings with sound levels greater than 95 dB for which the railroad could show that coupling occurred at speeds of four miles per hour or less. The basis for choosing this level was that the majority of railroads stated to the Agency that four miles per hour was their operating rule or recommended practice. There is substantial evidence, however, that railroads do not, as a matter of course, comply with their own published operating rules or recommended practices. Because we must presume that the railroads would comply with such a coupling speed limit if it were a federal rule, the Agency assessed the potential adverse operational impacts of the proposed rule on the railroads. There is some evidence that train movements could be adversely affected if rail carriers were to comply fully with the proposed rule on a nationwide basis, causing delays in product deliveries. Because of this the Agency has made the final rule less stringent. The rule requires that after January 15, 1984, the adjusted average maximum A-weighted sound level for car coupling operations not exceed 92 dB at any receiving property measurement location when measured according to Subpart C of this part (see Table 2.4). Data available to the Agency, as part of the docket and background studies indicate that this standard can be complied with if car coupling speeds are no greater than eight miles per hour. The Agency believes that the standard can be met at almost all railyards with no change in operations, thus avoiding further technology applications or additional costs.

The final standard clarifies the proposed measurement procedures by providing for measurement on receiving property and allowing an energy average of 30 car impacts during at least a one hour period. The exception provision has been changed so that if it is demonstrated that the standard is exceeded when representative cars are coupled at similar locations at speeds that do not exceed eight miles per hour, car coupling is deemed to be in compliance with the standard. The rail carrier has the burden of demonstrating the applicability of this exception. One method of demonstrating the applicability of this exception is to measure the noise impact from couplings using cars, loads, and locations representative of the coupling operation where the standard was exceeded.

Table 2.4.—*Car Coupling Noise Standard*

Effective date	Standard, L_A
Jan. 15, 1984	92 dB at receiving property.

2.3. Deferment of Property Line Standard

The Agency has decided not to promulgate a receiving railyard property line standard in this rulemaking, but to wait for further assessment of the extensive comments received on this proposed standard. The Court has agreed to this approach, the EPA will issue the property line in accordance with the court order. The regulation will include the control of a wide variety of rail equipment and facilities associated with yard activity that is not specifically covered by the four source standards.

3.0 Public Participation

EPA had originally established a 45 day comment period for this rule. The review period was lengthened by EPA's granting a 30-day comment period extension on May 30, 1979, in response to a written request by the Association of American Railroads (AAR).

Because the review period was relatively short, a special effort was made to put the proposed regulation promptly before the public and encourage the submission of comments. This was accomplished through a massive direct mailing of the proposed regulation and related documents, such as the Act, the court decision, and seven other documents, written specifically to stimulate public participation. Mailings were made to over 1700 selected organizations and individuals, including those in the industry, the Congress, state and local governments, labor, public interest, news media, and many private citizens.

A press release was included in the mailing packages or sent separately, so that most recipients, including the news media, had the information within one day of the appearance of the proposed regulation in the **Federal Register**. In Addition to the direct mailing, a number of briefings were conducted immediately before and after publication in the **Federal Register**.

4.0 Docket Analysis

The Agency received 159 written comments which were placed in our official docket. A brief summary of these comments appears below. A more detailed summary of the comments and of the Agency's response appears in the Background Document to this regulation.

4.1 Summary

Of the 159 official docket entries, the respondent source mix was as follows: 30% private citizens, 22% city/county governments, 20% state agencies, 13% industry, 10% federal governments and agencies, 5% associations.

Numerous respondents addressed conceptual issues in their submissions. Strong concerns with the property line standard and the L_{dn} descriptor were voiced by some commenters in all categories. State and local entities argued that the proposed property line standard was too lenient to benefit their citizens, too complex and costly to be enforced adequately, as well as lacking non-degradation provisions and thereby allowing increased noise in currently relatively quiet railyards. Industry comments urged that the proposed standards were unreasonably stringent, considering the cost of compliance and effectiveness of abatement technologies and techniques. Additionally, they criticized both the use of L_{dn} as the appropriate descriptor and EPA's estimate of the health and welfare benefits. Arguments were made for a more precise delineation of receiving land use classes, as well as for elimination of the property line concept in favor of source standards alone.

Questions on the technical aspects of the regulation were also raised by many respondents. Specific questions dealt with the adequacy, effectiveness, and cost of the yard noise level standard and the individual source standards. Faulty, inappropriate, and inaccurate measurement procedures were alleged.

Doubt was expressed concerning the effectiveness of various abatement technologies suggested as available for complying with the regulation. Most industry sources claimed that EPA had overestimated the degree of quieting that was achievable with the techniques described.

Many respondents addressed the costs associated with the regulatory package. State and local commenters were particularly concerned with the costs required for state or local enforcement of standards, including manpower, equipment, training, and technical consultant costs. The railroad industry asserted that EPA either omitted or underestimated the costs associated with equipment, yard, and system-wide operational changes. They highlighted the possible additional costs to them if new technology or more stringent yard or noise source levels were required.

Comments not falling into these three major categories addressed a variety of topics, including the need for a federal enforcement program in the regulation, opposition to preemption of state and local regulation, the lack of land use planning provisions in the regulation, the exclusion of regulations on warning devices, the need for an extended comment period and more public participation, and health and welfare concerns.

Taking into account the wide range of views, concerns and interests of the commenters and their submissions, EPA believes that this final rule is responsive. Since commenters were especially critical of the property line portion of the rule, the Agency has separated the rulemaking into two parts, promulgating source standards as part one, and allowing more time to address the property line standard as part two. Additionally, EPA has responded to the commenters by requiring noise abatement only when necessary to protect receiving property; by simplifying the measurement procedure; and by adjusting compliance requirements through a reevaluation of costs and technology estimates and assumptions.

4.2 Analysis

A. Retarder Noise Standard

EPA originally proposed a retarder noise standard that would have required retarder noise to be abated to an A-weighted sound level of 90 dB at a distance of 30 meters (100 feet) from the centerline of the retarder track. The proposed standard would have required compliance for all active retarders.

Commenters outside of the railroad industry agreed with EPA, that retarder noise must be abated, particularly where receiving property abuts railyards. However, many of this group were concerned that to determine compliance with the standard at 30 meters (100 feet) from the source, measurements must be made within the railyard property in many instances.

The majority of substantive public comments on the retarder noise standard were submitted by the railroad industry. Railroad industry respondents questioned the effectiveness of noise barriers as a noise abatement technique. Assuming the use of barriers for abatement, however, they argued that EPA cost estimates were extremely low because the Agency had underestimated material and labor costs and excluded down time costs in the calculations. They stated that adoption of this standard would require that barriers be unnecessarily constructed around every retarder, which would create exorbitant implementation costs.

Rail industry respondents further claimed that barriers could not be constructed around approximately 50% of the group retarders as a result of close trackage and other geographic factors. Also, they expressed concern as to safety and maintenance problems associated with barriers surrounding group retarders.

Some respondents observed that not all retarders are parallel to the railyard property line, but may actually point at an angle to receiving property in such a way as to render barriers parallel to the retarders of limited effectiveness.

Although the final regulation takes these situations into consideration, it does not deviate greatly from the proposed regulation. However, EPA has changed the measurement methodology, which is now applicable only at receiving property measurement locations. Where there is no adversely affected receiving property, no noise abatement by rail carriers is required. The rail carriers now have the option of placing barriers, if that is the selected abatement approach, at greater distances from the retarders than originally contemplated. This change minimizes the cost to the industry while maximizing the benefit to receiving property adversely affected by retarder noise. The new receiving property approach to measurement location may necessitate the use of barriers which are longer or higher or at an angle other than parallel to the retarder in some situations, or located at the facility boundary rather than at the retarder to achieve the specified noise level limits, but this approach avoids the problems of close trackage and other geographic factors which were the most serious problems with the proposed standard. In addition, because EPA has changed the measurement procedures, the total number of barriers needed for abatement is greatly reduced, since the railroad need only install barriers where they are most effective and are necessary to protect receiving property.

EPA believes that the application of absorptive barriers around master retarders, and reflective barrier walls at the railroad facility boundary where necessary to protect receiving property, constitutes technologies or techniques available to comply with the noise levels set by this regulation. The costs of this abatement approach are comparable to the costs set forth in the proposed regulation and are considered by the Agency to be acceptable.

B. Car Coupling Standard

EPA originally proposed a car coupling regulation based on a four mile per hour limit and the noise emission level associated with that speed. This was consistent with what was believed to be the industry's practice as reflected in operating rules and guidelines of individual companies and in the guidelines of the Association of American Railroads (AAR).

The AAR and several individual railroad carriers voiced strong objections to this standard. They observed that the technology has not been developed to achieve the four mile per hour car coupling speed and that many car couplings actually occur at much higher speeds than four miles per hour. They argued that car coupling speed is directly related to the judgment of the brakemen and certain external forces, e.g., weather conditions, conditions of retarders, weight of car, type of car, contents of car.

Several industry respondents expressed concern over the possible safety implication of coupling at lower speeds. Operational considerations were a major topic for comment. For the proposed rule EPA had assumed that railroads adhered to their published and stipulated operating rules or that, at least, most rail carriers attempted to comply with industry recommended practice. However, the railroad industry stated that in practice the companies often cannot adhere to these rules. They contend, with supporting data, that in actuality many couplings occur at much higher speeds than four miles per hour. Some argued that if they were forced to slow down to four miles per hour, the flow of rail traffic would be impeded. Major operational changes would be needed to accommodate this changed flow rate. The AAR claimed that this would result in estimated costs of $10 billion while bringing railroad traffic to a near standstill.

Other comments indicated that in order to minimize freight damage, coupling speeds no higher than eight miles per hour are desirable.

State and local governments and numerous other commenters found the enforcement aspect of the proposed coupling standard apparently too difficult to implement using a speed measure. They raised the question of how satisfactory compliance determinations can be made in active railyards during operations, particularly as the measurements made include coupling speed as well as the coupling noise generated. Several commenters were critical of the number of measurements required to determine compliance. As a result, the Agency has refined the measurement methodology to allow the measurement to take place at a receiving property location rather than 30 meters (100 feet) from the point of coupling. Further, at least 30 consecutive car coupling impact sounds are required for a period of not less than 60 minutes nor more than 240 minutes.

EPA has completed a further review of the actual car coupling practices of the industry, notwithstanding the railroads' own written operating rules and guidelines. As indicated by industry commenters, a large percentage of the time cars are actually coupled at speeds greater than 4 miles per hour, although most cars appear to be coupled at less than 8 miles per hour. Since elements of the industry assert that a four mile per hour speed limit requirement would seriously hamper railyard traffic flow, the speed parameter method of determining compliance has been amended. After careful review and evaluation, EPA feels it must establish a noise standard for this source on what is close to a lowest common denominator basis. Consequently, the Agency has substituted an equivalent noise level standard for cars coupling at eight miles per hour which appears more representative of industry operational practice than its published statements. This standard will not affect the coupling operations of all yards, but will control the case of excessive coupling speed which is unduly disturbing to the residents adjacent to these yards. A significantly lower decibel level (and consequently lower coupling speed) could be possible at many yards without any significant disruption of operations. However, in writing a national rule, the Agency found it had to write a rule which could be met by almost all yards to avoid exceedingly high compliance costs.

There remains considerable conflicting information regarding railroad car coupling speeds. Most major railroads have indicated in writing that their policy is to couple rail cars at 4 miles per hour or less (see Background Document, Appendix H). Other information including a large quantity of data on actual car coupling speeds during routine railyard operation indicated that in practice rail cars are coupled at speeds over 4 miles per hour a large portion of the time. This area of potential car coupling noise control will continue to be investigated.

EPA recognizes that the noise level generated at 8 miles per hour is high. However, based on the car coupling speed data available to the Agency at this time a standard reflecting lesser speeds could result in some operational slowdowns which might result in national railroad system shutdowns and high cost impact. The Agency encourages further industry attempts to reduce car coupling speed. In selective cases where communities are adversely affected by car impact noise it would appear that the railroad concerned might well voluntarily reduce coupling speed without any disruptive effect on its operations or on those of the rail system.

C. Refrigerator Car Standard

EPA proposed a refrigerator rail car standard of 78 A-weighted decibels measured at 7 meters (23 feet) perpendicular to the centerline of the car. Abatement techniques the Agency identified as being available were muffler improvement, noise insulation, and fan modifications. The railroad industry was expected to incur minimal costs in applying these noise abatement technologies.

The major criticisms and issues raised in comments on the proposed refrigerator car standard were: (a) The baseline noise levels used in developing the proposed standard appear to be unrealistically low. (b) The present noise levels for refrigerator cars already represent the application of best available technology. (c) The technology used for quieting truck-mounted refrigerator car noise is unproven and inappropriate for railroad refrigerator cars. Proposed technological modifications for noise abatement purposes would not be effective in reducing refrigerator car noise to the proposed levels. Improvements which could properly abate refrigerator car noise would require more extensive system redesign or equipment modification at large costs to the industry. (d) EPA erred, both when estimating the simplicity and when estimating the moderate cost of meeting the standard. (e) The trend in transport of perishable goods has shifted away from mechanical refrigeration rail cars and these cars are now rarely manufactured.

Numerous respondents suggested solutions to the noise problems created by parked refrigerator cars, among which were the use of disconnects from the diesel generator system and a reconnect to an electrical AC line source, and relocating these cars away from boundary lines adjoining residential and commercial areas when their refrigeration equipment is in operation.

EPA had decided not to promulgate a source standard for refrigerator cars at this time, in part to allow time to evaluate the effect of their declining use. Their function is being replaced by containers on flat cars (COFC) and truck-mounted (trailer) refrigerator units on flat cars (TOFC), which were not addressed by EPA in the proposed rules. Further, the Agency was not able to evaluate fully at this time the potential for more significant noise reduction through technology applications. The Agency expects to respond to these comments in its promulgation scheduled for January 1981.

D. Locomotive Load Cell Test Stand Standard

The proposed regulation included locomotive load cell test stand noise abatement as a part of the property line standard. Available abatement technology for these facilities constituted relocation of locomotive load cell test stands away from receiving property lines, or total enclosure of these facilities.

The railroad industry commented that the load cells for conducting tests are generally located near repair facilities, and that relocation of the load cell test sites would be impractical as an alternative abatement technique. It was claimed that load cell relocations would result in substantial costs, losses in productivity, and a decrease in efficiency due to increased requirements for both manpower and locomotive movements to and from the repair facilities.

After reviewing available abatement technology, techniques, and cost data, EPA has modified its assessment and now believes that the application of absorptive barrier walls will serve as well as, or better than, the relocation or total enclosure approaches. For costing purposes EPA has assumed the use of 150 foot (length) by 25 foot (height) absorptive barrier walls around the test facilities and locomotives being tested, which EPA technology analysis showed were more attractive than total enclosure of test stands.

E. Switcher Locomotives

In the proposed rulemaking, EPA did not propose a specific source standard for switcher locomotives. Rather, switchers were identified as a noise source likely to require noise abatement in order that the industry meet the proposed L_{dn} receiving property line standard that limited noise from all railroad noise sources collectively.

The railroad industry took strong exception to EPA's recommended procedures for engine shutdown when not in use, parked locomotive relocation, and muffler installation for reducing noise from switch engines and idling locomotives.

The industry asserted that to reduce noise by measures such as engine shutdown or locomotive relocation is impractical and infeasible. Shutdown was claimed to bring about a high risk of damage from hydraulic lock on engine start up, while relocation was seen as feasible only in special limited circumstances. It was also claimed that muffler technology alone could not reduce the noise from switch engines an average of 3 dB at idle and 4 dB at higher throttle ratings, as EPA had estimated.

EPA considered these comments in arriving at this final regulation and believes that switcher locomotive noise emission levels should be addressed specifically. Further, the Agency believes that technology is available to control switcher locomotive noise emissions at an acceptable cost.

Switcher locomotives are deemed to be in compliance with the standard if the sound level from stationary switcher locomotives or combinations of stationary switcher and other locomotives does not exceed an A-weighted sound level of 65 dB at a receiving property. If the noise level from locomotives measured at a receiving property location(s) exceeds this level, all switcher locomotives must meet the specified noise standard, which requires switchers not to exceed specific noise levels measured at 30 meters (100 feet) under various operating modes.

Additionally, the Agency has eliminated the requirement that locomotives be connected to a load cell when undergoing a stationary test for the idle throttle setting.

F. Measurement Methodology

The proposed regulations specified noise levels at the perimeter of the railyard to be monitored by Type 1 instrumentation. The procedure would require that all noise not associated with the railyard, such as passing rail traffic, be excluded. Respondents argued that Type 2 meters should be adequate and that the requirement to factor out "extraneous" noise would require either modeling or a noise expert, or perhaps both. The proposed regulations did not include estimates of funds for state and local equipment/personnel acquisition. Hence, some respondents concluded that the requirement in the regulation for Type 1 sound meter use would impose undue costs on the enforcing body.

EPA's analysis has shown that railyard sounds are substantially different from those associated with highways or airports. Acoustically, the latter facilities have relatively homogeneous noise sources. Quantification of sound emitted by railyards is much more difficult than quantification of highway or airport noise because railyards have many different types of noise sources, some possessing impulsive and high frequency characteristics.

Examination of Type 1 (precision) and Type 2 (general purpose) sound level meters as specified in the American National Standards Institute's standard for sound level meters, ANSI S 1.4–1971, has convinced the Agency that either the Type 1 or Type 2 sound level meter is appropriate as a measurement tool for railyard standards, if appropriate adjustments are made for use of Type 2 instrumentation. In many cases the effectiveness of enforcement efforts may be enhanced by the use of the more precise Type 1 equipment. The adjustments for use of Type 2 instrumentation for each of the source standards are shown in Table 4.1.

With respect to the standard for retarders, Type 1 sound level meters are especially appropriate, since a very large (4 dB) adjustment is necessary if Type 2 meters are used.

Table 4.1.—*Adjustments to Levels for Type 2 Sound Level Meter Usage*

Measurement section in regulation	Source	Decibels [1]
201 24	Locomotives	0
	Rail car	0
	Locomotive load cell test stand	0
201 26	Retarder	4
	Car coupling	2
201 27	Locomotive load	0
	Cell test stand stationary locomotive	0

[1] Amount of correction to be subtracted from measured level (dB).

This rule establishes specific source standards but avoids the technical problems of selectively excluding some noise sources such as through trains from the measurement.

G. *Health and Welfare*

Health and welfare aspects of the proposed regulation also received attention by public commenters. It was suggested that the proposed standards were not sufficiently stringent to provide adequate protection to people exposed to noise from railroad operations.

The proposed federal emission standards were higher (allow a greater level of noise from operations) than some state and local regulations now in effect. Respondents were concerned that the federal standards would (1) preempt the state and local standards and lead to degradation of state and local regulations currently in force, and (2) allow rail operations to be established in areas of presently little or no activity and to emit noise up to the levels allowed by the proposed federal regulations.

The industry questioned the health and welfare impacts of the proposed regulation. They suggested that EPA's railyard noise impact model may considerably overestimate the Equivalent Noise Impact (ENI, which is a method to account for the extent and severity of noise impact) due to the use of an "average" population density around the yards which does not account for the lower densities the AAR would expect near the yard boundaries (i.e., in industrial and commercial areas) in the higher noise regions. EPA anticipated this potential problem in the proposed regulation and conducted analyses using available data during the model development to estimate the possible error. EPA counted the population around the 120 sample railyards on which the model is partly based. The population data obtained in many cases indicated very high local average population densities around large railyards where residential land uses were mixed with industrial and commercial land uses. If the model "squeezed" the people back into the residential land uses rather than averaging, this would have the effect of reducing the area of impact with the given population, resulting in a higher population density and thus no net change in ENI. Furthermore, an analysis of ENI for actual population density distributions around seven hump yards (using data from the 1975 Background Document), as compared to the ENI results using an average density, indicated that on the average if EPA did overestimate, it was on the order of less than five percent. At the same time, EPA's use of ENI substantially underestimates noise impact because it addresses only residential exposures rather than exposure of people in all land use environments, particularly in sensitive land uses, such as hospitals, schools, and churches.

The railroad industry was also concerned that the railyard noise impact model was technically incorrect in the method of aggregating ENI. However, under the assumptions of the analyses, EPA believes the model is technically correct. The key assumptions are that certain stationary sources are grouped in a relatively small area, that moving sources are on the same line, and that the source groups are sufficiently separated so that the $L_{dn}=55$ contours from any group do not overlap the next nearest group. There are insufficient data on railyard operations and noise source locations or interactions to compute connected L_{dn} contours around the typical railyards.

Anticipating that there could be complex noise overlap patterns from various noise sources in railyards, EPA conducted two types of analyses to determine the potential error. Analytical models were used to calculate the variation in ENI as two separate point sources and two separate line sources were merged in various degrees of overlap, from two completely separated sources to a combined source of twice the noise energy of a single source. The results indicated that the ENI for two superimposed sources of equal strength was equal to the sum of the ENI from two completely separated sources. However, at intermediate degrees of overlap of two sources, the average difference between ENI for the separated sources vs. overlapped noise patterns was about 15 percent. Also, the railyard noise impact model was programmed to compare the results using the regular source groups (4 to 5 source groups at each type of yard) to the results of completely separating all types of sources (4 to 11 sources). The case of completely separated sources resulted in an 18 percent increase in total ENI compared to the 4 to 5 source group case. These analyses provide a reasonably good bound on the "error," which is less than 18 percent, since the length of the railyards precludes any significant overlapping of noise patterns from more than any two source groups. Once again, the result is an underestimate of impact.

H. *Costs and Economics*

Although the Agency has provided in Table 5.2 some cost comparative information, we feel that a meaningful cost comparison is not feasible. First, each of the rules is different as to its scope; i.e., the proposed rule encompassed a property line standard and three source standards (active retarders, refrigerator cars and car coupling) and the final rule four source standards (active retarders, car coupling, load cell test stands and switcher locomotives), the latter two being primary noise sources in the proposed property line standard. Second, the technologies and alternatives available to achieve abatement to meet the final standards are different. Third, the Agency feels that the cost estimates provided by the industry in response to the proposal significantly inflated the costs or portrayed a worst case situation.

A number of commenters took issue with the EPA's assessment of the costs of compliance and economic impacts associated with the proposed property line and individual source standards.

The railroad industry in general took exception to EPA's estimates of the capital, operating, and maintenance costs, and the potential costs associated with various operational changes or opportunity costs which might occur. These latter costs would be due to installation of noise control devices, the rescheduling and rearrangement of railroad operations, or the potential redesign of the yards in order to meet the proposed rules. The curtailment of nighttime operations, the reduction of car coupling speeds, the need for shutdown of idling locomotives, and the potential track clearance problems associated with the installation of barriers around active retarders were heavily criticized. Another major assertion was that an additional 450 road locomotives would have to be purchased to replace a portion of the existing road fleet which would have to be retrofitted and dedicated to yard service in order to meet the proposed rules. Industry estimates of compliance costs were approximately ten times greater than those estimated by the EPA for the total capital costs of the regulation. Annualized costs similarly were estimated by the railroad industry to be 7.5 times greater than the EPA estimates.

Because of the time constraints the Agency is not in a position to resolve fully all cost discrepancies. For example, estimates received from industry and state and local agencies relative to the costs of absorptive barriers required to meet the retarder standard ranged from $50 to more than $200 per linear foot for materials and installation, while the original EPA estimate was $75 per linear foot. Additional review has indicated to the Agency that barrier costs of $100 to $162 per linear foot, depending on height, for materials and installation represent the best "average" cost to use for regulatory purposes.

Since the proposed rule required all master, group, intermediate, and tangent point retarders to comply with the standard, barriers were to be required around each such retarder.

As a result of the potential operational costs associated with a source standard requiring barriers around all active retarders, EPA has decided to base its active retarder standard on a receiving properly not-to-exceed limit, to allow the industry the flexibility to choose its abatement procedures to mitigate or eliminate the various potential operational opportunity costs involved. It is anticipated that the industry will be able to comply with the receiving property retarder standard by using combinations of absorptive barriers around most master retarders, some group retarders (if located very near the railroad property line), and reflective walls at railyard boundaries adjacent to receiving property. This approach could eliminate the need for placing absorptive barriers around each active retarder.

Additionally, bankrupt firms or financially distressed firms were concerned that they would be unable to raise the required capital to purchase and install the requisite noise abatement equipment. Concerns were also expressed that the industry would not be able to pass through the noise abatement costs via rate increases because of trucking and waterborne competition, ICC rate regulations, and associated federal inflationary guidelines. Another concern of the weak and bankrupt firms was that because of their low profit margins, they could not take advantage of investment tax credits to offset the noise abatement expenditures.

State and local agencies were concerned that the complexity of the measurement techniques involved in determining compliance would impose costs in excess of those estimated by the EPA. These costs involved the need for purchase of new noise measurement equipment and costs associated with extensive training of existing personnel and the hiring of engineers and technicians. Some state and local agencies provided capital and operating cost estimates for source abatement techniques that were substantially lower than those of the railroad industry and also somewhat lower than EPA's estimates.

Several federal agencies commented on the costs and economic impacts associated with the proposed rules. Concerns were expressed that the proposed rules were not cost-effective because the costs of compliance for industrial uses were not justified by the potential benefits involved. An additional concern was that the incremental benefits achieved by lowering the property line standard for hump yards to an L_{dn} value of 65 dB were not justified by the extra costs involved. On the other hand, several commenters argued that imposing a nationally uniform property line and individual source standards should be limited to worst case situations to avoid excessive cost. EPA recognizes that regulations adequate to protect public health and welfare would require more stringent property line and source levels which would of necessity be more costly.

5.0 Impact of the Regulation

5.1 Health and Welfare Impact

The impact of the final source standards on the health and welfare of the nation's population can be examined by first measuring the exposure levels and total number of persons subjected to railyard noise that may jeopardize their health and welfare, prior to the institution of source standards, and second, the reduction in the extent and severity of harmful railyard noise after the source standards become effective.

The Agency has identified an outdoor L_{dn} value of 55 dB as the noise level protective of public health and welfare with an adequate margin of safety. It is estimated by EPA that between 6.5 and 10.0 million people in the United States are currently exposed to day-night average sound levels in excess of 55 dB resulting from railyards.[3] Compliance with the final source standards will result in approximately a 10–15% reduction in impact, considering both extent and severity.

The total number of persons affected by railyard noise is a function of the penetration of noise into the community and the number of people in proximity to railyard property. The Agency has chosen to consider only residential and commercial property in formulating the final source standards. Given the extensive intermingling of land uses surrounding railyards as demonstrated by aerial photography, EPA believes that a regulation based on noise emissions received on residential and commercial property should provide significant protection for other land uses.

5.2 Cost Impact

The estimated cost of this final source standard regulation was developed using the following sequential procedure:

1. Determination of the noise sources located in railroads which need to be abated.

2. Identification of the various noise abatement techniques and technologies that can be applied to each noise source.

3. Estimation of noise abatement resulting from each abatement technique or technology, based on available data.

4. Calculation of the cost of each abatement technique or technology.

[3] This figure is based on an assumption of a background ambient noise level of L_{dn} = 55 dB. The ambient noise is assumed to add to railyard noise levels, but the railyard noise is still dominant.

5. Calculation of the total cost of the abatement technique or technology selected.

6. Comparison of costs and noise reduction benefits of the abatement technique or technology selected. Computations are made from individual unit costs to establish total capital cost, operation and maintenance cost, and uniform annualized cost.

Table 5.1 presents the estimated cost by noise source for compliance with this regulation.

Table 5.1.—*Cost Estimates for Noise Abatement of Railyard Source Standards*

Noise sources	Control techniques/technologies	Unit cost range	In thousands of dollars: Capital costs	O&M costs	Uniformed annualized costs
Active retarders	Barrier sets	$100–$162/ft	40.1	0.9	3.5
Switcher locomotives	Exhaust Silencers	$7,275–$12,500.	54.6	6.4	17.2
Locomotive load cell test stands	Barrier sets	$325/ft	14.0	1.1	2.4
Car coupling	Speed control	NA	NA	NA	NA
Measurement	Instrumentation	$10,000	1.0	1.4	1.2
Totals			109.7	9.8	24.3

NA = Cost on a national basis has been determined to be minimal relative to other noise source and abatement costs of this rulemaking.

After making the necessary adjustment for the effective date of this final regulation, the total capital investment by the railroad industry for compliance with the rulemaking is estimated to be approximately $110 million. The total industry-wide uniform annualized cost of compliance is estimated to be approximately $24 million. Cost estimates for installing active retarder barriers and for retrofitting of switcher locomotive exhaust silencers incorporate sufficient downtime cost to accomplish the modifications required, which is part of the total compliance cost of the particular standard. The car coupling standard is associated with a speed in excess of that cited as the standard operating practice within the railroad industry.

To assess further the estimated cost of the four source specific regulations compared with the proposed rule, the Agency carefully reviewed the cost impact comments received in the docket. Table 5.2 illustrates comparisons of costs examined in determining the final rule.

Table 5.2.—*Estimated Costs of Implementing Regulation*

[Annualized costs $ × 10^6] [1]

	EPA estimates of proposed regulation	Industry estimates of proposed regulation	EPA estimates of final regulation
Active retarders [2]	$3.0	$38.0	$6.0
Car coupling [3]	[6]	10,000.0	[7]
Switcher locomotives [4]	3.6	144.3	23.9
Locomotive load [5] cell test stands	4.0	20.1	3.3

[1] Annualized costs include capital investment, operating and maintenance costs, and costs of operational changes.

[2] EPA's proposed regulation assumed installation of barriers on both sides of each master and group retarder (all active retarders). EPA assumed no costs for operational changes due to problems of installation of retarder barriers. AAR asserts that clearance problems exist at approximately one-half of the retarder locations requiring (a) track and retarder relocation, (b) rewiring of retarders and switchers, (c) extra downtime, and (d) purchase of additional real estate to maintain existing car capacity. The final regulation assumes installation of absorptive noise control barriers on both sides of all master retarders which affect residential or commercial land use, and reflective barriers at the facility boundary line where necessary to reduce noise from group and tangential retarders.

[3] EPA's proposed car coupling standard was estimated by the Agency to be a no cost rule, given that the 4 mph limit was believed to be consistent with industry-published policy on car coupling speed. Industry representatives, however, claimed that imposition of a 4 mph speed limit would impede the flow of rail traffic, necessitating major operational changes. The Agency's final regulation is reflective of an 8 mph speed limit. The cost on a national basis is expected to be minimal relative to other noise source and abatement aspects of this rulemaking.

[4] The proposed regulation assumed a mix of retrofit of the entire road haul and switcher locomotive fleet used in railyard duty, and incremental cost of installation on new switcher locomotives. EPA neither assumed out of service costs of retrofit switcher engines nor assigned operational change costs involving the extra quieung of road locomotives and the purchase of new road locomotives. The industry cost estimates assumed the GM/EMD retrofit cost figures as the basis for their estimates (See Background Document). For costing purposes in the final rule EPA assumed switcher locomotives must be retrofitted only in those railyards near residential or commercial land uses.

[5] EPA's proposed regulation assumed construction of a simple enclosure performing no function other than noise reduction. Industry costs are based upon a more elaborate facility with heating, cooling, lighting, and ventilation adequate to allow the facility to be used for other purposes. The final regulation estimates are based on construction of 150'×25' absorptive barrier walls around the facility and the locomotive being tested.

[6] No cost.

[7] Minimal cost.

5.3 Economic Impact

An analysis of the economic impact of the noise regulations is included as part of the Background Document. It was based on the railroad industry's current financial and operating structure and its recent competitive history. Potentially important intermodal competition was not considered because the regulation of noise emission from other modes of transportation should offset the impact of these regulations on the railroad industry; i.e., while the noise regulations will increase railroads' costs, similar regulations now affect new medium and heavy duty trucks, so that a significant shift among competing modes is probably unlikely as a result of this regulation. In addition, the greater energy efficiency of rail transport may lead to increased demand for rail freight transportation services, further mitigating any adverse costs of the noise regulations.

The total capital expenditure (Initial capital costs plus out-of-service costs) required to comply with this regulation for residential and commercial receiving property is estimated to be $109.7 million. In 1978, Class I and Class II railroads invested $2,776 million in capital expenditures. Thus, the projected investment in the noise abatement technologies and techniques amounts to 4.0 percent of the industry's total capital expenditure in 1978. If the regulation were to be fully enforced and complied with only at residential receiving property lines, capital expenditures of only $90.7 million would be required, or 3.3 percent of total 1978 capital expenditures. These represent fairly large outlays relative to normal capital expenditures.

Several factors suggest that the magnitude of these capital expenditures relative to normal capital expenditures could increase some firms' difficulties in securing the necessary financing. Large capital expenditures are needed simply to maintain existing roads and to replace aging rolling stock. The firms' first priority is in maintaining these revenue producing components of their capital stock. As a result of inadequate cash flow and low rates of return relative to other industries, some railroads may find it difficult to finance capital expenditures for noise abatement technologies, as well as for other non-federally required actions, either internally or from external capital markets. However, it does not appear that these difficulties will preclude any firm from complying.

The general procedure for estimating impacts was first to calculate a weighted average demand price elasticity for each Class I railroad's range of commodities hauled. Next, a weighted total cost of compliance was calculated for each railroad based on the average cost of compliance per yard, with costs allocated by railroad according to the number of yards requiring investment in quieting technologies or techniques operated by each railroad. The short-run impact on each railroad was computed assuming no price increase; thus, increased costs were translated directly into reduced operating profits. Long-run impacts were computed assuming that the ICC would allow 100 percent of the costs to be passed on to customers in the form of rate increases. Existing literature suggests that average costs are relatively constant for railroads within the Class I category, so the average price increase was assumed to be equal to the average unit cost increase. Using this assumption, the percentage decrease in revenue ton-miles for each railroad in the long run was simply the percentage change in price multiplied by the weighted average price elasticity of demand.

The regulation is expected to have very little impact on the demand for rail freight transportation services. The weighted average demand price elasticity ranges between −.348 and −1.037. Based on annualized average capital and operating and maintenance costs, the cost per revenue ton-mile could increase approximately 0.1. This translates into a decrease in revenue ton-miles of between 0.04 percent and 0.15 percent. Based on a total of 858.1 billion ton-miles in 1978, ton-miles may decrease between 391 million and 1,279 million ton-miles. If other conditions, primarily fuel shortages or costs continue to worsen, even these small decreases will be compensated for as additional truck freight is diverted to the more fuel efficient rails.

Employment impacts were calculated assuming that labor-output ratios were constant for small changes in output. Thus, the percentage change in employment was simply the percentage change in output (measured in revenue ton miles) multiplied by the labor-output ratio. The net reduction in railroad employment ranges between 236 and 777 jobs, and total U.S. railroad employment in 1978 was 471,516 people. Again, this figure was for the long-run impact; due to the small changes in employment predicted and the long-run adjustment framework, it is likely that employment reductions could be accomplished through normal attrition and that no disproportionately adverse impacts will be borne by railroad employees.

The question as to what the impact will be on individual railroads is also a particularly important one. The impact of the noise abatement regulations on the railroad industry as a whole appears to be very small, but some railroads will be more adversely affected than others. Conrail is of particular interest because of the large governmental subsidies it already receives. EPA's analysis suggests that Conrail's costs will rise by about 0.2 percent of total capital plus operating costs. The number of revenue ton-miles shipped by Conrail could fall between 0.6 and 0.2 percent if the full increase in costs is passed through as a price increase. After Conrail the railroad with the next largest deficit relative to operating revenues (excluding the Long Island since they primarily provide commuter service) which will be affected by the regulations is the Chicago, Milwaukee, St. Paul and Pacific. It is a smaller railroad, ranking 15th in terms of revenue ton-miles of the 49 Class I and Class II railroads studied. Its total costs could increase by 0.2 percent but its traffic could decrease by 0.09 to 0.28 percent.

Two of the railroads with the largest potential increase in costs relative to total capital plus operating costs are the Pittsburgh and Lake Erie, and Richmond, Fredericksburg and Potomac. For both, their costs could increase by as much as 1.0 percent (or as little as 0.4 or 0.3 percent, respectively). Both are small railroads, ranking 38th and 39th respectively in revenue ton-miles shipped in 1978. However, both should be better able to absorb increased costs in the short run than many of their competitors. The Pittsburgh and Lake Erie's net income as a percent of total operating revenue was 16.6 percent in 1978, and that of the Richmond, Fredericksburg and Potomac was 43.8 percent.

The major conclusion is that the noise abatement of these final source regulations should lead to only minor impacts in the rail freight transportation industry in the short run as well as in the long run after railroads have had the chance to pass through added costs. Employment impacts likewise will be extremely small with no reduction in jobs in some firms. Conrail may experience a reduction of as many as 215. However, even this reduction in employment amounts to less than 0.25 percent of Conrail's total labor force. These firm by firm projections are based on a statistical analytical analysis that does not account, for example, for other employment controls such as union contracts, or for increases in employment which could occur by railroads in complying with this regulation.

6.0 Enforcement

The Noise Control Act places primary enforcement responsibility with the Federal Railroad Administration (FRA) of the Department of Transportation. Specifically, Section 17 of the Act directs the Secretary of Transportation to promulgate regulations to ensure compliance with the EPA railroad noise standards. In addition, Section 17 directs the Secretary of Transportation to carry out such regulations through the use of his powers and duties of enforcement and inspection authorized by the Safety Appliance Act, the Interstate Commerce Act, the Noise Control Act (as amended), and the Department of Transportation Act.

The FRA has indicated to EPA that it will promulgate compliance regulations, will conduct investigations to determine compliance, and use the FRA enforcement authorities and limited enforcement resources to enforce this regulation.

EPA believes that the FRA has adequate authority to enforce these regulations. While EPA has some concurrent authority to enforce, the Act clearly places the primary responsibility for enforcement with FRA, and EPA has not dedicated any resources to enforcement of these regulations.

EPA anticipates that the major enforcement activity will need to be conducted by state and local agencies if the regulation is to be effective. In fact, EPA has designed these regulations in a manner which will facilitate the adoption and enforcement of identical regulations by state and local governments.

7.0 Background Document

Information used as a basis for the final regulation has been compiled in a document entitled "Background Document for Final Interstate Rail Carrier Noise Emission Regulation: Source Standards." The document may be obtained from: U.S. Environmental Protection Agency, Public Information Center (PM-215), (Lobby West Tower Gallery No. 1), Waterside Mall, Washington, D.C. 20460, (202) 755-0717.

8.0 Evaluation Plan

The effectiveness and need for continuation of the provisions contained in this action will be reviewed no more than five years after the initial effective date of the final regulation. In particular, we will solicit comments from affected parties with regard to actual costs incurred and other burdens associated with compliance and will also review noise impact data in order to evaluate the regulation's effectiveness.

9.0 Reporting and Recordkeeping Requirements

This regulation should impose no significant new or additional reporting or recordkeeping requirements on affected parties. This regulation will be reviewed specifically with respect to reporting and recordkeeping requirements within five years of its effective date.

10.0 Regulatory Analysis

EPA has determined that this action is a "significant routine" regulation and therefore does not require a Regulatory Analysis under Executive Order 12044. However, in accordance with that Executive Order, we have prepared an economic analysis which is located in Section 6 of the Background Document (referenced in Section 7.0 of this Preamble).

11.0 Public Comment

At this time the Agency is reopening the public comment period on the proposed property line noise standards (44 FR 22960–22972) (Sections 201.17 and 201.30–201.33). Extensive comments were received on the property line standard, reflecting a variety of views. Further comment may now be submitted on any aspect of the proposed property line standards. Given the diversity of views already expressed, EPA particularly encourages and solicits further comment addressing arguments and information from comments on the proposed rule, including its applicability to particular land uses, such as residential, commercial, industrial, and agricultural.

The public comment period will close at 4:30 p.m. on April 4, 1980.

12.0 Environmental Impact Statement

The Agency has prepared an Environmental Impact Statement which presents the effect of the final regulation. This document may be obtained from EPA's Public Information Center (PM-215), (Lobby West Tower Gallery No. 1), Waterside Mall, Washington, D.C. 20460, (202) 755–0717.

This regulation is promulgated under the authority of Section 17 of the Noise Control Act of 1972 (42 U.S.C. 4916).

Dated: December 13, 1979.

Douglas M. Costle,

Administrator, U.S. Environmental Protection Agency.

Part 201 is being revised and amended as follows:

PART 201—NOISE EMISSION STANDARDS FOR TRANSPORTATION EQUIPMENT; INTERSTATE RAIL CARRIERS

Subpart A—General Provisions

Sec.
201.1 Definitions.

Subpart B—Interstate Rail Carrier Operations Standards

201.10 Applicability.
201.11 Standard for locomotive operation under stationary conditions.
201.12 Standard for locomotive operation under moving conditions.
201.13 Standard for rail car operations.
201.14 Standard for retarders.
201.15 Standard for car coupling operations.
201.16 Standard for locomotive load cell test stands.

Subpart C—Measurement Criteria

201.20 Applicability and purpose.
201.21 Quantities measured.
201.22 Measurement instrumentation.
201.23 Test site, weather conditions, and background noise criteria for measurement at a 30 meter (100 feet) distance of noise from locomotives, rail car operations, and locomotive load cell test stands.
201.24 Procedures for the measurement of noise from switcher locomotives, rail car operations, and locomotive load cell test stands, at a distance of 30 meters (100 feet).
201.25 Measurement location and weather conditions for measurement on receiving property of noise from retarders, car coupling, locomotive load cell test stands, and stationary locomotives.
201.26 Procedures for the measurement on receiving property of retarder and car coupling noise.
201.27 Procedures for: (1) determining applicability of the locomotive load cell test stand standard and switcher locomotive standard by measurement on a receiving property; (2) measurement of locomotive load cell test stands at more than 120 meters (400 feet) on a receiving property.
201.28 Demonstration of probable compliance with the standards for the measurement on receiving property of noise from retarders, car coupling, locomotive load cell test stands, and stationary locomotives.

Authority: Noise Control Act of 1972, sec. 17(a), 86 Stat. 1234 (42 U.S.C. 4916(a)).

Subpart A—General Provisions

§ 201.1 Definitions.

As used in this part, all terms not defined herein shall have the meaning given them in the Act:

(a) "Act" means the Noise Control Act of 1972 (Pub. L. 92–574, 86 Stat. 1234).

(b) "Car Coupling Sound" means a sound which is heard and identified by the observer as that of car coupling impact, and that causes a sound level meter indicator (FAST) to register an increase of at least ten decibels above the level observed immediately before hearing the sound.

(c) "Carrier" means a common carrier by railroad, or partly by railroad and partly by water, within the continental United States, subject to the Interstate Commerce Act, as amended, excluding street, suburban, and interurban electric railways unless operated as a part of a general railroad system of transportation.

(d) "Classification of Railroads" means the division of railroad industry operating companies by the Interstate Commerce Commission into three categories. As of 1978, Class I railroads must have annual revenues of $50 million or greater, Class II railroads must have annual revenues of between $10 and $50 million, and Class III railroads must have less than $10 million in annual revenues.

(e) "Commercial Property" means any property that is normally accessible to the public and that is used for any of the purposes described in the following standard land use codes (reference *Standard Land Use Coding Manual*, U.S. DOT/FHWA, reprinted March 1977): 53–59, Retail Trade; 61–64, Finance, Insurance, Real Estate, Personal, Business and Repair Services; 652–659, Legal and other professional services; 671, 672, and 673 Governmental Services; 692 and 699, Welfare, Charitable and Other Miscellaneous Services; 712 and 719, Nature exhibitions and other Cultural Activities; 721, 723, and 729, Entertainment, Public and other Public Assembly; and 74–79, Recreational, Resort, Park and other Cultural Activities.

(f) "dB(A)" is an abbreviation meaning A-weighted sound level in decibels, reference: 20 micropascals.

(g) "Day-night Sound Level" means the 24-hour time of day weighted equivalent sound level, in decibels, for any continuous 24-hour period, obtained after addition of ten decibels to sound levels produced in the hours from 10 p.m. to 7 a.m. (2200–0700). It is abbreviated as L_{dn}.

(h) "Decibel" means the unit measure of sound level calculated by taking ten times the common logarithm of the ratio of the magnitude of the particular sound pressure to the standard reference sound pressure of 20 micropascals and its derivatives. It is abbreviated as dB.

(i) "Energy Average Level" means a quantity calculated by taking ten times the common logarithm of the arithmetic average of the antilogs of one-tenth of each of the levels being averaged. The levels may be of any consistent type, e.g. maximum sound levels, sound exposure levels, and day-night sound levels.

(j) "Energy Summation of Levels" means a quantity calculated by taking ten times the common logarithm of the sum of the antilogs of one-tenth of each of the levels being summed. The levels may be of any consistent type, e.g., day-night sound level or equivalent sound level.

(k) "Equivalent Sound Level" means the level, in decibels, of the mean-square A-weighted sound pressure during a stated time period, with reference to the square of the standard reference sound pressure of 20 micropascals. It is the level of the sound exposure divided by the time period and is abbreviated as L_{eq}.

(l) "Fast Meter Response" means that the "fast" response of the sound level meter shall be used. The fast dynamic response shall comply with the meter dynamic characteristics in paragraph 5.3 of the American National Standard Specification for Sound Level Meters. ANSI S1.4–1971. These publications are available from the American National Standards Institute, Inc., 1430 Broadway, New York, New York 10013.

(m) "Idle" means that condition where all engines capable of providing motive power to the locomotive are set at the lowest operating throttle position; and where all auxiliary non-motive power engines are not operating.

(n) "Interstate Commerce" means the commerce between any place in a State and any place in another State, or between places in the same State through another State, whether such commerce moves wholly by rail or partly by rail and partly by motor vehicle, express, or water. This definition of "interstate commerce" for purposes of this regulation is similar to the definition of "interstate commerce" in section 203(a) of the Interstate Commerce Act (49 U.S.C. 303(a)).

(o) "Load Cell" means a device external to the locomotive, of high electrical resistance, used in locomotive testing to simulate engine loading while the locomotive is stationary. (Electrical energy produced by the diesel generator is dissipated in the load cell resistors instead of the traction motors).

(p) "Locomotive" means for the purpose of this regulation, a self-propelled vehicle designed for and used on railroad tracks in the transport or rail cars, including self-propelled rail passenger vehicles.

(q) "Locomotive Load Cell Test Stand" means the load cell § 201.1(o) and associated structure, equipment, trackage and locomotive being tested.

(r) "Maximum Sound Level" means the greatest A-weighted sound level in decibels measured at fast meter response § 201.1(l) during the designated time interval or during the event. It is abbreviated as L_{max}.

(s) "Measurement Period" means a continuous period of time during which noise of railroad yard operations is assessed, the beginning and finishing times of which may be selected after completion of the measurements.

(t) "Rail Car" means a non-self-propelled vehicle designed for and used on railroad tracks.

(u) "Railroad" means all the roads in use by any common carrier operating a railroad, whether owned or operated under a contract, agreement, or lease.

(v) "Receiving Property Measurement Location" means a location on receiving property that is on or beyond the railroad facility boundary and that meets the receiving property measurement location criteria of Subpart C.

(w) "Receiving Property" means any residential or commercial property that receives the sound from railroad facility operations, but that is not owned or operated by a railroad; except that occupied residences located on property owned or controlled by the railroad are included in the definition of "receiving property." For purposes of this definition railroad crew sleeping quarters located on property owned or controlled by the railroad are not considered as residences. If, subsequent to the publication date of these regulations, the use of any property that is currently not applicable to this regulation changes, and it is newly classified as either residential or commercial, it is not receiving property until four years have elapsed from the date of the actual change in use.

(x) "Residential Property" means any property that is used for any of the purposes described in the following standard land use codes (ref. *Standard Land Use Coding Manual*. U.S. DOT/FHWA Washington, D.C., reprinted March 1977): 1, Residential: 651, Medical and other Health Services; 68, Educational Services; 691, Religious Activities; and 711, Cultural Activities.

(y) "Retarder (Active)" means a device or system for decelerating rolling rail cars and controlling the degree of deceleration on a car by car basis.

(z) "Retarder Sound" means a sound which is heard and identified by the observer as that of a retarder, and that causes a sound level meter indicator at fast meter response § 201.1(l) to register an increase of at least ten decibels above the level observed immediately before hearing the sound.

(aa) "Sound Level" means the level, in decibels, measured by instrumentation which satisfies the requirements of American National Standard Specification for Sound Level Meters S1.4–1971 Type 1 (or S1A) or Type 2 if adjusted as shown in Table 1. This publication is available from the American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018. For the purpose of these procedures the sound level is to be measured using the A-weighting of spectrum and the FAST dynamic averaging characteristics, unless designated otherwise. It is abbreviated as L_A.

(bb) "Sound Exposure Level" means the level in decibels calculated as ten times the common logarithm of time integral of squared A-weighted sound pressure over a given time period or event divided by the square of the standard reference sound pressure of 20 micropascals and a reference duration of one second.

(cc) "Sound Pressure Level" (in stated frequency band) means the level, in decibels, calculated as 20 times the common logarithm of the ratio of a sound pressure to the reference sound pressure of 20 micropascals.

(dd) "Special Purpose Equipment" means maintenance-of-way equipment which may be located on or operated from rail cars including: Ballast cribbing machines, ballast regulators, conditioners and scarifiers, bolt machines, brush cutters, compactors, concrete mixers, cranes and derricks, earth boring machines, electric welding machines, grinders, grouters, pile drivers, rail heaters, rail layers, sandblasters, snow plows, spike drivers, sprayers and other types of such maintenance-of-way equipment.

(ee) "Special Track Work" means track other than normal tie and ballast bolted or welded rail or containing devices such as retarders or switching mechanisms.

(ff) "Statistical Sound Level" means the level in decibels that is exceeded in a stated percentage (x) of the duration of the measurement period. It is abbreviated as L_x.

(gg) "Switcher Locomotive" means any locomotive designated as a switcher by the builder or reported to the ICC as a switcher by the operator-owning-railroad and including, but not limited to, all locomotives of the builder/model designations listed in Appendix A to this subpart.

(hh) "Warning Device" means a sound emitting device used to alert and warn people of the presence of railroad equipment.

Appendix A.—Switcher Locomotives

The following locomotives are considered to be "switcher locomotives" under the general definition of this regulation.

Type	Engine
General Electric Co.	
44 ton	8-D17000(2).
70 ton	6-CBFWL-6T.
95 ton	6-CBFWL-6T.
Electromotive Division (GMC)	
SC	8-201A.
NC	12-201A.
NC1	12-201A.
NC2	12-201A.
NW	12-201A.
NW1	12-201A.
NW1A	12-201A.
NW2	12-567.
NW2	12-567A.
NW3	12-567.
NW4	12-201A.
NW5	12-567B.
SW	8-201A/6-567.
SW1	6-567A/AC.
SW2	6-567.
SW3	6-567.
SW600	6-567C.
SW7	12-567A.
SW8	8-567B/BC.
SW900	8-567B.
SW9	12-567B/BC/C.
SW1200	12-567C.
SW1000	8-645E.
SW1001	8-645E.
SW1500	12-645E.
MP15	12-645E.
MP15AC	12-645E.
GMD1	12-567C.
RS1325	12-567C.
Transfer Switcher including "Cow and Calf"	
T	12-201A(2)
TR	12-567(2)
TR1	16-567(2)
TR2	12-567A(2)
TR3	12-567(3)
TR4	12-567A(2)
TR5	12-567B(2)
TR6	8-567B(2)
Baldwin	
VO-660	6-VO.
DS-446	6-606NA.
DS4475	6-750.
S-8	6-606.
VO-1000	8-VO.
DS 4410	8-608NA.
DS-4410	6-606SC.
S-12	6-606A.
DRS-4410 [1]	6-606SC.
DRS-12 [1]	6-606A.
Fairbanks Morse	
H-10-44	6-OP.
H-12-44	6-OP.
H-12-44TS	6-OP.
H-12-46 [1]	6-OP.
Lima	
750 hp	6-Hamilton.
800 hp	6-Hamilton.
1000 hp	8-Hamilton.
1200 hp	8-Hamilton.
LRS [1]	8-Hamilton.
TL [1]	8-Hamilton (2).
ALCO and MLW	
S1	6-539NA.
S2	6-539T.
S3	6-539NA.
S4	6-539T.
S5	6-251.
S6	6-251A,B.
S7	6-539.
S10	6-539.
S11	6-539.
S12	6-539T.
S13	6-251C.
[illegible] [1]	6-539.
RSC-13	6-539.
RSC-24	12-244

Type	Engine
ALCO and MLW	
RS1	6-539T.
RS2 [1]	12-244.
RS3 [1]	12-244.
RS10 [1]	12-244.
RSC-2 [1]	12-244.
RS3 [1]	12-244.
RSD-4 [1]	12-244.
RSD-5 [1]	12-244.
T6	6-251B.
C-415 [1]	8-251F.
M-420TR	12-251.

[1] These models may be found assigned to road service as well as switcher service, but are considered switcher locomotives for the purpose of this regulation.

Subpart B—Interstate Rail Carrier Operation Standards

§ 201.10 Applicability.

The provisions of this subpart apply to all rail cars and all locomotives, except steam locomotives, operated or controlled by carriers as defined in Subpart A of this part, except that §§ 201.11 (a), (b), and (c) do not apply to gas turbine-powered locomotives and to any locomotive type which cannot be connected by any standard method to a load cell. They apply to the total sound level emitted by rail cars and locomotives operated under the conditions specified, including the sound produced by refrigeration and air conditioning units which are an integral element of such equipment. The provisions of this subpart apply to all active retarders, all car coupling operations, all switcher locomotives, and all load cell test stands. These provisions do not apply to the sound emitted by a warning device, such as a horn, whistle or bell when operated for the purpose of safety. They do not apply to special purpose equipment which may be located on or operated from railcars; they do not apply to street, suburban or interurban electric railways unless operated as a part of a general railroad system of transportation. When land use changes after the publication date of this regulation from some other use to residential or commercial land use around a specific railyard facility, this regulation will become effective four (4) years from the date of that land use change.

§ 201.11 Standard for locomotive operation under stationary condition.

(a) Commencing December 31, 1976, no carrier subject to this regulation shall operate any locomotive to which this regulation is applicable, and of which manufacture is completed on or before December 31, 1979, which produces A-weighted sound levels in excess of 93 dB at any throttle setting except idle, when operated singly or when connected to a load cell, or in excess of 73 dB at idle when operated singly, and when measured in accordance with the criteria specified in Subpart C of this part with slow meter response at a point 30 meters (100 feet) from the geometric center of the locomotive along a line that is both perpendicular to the centerline of the track and originates at the locomotive geometric center.

(b) No carrier subject to this regulation shall operate any locomotive to which this regulation is applicable, and of which manufacture is completed after December 31, 1979, which produces A-weighted sound levels in excess of 87 dB at any throttle setting except idle, when operated singly or when connected to a load cell, or in excess of 70 dB at idle when operated singly, and when measured in accordance with the criteria specified in Subpart C of this part with slow meter response at a point 30 meters (100 feet) from the geometric center of the locomotive along a line that is both perpendicular to the centerline of the track and originates at the locomotive geometric center.

(c) Commencing January 15, 1984, no carrier subject to this regulation may operate any switcher locomotive to which this regulation is applicable, and of which manufacture is completed on or before December 31, 1979, which produces A-weighted sound levels in excess of 87 dB at any throttle setting except idle, when operated singly or when connected to a load cell, or in excess of 70 dB at idle, and when measured in accordance with the criteria specified in Subpart C of this part with slow meter response at a point 30 meters (100 feet) from the geometric center of the locomotive along a line that is both perpendicular to the centerline of the track and originates at the locomotive geometric center. All switcher locomotives that operate in a particular railroad facility are deemed to be in compliance with this standard if the A-weighted sound level from stationary switcher locomotives, singly or in combination with other stationary locomotives, does not exceed 65 dB when measured with slow meter response at any receiving property measurement location near that particular railyard facility and when measured in accordance wtih Subpart C of this regulation.

§ 201.12 Standard for locomotive operation under moving condition.

(a) Commencing December 31, 1976, no carrier subject to this regulation may operate any locomotive or combination of locomotives to which this regulation is applicable, and of which manufacture is completed on or before December 31, 1979, which produces A-weighted sound levels in excess of 96 dB when moving at any time or under any condition of grade, load, acceleration, or deceleration, when measured in accordance with the criteria specified in Subpart C of this regulation with fast meter response at 30 meters (100 feet) from the centerline of any section of track having less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2865 feet)).

(b) No carrier subject to this regulation may operate any locomotive or combination of locomotives to which this regulation is applicable, and of which manufacture is completed after December 31, 1979, which produce A-weighted sound levels in excess of 90 dB when moving at any time or under any condition of grade, load, acceleration, or deceleration, when measured in accordance with the criteria specified in Subpart C of this part with fast meter response at 30 meters (100 feet) from the centerline of any section of track having less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2,865 feet)).

(c) Commencing January 15, 1984, no carrier subject to this regulation may operate any switcher locomotive or a combination of switcher locomotives to which this regulation is applicable, and of which manufacture is completed on or before December 31, 1979 which produce A-weighted sound levels in excess of 90 dB when moving at any time or under any condition of grade, load, acceleration or deceleration, and when measured in accordance with the criteria in Subpart C of this part with fast meter response at 30 meters (100 feet) from the centerline of any section of track having less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2,865 feet)). All switcher locomotives that operate in a particular railroad facility are deemed to be in compliance with this standard if the A-weighted sound level from stationary switcher locomotives, singly or in combination with other stationary locomotives, does not exceed 65 dB when measured with fast meter response at any receiving property measurement location near that particular railyard facility and when measured in accordance with Subpart C of this regulation.

§ 201.13 Standard for rail operations.

Effective December 31, 1976, no carrier subject to this regulation shall operate any rail car or combination of rail cars which while in motion produce sound levels in excess of (1) 88 dB(A) at rail car speeds up to and including 75 km/hr (45 mph); or (2) 93 dB(A) at rail car speeds greater than 72 km/hr (45 mph); when measured in accordance with the criteria specified in Subpart C of this part with fast meter response at 30 meters (100) feet from the centerline of any section of track which is free of special track work or bridges or trestles and which exhibits less than a two (2) degree curve (or a radius of curvature greater than 873 meters (2,865 feet)).

§ 201.14 Standard for retarders.

Effective January 15, 1984, no carrier subject to this regulation shall operate retarders that exceed an adjusted average maximum A-weighted sound level of 83 dB at a receiving property measurement location, when measured with fast meter response in accordance with Subpart C of this part.

§ 201.15 Standard for car coupling operations.

Effective January 15, 1984, no carrier subject to this regulation shall conduct car coupling operations that exceed an adjusted average maximum A-weighted sound level of 92 dB at the receiving property measurement location, when measured with fast meter response in accordance with Subpart C of this part, except, such coupling will be found in compliance with this standard and the carrier will be considered in compliance, if the railroad demonstrates that the standard is exceeded at the receiving property measurement locations (where the standard was previously exceeded) when cars representative of those found to exceed the standard are coupled at similar locations at coupling speeds of eight miles per hour or less.

§ 201.16 Standard for locomotive load cell test stands

(a) Effective January 15, 1984, no carrier subject to this reguation shall operate locomotive load cell test stands that exceed an A-weighted sound level of 78 dB when measured with slow meter response in accordance with Subpart C of this part excluding § 201.23 (b) and (c), at a point 30 meters (100 feet) from the geometric center of the locomotive undergoing test, along a line that is both perpendicular to the centerline of the track and originates at the locomotive geometric center, and in the direction most nearly towards the closest receiving property measurement location. All locomotive load cell test stands in a particular railroad facility are in compliance with this standard if the A-weighted sound level from the load cells does not exceed 65 dB at a receiving property measurement location near that particular railyard facility and when measured with fast meter response in accordance with Subpart C of this regulation.

(b) If the conditions of any part of § 201.23(a) cannot be met at a specific load cell test stand site, then the A-weighted sound level from that specific load cell test stand must not exceed 65 dB when measured with fast meter response at a receiving property measurement location more than 120 meters (400 feet) from the geometric center of the locomotive being tested and in accordance with Subpart C of this regulation.

Subpart C—Measurement Criteria

§ 201.20 Applicability and purpose.

The following criteria are applicable to and contain the necessary parameters and procedures for the measurement of the noise emission levels prescribed in the standards of Subpart B of this part. These criteria are specified in order to further clarify and define such standards. Equivalent measurement procedures may be used for establishing compliance with these regulations. Any equivalent measurement procedure, under any circumstance, shall not result in a more stringent noise control requirement than those specified in this regulation using the measurement procedures in Subpart C.

§ 201.21 Quantities measured.

The quantities to be measured under the test conditions described below, are the A-weighted sound levels for "fast" or "slow" meter response as defined in the American National Standard S1.4—1971.

§ 201.22 Measurement instrumentation.

(a) A sound level meter or alternate sound level measurement system that meets, as a minimum, all the requirements of American National Standard S1.4—1971 [1] for a Type 1 (or S1A) instrument must be used with the "fast" or "slow" meter response chacteristic as specified in Subpart B. To

[1] American National Standards are available from the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

insure Type 1 response, the manufacturer's instructions regarding mounting or orienting of the microphone, and positioning of the observer must be observed. In the event that a Type 1 (or S1A) instrument is not available for determining non-compliance with this regulation, the measurements may be made with a Type 2 (or S2A), but with the measured levels reduced by the following amount to account for possible measurement instrument errors pertaining to specific measurements and sources:

Table 1.—*Sound Level Corrections When Using a Type 2 (or S2A) Instrument*

Measurement section	Source	Decibels [1]
201.24	Locomotives	0
	Rail cars	0
	Locomotive load cell test stand	0
201.26	Retarder	4
	Car coupling	2
201.27	Locomotive load cell test stand.	0
	Stationary locomotive	0

[1] Amount of correction to be subtracted from measured level (dB).

(b) A microphone windscreen and an acoustic calibrator of the coupler type must be used as recommended by: (1) the manufacturer of the sound level meter or (2) the manufacturer of the microphone. The choice of both devices must be based on ensuring that Type 1 or Type 2 performance, as appropriate, is maintained for frequencies below 10,000 Hz.

§ 201.23 Test Site, weather conditions and background noise criteria for measurement at a 30 meter (100 feet) distance of the noise from locomotive and rail car operations and locomotive load cell test stands.

(a) The standard test site shall be such that the locomotive or train radiates sound into a free field over the ground plane. This condition may be considered fulfilled if the test site consists of an open space free of large, sound reflecting objects, such as barriers, hills, signboards, parked vehicles, locomotives or rail cars on adjacent tracks, bridges or buildings within the boundaries described by Figure 1, as well as conforms to the other requirements of this § 201.23.

(b) Within the complete test site, the top of at least one rail upon which the locomotive or train is located shall be visible (line of sight) from a position 1.2 meters (4 feet) above the ground at the microphone location, except as provided in paragraph (c) of this section.

(c) Ground cover such as vegetation, fenceposts, small trees, telephone poles, etc., shall be limited within the area in the test site between the vehicle under test and the measuring microphone such that 80 percent of the top of at least one rail along the entire test section of track be visible from a position 1.2 meters (4 feet) above the ground at the microphone location; except that no single obstruction shall account for more than 5 percent of the total allowable obstruction.

(d) The ground elevation at the microphone location shall be within plus 1.5 meters (5 feet) or minus 3.0 meters (10 feet) of the elevation of the top of the rail at the location in-line with the microphone.

(e) Within the test site, the track shall exhibit less than a 2 degree curve or a radius of curvature greater than 873 meters (2,865 feet). This paragraph shall not apply during a stationary test. The track shall be tie and ballast, free of special track work and bridges or trestles.

(f) Measurements shall not be made during precipitation.

(g) The maximum A-weighted fast response sound level observed at the test site immediately before and after the test shall be at least 10 dB(A) below the level measured during the test. For the locomotive and rail car pass-by tests this requirement applies before and after the train containing the rolling stock to be tested has passed. This background sound level measurement shall include the contribution from the operation of the load cell, if any, including load cell contribution during test.

(h) Noise measurements may only be made if the measured wind velocity is 19.3 km/hr (12 mph) or less. Gust wind measurements of up to 33.2 km/hr (20 mph) are allowed.

§ 201.24 Procedures for measurement at a 30 meter (100 feet) distance of the noise from locomotive and rail car operations and locomotive load cell test stands.

(a) *Microphone positions.* (1) The microphone shall be located within the test site according to the specifications given in the test procedures of paragraphs (b), (c) and (d) of this section, and shall be positioned 1.2 meters (4 feet) above the ground. It shall be oriented with respect to the source in accordance with the manufacturer's recommendations.

(2) The observer shall not stand between the microphone and the source whose sound level is being measured.

(b) *Stationary locomotive and locomotive load cell test stand tests.* (1) For stationary locomotive and locomotive load cell test stand tests, the microphone shall be positioned on a line perpendicular to the track at a point 30 meters (100 feet) from the track centerline at the longitudinal midpoint of the locomotive.

(2) The sound level meter shall be observed for thirty seconds after the test throttle setting is established to assure operating stability. The maximum sound level observed during that time shall be utilized for compliance purposes.

(3) Measurement of stationary locomotive and locomotive load cell test stand noise shall be made with all cooling fans operating.

(c) *Rail car pass-by test.* (1) For rail car pass-by tests, the microphone shall be positioned on a line perpendicular to the track 30 meters (100 feet) from the track centerline.

(2) Rail car noise measurements shall be made when the locomotives have passed a distance 152.4 meters (500 feet) or 10 rail cars beyond the point at the intersection of the track and the line which extends perpendicularly from the track to the microphone location, providing any other locomotives are also at least 152.4 meters (500 feet) or 10 rail car lengths away from the measuring point. The maximum sound level observed in this manner which exceeds the noise levels specified in § 201.13 shall be utilized for compliance purposes.

(3) Measurements shall be taken on reasonably well maintained tracks.

(4) Noise levels shall not be recorded if brake squeal is present during the test measurement.

(d) *Locomotive pass-by test.* (1) For locomotive pass-by tests, the microphone shall be positioned on a line perpendicular to the track at a point 30 meters (100 feet) from the track centerline.

(2) The noise level shall be measured as the locomotive approaches and passes by the microphone location. The maximum noise level observed during this period shall be utilized for compliance purposes.

(3) Measurements shall taken on reasonably well maintained tracks.

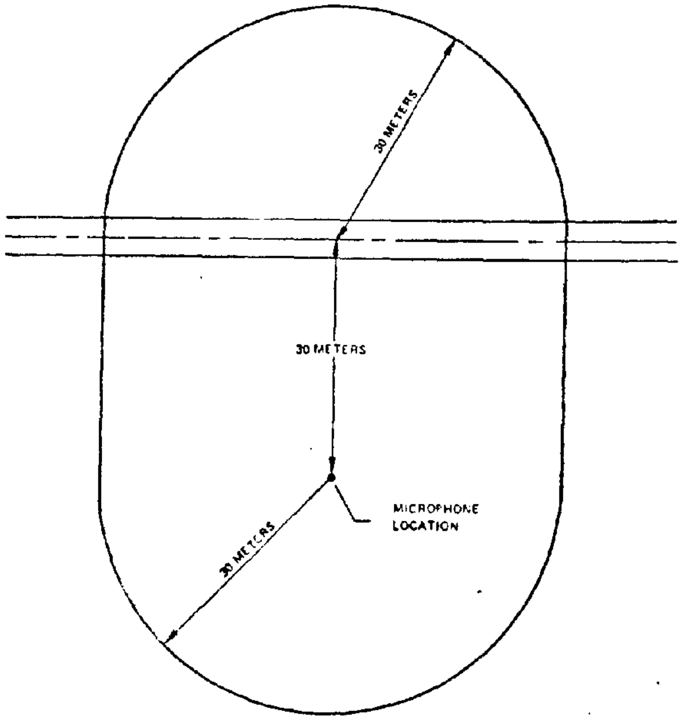

Figure 1. Test Site Clearance Requirement for Stationary Locomotive, Locomotive Pass-by, Rail Car Pass-by, and Locomotive Load Cell Test Stand Tests.

§ 201.25 Measurement location and weather conditions for measurement on receiving property of the noise of retarders, car coupling, locomotive load cell test stands, and stationary locomotives.

(a) Measurements must be conducted only at receiving property measurement locations.

(b) Measurement locations on receiving property must be selected such that no substantially vertical plane surface, other than a residential or commercial unit wall or facility boundary noise barrier, that exceeds 1.2 meters (4 feet) in height is located within 10 meters (33.3 feet) of the microphone and that no exterior wall of a residential or commercial structure is located within 2.0 meters (6.6 feet) of the microphone. If the residential structure is a farm home, measurements must be made 2.0 to 10.0 meters (6.6 to 33.3 feet) from any exterior wall.

(c) No measurement may be made when the average wind velocity during the period of measurement exceeds 19.3 km/hr (12 mph) or when the maximum wind gust velocity exceeds 32.2 km/hr (20 mph).

(d) No measurement may be taken when precipitation, e.g., rain, snow, sleet, or hail, is occurring.

§ 201.26 Procedures for the measurement on receiving property of retarder and car coupling noise.

(a) *Retarders.* (1) *Microphone:* The microphone must be located on the receiving property and positioned at a height between 1.2 and 1.5 meters (4 to 5 feet) above the ground. The microphone must be positioned with respect to the equipment in accordance with the manufacturers' recommendations for Type 1 or Type 2 performance as appropriate. No person may stand between the microphone and the equipment being measured or be otherwise positioned relative to the microphone at variance with the manufacturers' recommendations for Type 1 or Type 2 performance as appropriate.

(2) *Data:* The maximum A-weighted sound levels (FAST) for every retarder sound observed during the measurement period must be read from the indicator and recorded. At least 30 consecutive retarder sounds must be measured. The measurement period must be at least 60 minutes and not more than 240 minutes.

(3) *Adjusted average maximum A-weighted sound level:* The energy average level for the measured retarder sounds must be calculated to determine the value of the average maximum A-weighted sound level ($L_{ave\ max}$). This value is then adjusted by adding the adjustment (C) from Table 2 appropriate to the number of measurements divided by the duration of the measurement period (n/T), to obtain the adjusted average maximum A-weighted sound level ($L_{adj\ ave\ max}$) for retarders.

(b) *Car coupling impact.*

(1) *Microphone:* The microphone must be located on the receiving property and at a distance of at least 30 meters (100 feet) from the centerline of the nearest track on which car coupling occurs and its sound is measured (that is, either the microphone is located 30 meters (100 feet) from the nearest track on which couplings occur, or all sounds resulting from car coupling impacts that occur on tracks with centerlines located less than 30 meters (100 feet) from the microphone are disregarded). The microphone shall be positioned at a height between 1.2 and 1.5 meters (4 and 5 feet) above the ground, and it must be positioned with respect to the equipment in accordance with the manufacturers' recommendations for Type 1 or Type 2 performance as appropriate. No person may stand between the microphone and the equipment being measured or be otherwise positioned relative to the microphone at variance with the manufacturers' recommendations for Type 1 or Type 2 performance as appropriate.

(2) *Data:* The maximum A-weighted sound levels (FAST) for every car coupling impact sound observed during the measurement period must be read from the indicator and recorded. At least 30 consecutive car coupling impact sounds must be measured. The measurement period must be at least 60 minutes and not more than 240 minutes, and must be reported.

Table 2.—*Adjustment to $L_{ave\ max}$* To Obtain $L_{adj\ ave\ max}$ for Retarders and Car Coupling Impacts [1]

n/T = number of measurements / measurement duration (min)	C = Adjustment in dB
0.111 to 0.141	-9
0.142 to 0.178	-8
0.179 to 0.224	-7
0.225 to 0.282	-6
0.283 to 0.355	-5
0.256 to 0.447	-4
0.448 to 0.562	-3
0.563 to 0.708	-2
0.709 to 0.891	-1
0.892 to 1.122	0
1.123 to 1.413	+1
1.414 to 1.778	+2
1.779 to 2.239	+3
2.240 to 2.818	+4
2.819 to 3.548	+5
3.549 to 4.467	+6

[1] $L_{adj\ ave\ max} = L_{ave\ max} + C$ in dB.

Values in Table 2 were calculated from [$C = 10 \log n/T$] with intervals selected to round off values to the nearest whole decibel. The table may be extended or interpolated to finer interval gradations by using this defining equation.

(3) *Adjusted average maximum A-weighted sound level:* The energy average level for the measured car coupling sounds is calculated to determine the average maximum sound level ($L_{ave\ max}$). It is then adjusted by adding the adjustment (C) from Table 2 appropriate to the number of measurements divided by the duration of the measurement period (n/T), to obtain the adjusted average maximum A-weighted sound level ($L_{adj\ ave\ max}$) for car coupling impacts.

§ 201.27 Procedures for: (1) determining applicability of the locomotive load cell test stand standard and switcher locomotive standard by noise measurement on a receiving property; (2) measurement of locomotive load cell test stands more than 120 meters (400 feet) on a receiving property.

(a) *Microphone:* The microphone must be located at a receiving property measurement location and must be positioned at a height between 1.2 and 1.5 meters (4 and 5 feet) above the ground. Its position with respect to the equipment must be in accordance with the manufacturers' recommendations for Type 1 or Type 2 performance as appropriate. No person may stand between the microphone and the equipment being measured or be otherwise positioned relative to the microphone at variance to the manufacturers' recommendations for Type 1 or Type 2 performance as appropriate.

(b) *Data:* (1) When there is evidence that at least one of these two types of nearly steady state sound sources is affecting the noise environment, the following measurements must be made. The purpose of these measurements is to determine the A-weighted L_{90} statistical sound level, which is to be used as described in subparagraph (c) below to determine the applicability of the source standards. Before this determination can be made, the measured L_{90} is to be "validated" by comparing the measured L_{10} and L_{90} statistical sound levels. If the difference between these levels is sufficiently small (4 dB or less), the source(s) being measured is considered to be a nearly steady state source.

(2) Data shall be collected by measuring the instantaneous A-weighted sound level (SLOW) at a rate of at least once each 10 seconds for a measurement period of at least 15 minutes and until 100 measurements are obtained. The data may be taken manually by direct reading of the indicator at 10 second intervals (±1 second), or by attaching a statistical analyzer, graphic level recorder, or other equivalent device to the sound level meter for a more continuous recording of the instantaneous sound level.

(3) The data shall be analyzed to determine the levels exceeded 99%, 90%, and 10% of the time, i.e., L_{99}, L_{90}, and L_{10}, respectively. The value of L_{90} is considered a valid measure of the A-weighted sound level for the standards in § 201.16 only if the difference between L_{10} and L_{99} has a value of 4 dB or less. If a measured value of L_{90} is not valid for this purpose, measurements may be taken over a longer period to attempt to improve the certainty of the measurement and to validate L_{90}. If L_{90} is valid and is less than the level in applicable standards for these source types, the sources are in compliance. If the measured value of L_{90} is valid and exceeds the initial 65 dB requirement for any of the source types that appear to be affecting the noise environments, the evaluation according to the following subparagraph (c) is required.

(c) *Determination of Applicability of the Standard When L_{90} is Validated and is in Excess of One or More of the Source Standards.* The following procedures must be used to determine the compliance of the various source types when L_{90} is validated and in excess of one or more of the applicable standards.

(1) The principal direction of the nearly steady-state sound at the measurement location must be determined, if possible, by listening to the sound and localizing its apparent source(s). If the observer is clearly convinced by this localization process that the sound emanates only from one or both of these two sources, then:

(i) If only stationary locomotive(s), including at least one switcher locomotive, are present, the value of L_{90} is the value of the A-weighted sound level to be used in determining if the 65 dB requirement is exceeded and compliance with the standards in § 201.11(c) and § 201.12(c) is necessary.

(ii) If only a locomotive load cell test stand and the locomotive being tested are present and operating, the value of L_{90} is the value of the A-weighted sound level to be used in determining applicability of the standard in § 201.16.

(iii) If a locomotive load cell test stand(s) and the locomotive being tested are present and operating with stationary locomotive(s), including at least one switcher locomotive, the value L_{90} minus 3 dB is the value of the A-weighted sound level to be used in determining applicability of the standards in § 201.11(c), § 201.12(c) and § 201.16.

(iv) If a locomotive load cell test stand(s) and the locomotive being tested are present and operating, and a stationary locomotive(s) is present, and if the nearly steady-state sound level is observed to change by 10 dB, coincident with evidence of a change in operation of the locomotive load cell test stand but without apparent change in the location of stationary locomotives, another measurement of L_{90} must be made in accordance with paragraph (b) of this section. If this additional measure of L_{90} is validated and differs from the initial measure of L_{90} by an absolute value of 10 dB or more, then the higher value of L_{90} is the value of the A-weighted sound level to be used in determining applicability of the standard in § 201.16.

(2) In order to accomplish the comparison demonstration of (3) below, when one or more source types is found not to be in compliance with the applicable standard(s), documentation of noise source information shall be necessary. This will include, but not be limited to, the approximate location of all sources of each source type present and the microphone position on a diagram of the particular railroad facility, and the distances between the microphone location and each of the sources must be estimated and reported. Additionally, if other rail or non-rail noise sources are detected, they must be identified and similarly reported.

(3) If it can be demonstrated that the validated L_{90} is less than 5 dB greater than any L_{90} measured at the same receiving property location when the source types that were operating during the initial measurement(s) are either turned off or moved, such that they can no longer be detected, the initial value(s) of L_{90} must not be used for determining applicability to the standards. This demonstration must be made at a time of day comparable to that of the initial measurements and when all other conditions are acoustically similar to those reported in paragraph (c)(2) of this section.

§ 201.28 Testing by railroad to determine probable compliance with the standard.

(a) To determine whether it is probably complying with the regulation, and therefore whether it should institute noise abatement, a railroad may take measurements on its own property at locations that:

(1) Are between the source and receiving property

(2) Derive no greater benefit from shielding and other noise reduction features that does the receiving property; and

(3) Otherwise meet the requirements of § 201.25.

(b) Measurements made for this purpose should be in accordance with the appropriate procedures in § 201.26 or § 201.27. If the resulting level is less than the level stated in the standard, then there is probably compliance with the standard.

(c) This procedure is set forth to assist the railroad in devising its compliance plan, not as a substantive requirement of the regulation.

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DEPARTMENT OF TRANSPORTATION

Federal Railroad Administration

49 CFR Part 229 and 230

[Docket No. LI-6, Notice No. 3]

Railroad Locomotive Safety Standards and Locomotive Inspection

AGENCY: Federal Railroad Administration (FRA), Department of Transportation (DOT).

ACTION: Final rule.

SUMMARY: This document revises Part 230 (49 CFR Part 230) and establishes a new Part 229 (49 CFR Part 229). The parts contain FRA's rules applicable to railroad locomotive inspection. The revised rules update, consolidate, and clarify the old rule and eliminate certain rules no longer considered necessary for safety. This action is taken by FRA to improve its safety regulatory program.

EFFECTIVE DATE: These rules will become effective on May 1, 1980.

FOR FURTHER INFORMATION CONTACT: Principal Authors Principal Program Person: Arthur T. Ireland, Office of Standards and Procedures, Federal Railroad Administration, Washington, D.C. 20590. Telephone 202-426-9186. Principal Attorney: Michael E. Chase, Office of the Chief Counsel, Federal Railroad Administration, Washington, D.C. 20590. Telephone 202-426-8836.

SUPPLEMENTAL INFORMATION:

Background

Regulatory reform.—On March 23, 1978, the President issued Executive Order 12044. In that Order, he directed all Executive Agencies to adopt procedures to improve existing and future regulations. As a matter of policy, the Order requires that regulations be as simple and clear as possible, achieve legislative goals effectively and efficiently, and not impose unnecessary burdens. To achieve this policy objective, the Order requires Agencies to address the following considerations, among others, when developing regulations: (1) The need for and purpose of the regulation must be clearly established; (2) An opportunity must be provided for early participation and comment by other Federal Agencies, State and local governments, businesses, organizations, and individual members of the public; (3) Meaningful alternatives must be considered and analyzed before the regulation is issued; and (4) Compliance costs, paperwork, and other burdens on the public must be minimized.

In response to the policies set forth in Executive Order 12044, FRA initiated a General Safety Inquiry for the purpose of evaluating and improving its safety regulatory program. This inquiry was announced in the May 8, 1978, issue of the Federal Register (43 FR 19696). That notice also announced that FRA would conduct a series of two-day public hearings. The notice stated that the purpose of the hearings would be to obtain information from the public that would help FRA to determine whether many of its existing regulations should be expanded in scope, revised, or revoked.

FRA has conducted all of the hearings announced in the notice. These hearings dealt with the following subjects: (1) locomotives (June 14 and 15, 1978); (2) freight cars and safety appliances (July 12 and 13, 1978); (3) power brakes (September 13 and 14, 1978); (4) track and related structures, appliances, and devices (November 15 and 16, 1978); and (5) signal and communications systems (February 21 and 22, 1979).

After reviewing the testimony presented at those hearings, and the written comments submitted in response to the hearing notice, FRA has begun the process of issuing proposed rules for the purpose of improving many of its existing rules and eliminating others no longer considered necessary for safety. To date, three notices of proposed rulemaking (NPRM) have been issued. These are as follows: (1) Freight Car Safety Standards (44 FR 1419; January 5, 1979); (2) Locomotive Inspection (44 FR 29604; May 21, 1979); and (3) Track Safety Standards (44 FR 52104; September 6, 1979). The Freight Car Safety Standards were revised and the final rule published on December 31, 1979 (44 FR 77328).

As announced in the NPRM, the FRA held a two-day public hearing on the proposed revision to the locomotive inspection regulations. The hearing, originally scheduled to begin on July 10, 1979, was postponed until September 12, 1979, at the request of the Association of American Railroads (44 FR 38609; July 2, 1979). At that hearing, testimony was presented by eight railroads, one state regional transportation agency, the Association of American Railroads (AAR), the Railway Labor Executives Association (RLEA), and one manufacturer of railroad locomotives. In addition, written comments were submitted by a number of railroads, including some which did not testify at the hearing, rail labor groups, state transportation agencies, a Federal agency, locomotive manufacturers, and private persons. All of the testimony and comments have been reviewed and fully considered during the formulation of the final rules set forth in this document.

Most commenters expressed strong support in general for the proposed rules. However, many recommended that revisions be made to one or more of the changes proposed by FRA. Most of the suggestions were minor or technical in nature, although certain proposed changes sparked sharp disagreement from one or more commenters. These latter changes included the extention from a 30-day inspection to a 92-day inspection, the consecutively numbered periodic inspection system, the movement of locomotives for repair, and the requirements for wheel slip/slide protection. Only one commenter, RLEA, concluded that on balance the benefits of the proposed revision were outweighed by what it believed to be the possible adverse effects. However, many of RLEA's comments were focused on entirely new safety requirements that it believed should have been included the proposed rules rather than on the changes actually included the proposed rules.

The following is a summary of many of the comments received and an explanation of the revisions made by FRA in response to those comments. The comments and related revisions have been organized in a section by section format. Minor editorial or language changes have been made to a few sections without a specific explanation.

Section by Section Analysis

PART 230—STEAM LOCOMOTIVE INSPECTION

§ 230.0 *Steam power locomotives.*

No specific comments were received and no change has been made. Hence, Subpart A and Subpart B of 49 CFR Part 230 will be removed from the Code of Federal Regulations (CFR). The regulations remain in effect even though their complete text will no longer be reprinted in future additions of the CFR.

PART 229—RAILROAD LOCOMOTIVE SAFETY STANDARDS

Subpart A—General

§ 229.3 *Scope.*

No comments were received and no change has been made.

§ 229.3 *Applicability.*

The AAR suggested that the part not apply to locomotives operated occasionally in the United States that are owned by railroads in Canada and that comply with Candian Transport proposed requirement relating to closed metal containers.

As part of its comments on § 229.119, RLEA proposed that the rule include a number of new substantive requirements. These items, many of which are beyond the scope of the notice of proposed rulemaking, include minimum cab floor space requirements, clean cab requirements, position of the engineer in the cab, detailed specifications for cab seats, drinking water requirements, layout of indicators and controls in the cab, uniformity of cab design and location, air conditioning, air filter requirements, and crashworthiness of the cab. NTSB also addressed the crashworthiness issue. FRA does not believe that any of these items warrant action at this time for a variety of reasons. Some are already being addressed without Federal regulation through voluntary action, e.g., Clean Cab Committee. Others are more properly the subject of collective bargaining. Many are not significantly related to rail safety or have not been justified on a cost/benefit basis. With respect to the issue of crashworthiness, FRA believes that additional study is necessary to develop meaningful standards. A study is presently being made by FRA with a final report tentatively scheduled for completion in 1982.

§ *229.121 Locomotive cab noise.*

This section sparked numerous comments. AAR and several railroad commenters did not believe that FRA should adopt an occupational noise standard for the locomotive in-cab environment. Specifically, they questioned the justification for such a regulation due to an absence of accident data or medical evidence linking crew member impairment to high noise exposure. It was also contended that this occupational noise standard, adopted from that contained in the Occupational Safety and Health Administration (OSHA) regulations, was not appropriate for the railroad environment. The extensive litigation and controversy surrounding its enforcement were cited to support their claim that it should not be applied across-the-board to all industries. Finally, the commenters alleged that economic feasibility was an important determinant and questioned whether FRA had considered the cost effects of this standard, or whether a means of compliance had been determined.

Despite the concerns expressed above, the FRA believes that regulation in this area is warranted. Medical and accident data cannot always be correlated with noise exposure. Frequently, noise induced hearing loss is not recognized for many years, and even then is not always associated with working conditions, but dismissed as hearing loss due to advancing age (presbycusis). Thus, occupational illness data may not reliably indicate the true nature of an occupational noise problem.

It is now generally accepted that extended periods of exposure to high noise levels cause varying degrees of temporary and permanent hearing loss. Aside from hearing loss, exposure to high noise levels has also been related to changes in cardiovascular, endocrine, neurologic, and other physiologic functions. All of these are suggestive of a general stress reaction with resultant complaints of fatigue and irritability. Although the effects of these reactions on accident rates cannot be quantified, noise level distraction from normal surveillance of wayside signals and from locomotive controls can be a significant causal factor.

As far as the cost effects and economic feasibility of this regulation, FRA estimates that less than 5 percent of the locomotives now in service produce interior noise levels in excess of the prescribed limits. A substantial proportion of these can be brought into compliance by relatively simple maintenance procedures, such as improving seals and gaskets or replacing missing electrical cabinet panels. Also, substantial noise reductions can be achieved in the areas of controlling air brake exhaust and excessive horn noise in the cab. Reduction of horn and air brake noise is the most significant factor in regards to crew exposure and is the most cost effective approach. The following discussion identifies some engineering controls that have been utilized in these areas.

Major locomotive manufacturers presently offer, as an option, a method for piping the automatic brake valve service application and independent brake valve exhaust into the sub-base of the locomotive. This option provides an audible indication of brake performance while, at the same time, it has been estimated to reduce the cab occupants' noise dosage by 15 to 20 percent. It is available at an additional cost of approximately $100 to $150, and is presently specified by two railroads for their new units. One railroad has retrofitted their existing equipment as well.

Excessive air horn noise in the cab is most easily controlled by proper location of the horn on the locomotive. It should be away from air vents and not located on the cab roof in close proximity to any crew member's seat. It is estimated that relocation can be accomplished at labor costs of less than one hour.

The costs involved in lowering employee exposure to noise may be balanced by reduced compensation costs associated with high noise work environments. A recent analysis of the Federal Employers' Liability Act cases of five railroad employees seeking compensation for occupational hearing loss showed that they suffered from 37 to 82dB hearing loss and received awards of a mean value of $32,000.

One commenter stated that the cab noise standard was unnecessary because newer locomotives are quieter than the older ones, and that the cab noise situation will improve even more due to the EPA wayside noise standards.

FRA does not disagree with the contention that locomotives are now, generally speaking, quieter than those built in the past. However, these older units may remain in service for many years. As far as the effect of the EPA standards on interior noise levels, based on test data from major locomotive manufacturers, it appears that the noise reduction techniques incorporated in the post-1980 units to meet exterior passby noise standards will have little or no effect on the interior cab noise environment.

One commenter recommended that the interior cab noise standard only apply to new locomotives. It was questioned whether it would be prudent to retrofit locomotives that were very close to being retired.

FRA does not agree that a blanket exemption to this regulation is appropriate for existing locomotives. As previously mentioned, these units may remain in service for many years and, if required, can often be brought into compliance by the implementation of the maintenance procedures or the identified methods to reduce horn and brake noise in the cab.

The cab noise requirement becomes effective on September 1, 1980, and the compliance time between issuance and the effective date provides ample time for any retrofitting that may be required. Of course, an application for waiver of this standard may be appropriate for those special cases where it can be demonstrated that retrofit is not cost/effective and that an alternate hearing conservation program is to be implemented.

Three commenters alleged that this regulation should only apply to MU cars built after January 1, 1981, and should not apply to emergency application of air brakes on multiple unit equipment. They claimed that although their older cars exceed the 115dB(A) limit on emergency application of brakes, they have operated without crew complaints concerning cab noise for over 15 years.

FRA does not agree with this suggestion. The absence of complaints does not always correlate with conditions of non-excessive noise. Tolerance to noise is subjective with some people more sensitive than others. In addition, after years of excessive exposure, the onset of hearing loss may further minimize annoyance effects.

In addition to the technologies discussed above to reduce air brake valve noise, the efforts of a major air brake manufacturer concerning the PS-68-C air brake valve installed on multiple unit cars should be noted. This alternative, which was chosen among others because of ease of installation and maintenance, resulted in a substantial reduction in the noise level in comparison with the noise produced by the unmodified valve.

Three commenters objected to the fact that the proposed noise limits differed from the OSHA standard by the omission of the provision that "exposure to impulsive or impact noise should not exceed 140dB peak sound pressure level". They contended that this provision should have been inserted in lieu of the provision in the proposal stating that no exposure shall exceed 115dB(A).

FRA did not incorporate the 140dB impact/impulse noise limit because this type of noise is not normally present in the locomotive cab. Impact or impulse noise is characterized by very brief (less than one second) excursions of sound pressure and is normally associated with industrial processes in which two objects collide or which use explosive means of production. Ear tolerance is directly related to its characteristic rise time, peak sound level, and peak duration. Continuous noise, on the other hand, is typically associated with the 115dB(A) limit which is derived from the 90dB(A)-5dB doubling rate criterion. To minimize confusion in this area, the final rule distinguishes continuous or intermittent noise from impulse/impact noise by defining continuous noise as to its rise time to peak intensity and duration at that level.

The concern about the 115dB(A) limitation may be somewhat alleviated by the accuracy limitations of the noise measuring instrumentation. For compliance purposes, readings with the Type 2 sound level meter and the personal noise dosimeter are considered to have an accuracy of ±2dB. FRA will use this measurement tolerance in our enforcement activities.

One commenter, RLEA, took exception to the proposed 90dB(A) 8-hour limit and suggested that 85dB(A) was more appropriate as the time-weighted average. Various research studies were quoted to support their contention that a lower standard was required to minimize noise level distraction from normal surveillance of wayside signals and locomotive controls, to ensure that communication between crew members is unimpaired, and to minimize the risk of hearing impairment. For example, the Swedish goal of no more than 78dB(A) inside the cab of their locomotives was mentioned by this commenter to support his contention.

In selecting the proposed noise exposure limits, FRA has attempted to strike a balance between that which is most desirable and that which is feasible. While the Swedish goal is commendable, it should also be realized that their operations rely more on the usage of generally quieter electric locomotives than rail operations in the United States. With regard to the risk of hearing loss, FRA recognizes that comparatively more crew members will be at lower risk at 85dB(A) than at 90dB(A). However, we also recognize the technical feasibility problems and the economic impact associated with an 85dB(A) requirement. Significant reduction in interior noise levels has been achieved in recent years by locomotive manufacturers by additional insulation installed in the cab roof and electrical cabinets, piping the brake valve exhaust outside the cab, and by horn location considerations. Further reductions may not be prudent due to significant increases in costs without a commensurate reduction in crew exposure.

In summary, FRA has determined that the 90dB(A)-8 hour noise exposure limit will provide adequate protection for the hearing, communication, and comfort of locomotive crews under presently accepted standards. More restrictive criteria will be considered if future research indicates that noise-induced fatigue at these levels adversely affects the safety of train operations.

Three commenters asserted that FRA should not have included the noise exposure of employees at 85dB(A) for 16 hours because under the Hours of Service Act, the maximum work day shift is only 12 hours. They recommended that the exposure limit only be extended to cover a 12-hour exposure of 87dB(A). Two other commenters believed that the exposure limit should, like the OSHA standard, cover only 8 hours.

FRA's intention in the proposal was to limit employee exposure to 90dB(A) as an eight-hour time-weighted average, with a 5dB doubling rate (the amount by which the exposure intensity may be increased when exposure time is decreased). As specified in the NPRM, this standard is generally accepted and is the General Industry Standard adopted by the Occupational Safety and Health Administration. (Although OSHA's present standard limits employee exposure to noise to 90dB(A) as an eight-hour time-weighted average with a 5dB doubling rate, a subsequent NPRM proposed to extend these limits to 85dB(A) for 16 hours. (42 FR 37773, October 24, 1974))

FRA has re-examined its approach in this area and now believes that neither the 8 or 16 hour limit is appropriate for the railroad operating environment. Rather, the 12-Hours of Service limitation should govern the extension of the 5dB doubling rate. Accordingly, the final rule has been modified by deleting the entry in the table limiting exposure at 16 hours to 85dB(A) and thus effectively specifies that only exposures above 87dB(A) be included when calculating an employee's noise dose.

A major locomotive manufacturer recommended that FRA specify test parameters and conditions for sound measurement to permit an objective assessment of compliance. A related comment in this area was the suggestion by one railroad that FRA relate measured noise levels to assigned duty cycles for comparison with the specified exposure limits.

FRA appreciates these commenters' concerns. A requirement has been added in the final rule on microphone location and orientation to minimize test result variability due to measurement procedures. At the same time, to best approximate the crew member's exposure due to operational variability, the final rule requires that all measurements for determination of compliance be performed under typical operating conditions of the locomotive under test.

FRA is aware that the crew's exposure dose is strongly influenced by operational characteristics such as duty cycles and the frequency of grade-crossings. It is for this reason that FRA, in cooperation with the AAR, has sponsored efforts by the National Bureau of Standards to develop a simplified stationary test procedure that will correlate crew exposure and noise level data for these effects. The stationary test procedure, if valid, would yield a value that could be correlated to the specified time-weighted average limits. In addition, remedial action would be facilitated by the identification of high noise sources in the locomotive under test. If such a valid test procedure can be developed, FRA will incorporate it as an appendix to these regulations as a suggested method of compliance.

Finally, it was suggested by one commenter that language be added stating that a locomotive, at the time of its manufacture, be certified as complying with this section. Unlike the EPA standards and FRA Compliance Regulations (49 CFR 210), this section does not limit noise emissions. Rather, the limits relate to the noise level exposure of the locomotive occupants. Noise level exposure, in turn, is operational dependent and thus, influenced by duty cycles, and the particular characteristic of train operation. It is questionable whether, at this time, a manufacturer could certify, with acceptable accuracy, compliance with the prescribed noise exposure limits.

§ *229.123 Pilots, snowplows, end plates.*

The final rule is the same as proposed except that the effective date is postponed until January 1, 1981. The effective date is delayed in order to provide time to equip locomotives that do not now have either a pilot, a snowplow, or an end plate.

RLEA requested that the rule include design standards for these components. FRA does not agree that this is necessary since locomotive suppliers and railroads are capable of designing and installing these items. There is no indication that presently equipped locomotives, which constitute the vast majority of the current fleet, have inadequate or structually unsound end plates, snowplows, or pilots.

Several other commenters who operate MU locomotives indicated that MUs are not equipped. They suggested that MU locomotives be excluded from the requirement. FRA disagrees because it believes a device to deflect objects on the track is an important safety device. The need for such a device is greater now than in the past because of sharply increased incidents of vandalism.

§ *229.125 Headlights.*

The final rule has modified the proposed rule in two respects. It was noted by one commenter that there is no need for the second locomotive in a locomotive consist to have an operative headlight. An inoperative headlight on a locomotive that is not the lead locomotive is unrelated to safety and should not be a non-complying condition. FRA agrees with this analysis and has drafted the final rule to require only the lead locomotive to meet the headlight requirement.

A number of commenters noted that rule did not require alignment and focus of the headlight. FRA agrees and has included language from the prior rule that the light be arranged to illuminate a person ahead and in front of the locomotive at a given distance.

RLEA stated that the rule ought to require that new locomotives be built with sealed beam dual headlights on both ends. FRA does not believe that this detailed design requirement is necessary for safety, although FRA notes that most locomotives are currently so built. Safety is met so long as the locomotive has a headlight that meets the candela requirements of the rule.

Several railroad commenters disagreed with the required candela ratings included in the proposal. They did not, however, challenge the statement in the preamble to the NPRM that the candela levels selected correspond to the intensity level implicitly required under the prior rule. What these commenters apparently were saying is that the FRA could take exception under the prior rules to certain locomotives in their fleets, but FRA had not done so. FRA is not inclined to reduce the candela limits of the proposal since they reasonably reflect the prior rule. Nor should the use of a modern standard for light intensity be viewed as reflecting a change in FRA's enforcement approach. The waiver process can be utilized if a compliance problem arises for certain categories of locomotives.

§ *229.127 Cab lights.*

The final rule reflects two changes to the proposed rule. First, the comma between the words "cab passageways" is deleted. This was a typographical error in the NPRM and this language in the final rule now identically tracks the language of § 230.233(b). Second, the word "excessively" has been added to the requirement in paragraph (c) of the NPRM that batteries may not gas and the entire paragraph is moved to § 229.43(b) of the final rule. Both changes were made as a result of comments from the AAR and several railroads. RLEA requested that the final rule include a new requirement that cab lights have an on/off switch accessible to the crew. FRA does believe that safety warrants adding this requirement. The final rule provides that the lights illuminating the control instruments shall shine only on those parts requiring illumination and shall not interfere with the crew's vision of the track and signals. The rule also provides that the light for reading timetables and train order shall have an on/off switch.

§ *229.129 Audible warning device.*

The final rule reflects several changes from the NPRM. A number of commenters suggested that FRA delete the proposed language and retain the present standard. These commenters contended that there was a lack of data to support the proposed change and that present devices are loud enough. One commenter suggested that FRA study the current audible warning system in light of the strobe light NPRM.

FRA has sponsored extensive research to determine the most effective means of alerting motorists and pedestrians of approaching trains. The reports of the research focusing on audible warning devices indicate that primary reliance on these devices to warn motorists is not justified, and that to be loud enough to warn in all ordinary circumstances, the sound level would have to be increased greatly. The increased sound level would produce intolerable community and interior cab noise.

At the same time, FRA recognizes that there are circumstances where the use of the audible warning system plays an integral role in minimizing hazards due to approaching trains. It is for this reason that FRA has prescribed an objective measure of their performance by the specification of minimum decibel levels. The performance of an audible warning device may vary for a number of causes including not only its construction and its location, but also its general maintenance, problems involving the filtration of the air supply, and deterioration of the diaphragm. The present standard does not afford a convenient method for verifying that the audible warning device is "safe and suitable for service," other than the extremely subjective belief that it may not sound right. The most accurate method of determining the effectiveness is to rate its decibel output which can be readily verified with sound measurement equipment.

A major locomotive manufacturer claimed that their present three chime horn would not meet the proposed decibel levels. In particular, they were concerned that they could not meet the proposed 96dB(A) requirement at 100 feet from the rear of the locomotive and recommended that FRA specify 92dB(A) at this position.

FRA's intention in setting minimum decibel levels for audible warning devices was to prescribe a method for determining if these devices were being maintained and working properly. It was limits. In addition, remedial action would be facilitated by the identification of high noise sources in the locomotive under test. If such a valid test procedure can be developed, FRA will incorporate it as an appendix to these regulations as a suggested method of compliance.

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FRA's intention in setting minimum decibel levels for audible warning devices was to prescribe a method for determining if these devices were being maintained and working properly. It was not our intention to consign the well-maintained, standard three chime horn, to be out of compliance. FRA has further examined the measurement data relied upon when selecting the proposed levels, and a strong dependency on test measurement criteria such as weather conditions, topographical considerations, instrument tolerances, and reflecting objects has been revealed. In addition, measurements taken from the rear of the locomotive are heavily influenced by shadow effects of the hood structure, and line-of-sight limitations.

Accordingly, the final regulation has been revised to account for these effects by allowing a 4dB measurement tolerance. (Included in this tolerance is the generally accepted 2dB instrument tolerance.) It should also be recognized that a listener perceives a change of this magnitude as a relatively small difference in loudness.

A number of commenters claimed that the requirement that one chime of the audible warning device face in the direction of travel was redundant and should be deleted. Another commenter suggested that FRA require at least two chimes face in the forward direction.

FRA has re-examined its approach regarding the additional requirement on the chime direction of the warning device. The commenters' concerns regarding this issue have merit. FRA has specified a minimum decibel standard for the audible warning device to ensure that it is functioning properly. In addition, to account for reverse movement, we have required that this decibel level must be satisfied in the direction of travel of the locomotive. To impose a further requirement on chime direction is redundant and not integral to our stated goal. FRA has also concluded that it is not prudent to mandate a particular horn location or orientation for all locomotives. Accordingly, the chime direction requirement has been deleted in the final rule.

One commenter suggested that this section be revised to ensure that the occupants of the cab are protected from the noise of the audible warning device. In particular, it was suggested that FRA require that the device be located on the center line of the roof of the locomotive as far forward as possible and that a means be devised to deflect the sound away from the cab. The commenter's concerns over interior cab noise levels are addressed in § 229.121 by the specific occupational noise limits for cab noise exposure contained in that section.

A few commenters were concerned that FRA did not prescribe a measurement methodology to account for topography, speed, and other factors. The commenters' concern over the lack of a measurement methodolgy is partially addressed by the incorporation in the final rule of the measurement tolerance which will account for the cited variables. We believe this approach is preferable to imposing restrictive test criteria. However, to further minimize test variability, the requirements on sound level type and meter response characteristic have been expanded by a specification on microphone position when performing measurements.

Three commenters were concerned that their audible warning devices on MU cars would not meet the decibel or direction of at least one chime requirement. They suggested that these cars should be exempt from this section, or alternatively, that the effective date be adjusted to allow for waiver applications. They based this contention on the fact that their operations were unique due to grade crossing protection, speed restrictions, and travel through noise-sensitive areas.

FRA agrees that due to the diversity of the railroad industry, differing individual circumstances may justify waiver of the provisions of this rule. However, FRA does not believe, based on the information supplied, that there is a reasonable basis to generally exempt these operations from the rule itself. Rather, a petition for waiver of this provision is a more appropriate method by which to address the special problems of an individual carrier or particular operation. The effective date of the section has been delayed for a period of several months. This time period will allow for both a familiarization period as well as an opportunity to seek a waiver from the requirements if appropriate.

§ 229.131 Sanders.

No comments were received and no change has been made.

§ 220.141 Body structure, MU locomotives.

No comments. No change.

Civil Penalty Policy

RLEA was the only commenter that addressed the issue of civil penalties. RLEA stated that the minimum penalty for any violation should be higher than $250. FRA's discretion regarding the amount of civil penalties assessed is circumscribed by the provisions of the Locomotive Inspection Act, as amended. Section 9 of that Act (45 U.S.C. 34) provides that penalties for violations of rules, regulations or orders made under it shall be not less than $250 and not more than $2,500.

Appendix B to the final rule contains a revised penalty schedule that equates the amount of penalties to be assessed with the nature and degree of violations.

The purpose of Federal regulation of locomotives is to promote the safety of employees and the public. The achievement of that purpose is directly dependent upon compliance with the regulations. Therefore, the penalty levels for non-compliance should be structured in a manner that will effectively promote future compliance with the regulations. FRA believes that the revised penalty schedule will help to achieve that objective by refining the correlation between the degree of hazard presented by a violative condition and the amount of penalty assessed.

Appendix B of the final rule prescribes substantial penalties for violations of the rule. Where the degree of non-compliance could be objectively quantified, corresponding distinctions have been established in the penalty levels. In general, the highest penalities have been reserved for conditions that involve the greatest threat to the safety of employees and the public.

Appendix B provides for higher penalties where the circumstances indicate violations to be intentional. An intentional violation is the knowing and willful failure of a carrier to comply with the provisions of this final rule. The knowledge required for an intentional violation is knowledge of the facts constituting the violation. Knowledge of the regulations by a carrier is presumed by law. There are two instances that constitute *prima facie* evidence that a violation was knowing and willful; first, where there is evidence that a violation has been committed or has been allowed to continue by a carrier after an FRA Inspector has provided the carrier with notification of deviation from the requirements of this rule; and second, where a carrier has made any repair to the locomotive component or appurtenance but has not brought that component or appurtenance into full compliance with this rule.

Under the penalty schedule, the locomotive (as opposed to individual deviations from this rule of individual components and appurtenance) remains the essential unit of violation. However, failure to perform, with respect to a particular locomotive, any of the inspections and tests required under Subpart B of this rule will be treated as a violation separate from, and in addition to, any other violative conditions detected on that locomotive. Penalties associated with individual

§ 229.121 Locomotive cab noise.

(a) After August 31, 1980, the permissible exposure to a continuous noise in a locomotive cab shall not exceed an eight-hour time-weighted average of 90dB(A), with a doubling rate of 5 dB(A) as indicated in the table. Continuous noise is any sound with a rise time of more than 35 milliseconds to peak intensity and a duration of more than 500 milliseconds to the time when the level is 20dB below the peak.

Duration permitted (hours)	*Sound level (dB(A))*
12	87
8	90
6	92
4	95
2	100
1½	102
1	105
½	110
¼ or less	115

(b) When the continuous noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect shall be considered. Exposure to different levels for various periods of time shall be computed according to the following formula:

$D = T_1/L_1 + T_2/L_2 + \ldots T_n/L_n$

Where:
D = noise dose.
T = the duration of exposure (in hours) at a given continuous noise level.
L = the limit (in hours) for the level present during the time T (from the table).
If the value of D exceeds 1, the exposure exceeds permissible levels.

(c) Exposure to continuous noise shall not exceed 115dB(A).

(d) Noise measurements shall be made under typical operating conditions using a sound level meter conforming, at a minimum, to the requirements of ANSI S1.4-1971, Type 2, and set to an A-weighted slow response or with an audiodosimeter of equivalent accuracy and precision.

(e) In conducting sound level measurements with a sound level meter, the microphone shall be oriented vertically and positioned approximately 15 centimeters from and on axis with the crew member's ear. Measurements with an audiodosimeter shall be conducted in accordance with manufacturer's procedures as to microphone placement and orientation.

§ 229.123 Pilots, snowplows, end plates.

After January 1, 1981, each lead locomotive shall be equipped with an end plate that extends across both rails, a pilot, or a snowplow. The minimum clearance above the rail of the pilot, snowplow or end plate shall be 3 inches, and the maximum clearance 6 inches.

§ 229.125 Headlights.

(a) Each lead locomotive used in road service shall have a headlight that produces at least 200,000 candela. If a locomotive or locomotive consist in road service is regularly required to run backward for any portion of its trip other than to pick up a detached portion of its train or to make terminal movements, it shall also have on its rear a headlight that produces at least 200,000 candela. Each headlight shall be arranged to illuminate a person at least 800 feet ahead and in front of the headlight.

(b) Each locomotive or locomotive consist used in yard service shall have two headlights, one located on the front of the locomotive or locomotive consist and one on its rear. Each headlight shall produce at least 60,000 candela and shall be arranged to illuminate a person at least 300 feet ahead and in front of the headlight.

(c) Headlights shall be provided with a device to dim the light.

§ 229.127 Cab lights.

(a) Each locomotive shall have cab lights which will provide sufficient illumination for the control instruments, meters, and gauges to enable the engine crew to make accurate readings from their normal positions in the cab. These lights shall be located, constructed, and maintained so that light shines only on those parts requiring illumination and does not interfere with the crew's vision of the track and signals. Each controlling locomotive shall also have a conveniently located light that can be readily turned on and off by the persons operating the locomotive and that provides sufficient illumination for them to read train orders and timetables.

(b) Cab passageways and compartments shall have adequate illumination.

§ 229.129 Audible warning device.

(a) After August 31, 1980, each lead locomotive shall be provided with an audible warning device that produces a minimum sound level of 96db(A) at 100 feet forward of the locomotive in its direction of travel. The device shall be arranged so that it can be conveniently operated from the engineer's normal position in the cab.

(b) Measurement of the sound level shall be made using a sound level meter conforming, at a minimum, to the requirements of ANSI S1.4-1971, Type 2, and set to an A-weighted slow response. While the locomotive is on level tangent track, the microphone shall be positioned 4 feet above the ground at the center line of the track, and shall be oriented with respect to the sound source in accordance with the manufacturer's recommendations.

(c) A 4dB(A) measurement tolerance is allowable for a given measurement.

§ 229.131 Sanders.

Except for MU locomotives, each locomotive shall be equipped with operable sanders that deposit sand on each rail in front of the first power-operated wheel set in the direction of movement.

Subpart D—Design Requirements

§ 229.141 Body structure, MU locomotives.

(a) MU locomotives built new after April 1, 1956 that are operated in trains having a total empty weight of 600,000 pounds or more shall have a body structure designed to meet or exceed the following minimum specifications:

(1) The body structure shall resist a minimum static end load of 800,000 pounds at the rear draft stops ahead of the bolster on the center line of draft, without developing any permanent deformation in any member of the body structure.

(2) An anti-climbing arrangement shall be applied at each end that is designed so that coupled MU locomotives under full compression shall mate in a manner that will resist one locomotive from climbing the other. This arrangement shall resist a vertical load of 100,000 pounds without exceeding the yield point of its various parts or its attachments to the body structure.

(3) The coupler carrier and its connections to the body structure shall be designed to resist a vertical downward thrust from the coupler shank of 100,000 pounds for any horizontal position of the coupler, without exceeding the yield points of the materials used. When yielding type of coupler carrier is used, an auxiliary arrangement shall be provided that complies with these requirements.

(4) The outside end of each locomotive shall be provided with two main vertical members, one at each side of the diaphragm opening; each main member shall have an ultimate shear value of not less than 300,000 pounds at a point even with the top of the underframe member to which it is attached. The attachment of these members at bottom shall be sufficient to develop their full shear value. If reinforcement is used to provide the shear value, the reinforcement shall have full value for a distance of 18 inches up from the underframe connection and then taper to a point approximately 30 inches above the underframe connection.

APPENDIX D

Recommended Reading Material on Noise Measurement, Assessment, and Control

The following books are recommended for further reading in the field of noise measurement, assessment, and control:

1. Noise and Vibration Control, L.L. Beranek, McGraw-Hill Book Company, 1971.
2. Environmental Noise Control, E.B. Magrab, Wiley & Sons, 1975.
3. Noise and Noise Control, Volume I, M.J. Crocker and A.J. Price, CRC Press, 1975.
4. Noise Control – Handbook of Principles and Practices, D.M. Lipscomb and A.C. Taylor, Van Nostrand, 1978.
5. Handbook of Noise Assessment, D.N. May, Van Nostrand, 1978.
6. Handbook of Noise Control, C.M. Harris, McGraw-Hill Book Company, 1979.

The following journals and magazines are recommended for current information on noise measurement, assessment, and control:

1. Journal of the Acoustical Society of America, American Institute of Physics, 335 East 45th Street, New York, NY 10017.
2. Journal of Sound and Vibration, Academic Press, Inc., 111 Fifth Avenue, New York, NY 10003.
3. Noise Control Engineering, Noise/News, and Proceedings of InterNoise, Institute of Noise Control Engineering, P.O. Box 3206, Arlington Branch, Poughkeepsie, New York 12603.
4. Sound and Vibration and Proceedings of NOISEXPO, Acoustical Publications, Inc., P.O. Box 9665, 27101 E. Oviatt Road, Bay Village, Ohio 44140.
5. Noise Regulation Reporter, Bureau of National Affairs, Inc., 1231 25th Street, N.W., Washington, D.C. 20037.
6. Noise Control Report, Business Publishers, Inc., P.O. Box 1067, Blair Station, Silver Spring, Maryland 20910.

The following reports contain detailed information on the noise emissions from specific railroad noise sources, as well as procedures for estimating noise levels around railroad yards:

1. "Assessment of Noise Environments Around Railroad Operations," J.W. Swing and D.B. Pies, Wyle Laboratories Report WCR 73-5, July 1973.
2. "Railroad Environmental Noise: A State-of-the-Art Assessment," E.K. Bender et al., BBN Report No. 2709, January 1974.
3. "Measurements of Railroad Noise-Line Operations, Yard Boundaries, and Retarders," J.M. Fath et al., National Bureau of Standards Report NBSIR 74-488, December 1974.
4. "An Assessment of Railroad Locomotive Noise," P.J. Remington and M.J. Rudd, DOT-TSC-OST-76-4/FRA-OR&D-76-142, August 1976.
5. "Railroad and Rail Transit Noise Sources," R. Lotz, Journal of Sound & Vibration, Vol. 51, No. 3, April 1977.
6. "Final Report on Measurement and Analysis of Freight Train Noise," C.W. Rodman, M. Kurze, and R.H. Prause, Battelle Columbus Laboratories, July 1978.
7. "Prediction and Control of Noise and Vibration in Rail Transit Systems," L.G. Kurzweil and R. Lotz, UMTA Report No. UMTA-MA-06-0025-78-8, September 1978.
8. "Measurement and Diagnosis of the Noise From a General Electric C36-7 Diesel Electric Locomotive," P.J. Remington et al., BBN Report No. 4167, August 1979.

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9. "Rail Transportation Noise," R. Lotz and L.G. Kurzweil, Ch. 33 in Handbook of Noise Control, edited by C.M. Harris, McGraw-Hill, 1979.

10. "The Measurement of Locomotive Noise at Existing Railroad Test Sites," P.J. Remington et al., FRA/ORD-79/55, November 1979.

The following U.S. Environmental Protection Agency reports were prepared as part of the development of some of the regulations discussed in the Handbook.

- "Background Document/Environmental Explanation for Proposed Interstate Rail Carrier Noise Emission Regulations," EPA-550/9-74-005a, June 1974.
- "Background Document for Railroad Noise Emission Standards," EPA-550/9-76-005, December 1975.
- "Background Document for Proposed Revision to Rail Carrier Noise Emission Regulations," EPA-550/9-78-207, February 1979.
- "Background Document for Final Interstate Rail Carrier Noise Emission Regulation: Source Standards," EPA-550/9-79-210, December 1979.