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BACKGROUND DOCUMENT/ ENVIRONMENTAL EXPLANATION FOR PROPOSED INTERSTATE RAIL CARRIER NOISE EMISSION REGULATIONS

June 1974

OFFICE OF NOISE ABATEMENT AND CONTROL
WASHINGTON, D.C. 20460

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FOREWORD

The study of railroad noise is relatively new. Most of the information and data contained in this report has been generated during the past year. It is important to note that this report and the proposed regulations are an initial step in a continuing effort to understand and reduce railroad noise.

The Agency wishes to acknowledge the cooperation of a multitude of parties and to extend its appreciation for their efforts. Those parties include, but are by no means limited to, The Department of Transportation, Association of American Railroads, the Department of Commerce, and the National Bureau of Standards.

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SECTION 1

PROLOGUE

STATUTORY BASIS FOR ACTION

Through the Noise Control Act of 1972 (86 Stat. 1234), Congress established a national policy "to promote an environment for all Americans free from noise that jeopardizes their health and welfare." In pursuit of that policy, Congress stated, in Section 2 of the Act, "that while primary responsibility for control of noise rests with State and local governments, Federal action is essential to deal with major noise sources in commerce, control of which requires national uniformity of treatment." As a part of this essential Federal action, Section 17 requires the Administrator to publish proposed noise emission regulations that "shall include noise emission standards setting such limits on noise emissions resulting from operation of the equipment and facilities of surface carriers engaged in interstate commerce by railroad which reflect the degree of noise reduction achievable through the application of the best available technology, taking into account the cost of compliance."

These two sections of the Act establish the criteria the Administrator has followed in the development of these proposed regulations. Section 17 does not contemplate the promulgation of regulations covering every aspect of the massive, complex interstate railroad industry, but only those on noise emissions from particular equipment and facilities of that industry. The types of equipment and facilities to be covered by Federal regulations are those that are "major noise sources in commerce," which require "national uniformity of treatment." The need for national uniformity of treatment depends largely upon interference with interstate commerce that would be caused by the lack of national uniformity. Regardless of whether or not there are Federal regulations on noise emissions from any type of interstate railroad equipment or facility under Section 17, the states and localities are barred by the Commerce Clause of the Constitution from imposing any regulations that would constitute an undue burden on interstate commerce.

Regulations under Section 17 are to be promulgated after consultation with the Secretary of Transportation in order to ensure appropriate consideration for safety and technological availability. They are to take effect after such period as the Administrator finds necessary, after consultation with the Secretary of Transportation, to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period. Final regulations are to be promulgated within 90 days after publication of the proposed regulations and may be revised from time to time in accordance with Subsection 17(a)(2) of the Noise

Control Act. These regulations under Section 17 of the Noise Control Act shall be in addition to any regulations that may be proposed under Section 6 of the Act.

Section 17(b) of the Noise Control Act requires the Secretary of Transportation, after consultation with the Administrator, to promulgate regulations to ensure compliance with all standards promulgated by the Administrator under Section 17. The Secretary of Transportation shall 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, and the Department of Transportation Act. Regulations promulgated under Section 17 shall be subject to the provisior of Sections 10, 11, 12, and 16 of the Noise Control Act.

INTERNAL EPA PROCEDURE

The rulemaking process of EPA started with the publication of an Advanced Notice of Proposed Rulemaking in the *Federal Register*. At that time EPA informed the public of the requirement that regulations be developed and requested that pertinent information be submitted to the Agency for consideration. In the case of interstate rail carrier regulations, a task force was formed about the same time and was composed of Federal, State, and local government officials and consultants. The Office of Noise Abatement and Control considered recommendations of the Task Force with the recommendations of the EPA Working Group, which is comprised of representatives from various parts of the Agency, in developing the proposed regulation. After the Deputy Assistant Administrator for Noise Control Programs approved the proposed regulations, they were submitted to the Assistant Administrator for Air and Waste Management Programs, who has responsiblity for the Noise Control Program as well as several other programs. Following the Assistant Administrator's approval, the proposed regulations were submitted to the EPA Steering Committee, which is comprised of "' the Deputy Assistant Administrators of EPA. Upon the Steering Committee's approval, the proposed regulations were forwarded to the Office of Management and Budget, and other interested Federal agencies, for review. After these comments were analyzed and satisfactorily addressed, the proposed regulations were submitted through the Assistant Administrator for Air and Waste Management Programs to the Administrator for final approval and ultimate publication in the *Federal Register*. The resulting public comments will be analyzed and a recommendation for the final regulation will be prepared by the Deputy Assistant Administrator for Noise Control Programs. The review process followed in the case of the proposed regulation will then be initiated again, culminating in the promulgation of the regulation.

PREEMPTION

Under Subsection 17(c)(1) of the Noise Control Act, after the effective date of these regulations no State or political subdivision thereof may adopt or enforce any standard applicable to noise emissions resulting from the operation of locomotives or railroad cars of surface carriers engaged in interstate commerce by railroad unless such standard is identical to the standard prescribed by these regulations. Subsection 17(c)(2), however, provides that this section does not diminish or enhance the rights of any State or political subdivision thereof to establish and enforce standards or controls on levels of environmental noise, or to control, license, regulate, or restrict the use, operation, or movement of any train if the Administrator, after consultation with the Secretary of Transportation, determines that such standard, control, license, regulation, or restriction is necessitated by special local conditions and is not in conflict with regulations promulgated under Section 17.

Conversely, Subsection 17(c)(1) does not in any way preempt State or local standards applicable to noise emissions resulting from the operation of any equipment or facility of interstate railroads not covered by Federal regulations. Thus, under the proposed regulations, the States and localities will remain free to enact and enforce noise standards on railroad equipment and facilities other than trains without any special determination by the Administrator. Only after a Federal regulation on noise emissions resulting from the operation of a particular type of railroad equipment or facility has become effective must the States and localties obtain a determination by the Administrator under Subsection 17(c)(2) where it is believed that special local conditions necessitate particular consideration.

Some types of railroad equipment and facilities on which no Federal noise standards or regulations have become effective, and which may, therefore, be subjected to State and local noise standards without any special determination by the Administrator, may include other types of equipment or facilities that are covered by preemptive Federal regulations. Railroad maintenance shops, for example, may from time to time emit the noise of locomotives undergoing tests along with noises common to many industrial operations such as forging and grinding. Also, railroad marshaling yards include locomotives among their many types of noise sources.

In most instances, State or local standards on non-Federally regulated equipment or facilities of railroads can be met without affecting the Federally regulated equipment within them. Standards on noise emission from repair shops, for example, can be met by many measures including improved sound insulation in the walls of the shop, buffer zones of land between the shop and noise-impacted areas, and scheduling the operation of the shop to reduce noise at those times of the day when its impact is most severe. Standards on railroad marshaling yards can be met by a variety of steps including: reducing the volume of loudspeaker systems by using a distributed sound system or replacing speakers with two-way radios, reducing noise emissions from equipment not covered by Federal regulations, installing noise barriers, acquiring additional land to act as a noise buffer, and locating noisy equipment such as parked refrigerator cars or idling locomotives as far as possible from adjacent noise-sensitive property. Since State or local regulations on noise emissions from railroad facilities that the railroad can meet by initiating measures such as these are not standards applicable to noise emission resulting from the operation of locomotives or railroad cars, they would not be preempted by the proposed regulations. Thus no special determination by the Administrator under Subsection 17(c)(2) would be necessary. State or local noise standards on facilities involved in interstate commerce such as railroad marshaling yards are, of course, subject to Constitutional prohibition if they are so stringent as to place an undue burden on commerce.

In some cases, however, a State or local noise standard that is not stated as a standard applicable to a Federally regulated type of equipment or facility may, in effect, be such a standard if the only way the standard can be met is by modifying the equipment to meet the Federal standard applicable to it. This would be the case, for example, if after the proposed regulations become effective a State or locality attempted to adopt or enforce a limit on noise emissions from railroad rights-of-way in urban areas that could not reasonably be met by measures such as noise barriers. Such a standard, would, in effect, require modifications to trains even though they met the Federal standards, and would be preempted under Subsection 17(c)(1). It could not stand if it differed from the Federal standards, unless the Administrator made the determinations specified in Subsection 17(c)(2). The same would be true of any State or local standard on railroad yards that could not reasonably be met except by modifying locomotives or railroad cars subject to the Federal standards.

State or local use or operation regulations directly applicable to noise emissions resulting from the operation of Federally regulated equipment and facilities can, of course, stand if the Administrator makes the determinations specified in Subsection 17(c)(2) regarding them.

State or local noise emission standards directly applicable to noise emissions resulting from the operation of Federally regulated equipment and facilities may also stand without any special determination by the Administrator if those standards are identical to the Federal standards. By adopting such identical standards, States and their political subdivisions can add their enforcement capability to that of the Department of Transportation. The Environmental Protection Agency recommends and encourages such adoption of standards identical to the Federal standards.

SECTION 2

DATA BASE FOR THE REGULATION

The program for compiling data on train noise began with a search for already existing data. By compiling the existing data, it was possible to avoid repeating the few measurements completed by others, and the limitations of the existing data indicated what measurements needed to be made to extend the data. Technical journals were searched for reports of pertinent measurements. Published accounts of measurements in Europe and Asia were considered along with the accounts of measurements in the United States and Canada. A bibliography of relevant articles appears after Section 9.

Much of the needed data was obtained by the EPA Regional Offices and under contract by acoustical consultants. Some data were obtained through informal communication with members of the acoustics community to obtain unpublished accounts of measurements and proceedings of appropriate seminars. Leaders in the engineering departments of the two locomotive manufacturers that remain in business (Electro-Motive Division of General Motors–EMD, and General Electric–GE) were also interviewed in order to ascertain the extent of their data files, as well as to determine what problems may be created by attempts to control locomotive noise. At a meeting hosted by the Association of American Railroads, EMD and GE engineers reported measurements of locomotive noise and discussed some possible effects of locomotive noise controls. Three leading muffler manufacturers (Donaldson, Harco Engineering, and Universal Silencer) were contacted in order to evaluate the feasibility and the impact of fitting locomotives with exhaust mufflers.

Railroad company personnel who worked in various capacities at various levels were contacted in order to determine the mix of equipment used by railroads, the configurations of properties and equipment, scheduling of operations, and modes of operation. In particular, yard masters, yard superintendants, or engineering personnel were contacted to obtain information about yard configuration, layout, and equipment. Railroad personnel were asked for information related to schedules and speeds of trains. The railroad companies that participated are listed in the bibliography at the end of this report.

SECTION 3

THE RAILROAD INDUSTRY

ECONOMIC STATUS

There are currently 72 Class I railroads in the U.S.* These tend to break down into two groups: large transportation companies such as the Union Pacific or the Penn Central and railroads that are owned by large industrial firms such as U.S. Steel. The latter roads primarily provide transportation services to the "parent company." Since railroads are regulated by the Interstate Commerce Commission (ICC), the degree of competition is also regulated. The size of the firms has in many cases been determined by whether the ICC has allowed or disapproved mergers. Most large roads have grown through mergers. In addition, the favorable financial position of some roads results from their nontransportation activities.

The total tonnage of freight moved in the U.S. has been rising over time, but the transportation sector of the economy has declined in relative importance. In 1950, 5.6% of national income originated in the transportation sector; by 1968 this figure declined to 3.8% and has remained at about that level. This trend reflects the higher relative growth rates in those industries that require a smaller transportation input.

The rail industry has declined more rapidly than the transportation sector. In 1950 the rail sector constituted 53% of the national income originating in the transportation sector. By 1968 it had declined to 25.8% of the transportation sector and has remained relatively stable since then. Table 3-1 summarizes these statistics.**

Accompanying the decline in the rail sector's share in national income originating in the transportation sector, the proportion of total freight hauled by rail has declined. In 1940 the railroads hauled 63.2% of all freight, dropping to 44.7% by 1960 and 39.9% by 1970. Motor carriers and oil pipelines have rapidly increased their share during this period. Air freight has increased more rapidly than either motor carriers or pipelines but it accounts for only .18% of total freight. In spite of the decreasing proportion of shipments by rail, the total volume of freight hauled by rail increased from 411.8 million ton miles in 1940 to 594.9 in 1960 and to 768.0 in 1970. Table 3-2 summarizes these trends.

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*Class I railroads are those having annual revenues of $5 million or more. They account for 99% of the national freight traffic.

**Unless otherwise stated, the data presented in Tables 3-1 through 3-6 were obtained from the Statistical Abstract of the United States (1971 and 1972).

TABLE 3-1
NATIONAL INCOME ORIGINATING IN THE TRANSPORTATION AND RAIL SECTORS
($ In Billions)

Year	National Income	Transportation	Transportation as % of National Income	Rail	Rail as % of Transportation
1950	$241.1	$13.4	5.6%	$7.1	53.0%
1960	414.5	18.2	4.5	6.7	36.8
1965	564.3	23.2	4.1	7.0	30.2
1968	712.7	27.1	3.8	7.0	25.8
1969	769.5	29.2	3.8	7.4	25.3
1970	795.9	29.5	3.7	7.2	24.4

TABLE 3-2
INTERCITY FREIGHT (In Millions of Ton Miles)

Year	Total Freight Volume in 10^6 Ton Miles	Rail Freight in 10^6 Ton Miles	Rail %	Motor Vehicles %	Oil Pipelines %	Air %	Inland Water %
1940	651.2	411.8	63.2	9.5	9.1	.002	18.1
1956	1376.3	677.0	49.2	18.1	16.7	.04	16.0
1960	1330.0	594.9	44.7	21.5	17.2	.06	16.6
1965	1651.0	721.1	43.7	21.8	18.6	.12	15.9
1968	1838.7	765.8	41.2	21.6	21.3	.16	15.9
1969	1898.0	780.0	41.1	21.3	21.7	.17	15.8
1970	1921.0	768	39.9	21.44	22.4	.18	15.98

Rail passenger service declined from 6.4% of intercity travel in 1950 to less than 1% in 1970. The real impact of railroads on the national economy is in terms of freight rather than passengers. The decline of the rail industry's share of the transportation sector is less dramatic when passenger service (air, local, suburban, and highway) is eliminated from calculations. Table 3-3 gives the transportation sectors' percentage contributions to national income, less the passenger sectors mentioned above, and the rail industry's percent of the transportation sector.

From comparison of Tables 3-1 and 3-3, it can be seen that the freight sector has declined more rapidly than the total transportation sector. It can also be seen that the railroads' decline is somewhat less dramatic in terms of freight alone than in terms of both freight and passenger service.

TABLE 3-3
PERCENT OF NATIONAL INCOME ORIGINATING IN THE TRANSPORTATION SECTOR (LESS AIRLINE AND LOCAL SUBURBAN AND HIGHWAY PASSENGERS) AND THE RAIL SECTOR AS A PERCENT OF TRANSPORTATION

Year	Transportation* (Adjusted) as % of National Income	Railroads as % of Transportation (Adjusted)
1950	4.8%	61.7%
1960	3.7	44.1
1965	3.3	37.6
1968	3.0	33.0
1969	3.0	32.3
1970	2.9	Not Available

*Transportation minus air carriers and local suburban and highway passengers.

EMPLOYMENT

The railroads' importance as a source of employment within the economy has decreased along with their share of the nation's transportation output. In 1950 the railroads accounted for 2.7% of all employees in nonagricultural establishments. By 1970 this had fallen to less than 1%. Not only has the relative importance of railroads declined but also the absolute level of employment from 1950 to 1970 decreased by over 50%, as shown in Table 3-4.

Wages in the rail sector have consistently been above the average of all manufacturing employees and this differential has increased over the years. In 1950 the average hourly compensation in the rail sector was $1.60, which was 110% of the average hourly compensation in manufacturing. In 1968 average compensation was $3.54, or 118% of that in manufacturing. By 1971 rail compensation had increased to 126% of the average compensation in the manufacturing sector.

Increases in wage rates in the rail sector have been greater than the increases in the wage rates in the manufacturing sector. Using 1967 as the base (= 100), the index of wage rates in manufacturing in 1970 was 121.6 while the rail industry index was 125.6. Over the same period the increase in productivity in the rail industry has been less than productivity increases in manufacturing. In 1970 the index of output for all railroad employees was 109.9* while in manufacturing it was 111.6 (using a 1967 base of 100). Table 3-5 summarizes the wage and productivity data.

*Computed on the basis of revenue per man hour.

TABLE 3-4
EMPLOYMENT IN THE RAIL INDUSTRY
RELATIVE TO THE NATIONAL ECONOMY

Year	National Employees in All Nonagricultural Establishments (1000)	Railroad Employment (1000)	Railroad as % of National
1950	45,222	1220	2.7%
1960	54,234	780	1.4
1965	60,815	640	1.1
1968	67,915	591	.9
1969	70,274	578	.8
1970	70,664	566	.8

TABLE 3-5
INDEX OF OUTPUT PER MAN HOUR AND WAGES
(1967 = 100)

Year	Rail Wage	Manufacturing Wage	Rail Productivity	Manufacturing Productivity
1950	41.5	44.7	42.0	64.4
1960	74.3	76.6	63.6	79.9
1965	88.9	91.2	90.8	98.3
1968	106.3	107.1	104.4	104.7
1969	113.6	113.9	109.3	107.7
1970	125.6	121.6	109.9	116.6

The fact that productivity increases have not kept pace with wage rate increases indicates that unit labor cost is rising.

In the years since 1970, wages in the rail industry have, as in most industries, increased rapidly. The index of wages in 1971 was 136.8; in 1972, 136.8; and in 1973, 165.4 (estimated).

HEALTH OF THE INDUSTRY

There are a number of measures one might use to judge the "health" or financial stability of the rail industry. Two of these are the rate of return on stockholders' equity and the percent of revenue carried through to net operating revenue. Shareholders' equity is the excess of assets over liabilities, which is equal to the book value of capital stock and surplus.

In 1971 the rate of return on stockholders' equity for all manufacturing firms was 10.8%. The rates of returns in some selected industries are as follows:

instruments, photo goods, etc.	15.8%
glass products	11.1%
distilling	9.9%
nonferrous metals	5.2%

The return for the total transportation sector was 3.1%. Railroads showed a 2.1% on stockholders' equity, slightly above the airlines' 2.0%.

The rate of return on stockholders' equity increased from 1.3% in 1971 to 3.0% in 1972. The use of industry data, however, tends to give a misleading impression of the industry.*

The Eastern District had a negative rate of return for the three years from 1970 to 1972 while both the Southern and Western Districts had positive and increasing rates of returns. The Southern District showed an increase from 5.2% to 6.1% and the West from 3.7 to 5.1%. The rates of returns in these districts are well above the 3.1% for total transportation and are about equal to the textile and paper industries.

These trends indicate that the problem in the rail industry is not with all districts but primarily with roads in the Eastern District. Using operating ratios** as the measure of financial stability, one draws the same conclusions.

The historical trends in the profitability of the industry can be measured by the percent of gross revenue that is carried through to net operating income before Federal income taxes. This measure is similar to the rate of return on sales before taxes. For the industry as a whole, the percent of gross revenue carried through has been declining. This is also true of each district, with the Eastern being the worst. Table 3-6 summarizes these trends.

The performance of the Southern and Western Districts is much better than the Eastern. In fact, one would conclude that compared with nonregulated industries such as steel, the Southern and Western roads are reasonably good performers. Compared with other regulated industries, such as public utilities (10.5% return on stockholders' equity) and telephone and telegraph companies (9.5% return on stockholders' equity), the railroads' rate of return is low. One point that should be made is that railroads follow a "betterment" accounting procedure, which tends to overstate the value of their assets. We have not attempted to adjust rate of return in the rail industry to reflect this.

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*Because the railroads use a nonstandard accounting procedure (the so-called betterment technique), the rate of return is low relative to what it would be if they used a procedure comparable to those used in the nonregulated sector.

**Operating ratio equals operation expenses divided by operating revenues.

TABLE 3-6
PERCENT OF GROSS REVENUE CARRIED THROUGH
TO NET OPERATING INCOME BEFORE FEDERAL INCOME TAXES

Year	All Class I RR's	Southern District	Eastern District	Western District
1950	17.3%	20.1%	12.0%	19.8%
1960	8.3	10.7	2.1	10.0
1965	11.0	12.1	10.0	11.6
1968	6.9	11.0	3.7	8.4
1969	6.6	12.1	2.7	8.0
1970	4.2	11.8	Nil	7.7
1971	4.0	10.3	0.5	7.2

The historical decline in the profitability of railroads came as a result of a decrease in the relative importance of high-weight, low-value cargo, which has traditionally been handled by rail. The increased competition from motor carriers and pipelines has further reduced the relative importance of railroads. Federal and State funding of highways has improved the competitive position of trucks and has led to the diversion of high-valued freight to motor carriers.

In 1935 when motor carriers came under Interstate Commerce Commission regulation, the value-of-service rate structure applied to railroads was also applied to motor carriers. (The value-of-service rate-making policy was originally applied to railroads in order to favor agricultural products. Under value-of-service rates, low-valued products have a lower rate per ton mile than do high-value products.*) his measure reduced intermodal price competition and in fact gave an advantage to trucks in carrying high-valued freight when they could give faster service. Railroads were unable to lower prices on this type of freight, which could have offset the faster service offered by trucks. The decline of some manufacturing industries in the East has led to a more intense financial crisis among eastern roads. Also the capital stock of these railroads tends to be older than that of the other roads. They spend a larger portion of total cost on yard switching than do either southern or western roads, due to shorter hauls and a larger number of interchanges among roads. Since shippers pay for movement from one point to another (i.e., rate per mile), the competitive position of railroads tends to be diminished if these nonline-haul expenses rise. The greater yard-switching results

*These points are examined in an article by R.H. Harbeson in the 1969 *Journal of Law and Economics*, pp. 321–338.

in having rail cars sit in switching yards waiting for a train to be made up, thus resulting in longer time in transit and higher comparative costs.

GROWTH

In projecting growth rates in any industry, it is assumed that historical trends and relationships will continue to hold in the future to some extent. If these relationships do continue, then rail freight can be projected based on projection of other figures. For example, rail freight service on the basis of population or gross national product can be projected. If the population continues to consume similar commodities, if these commodities move by the same modes of transportation, and if increases in income are ignored, then projections based on accurate population projections will be valid.

The ton miles of railroad freight per capita in the U.S. has remained quite stable over the past five years. It was 3.73 in 1965, 3.77 in 1968, and 3.75 in 1970. Given this stability, short-run projections based on population growth may be quite accurate. Based on the population projections for the U.S., about a 1% annual increase over the next 5 years is estimated. This would mean an increase from 768 million ton miles in 1970 to about 822 million ton miles in 1975.

The rail industry's contribution to national income has remained relatively constant over the period from 1968 to 1970 at about 1%. The long-run rate of growth in GNP has been about 3.5%. Again, under the assumption that these historical relationships hold, the long-run growth should be around 3.5%.

One factor which may reverse these trends is that rail movement uses less energy than other forms of freight movement. A ton mile of freight moved by rail requires 750 British thermal units (BTU), while pipelines require 1850, trucks 2400, and air freight 63,000. The only mode of freight movement more efficient (in terms of energy) than rail is water, which requires 500 BTU.*

Energy may come to be an important factor, but it seems unlikely that rail freight will increase more rapidly than the growth in national income. The factor militating against a more rapid increase is that consumption patterns have continued to move toward more services and fewer manufactured products. This means a smaller transportation input. In addition, rising interest rates and greater product differentiation have caused shippers to be increasingly concerned with time in transit. The railroads' real advantage is in rates, not speed. However, the advent of transporting entire truck trailers by rail has aided in reducing delivery time substantially in areas where this is practiced.

**Business Week*, McGraw-Hill, Inc., September 8, 1973, p. 63.

SECTION 4

RAILROAD NOISE SOURCES

GENERAL

Noise is generated by railroad operations in two basic locations: in yards and on lines. In railroad yards, trains are broken down and assembled and maintenance is performed. Line operations involve the sustained motion of locomotives pulling a string of cars over tracks.

The hump yard is an efficient system for disengaging cars from incoming trains and assembling them into appropriate outgoing trains. A locomotive pushes a string of cars up a small hill, known as a hump, allowing each car to roll individually down the other side through a series of switches onto the appropriate track where a train is being assembled. As each car rolls down the hump, it is first slowed by the "master" retarder. The slowing, or retarding, is accomplished by metal beams that squeeze the wheel of the rail car. After the cars leave the master retarder, they coast into a switching area that contains many tracks. As each car is switched onto a particular track, it is slowed by a "group" retarder. After a car moves out of a group retarder, it is switched onto one of many (approximately 50) tracks in the "classification" area where the car collides with another car. The collision causes the cars to couple, forming a train. In some yards, the first car that moves into the classification area along a particular track is stopped by an "inert" retarder, so-called because the retaining beam is spring-loaded and requires no external operation. Inert retarders differ from the master and group retarders, which are controlled continuously by an operator or automatically by a computer.

All three of the retarding processes described above produce noise. When the beam of a master or group retarder rubs against the wheels, a loud squeal often is generated. The most significant noise generated by inert retarders occurs when a string of cars is pulled through the retarders. If the inert retarders are short and exert small forces, they may generate noise that is negligible compared with the noise generated by the group retarders. Some yards are equipped with inert retarders that can be manually or automatically released when a string of cars is pulled through them thereby preventing retarder squeal. There are no inert retarders in some yards, so an individual brakeman must ride some cars and brake them manually.

Noise is also produced when cars couple in the classification area of the yard. The impact points, and thus the origins of the noise, are scattered over the classification yard. The noise is impulsive, and sometimes it is followed by a thunderlike rumble that is audible for several seconds after the impact.

Locomotive engines generate noise as the locomotives move around or pass through yards. When the locomotives are not in use, their engines are often allowed to idle continuously (even overnight), which also results in significant noise. When the locomotives are in motion, their horns, whistles, and bells may produce noise for warning purposes.

Some noise originates in the yard shops where locomotives and cars are repaired and maintained. Power tools and ventilation fans represent such sources. However, the most readily identifiable sources of shop noise are the locomotives themselves when undergoing testing.

Most yards are equipped with a number of loudspeakers that are used for conveying verbal instructions and warning sounds to workers in the yard. The speakers are scattered about the yard, and a given speaker issues sound on an unpredictable schedule.

Line, or wayside, noise--the noise in communities from passing trains--is comprised of many high noise sources. The locomotive engine and its components, such as exhaust systems and cooling fans, and the interaction of railroad car wheels with rails results in significant noise. Wheel/rail noise is caused principally by impact at rail joints, giving rise to the familiar "clickety-clack," and by small-scale wheel and rail roughness. A severe form of wheel roughness that generates high noise levels is caused by flat spots developed during hard braking. Also, wheels squeal on very sharp curves and generate noise by flange-rubbing on moderate curves. The operation of such auxiliaries as refrigeration equipment also contributes to the overall noise level. Horns or whistles are sounded at crossings and are significantly louder than the other wayside noises. In addition, some crossings are equipped with stationary bells that sound before and during the passage of trains.

The remainder of Section 4 treats each of the noise sources mentioned above separately and in as much detail as the state-of-the-art allows. Included in the discussion of each source is a description of abatement techniques.

CONSIDERATION OF RAILROAD NOISE SOURCES FOR FEDERAL REGULATION

Many railroad noise problems can best be controlled, at this time, by measures that do not require national uniformity of treatment to facilitate interstate commerce. The network of railroad operations is embedded into every corner of the country, including rights-of-way, spurs, stations, terminals, sidings, marshaling yards, maintenance shops, etc. Protection of the environment for such a complex and widespread industry is not simply a problem of modifying noisy equipment; it also gets into the minutiae of countless daily operations at thousands of locations across the country. The environmental impact of a given operation will vary depending on where it takes place, for example, whether it occurs in a desert or adjacent to a residential area. For this reason, state and local authorities appear better suited than the Federal government to consider fine details such as the addition of sound insulation or noise barriers to particular facilities, the location of noisy equipment within those facilities as far as possible from noise-sensitive areas, etc. There is no indication at present that differences in requirements for such measures from place to place impose any burden on interstate commerce. At this time, therefore, it appears that national uniformity of treatment of such measures is not needed to facilitate interstate commerce, and would not be in the best interest of environmental protection.

However, since the national effort to control noise has only just begun, it is inevitable that some presently unknown problems will come to light as the effort progresses. Experience may teach that there are better approaches to some aspects of the problem than those that now appear most desirable. The situation may change so as to call for a different approach. Section 17 of the Noise Control Act clearly gives the Administrator of the Environmental Protection Agency authority to set noise emission standards on the operation of all types of equipment and facilities of interstate railroads. If in the future it appears that a different approach is called for, either in regulating more equipment and facilities, or fewer, or regulating them in a different way or with different standards consistent with the criteria set forth in Section 17, these regulations will be revised accordingly.

The Administrator has considered the following broad categories of railroad noise sources in order to identify those types of equipment and facilities which reguire national uniformity of treatment through Federal noise regulations to facilitate interstate commerce.

Office Buildings

Many, if not all, surface carriers engaged in interstate commerce by railroad own and operate office buildings. These buildings are technically "facilities" of the carriers. Like all office buildings they may emit noise from their air conditioning and mechanical equipment. But since each building is permanently located in only one jurisdiction and is potentially subject only to its regulations, it is not affected in any significant way by the fact that different jurisdictions may impose different standards on noise emissions from the air conditioning and mechanical equipment of other buildings. At this time, there appears to be no need for national uniformity of treatment of these facilities, and they are therefore not covered by these proposed regulations.

Repair and Maintenance Shops

Railroad repair and maintenance shops are similar in many ways to many nonrailroad industrial facilities, such as machine shops, foundries, and forges. All such facilities can reduce their noise impact on the surrounding community by a variety of measures including reduction of noise emissions at the source, providing better sound insulation for their buildings, erecting noise barriers, buying more land to act as a noise buffer, scheduling noisy operations at times when their impact will be least severe, or simply moving noisy equipment to locations more remote from adjoining property. Such detailed and highly localized environmental considerations are best handled by local authorities. Like office buildings, shops are permanently located in only one jurisdiction and thus are not potentially subject to differing or conflicting noise regulations of other jurisdictions. At this time, therefore, there appears to be no need for national uniformity of treatment of these facilities, and they are not covered by these proposed regulations.

At times, railroad maintenance shops may contain major noise sources that do require national uniformity of treatment, such as locomotives. But the fact that some such individual noise sources within a shop may be subject to Federal noise emission regulations is irrelevant to the validity of State or local noise emission regulations applied to the shop as a whole, as long as the State or local regulation on the shop can reasonably be complied with without physically affecting the Federally regulated noise source within the shop (for example, by installing sound insulation in the shop building). This will be discussed further in the section on preemption below.

Terminals, Marshaling Yards, and Humping Yards

Like office buildings and shops, railroad terminals and yards are permanent installations normally subject to the environmental noise regulations of only one jurisdiction. Noise emissions from terminals and yards can also be reduced by many measures that do not require national uniformity of treatment and that can best be handled by local environmental authorities. These include measures such as placing noise barriers around such noise sources, for example, as retarders, acquiring land to act as a noise buffer, locating noisy equipment as far as possible from adjacent noise-sensitive property, and reducing the volume of loudspeaker systems or replacing them with two-way radios. At this time, there appears to be no need for national uniformity of treatment of these facilities, and they are not covered by the proposed regulations.

Some noise sources in railroad yards may at some point require national uniformity of treatment through Federal noise regulations, even though such sources may be permanently physically located in a yard. Such a circumstance could be occasioned because of the noise sources' intimate relationship to the movement of railroad trains. Rail car retarding operations in humping and marshaling yards, for example, produce individual peak noise levels of up to 120 dB(A) at 100 feet. Such retarding operations are an integral part of the movement of railroad trains. A number of measures are now being investigated which may make it technologically and economically feasible to control this noise at its source, i.e., the retarder. Such measures include lubrication of retarder beams, changes in the composition or design of the beams, and changes in the method of application of retarding force. At this time, however, it is the Agency's position that retarder noise is an element of fixed facility railroad yard noise which, as such, can best be controlled by measures which do not in themselves affect the movement of trains and therefore do not require national uniformity of treatment. Such noise control measures might include, for example, the erection of noise barriers. The Agency's study of railroad yard noise indicates that concern for noise from railroad yards is more local than national. This is due in large part to the location of a number of yards in non-urban areas. Accordingly, the establishment of a uniform national standard could potentially incur significant costs to the railroads with only limited environmental impact resulting in terms of population relief from undesirable noise levels. This subject is discussed in more detail in Appendices C and D of this document.

Like railroad maintenance shops, marshaling and humping yards contain some noise sources that are covered by the proposed regulations. As is discussed in greater detail in the preamble to the proposed regulations, a State or local noise regulation on a railroad terminal or yard is in effect a regulation on the Federally regulated noise sources within the terminal or yard when it can be met only by physically altering the Federally regulated noise sources.

Track and Right-of-way Design

Due to the intimate relationship between the track and the rail car wheels in the generation of rail car noise, the proposed regulations must preempt State and local regulations specific to track.

However, some steps can be taken to reduce noise emissions from railroad rights-of-way that do not in any way affect the operation of trains on the rights-of-way, such as the erection of noise barriers. State and local governments are much better situated than the Federal Government to determine if some noise-sensitive areas need such protection; and the existence of differing requirements for such measures in different areas does not at this time appear to impose any significant burden on interstate commerce. There is, at present, no need for national uniformity of treatment of such noise abatement techniques; and they are, therefore, not covered by the proposed regulations.

Horns, Whistles, Bells, and Other Warning Devices

These noises are different in nature from most other types of railroad noise since they are created intentionally to convey information to the hearer instead of as an unwanted by-product of some other activity. Railroad horns, whistles, bells, etc., are regulated at the Federal and State levels as safety devices rather than as noise sources. Federal safety regulations are confined to the inspection of such devices on locomotives, so as to ensure that, if present, they are suitably located and in good working order (Safety Appliance Act, 45 USCA; 49 Code of Federal Regulation, 127, 234, 236, 428, 429). State regulations are oriented toward specifying the conditions of use of these devices and, for the most part, do not specify any maximum or minimum allowable noise level for them. A recent survey of the 48 contiguous States (See Appendix B) has revealed the following:

1. At least 43 States require that trains must sound warning signals when approaching public crossings.
2. 35 of these States specify some minimum distance from a public crossing at which a train approaching that crossing may sound a warning signal.
3. 3 States specify a maximum distance from a public crossing at which a train approaching that crossing may sound a warning signal.
4. 35 States specify that these warning signals must be sounded until the train reaches the crossing.

5. 3 States specify that these warning signals must be sounded until the train completely clears the crossing.
6. 16 States provide for exceptions to their regulations for trains operating in incorporated areas.
7. At least two States provide for exceptions to their regulations for trains approaching public crossings that are equipped with satisfactory warning devices.

Two frequently proposed solutions to eliminate the need for trains to sound warning devices when approaching public crossings are:

1. Eliminate all public grade level railroad crossings.
2. Install active protection systems (e.g., flasher-gate combinations) at all public grade level railroad crossings.

This first solution would be the most effective since it would eliminate the source of the problem, the public grade level railroad crossing. However, it would be extremely costly because it would involve the elevating or depressing of either the railroad line or the public thoroughfare at each public crossing. This solution may be infeasible for solving existing conditions but it should be seriously considered in all future public thoroughfare or railroad line construction projects.

The second solution, although it does not attack the source of the problem, does seem to be an effective protection measure in that it could eliminate the need for the sounding of warning signals by trains approaching public crossings. This solution has its drawbacks, however. Flasher-gate-type devices cost $30,000-$40,000 with some installations costing up to $60,000. In the State of Illinois there are 16,250 grade level crossings of which 1,625 have flasher-gate protection devices. To outfit the remaining 15,000 crossings with these devices in that state alone would cost $450 million or more. The nationwide cost of this solution would be prohibitive.

Since train horns, whistles, bells, etc., are designed to emit a great deal of noise in the interests of safety, and since any regulation restricting the noise output of these devices could be construed as contrary to these interests, no regulatory action affecting these devices is being proposed at this time.

Special Purpose Equipment

Interstate rail carriers operate a number of types of special purpose rail cars, including snow plows, track laying equipment, and cranes. It is not clear to EPA at this time whether such equipment is used in such a manner as to require national uniformity of treatment; or, if such treatment is requisite, what noise emission standards should be applied to its operation. In any event, there does not appear to be any conflicting State or local regulations on such equipment at present. Accordingly, such special purpose equipment which may be located on or operated from rail cars is not covered by the proposed standards. However, the rail cars themselves on which such special purpose equipment is located or operated from are included under the proposed standards for rail car operations. If in the future it appears that national uniformity of treatment of such equipment is necessary, appropriate noise emission standards for it pursuant to Section 17 will be proposed.

Trains

Unlike the categories of railroad equipment and facilities discussed above, train noise is potentially subject to the noise regulations of more than one jurisdiction. Trains are constantly moving from one jurisdiction to another, and it is not feasible to have them stopped at political boundaries and adapted to meet a different noise standard. Moreover, they constitute a major source of noise to people close to railroad rights-of-way. The various sources of train noise (other than warning devices) are therefore covered by these proposed regulations in order to facilitate interstate commerce through national uniform treatment of their control.

CHARACTER OF RAILROAD NOISE SOURCES AND ABATEMENT TECHNOLOGY

Locomotives

Railroad locomotives are generally categorized as (1) steam, (2) diesel-electric, (3) electric or (4) gas turbine. The few remaining steam locomotives in the United States are preserved primarily as historical curiosities and are, therefore, not covered by the proposed regulations. In this subsection, noise associated with diesel-electric and electric/gas turbine locomotives are presented.

All measurements discussed in this section are A-weighted levels obtained by means of a microphone placed alongside a locomotive, and refer to 100 ft., unless otherwise noted. Details of the measurements are given in Section 6.

Diesel-Electric Locomotives

Three types of engines are currently in use: 2-stroke Rootes blown, 2-stroke turbocharged, and 4-stroke turbocharged. A turbocharged engine produces about 50% more power than does a Rootes blown engine. The number of cylinders on a diesel engine may be 8, 12, 16, or 20, with each cylinder having a displacement of 650 cu in. Each cylinder produces 125 hp when Rootes blown and 187.5 to 225 hp when turbocharged. These engines are employed on the two basic types of locomotive: the switcher, which is used primarily to shunt cars around the railroad yard and is powered by engines of under 1500 hp, and the road locomotive, which is used primarily for long hauls and is powered by engines of 1500 hp or more.

A diesel locomotive engine drives an electric alternator that produces electricity to run the electric traction motors attached to each axle of the locomotive. The rated power of the engine is the maximum electrical power delivered continuously by the alternator. The engine has eight possible throttle settings. As can be seen in Table 4-1, engine power and noise levels increase with throttle position. The data in this table are taken from a presentation given at an Association of American Railroads (AAR) meeting in August 1973, by the Electro-Motive Division (EMD) of General Motors Corporation, and were developed from a study of load cell information for a number of U.S. railroads. Of the approximately 27,000 locomotives in service on major railroads (see Appendix A), about 20,000 were built by EMD. The percent of horsepower and percent of time

TABLE 4-1
EFFECT OF THROTTLE POSITION ON
ENGINE POWER AND NOISE LEVELS

Throttle Position*	% of Rated hp for Diesel Engines	% of Time at Throttle Position		dB(A) at 100 Ft for 2000 hp Engine
		Road Loco	Switcher	
Idle	0.75†	41	77	69.5
1	5	3	7	72.0
2	12	3	8	74.0
3	23	3	4	77.0
4	35	3	2	80.0
5	51	3	1	84.5
6	66	3	–	86.0
7	86	3	–	87.5
8	100	30	1	89.0*

*Three cooling fans were operating during measurement for throttle position 8, only one fan for other measurements.
†Locomotive auxiliary hp only—no traction.

given for each throttle position are typical of all locomotives. The dB(A) levels vary, of course, from engine to engine. The example here is for a 2000 hp EMD GP40-2 locomotive.

Locomotive at Rest

During the course of this study, sound level measurements were made on individual locomotives at different power settings during load cell or self load testing. The results of these tests are shown in Table 4-2.

For purposes of separating the contributions of various components to overall engine noise levels, the prediction schemes employed in the Department of Transportation Report of 1970 were used. The predictions involve (1) determining the mechanical power and type of engine required to perform a given task, (2) determining the throttle setting required to perform a given task, and (3) converting from engine type and throttle setting to sound level. The expression for unmuffled diesel exhaust noise is

$$\text{dB(A) at 100 ft} = 92 + 10 \log (\text{hp}/1500) - 3\,(8\text{-throttle settings}) - T$$

where T is 6 for turbocharged engines and 0 otherwise. As can be seen in Figure 4-1, the predicted exhaust noise level for an EMD F7A locomotive at each throttle setting is very close to the measured total noise level. This result agrees well with the assumption that engine exhaust is the dominant

TABLE 4-2

STATIONARY NOISE EMISSION DATA FOR
GENERAL MOTORS AND GENERAL ELECTRIC LOCOMOTIVES

Locomotive Identification	Horsepower	Loading Conditions	Aspiration	Throttle Setting 0	Throttle Setting 8	Reference
EMD-SW1500	1500	T	----	---	84.5**	3
EMD-F7A	1500	T	--	66*	86	1
EMD-SW1500	1500	T	---	69*	92*	1
EMD-SW1500	1500	T	--	--	93	3
EMD SD 9 SD 4328	1750	T	RB	68	89	11
EMD 25014 SD 9	1750	--	RB	70	--	10
EMD-GP/SD38	2000	T	---	--	91.5	3
EMD 5077 GP 38-2	2000	S	RB	65	91	7
EMD GP 38-2 535	2000	S		67	88.5	7
EMD GP 38-2 535	2000	T	--	66.5	88.5	7
EMD 4115 72635-1 GP 38-2	2000	S	TC	66*	91	8
EMD 4111 72735-12 GP 38-2	2000	S	RB	63*	90	8
EMD 4053 5806-4 GP 38-2	2000	S	RB	62*	88	8
EMD 4050 5806-1 GP 38-2	2000	S	RB	61*	89	8
EMD 4508 SD 24	2400	T	TC	68	86.5	9
SD 35 1921	2500	T	---	69	86	7
EMD 29355 SD 35	2500	T	TC	68	88	8
EMD 1952 29340 SDP 35	2500	S	TC	70	88	8
EMD FP/SD-40	3000	T	----	72	89.5	3

TABLE 4-2 (Cont'd)

STATIONARY NOISE EMISSION DATA FOR
GENERAL MOTORS AND GENERAL ELECTRIC LOCOMOTIVES

Locomotive Identification	Horsepower	Loading Conditions	Aspiration	Throttle Setting 0	Throttle Setting 8	Reference
EMD GP 40 3049	3000	T	--	64.5	88	7
EMD GP 40 3018	3000	T	--	69.5	88.5	7
EMD GP 40 3182	3000	T	--	67	85.5	7
EMD GP 40 3195	3000	T	--	68.5	88	7
EMD GP 40 3156	3000	T	--	67	88	7
EMD 1559 32623 GP 40	3000	T	TC	69	92	8
EMD 1562 32960 GP 40	3000	T	TC	68	87	8
EMD GP40-2	3000	T	--	70*	88*	7
EMD 3115 SD 45	3200	S	TC	68	90	8
EMD 3124 SD 45	3200	S	TC	70	90	8
EMD SD 45-T2 SP 9212	3600	S	TC	72	94	11
EMD SD 45	3600	T	--	--	90.5	3
GE U25	2500	T	--	--	86*	5
GE 38573 4300	3000	---	TC	72	--	10
GE 1472 38417 U30C	3000	S	TC	66*	89	8
GE 1581 37970 U30C	3000	S	TC	65*	87	8

TABLE 4-2 (Cont'd)

STATIONARY NOISE EMISSION DATA FOR
GENERAL MOTORS AND GENERAL ELECTRIC LOCOMOTIVES

Locomotive Identification	Horsepower	Loading Conditions	Aspiration	Throttle Setting 0	Throttle Setting 8	Reference
GE 1473 38418 U30C	3000	S	TC	67*	87	8
GE U30	3000	T	--	--	86*	4
GE 3811 U33C	3300	S	TC	68	90	8
GE 8717 U36C 38879	3600	S	TC	72	91.5	9
GE U36B 1759	3600	S	--	68	91	
GE U36B 1825	3600	S	--	67	93	7
GE U36B 1780	3600	S	--	66	90.5	7
GE U36B 1855	3600	S	--	66	85.5	7
GE U36B 1832	3600	S	--	65	89.5	7
GE U36B 1815	3600	S	--	64.5	90	7
GE 1767 37430 U36B	3600	S	TC	66	87	3
GE 1796 37792 U36B	3600	S	TC	67	91	8
GE 1766 37429 U36B	3600	S	TC	67	93	8
GE 1771 37434 U36B	3600	S	TC	67	91	8
GE 1764 37427 U36B	3600	S	TC	67	94	8

TABLE 4-2 (Cont'd)

STATIONARY NOISE EMISSION DATA FOR
GENERAL MOTORS AND GENERAL ELECTRIC LOCOMOTIVES

Locomotive Identification	Horsepower	Loading Conditions	Aspiration	Throttle Setting 0	Throttle Setting 8	Reference
GE 1526 38048 U36B	3600	T	TC	66	90	8
GE 1800 37796 U36B	3600	S	TC	68	92	8
GE U36B	3600	S	---	64.5	90	7
	Sample Size			47	51	

S - Self Load
T - Load Cell
TC - Turbo Charged
RB - Rootes Blown

* Data taken at 50 ft.; 6 dB(A) added
** Pre-1960 muffler

	Idle	Throttle 8
Range	61-72 dB(A)	84.5-94 dB(A)
Mean	67.3 dB(A)	89.3 dB(A)
Standard Deviation	2.45 dB(A)	3.36 dB(A)

source mechanism in locomotive noise. A similar expression is used in Ref. 4 to predict the contribution of casing-radiated noise.

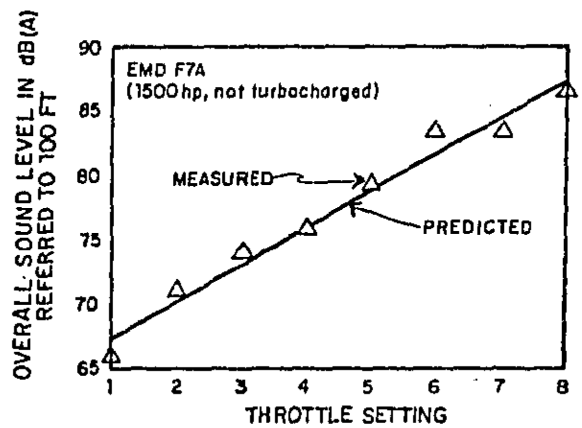

Figure 4-1. Measured Total and Predicted Exhaust Noise Levels

Table 4-3 gives the exhaust and casing noise levels predicted by the techniques in Ref. 4 for a number of locomotives as well as total noise measurements made by BBN, EMD, and GE. The measured data were gathered while the locomotive was stationary and under full load (throttle position 8) on a test cell. The engine was loaded by feeding the electric current into a resistor bank.

As can be seen in this table, the contribution of casing noise to overall level appears to increase with mechanical power. Thus, for small locomotives where the level of casing noise is considerably lower than exhaust levels, an exhaust muffler could provide substantial reduction in total locomotive noise. For larger locomotives, exhaust muffling alone cannot reduce overall levels as much as the small rootes-blown locomotives.

The average overall noise level for the EMD locomotives at 100 ft is 90 dB(A) ±4 db(A), where the variance includes allowances for all possible measurement and locomotive differences, for example, different observers and different test sites. The GE measurement for its 3000 hp locomotive is 86 dB(A) ±3 dB(A), again allowing for all possible measurement variations, slightly lower than those measured by EMD. The reason for this difference may be that on GE locomotives, the exhaust stacks rise about 6 in. above the hood, while on EMD locomotives the stacks are flush with the hood and radiate sound more efficiently.

In addition to exhaust and casing noise, the noise from cooling fans may be significant. Figure 4-2 shows that the noise from an EMD GP-40-2 3000 hp locomotive measured 9 dB(A) higher with three cooling fans running than with no fans running. Since it was necessary to open the

TABLE 4-3
COMPARISON OF PREDICTED AND MEASURED NOISE LEVELS AT 100 FT
FOR VARIOUS EMD AND GE LOCOMOTIVES IN THROTTLE POSITION 8

Mechanical Power and Type	Predicted Exhaust db(A)	Predicted Casing db(A)	Measured db(A)	No. of Samples	Spread db(A)	Source
EMD 1000 hp Switcher	90	78	–	0	–	–
EMD 1500 hp Switcher	92	80	93	2	±1	BBN
EMD 2000 hp Road Locomotive	93	81	89	2	±2	BBN
EMD 3000 hp Road Locomotive	89	83	89.5	1	–	EMD
GE 300 hp Road Locomotive	89	85.5	86	1	–	GE
EMD 3600 hp Road Locomotive	90	84	89	4	±3	BBN
GE 3600 hp Road Locomotive	90	86.5	–	0	–	–

engine access doors during the measurements, the recorded levels are somewhat higher than would be generated under normal operating conditions. However, there is little doubt that cooling-fan operation can contribute significantly to overall levels. The fans on GE engines run continuously, thus contributing to total noise level under all operating conditions. Fans on EMD locomotives are thermostatically controlled.

In summary, the major components of locomotive noise are, in order of significance, engine exhaust noise, casing-radiated noise, cooling fan noise, and wheel/rail noise. Table 4-4 shows average levels in dB(A) at 100 ft for each of these sources. Other sources, such as engine air intake, traction motor blowers, and the traction motors themselves, have noise levels too far below the other sources to be identified. Also, Rootes blown engines have a very unpleasant "bark" which does not show up in any generally used method of measurement.

Locomotive in Motion

Another method of characterizing locomotive noise is as a locomotive passes by a fixed point during normal operation. Levels recorded in this manner contain all sources of locomotive noise discussed previously. Measurements of this nature are very meaningful, since this is the noise that is emitted into the community. Unfortunately, the specific parameters that affect the level of noise produced are not easily controlled. These include horsepower, velocity, throttle setting and number

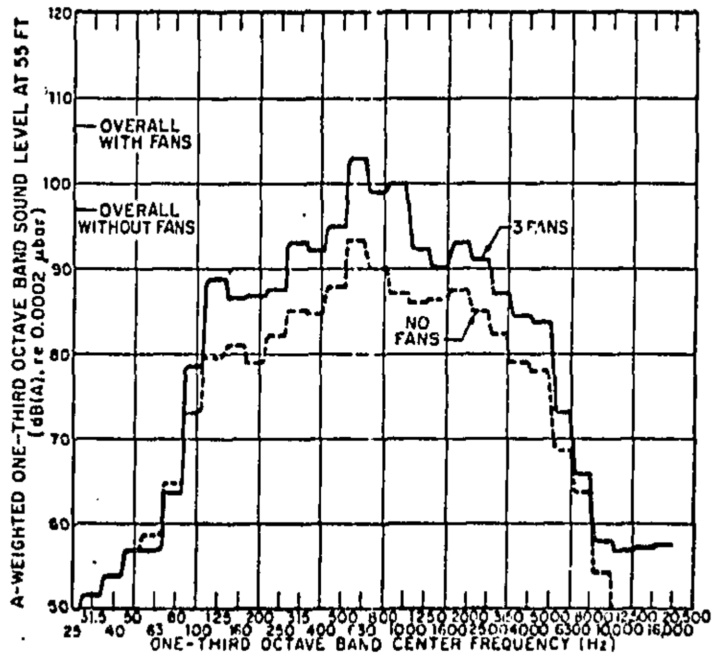

Figure 4-2. Effect of Fan Noise on the A-Weighted Spectrum of EMD GP40-2 Locomotive Noise at 55 ft (Engine Access Doors Open)

TABLE 4-4

SOURCE CONTRIBUTIONS TO LOCOMOTIVE NOISE LEVELS

(Based on Prediction Techniques of Ref. 4)

Source		dB(A) at 100 Ft (Throttle 8)
Exhaust		86–93
Casing		80–85.5
Cooling Fans		80–84
Wheel/Rail at 40 mph	Locomotive only	78
	Total train	81

of locomotive units coupled together. However, by recording the sound levels of a large number of pass-by events, typical levels may be established.

Figure 4-3 and Table 4-4.1 display the results of approximately 105 pass-by events. As indicated, locomotive pass-bys range from 74 dB(A) to 98 dB(A) when measured at 100 feet.

Figure 4-4 shows, for the same events, the maximum sound level as a function of the velocity. There does not appear to be a relationship between speed and maximum locomotive noise

Figure 4-5 relates, again for the same events, the maximum sound levels as a function of velocity and number of locomotives. There does not appear to be a definitive relationship between the number of coupled locomotives and the noise emitted.

The measurement of locomotive pass-by events is explained in Section 6.

Locomotive Noise Abatement

Locomotive noise abatement may be grouped into two broad categories (1) Abatement By Equipment Modification and (2) Abatement by Operational Procedures.

1. Abatement By Equipment Modifications:

Mufflers

Since locomotives contribute most of the noise of railroad operations and since exhaust noise dominates locomotive noise, the first step in reducing locomotive sound levels is to require that locomotives be fitted with an effective muffler. This section contains muffler manufacturer's estimates of various factors affecting the feasibility of supplying both new and in-service locomotives with mufflers.

One such factor is the amount of back pressure a muffler creates. Back pressures on the engine may affect its performance and life to a small extent. The engine must pump against the back pressure, thereby reducing the power that can be distributed to propel the train. Normally, this degradation in performance is about 1% when back pressures are held within manufacturers' limits. Back pressure may shorten engine life because when gases with increased temperature and density exhaust into a region of high pressure, they raise the temperature of exhaust valves and turbochargers. The following information on back pressure and its effects was determined by muffler manufacturers.

Engine Type	Back Pressure	Effect
Rootes Blown	47.5 in. H_2O measured at engine exhaust port	
Turbocharged	5 in. H_2O measured at exhaust stack	10°C rise in turbocharger temperature 20-hp loss on 3000 hp engine < 0.6% increase in fuel consumption

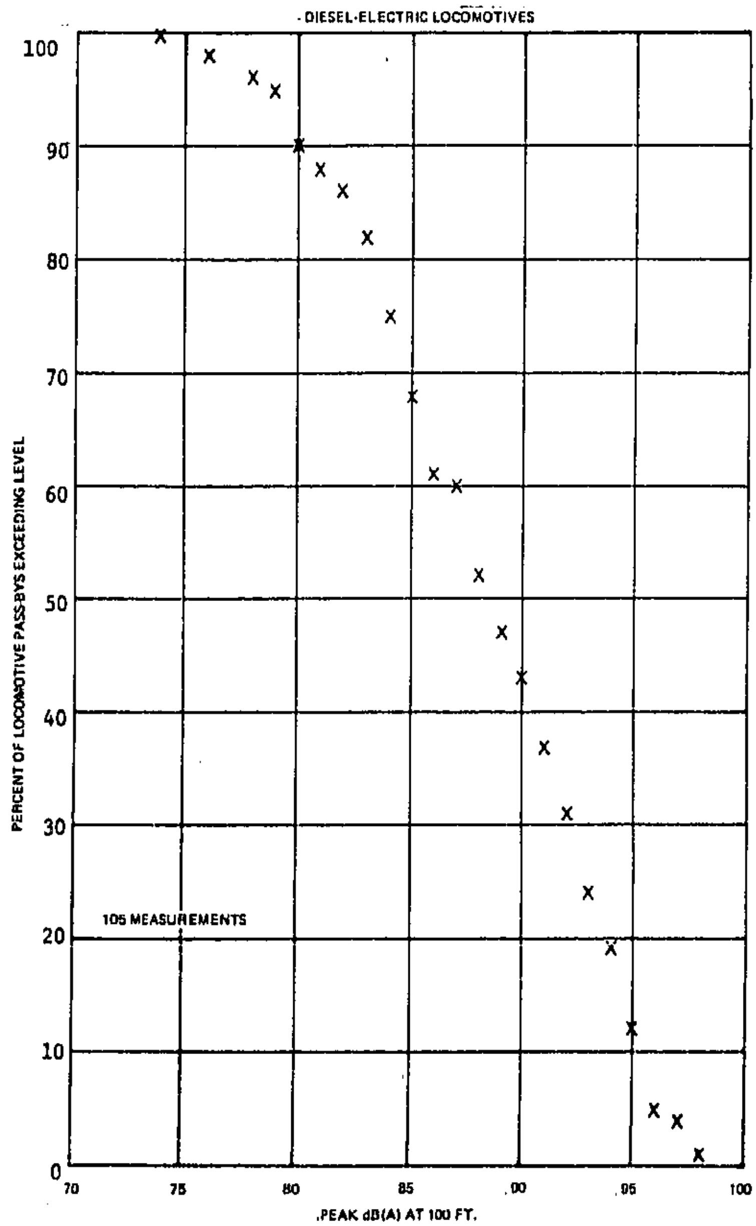

Figure 4-3. Diesel-Electric Locomotive Pass-Bys

TABLE 4-4.1
LOCOMOTIVE PASS-BY NOISE EMISSION LEVELS MEASURED AT 100 FEET
(see Figure 4-3)

Road Noise Studies

		I	II	III	IV	TOTAL
	74	1	1			2
	75					
	76				2	2
	77					
	78				1	1
	79	1	1	2	1	5
	80	2				2
	81				2	2
	82	2			2	4
	83	4	1	1	2	8
	84	3	1		3	7
	85	3	1		4	8
dB(A)	86			1		1
	87	1	2	3	2	8
	88	2			3	5
	89	1		2	1	4
	90	2	3	2		7
	91	4			2	6
	92	2	1	4		7
	93	3		2	1	6
	94	4		3		7
	95	3	1	2	1	7
	96	1				1
	97			2	1	3
	98	1		1		2

I. Department of Transportation – Office of Noise Abatement
II. Department of Commerce – National Bureau of Standards
III. Wyle Laboratories
IV. Environmental Protection Agency – Office of Noise Abatement and Control

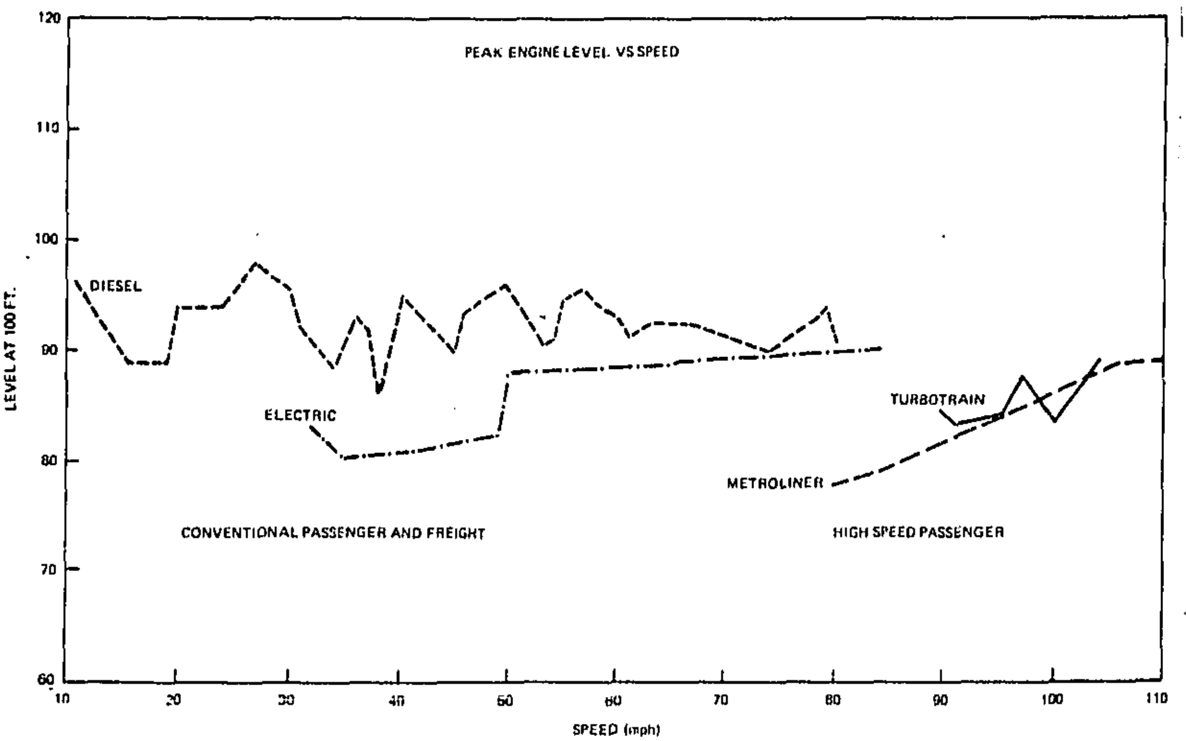

Figure 4-4. Peak Locomotive Noise Level vs. Speed

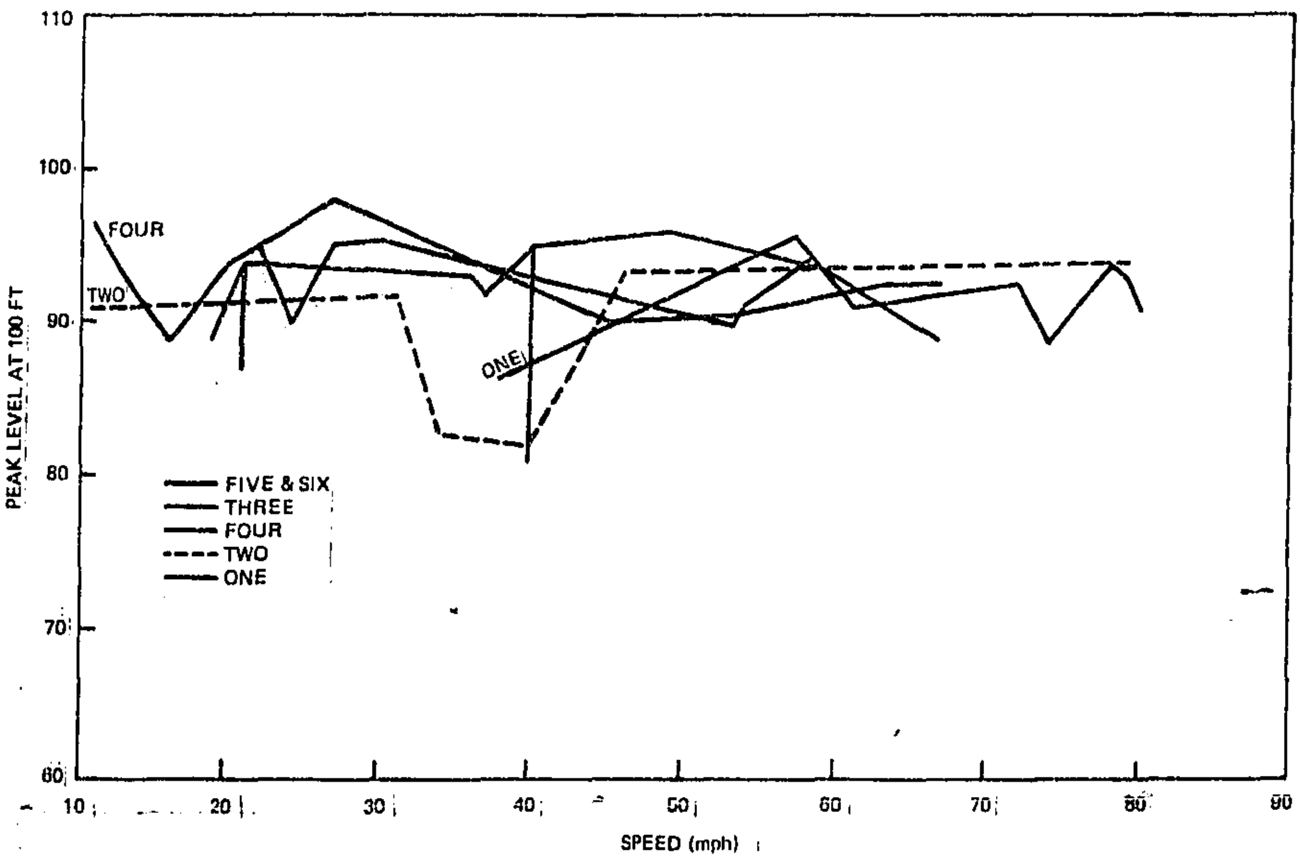

Figure 4-5. Relationship Between Maximum Noise Level and Number of Coupled Locomotives

Mufflers have no appreciable effect on exhaust emissions; muffler-equipped locomotives give off insignificant incremental amounts of NO_x, CO, and smoke [EMD (1973)]. One potential problem manufacturers want to investigate further is that condensed, unburned hydrocarbons might give rise to a stack fire. This has never occurred on locomotives having mufflers, although it has happened on stationary installations.

Three manufacturers with experience in fabricating mufflers for locomotives have indicated that their products will materially assist the railroads in complying with the proposed regulations: Donaldson of Minneapolis, Minn.; Harco Engineering of Portland, Ore.; and Universal Silencer of Libertyville, Ill. The following are these manufacturer's estimates of the attenuation that could be achieved with their mufflers, the approximate cost of the mufflers alone, without any allowance for installation, and the amount of back pressure they create.

Donaldson has had experience with the Chicago and Northwestern Railroad in equipping a locomotive with an off-highway truck type of muffler. The results were:

Muffler Cost – approximately \$800 for two mufflers
Back Pressure – further testing necessary

Harco Engineering has achieved the following results for a switcher locomotive. The muffler is fitted to a Harco spark arrester.*

Attenuation – approximately 5 dB(A)**
Muffler Cost – \$75

The results for road locomotives are:

Rootes Blown:

Attenuation – approximately 10 dB(A)**
Muffler Cost – \$750

Turbocharged:

Attenuation – approximately 10 dB(A)**
Muffler Cost – \$1000
Back Pressure – 13-20 in. H_2O (EMD claims that the back pressure is too high)

Universal Silencer has built mufflers for EMD locomotives (3 DRG and 40 Amtrack). According to EMD (presentation at AAR meeting, 1973) these mufflers achieved:

Attenuation – 9-10 dB(A) at full power
Muffler Cost – approximately \$1200
Back Pressure – 3 in. H_2O

The estimated overall noise that would result from equipping various locomotives with mufflers that give 5 dB(A) and 10 dB(A) attenuation in throttle 8 is indicated in Table 4-5.

Muffler manufacturers have said that they could supply fully developed and tested muffler systems for all locomotives by the following dates.

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*From EPA Docket 7201001, No. R007.

**This measurement was performed by the manufacturer.

HARCO

Switchers	1 January 1974
Road	1 January 1976

DONALDSON

All types	1 January 1976

UNIVERSAL SILENCER

Turbocharged Locos	1 January 1976
Rootes Blown	1 January 1977
Switchers	1 January 1978

EMD and GE have said that they could fit mufflers on new locomotives by the following dates.

EMD

Turbocharged	Road	1 January 1976
Rootes Blown	Road	1 January 1977
Switchers		1 January 1978*

GE

Turbocharged	1 January 1976

TABLE 4-5
LOCOMOTIVE NOISE LEVELS EXPECTED FROM EXHAUST MUFFLING, THROTTLE 8

Locomotive Type	5 dB(A) Exhaust Muffling		10 dB(A) Exhaust Muffling	
	Total Noise Level [dB(A)]	Total Attenuation [dB(A)]	Total Noise Level [dB(A)]	Total Attenuation [dB(A)]
EMD 1000-hp Rootes Blown Switcher	86.0	4.0	82.0	8.0
EMD 1500-hp Rootes Blown Switcher	88.0	4.0	84.0	8.0
EMD 2000-hp Rootes Blown Road Locomotive	89.0	4.0	85.0	8.0
EMD 3000-hp Turbocharged Road Locomotive	86.5	3.5	84.5	5.5
GE (or Alco) 3000-hp Turbocharged Road Locomotive	87.5	3.0	86.5	4.0
EMD 3600-hp Turbocharged Road Locomotive	87.5	3.5	85.5	5.5
GE (or Alco) 3600-hp Turbocharged Road Locomotive	88.5	3.0	87.5	4.0

*Because of problems integrating with spark arrester.

EMD and GE agree that mufflers can be incorporated in new locomotives. The cost of installing mufflers on locomotives must be compared with a total cost of $300,000 to $400,000 per locomotive (GE and EMD presentations to AAR meeting, 1973). The following methods would be used by each locomotive manufacturer in fitting mufflers on *new* engines.

New GE Road Locomotives

Mufflers would be installed above the engine and the hood roof would be raised 8 in. A locomotive would still clear the required 15-ft, 7-in. gauge. Cost = $1500 per locomotive.

New EMD Road Locomotives

Turbocharged: The muffler would be installed over the turbocharger. Mountings would have to be changed as would the roof structure, brake cabling, and extended range dynamic brakes. Cost = $2500 per locomotive.

Rootes blown: The muffler would be integrated with the spark arrester. There would be changes to the dynamic brake contactors, roof structure, and coolant piping. Cost = $3000 per locomotive.

New EMD Switchers

The muffler would be integrated with the spark arrester, but EMD is not quite sure how. Cost = $200–$500 (estimate based on Harco figures).

Retrofitting Older Locomotives

Retrofitting mufflers on locomotives involves finding out how many of each type of locomotive are still in service and adopting muffler installation procedure to the peculiarities of each model.

Table 4-6 illustrates the distribution of switchers in service, categorized by manufacturer.

Very few new switchers are being built, only about 120 per year, since switchers appear to run indefinitely. Furthermore, old road locomotives can be downgraded for switching use.

Most switching locomotives built before 1960 were equipped with mufflers, but after 1960 railroads generally fitted spark arresters instead.

In general, there does not seem to be any difficulty in fitting a muffler to the exhaust stack above the hood of a switcher. This has already been done in many cases which spark arrester, resulting in some loss in visibility for the driver. Harco has designed and tested a muffler that integrates with its spark arrester. The Harco muffler costs $75. However, this unit may have inadequate muffling for the regulation or too high a back pressure. Keeping this in mind, EPA estimates the cost for other spark arresters to be $200 to $500 plus 1 man-day labor for installation.

TABLE 4-6
SWITCHER LOCOMOTIVES IN SERVICE

Manufacturer	Year Built	No. in Service
EMD	1940–59	3200
	1960–present	1100
ALCO	1940–61	950
GE	1940–58	116
Baldwin, Lima Hamilton	1946–56	415
Fairbanks Morse	1944–58	220
		TOTAL 6000

The 8758 EMD Rootes blown road locomotives built before 1 January 1972 have less space for mufflers than the new model GP/SD 38-2. Care must be given to the siting of mufflers, but installation is considered to be possible. The dynamic brake grids will have to be resited, and the roof structure will have to be modified. Railroads might have changed exhaust systems on rebuilding. Discussions with a representative from Penn Central have led to the following cost estimates for fitting each of these older models with a muffler.

Muffler = $1500
Labor = 25 man-days ($/man-day = $46.40) (see Section 7)
Parts = $200-$500

Labor covers the resiting of dynamic-brake grids, plumbing and cabling, modifying the roof structure, and installing the muffler.

Thus, we see that mufflers can be fitted to new locomotives for less than a 1% increase in cost, and a retrofit program for mufflers is practical inasmuch as no locomotive has been identified that would be unduly difficult to retrofit.

Mufflers that product 5 to 10 dB(A) of exhaust muffling are currently feasible. It is important that a muffler be designed to give as good muffling at idle as at full power, since locomotives idle much of the time. Unless other noise sources on the locomotive are also treated, the net locomotive quieting will be only about 6-dB(A) due to contributions from these sources (see Table 4-4).

Mufflers could be developed and ready for production by 1 January 1976. The manufacturers have sufficient capacity to produce the mufflers required.

Cooling Fan Modification

The next contribution to locomotive noise that may be treated is the cooling fan. This component noise is essentially aerodynamic noise resulting from the air movement created by the fan.

Methods of treatment include increasing the diameter of the fan, adjusting clearances between blade and shroud, and varying the pitch of the blade. Although fan modifications are feasible, the application of fan retrofitting has not been developed for locomotives. Further, the impact of such a requirement could not be assessed with regard to cost and the effect of the total noise.

Engine Shielding

The vibrations of the engine casing is a significant component of the total locomotive noise. On a limited basis, work has been done to reduce the noise from this source by adding acoustic panels to the engine, stiffening the engine casing, and using sound-absorbing materials. This technique has not been developed to the extent that it could be applied to locomotives at this time.

2. Noise Abatement By Operational Procedures:

Parking Idling Locomotives Away from Residences

One of the most frequent complaints about railroad noise is that locomotives are left idling overnight. Railroads are reluctant to shut down locomotives because (1) shutting down and starting locomotives require a special crew, (2) engines do not contain any antifreeze in their cooling systems and would have to be heated in cold weather, and (3) locomotive engines are likely to leak cooling fluid into the cylinders, which could damage an engine on starting if precautions were not taken to drain it. Therefore, locomotives are usually shut down only during their monthly inspection.

Railroads are sometimes rather careless about where idling locomotives are left; frequently they are parked on the edge of a rail yard close to residences. With a little effort, locomotives could be parked near the center of a rail yard where they would be less troublesome to neighboring homes.

Speed Reduction

The power needed to pull a train increases almost directly with speed, but the noise of a given locomotive increases very rapidly with speed. Thus, one could achieve some noise reduction by lowering the speed limit for trains passing through residential areas. For example, the throttle settings of the locomotives of passing trains would generally be lower, and hence the locomotive noise would be reduced. Further, other noise sources, such as wheel/rail noise, would also be reduced.

This noise reduction method may not be practical generally, except perhaps in special urban areas, since the net effect would be to slow the movement of train traffic. The cost to the railroads of lower speeds has not been calculated.

A Ban on Night Operations

Many freight trains, particularly in the eastern United States, operate at night. Their noise is most disturbing at this time, since the background noise is lowest and people can be awakened from sleep. Thus, a significant impact on the annoyance resulting from train noise can be made by banning night-time operations. However, such a ban on night operations would frequently be impractical, since trains are scheduled for markets that open in the morning and the trains are loaded during the previous day. The resulting burden on the flow of interstate commerce could be extensive.

Use More or Larger Locomotives for a Given Train

One paradox emerged from the model of locomotive noise presented earlier. A large locomotive in a low throttle position develops less noise than a small locomotive in a high throttle position, even when the two develop the same horsepower. For example, a 3600-hp locomotive in throttle 4 generates 15 dB(A) less noise than a 2000-hp locomotive in throttle 8. Thus, a considerable noise reduction is achieved by using a 3600-hp engine to haul a train requiring only 2000-hp. Similarly, a 9 dB(A) reduction could be obtained by using four 3600-hp locomotives with lower throttle settings to pull a train that normally requires two 3600-hp locomotives, but which operate at high throttle settings.

This noise reduction technique is considered to be impractical in general, since the extra haulage power required is quite large. However, this method could be used in some situations such as switching operations. Locomotive engineers could use low throttle positions rather than "gunning" the engine in throttle 8.

Electric/Gas Turbine Locomotives

There are other means of train propulsion, apart from diesel-electric, currently in use on American railroads. All-electric and gas turbine locomotives are becoming more popular, particularly in the Northwest corridor. Rickley, Quinn, and Sussan have measured the wayside noise levels of the Metroliner, Turbotrain, and electric passenger and freight trains. The levels at 100 feet are given in Table 4-7. In general, levels do not exceed 88 dB(A). For those trains, namely two Metroliner trains and one standard passenger trains, exceeding 88 dB(A), it is felt that the exceedance was caused by wheel/rail interaction phenomena as opposed to locomotive engine generated noise, per se, since these vehicle travelled at rates of speed where rail noise is likely to predominate (see wheel/rail noise section).

Thus, in general, the non-diesel-electric locomotive noise is well below that of diesel-electric locomotives and the former are likely to comply with any regulation written for the latter.

Wheel/Rail Noise

Rail car noise includes all sources of train noise other than that produced by the locomotive. These sources are wheel/rail interaction, structural vibration and rattle, and refigerator car cooling system noise.

Of these sources, the interaction of the wheel and rail is the major component. As discussed in the Bolt, Beranek and Newman Report No. 2709, "Railroad Environmental Noise: A State of the Art Assessment," this source is generated by four mechanisms. These are labeled "roar," "impact," "flange rubbing" and "squeal."

TABLE 4-7
NOISE LEVELS FROM ELECTRIC AND GAS-TURBINE TRAINS

Train	No. of Cars	Direction	Speed (mph)	SPL [dB(A) 100 ft]
Metroliner	4	South	106	89
	4	South	110	89
	4	North	106	84
	6	North	110	84
	4	North	80	78
	6	North	84	80
Electric Pass	6	South	84	90 (wheel/rail)
Electric Freight (2 Locos)	3	South	49	88
Turbotrain	5	East	97	85
	5	West	91	85
	3	East	89	84
	3	West	104	88

"Roar" describes the noise that predominates on welded tangent track. It is believed that roar is due to roughness on the wheels and rails.

"Impact" noise refers to the noise produced by wheel and rail discontinuities such as wheel flats, rail joints, frogs and signal junctions. This noise is characterized by a "clickety clack" sound and may cause significant increase in wayside noise.

"Flange rubbing" describes the sound made when the flange contacts the rail and squeal does not occur. This noise is characterized by a low-frequency grinding sound. It could be caused by a stick-slip phenonmenon or by roughness on the flange and rail head.

"Squeal" is a very high pitched noise produced when a train negotiates a tight curve. Three possible ways in which squel can occur are: 1) differential slip between inner and outer wheels on a solid axle, 2) rubbing of the wheel flanges against the rails, and 3) "crabbing" or lateral motion of the wheel across the top of the rail.

Structural vibration and rattle emanate from from the car bodies and couplings. Noise from these sources may be distinguishable in a slowly moving train. Normally, however, this noise combines with the other sources of car noise and is not readily distinguishable.

Refrigerator cars are railroad cars used to transport perishable freight that requires refrigeration. It is necessary for the cooling equipment to operate continuously when the car is loaded, and also when the car is empty but a load is anticipated. This cooling equipment usually contains an unmuffled diesel engine to drive a compressor. These engines are similar in size and performance to engines used in other applications in a muffled configuration. It is believed that the muffler industry could supply the additional muffler requirement for rail refrigerator cars. However, application consideration would also have to include space availability and installation and replacement costs. The maximum noise level from this source is approximately 75 dB(A) at 50 ft. (Wyle Laboratories, 1973). When a train is moving, the noise levels emitted from a refrigerator car cannot be distinguished from overall train noise; however, if the train stops or if the cars are held over, the continuous operation of the compressor engine may be a source of undesirable noise.

Refrigerator cars parked with their cooling systems running, as they often are in marshaling and humping yards, may cause noise problems but only in places where refrigerator cars are parked near noise-sensitive areas. At this time, such localized problems can best be controlled as a part of railroad yard noise control, through measures such as parking refrigerator cars away from noise-sensitive areas or installing noise barriers, rather than by requiring modifications to the entire refrigerator car fleet.

Typical measured levels of rail car noise are illustrated in figures 4-6, 4-7 and 4-8. Figure 4-7 indicates that the A-weighted wheel/rail noise level varies as 30 log V where V is the train velocity. This relationship primarily describes the "roar" component of the noise. The higher levels present are most probably indicative of "impact," "flange rubbing" and "squeal" noise.

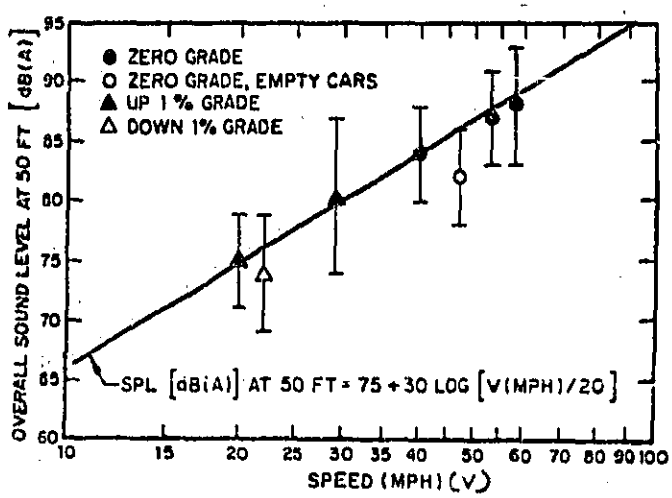

Figure 4-6. Wheel/Rail Noise Measured on Level Ground and on a 1% Grade

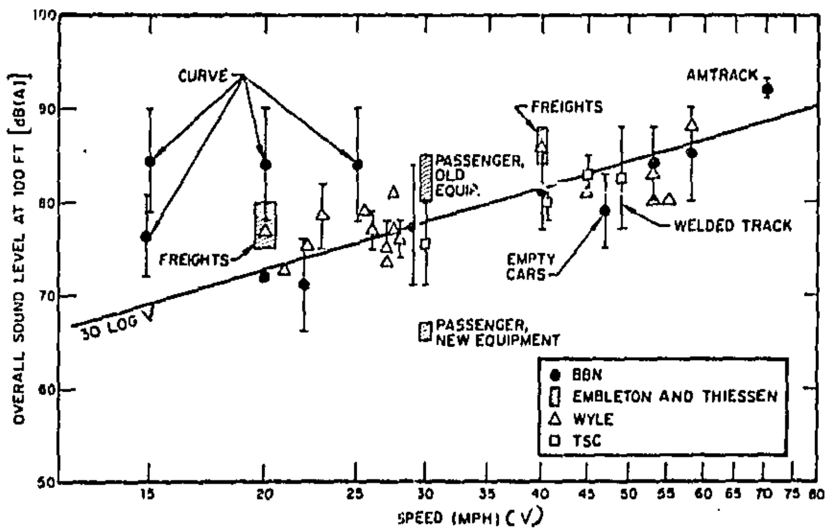

Figure 4-7. Measured Wheel/Rail Noise

Wheel/Rail Noise Abatement

A number of techniques have been suggested to reduce railroad car noise while operating on open track. In most cases testing has been very limited and, thus, the results regarding effectiveness are inconclusive.

Grinding of train wheels and rail would reduce "roar" noise by reducing the amplitude of the excitation. Bender and Heckl (1970) report differences of approximately 6 dB(A) between noise levels for ground and unground rails on the Munich Subway. The important parameter to control during grinding is irregularities having wavelengths of the order of 1/2 inch to one foot, rather than the micro-surface finish. Such wheel irregularities (wheel flats) can be controlled by spinning the wheel while grinding. For rail it is more difficult because running a vehicle with a grinding wheel attached slowly over the rails causes the grinder to move vertically in response to the vertical motion of the vehicle wheels.

The use of resilient wheels has undergone considerable development since they were invented in 1899. At present there are four different designs available:

1. "Penn Cushion" wheels, available in the U.S. from Penn Machine Co., Johnstown, Pa.
2. "Acousta Flex" wheels, marketed by the Standard Steel Division of Baldwin-Lima-Hamilton Corporation, Burnham, Pa.

PEAK, AVERAGE, AND MINIMUM RAIL-WHEEL SOUND LEVEL VS. SPEED
FOR TYPICAL RAILROAD CARS ON WELDED AND POLTED RAIL

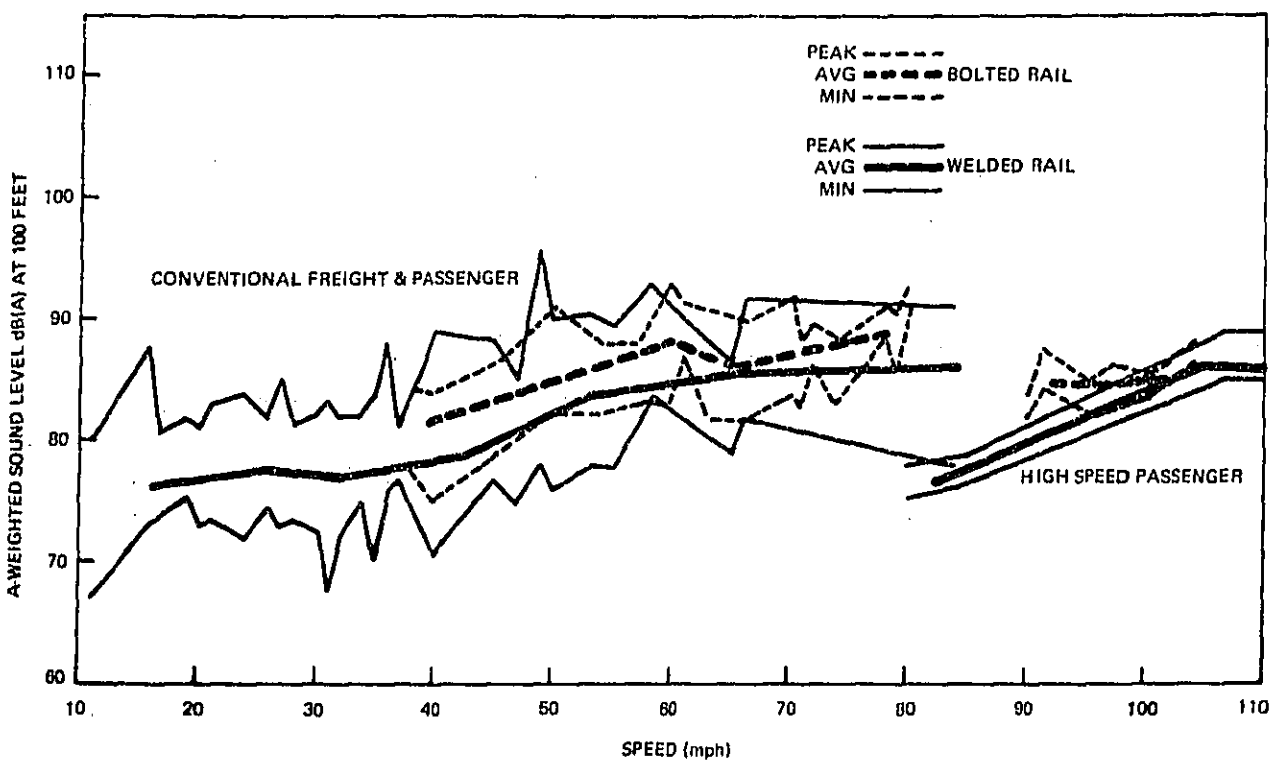

Figure 4-8. Average, and Minimum Rail-Wheel Sound Level vs. Speed for Typical Railroad Cars on Welded and Bolted Rail

3. "SAB" resilient wheels, marketed in the U.S. by American SAB Company, Inc., Chicago, Illinois
4. "P.C.C." wheels, made by Penn Machine Co., Johnstown, Pa.

The Penn Cushion and Acousta Flex wheels are similar in principle. Both utilize an elastomeric ring between the rim and the hub of the wheel. The SAB and PCC wheels also are similar to each other in principle. In these wheels, the rim is part of a steel disc, and the hub assembly consists of one or more parallel steel discs. The rim disc is connected to the hub assembly via rubber elements which deform as the wheel is loaded radially. The experimentation and data for resilient wheels on rapid transit cars indicate that such wheels would be of negligible benefit for reducing railroad freight car noise (Bolt Beranek and Newman 1974). Freight cars operate principally on tangent track where resilient wheels are least effective.

Another technique which has been explored is "wheel damping." B.F. Goodrich Company constructed a wheel with a layer of viscoelastic damping material bonded to the inside of the wheel rim and covered with a bonded steel "constraining layer." This treatment is said to have eliminated screech, reduced farfield noise obtained on tangent track by up to 2 dB(A) at high speeds, and also attenuated rail vibration. Some limited experiments by B.F. Goodrich showed that use of an "unconstrained" viscoelastic layer resulted in no significant noise reduction. However, the Toronto Transit Commission found a 12 to 15 dB(A) squeal noise reduction when applying unconstrained damping layers. Use of a four-layer damping configuration on a BART prototype car had no significant effect on interior and wayside noise on tangent track, but eliminated some screeching on curved track. Reductions of 20 dB(A) in screeching noise and 4 dB(A) for nonscreeching noise were realized for curved track.

Rail welding is a method that can be used to reduce the noise caused by the discontinuities at rail joints. On the average, it can be expected to reduce wayside noise by as much as 3.5 dB(A). However, maximum levels are as high on welded rail as on bolted rail (see figure 4-8). Other advantages of welded rail are the potential for less maintenance and a decrease in average rolling resistance. Both are due to the absence of rail joints.

Rail damping is a technique which has undergone very limited testing. A damping compound is applied to the nonrunning surfaces of the rails which should shorten the length of rail that vibrates when a wheel passes over it. At this time, experimentation is so limited that no conclusions can be reached as to the effectiveness of this technique.

In summary, although there are some new techniques and systems which show a degree of promise, the only available methods today for reducing moving rail car noise emissions is through the maintenance practices of car wheel and rail grinding in addition to the use of welded rail.

Retarder Noise

Within railcar classification yards, several thousands of cars are moved in each 24-hr period, as trains are assembled/disassembled. Two general methods are used for car movement, (1) small switcher locomotives are used to maneuver (one or more cars) and to create railcar vehicle velocity prior to release for self-movement to pre-selected tracks, or, (2) heavy duty pusher locomotives push rail cars up an incline and over a "hump" where the cars are released to travel on their own to pre-determined yard locations. As a result of the techniques used in hump yards a single railcar or several railcars coupled together may be traveling at 10 to 15 mph and accelerating while moving down the hump.

To manage the rail car(s), retarders are used to reduce car(s) speed or to stop them. In the process of slowing or stopping the car(s) intense noise, characterized as a squeal, is often generated. Figure 4-9 shows the amplitude distribution of noise associated with railcar movement through retarders. Noise levels as high as 120 dB(A) at 50 feet have been observed.

Although studies (Ungar, Strunk and Nayak, 1970; Kurze, Ungar and Strunk, 1971) have been conducted to determine the mechanism of wheel/retarder noise generation, a thorough understanding of the phenomenon is not yet at hand. It is thought that the intense wheel squeal is the result of excitation of the railcar wheel at its resonant frequencies. Apparently, the noise levels emitted by the car wheels are influenced by car type, car weight and loading, type of wheels, the structure and composition of the retarder and the decelerating force that the retarder applies to moving cars.

According to the Federal Railroad Administration there are approximately 130 hump yards in this country. A listing of the current in-use hump yards by location, railroad, and number of classification tracks is shown in Appendix C.

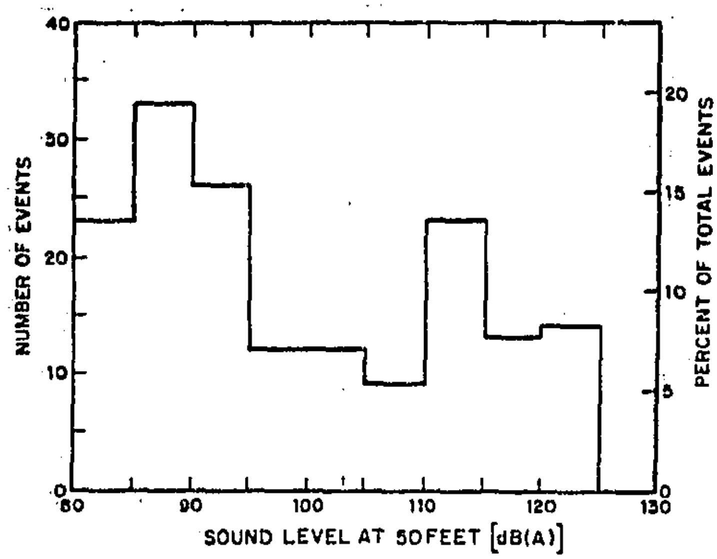

Figure 4-9. Retarder Squeal Amplitude Distribution

Retarder Noise Abatement

Though the mechanisms of wheel/retarder noise are not fully understood, several methods to control the noise are thought feasible. One method, namely the use of barriers would control the noise once generated, i.e., minimize the noise propagation efficiency; while four methods, (1) retarder lubrication, (2) use of ductile iron wheel shoes, (3) use of releasable inert retarders and (4) retarder control by computers would control noise at the source; i.e., minimize noise generation efficiency.

While the five methods cited are thought to be possible alternatives for retarder noise control, much further study is required to assess the benefits and costs associated with each method. To date, known benefit and cost information associated with the aforementioned methods are summarized below.

Benefits:

The only study that has been completed which models the impact on retarder noise reduction on people was of the Cicero Yard outside of Chicago. (See Appendix D.) The results of that study showed that the reduction of retarder noise levels by 20 dB(A) allowed about 200 more people to be exposed to less than an Ldn of 65 dB(A). The maximum reduction that would be experienced by any of the 200 people would be a 2 dB(A) change in Ldn. If retarders were completely silenced the noise reduction would benefit only 200 more people (total of 400) as per the above criteria, according to the study.

Although it is not altogether accurate to project a study of a single yard to a national impact, if the assumption was made that Cicero Yard is typical of all rail yards, approximately 26,000 more people would be exposed to less than an Ldn of 65 dB(A).

By reducing locomotive exhaust noise by 10 dB(A) in the Cicero Yard, approximately twice the benefit was realized (400 people less than 65 Ldn) than with the 20 dB(A) reduction in retarder noise, according to the study.

Costs*:

A. Barriers (material costs of initial installation only)
   1. $50 to $70 per linear foot.
   2. $50,000 – $100,000 per yard.
   3. $6.5 – 13.0 million for railroad industry.
   4. Maintenance/replacement costs unknown.
   5. Space and safety hazards unknown.
   6. Down time and track modification costs are unknown.

*The cost of shutting down a yard or part of a yard during installation or maintenance of these systems could double or triple the estimated costs.

B. Source Control

1. Lubrication Systems (excludes maintenance/operation costs).
   a. Specific costs unknown, estimated by industry to be $250,000 to $500,000 per retarder system (master plus 4 to 8 group retarders) or 5 to 10 percent of total capital investment.
   b. Estimated initial cost of new equipment on basis – $100 million (assuming 200 retarder systems)
   c. Maintenance and operational downtime, and modification costs to track system, are unknown.
2. Ductile Iron Shoes
   a. Initial Cost ($25 per foot) cost is twice that of regular retarder shoes.
   b. Ductile shoes wear 10 times faster than regular retarder shoes.
   c. Estimated additional cost for using ductile iron shoes to replace present shoes is $100,000 per retarder system.
   d. Estimate of national cost impact to industry is $100 million (assuming 200 retarder systems)
   e. Yard down time is not included in this cost estimate.
3. Releasable Inert Retarders
   a. Conversion of non-releasable inert retarders to releasables cost $5,000 per retarder, not including labor, down time, or operation costs.
   b. The number of non-releasable inert retarders in use is unknown. Gross estimate is 20,000.
   c. Estimate of national cost to convert $100 million.
4. Computer Control of Retarders
   a. Computer control of retarders seems practicable only at the newer yards where computer control systems were installed when the yard was initially built.
   b. There are approximately 40 computer controlled yards.
   c. The cost, during new construction of a yard, for computer control of a retarder system is $1.5 million.
   d. Cost of feasibility of retrofitting a yard with computer control is unknown.
   e. If hardware installation costs were assumed to triple the new installation cost, the national cost impact for retrofit of existing yards for computer control would be 540 million dollars, assuming 120 retarder systems.

Car-Car Impact Noise

The time histories of car-car impact noise illustrated in Figure 4-10 show some features of the physical phenomena that accompany car-car impact. The initial impact of the car couplers causes a "crack," as illustrated by the sharp rise in sound level in both parts of the figure. The high-frequency

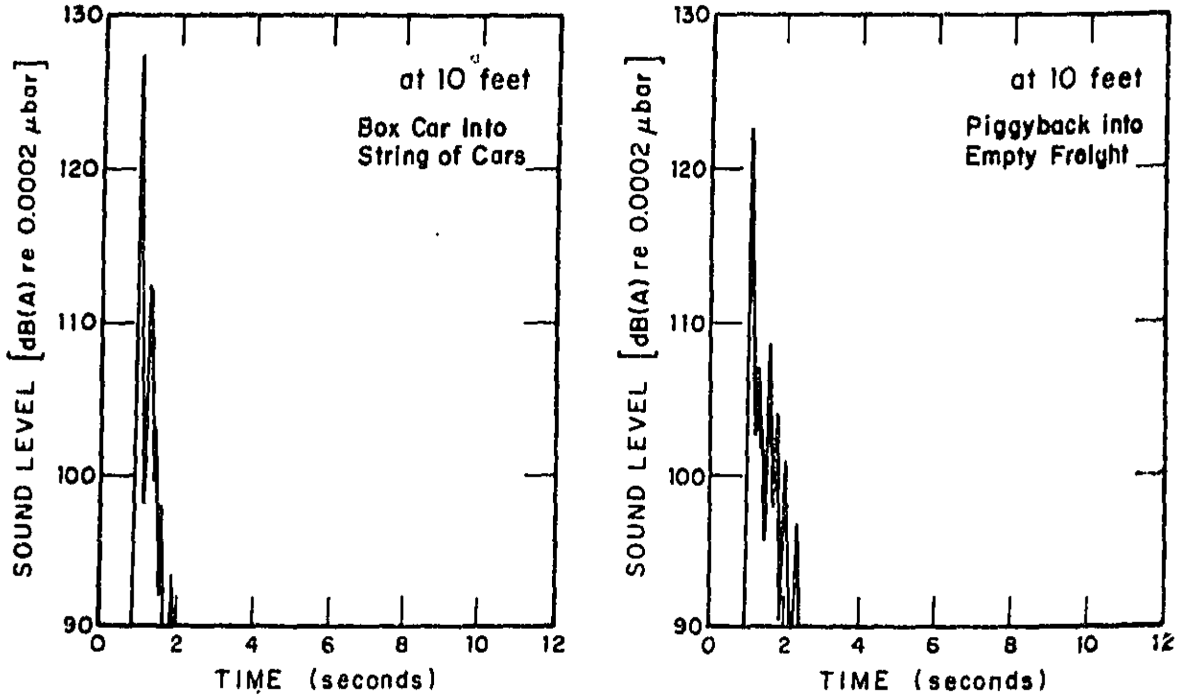

Figure 4-10. Car-Car Impact Noise Time Histories

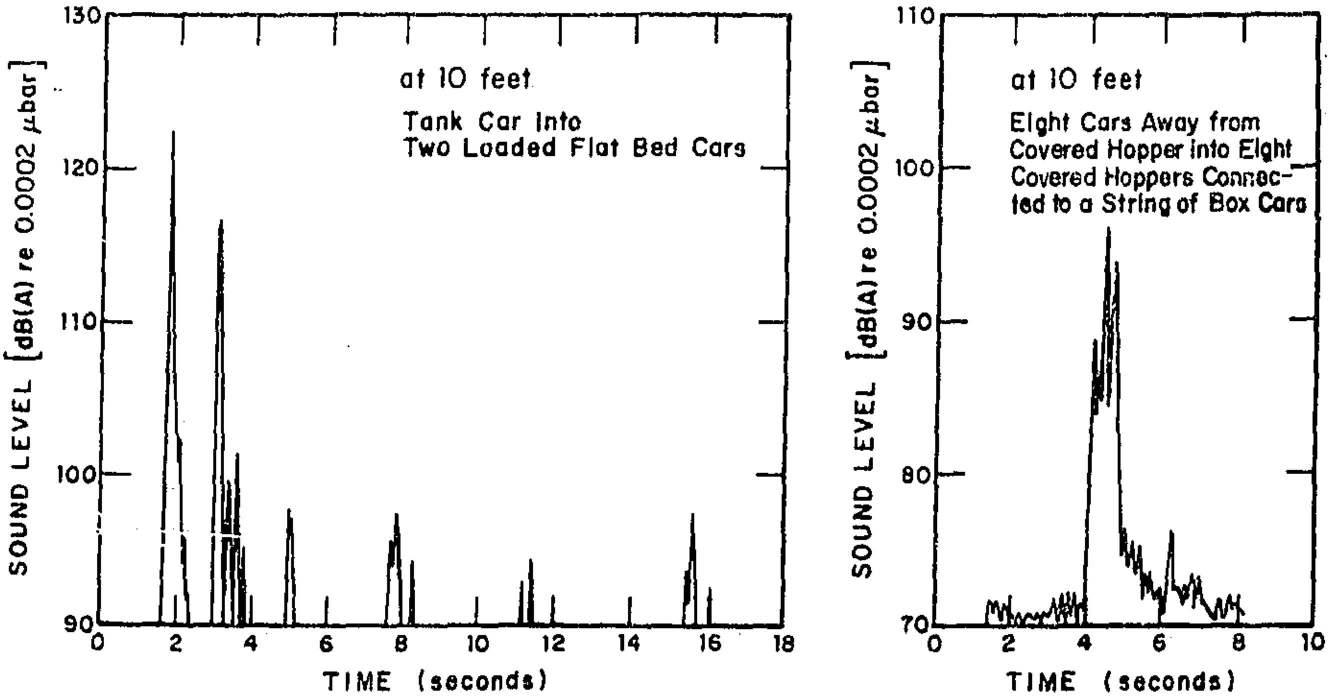

Figure 4-10. (Cont.)

portion of the mechanical energy ged into couplers often excites an entire car body. The second time trace in the figure shows how, as the resulting vibrational energy decays exponentially, the radiated noise falls off proportionally. The time trace for a tank car hitting two loaded flat bed cars shows the noise sometimes generated by secondary impacts as cars pull away from each other and coupler slack is subsequently taken up. The time trace for the noise measured eight cars away from a point of impact shows how the energy from an impact can propagate along a chain of cars.

Warning Devices

This source of noise includes bells, horns, and whistles, which are sounded to warn pedestrians and motorists that a train is approaching a grade crossing. The noise level at 50 ft due to either a horn or a whistle is 105 dB(A) ± 10 dB(A). Of prime consideration in addressing these sources of noise is the measure of safety that they provide.

Methods of noise abatement for warning devices have not been fully evaluated. Some localities have required that the devices not be sounded, while others have required just the opposite. Various alternatives for controlling their noise include requiring reduced levels, specifying directionality, or limiting the times and areas in which the devices should be sounded.

Public Address Systems

Although the frequency of occurrence of noise from loudspeakers in railroad yards is sporadic and unpredictable, the level of the noise from speakers is comparable to the level of noise from other sources in the yards. Where abatement is desired or necessary, more speakers could be strategically located so that less volume is necessary, or railroad yards could follow the recent trend to two-way radio communication.

Maintenance and Repair Shops

The noise from shops comes mainly from running the engines of stationary locomotives. Other noises from maintenance and repair shops are overshadowed by the noise from retarders, car impacts, and locomotives moving about the yard. If controls are applied to noise from locomotives, car impacts, and retarders, that part of shop noise not due to locomotive engines may then emerge as a significant part of the remaining noise.

Refrigerator Cars

These are railroad cars used to transport freight that requires refrigeration. It is necessary for the cooling equipment to operate continuously when the car is loaded, and when the car is empty but a load is anticipated. This cooling equipment usually contains an unmuffled diesel engine to drive a compressor. These engines are similar in size and performance to engines used in other applications in a muffled configuration. It is believed that the muffler industry could supply the additional muffler requirement for rail refrigerator cars. However, application consideration would also have to include space availability and installation and replacement costs. (see additional discussion under Wheel/Rail Noise in this section.)

REFERENCES TO TABLE 4-2

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SECTION 5

SUMMARY OF WHAT THE PROPOSED REGULATIONS WILL REQUIRE

"APPLICATION OF BEST AVAILABLE TECHNOLOGY TAKING INTO ACCOUNT THE COST OF COMPLIANCE"

Section 17 of the Noise Control Act requires that the proposed regulations . . . "reflect the degree of noise reduction achievable through the application of the best available technology, taking into account the cost of compliance." For this purpose, "best available technology" is defined as that noise abatement technology available for application to railroads which produces meaningful reduction in the noise produced by railroads. "Available" is further defined to include:

1. Technology which has been demonstrated and is currently known to be feasible.
2. Technology for which there will be a production capacity to produce the estimated number of parts required in reasonable time to allow for distribution and installation prior to the effective date of the regulation.
3. Technology that is compatible with all safety regulations and takes into account operational considerations, including maintenance, and other pollution control equipment.

The "cost of compliance," as used in the proposed regulation, means the cost of identifying what action must be taken to meet the specified noise emission levels, the cost of taking that action, and any additional cost of operation and maintenance caused by that action. The cost for future replacement parts was also considered.

As discussed in Section 4 of this report, the only source of railroad noise proposed to be regulated by the Federal government at the present time is trains. Therefore, the following pages will discuss the noise abatement technology for trains, in consonance with the statutory requirements and interpretation presented above.

Train noise is composed of locomotive noise and car noise. The latter is primarily the result of wheel/rail interaction and wheel/retarder interaction. The locomotive noise is composed of noise from the engine exhaust, casing, cooling fans, and wheel/rail interaction. The technology for treating casing, fans, and wheel/rail noise is in the early development and research stages and thus not "available" for application at this time. However, at the present time, the technology for exhaust silencing has been found to be "available." Further, the locomotive noise is dominated by the engine exhaust noise and, therefore, the application of exhaust muffler technology is the most effective initial step to require for locomotive noise abatement. The consequences of establishing a standard that would require modification of engine casing, cooling fans, and wheel/rail interaction have not been assessed in detail. It is clear, however, that without first reducing exhaust noise treatment of these components would result in little or no perceptible noise reduction. Muffler technology is well known, and its application to locomotives has been assessed (see Section 7). The costs and effects have been predicted and in the judgment of the Agency constitutes the "application of best available technology taking into account the cost of compliance."

LEVELS OF TRAIN NOISE CONTROL

In this section, noise levels that can be reasonably attained with appropriate maintenance of existing equipment and by the application of the best available technology are discussed for locomotives both at rest and in motion and for railcars in motion.

Locomotive Noise: Vehicle at Rest

As discussed in Section 4, locomotive noise is dominated by the exhaust of diesel engines, which operate at eight possible speed and power output levels. One way to attain environmental noise control would be to limit the noise at all of these throttle settings; however, this could lead to cumbersome enforcement practices. For ease of enforcement, permissible noise could be specified at the throttle setting with the most noise – throttle 8. However, this approach may lead muffler manufacturers to design mufflers that are tuned to the engine speed corresponding to that throttle setting. Such mufflers could be effective at the design setting and ineffective at other settings. Obviously, this would defeat the purpose of a locomotive regulation.

A compromise solution is to control locomotive noise at two conditions: idle and full power. Idle and full power apply to frequently used throttle settings. Specifying two throttle settings will probably preclude the design of specially tuned mufflers. Rather, it is anticipated that mufflers that will be uniformly effective at all throttle settings will result.

Although it is unrealistic to assume that mufflers can be designed, fabricated, and installed on locomotives as soon as a regulation is promulgated, it is not unreasonable to hold noise at the level of existing, well-maintained equipment. Data, for locomotives at throttle setting 8, indicate that almost no locomotives exceed 93 dB(A) at 100 ft. Likewise, data indicatd that locomotives at idle can be expected not to emit more than 73 dB(A) at 100 ft. Accordingly, the following levels have been identified as indicative of present noise emissions:

Idle	73
Overall Maximum	93

Section 4 indicates that mufflers capable of reducing exhaust noise by 10 dB(A) are feasible. Depending upon the relative contribution of the exhaust noise to the dominent sources of locomotive noise, this reduction may produce a 4 to 8 dB(A) reduction in the total noise (see Table 4-5). It is believed that the noisier locomotives have a higher exhaust noise component and, therefore, may achieve greater overall reduction in total noise by reducing exhaust noise. When exhaust noise is less dominant, smaller reductions in total noise will result. However, in this case, overall noise seems to be initially lower. Based on the considerations of available empirical data, an overall noise reduction of 6 dB(A) for the noisier locomotives seems reasonable. Accordingly, the application of an exhaust muffler can be expected to permit all locomotives to achieve the following levels:

Idle	67 dB(A)
Overall Maximum	87 dB(A)

The exhaust noise is primarily a function of the diesel engine horsepower and the method of engine aspiration. Rootes blown engines would have higher exhaust noise than an equal size turbocharged engine. Also, a larger engine has higher exhaust noise than a smaller engine if the aspiration is the same.

However, the larger engines are generally turbocharged, while the small engines are rootes blown. This leads to a partial cancellation of the effect of power and aspiration on the exhaust noise. It may be feasible in the future to establish separate standards for different types of locomotives, depending upon power or method of aspiration. This is not possible with the present data, however.

Section 4 also shows that muffler manufacturers could supply the needed hardware after approximately 2 years for design, development, and testing. Allowing another 2 years for installation (see Section 8 of this document for a discussion of installation costs), a 4-year program for completion of muffler retrofit appears reasonable.

Locomotive Noise: Vehicle in Motion

In addition to the stationary locomotive standard a pass-by standard which relates directly to the manner in which locomotives operate in the environment is also desirable. Such a standard also could be a useful tool for adoption and enforcement by local and State governments.

Based on available train pass-by data (see Figure 4-3) 96 dB(A) measured at 100 feet is achievable and represents the status quo for current locomotive noise emissions. As discussed above, a reduction in overall locomotive noise of 6 dB(A) for the noisier locomotive through proper muffler application is considered reasonable. Therefore, using the same projected design, development, testing, and installation times mentioned above a 90 dB(A) noise emission level measured at 100 feet for all locomotives during a pass-by test would be required in four years.

There seems to be a general relationship between the load cell and pass-by levels prescribed. The maximum levels observed differ by approximately 3 dB(A). This relationship cannot be definitively stated since measurements comparing the two procedures have not been conducted under controlled situations. However, by proposing both pass-by and load cell measurement tests in the proposed standard the public is allowed the opportunity to comment on both.

Railcar Noise: Vehicles in Motion on Line

Figure 4-8 shows that at a given speed, railcar noise ranges ±5 dB(A) above or below a mean value. At 45 mph the mean is approximately 83 dB(A). At 60 mph the mean is approximately 88 dB(A). As such, the following status quo standard measured at a 100 ft. distance for railcars in motion is considered appropriate:

Railcar Speed (v) mph	Noise Level dB(A)
$V \leq 45$	88
$V > 45$	93

Railcar Noise: Vehicles in Motion in Yards

As discussed in Section 4, railcar passage through a retarder causes the emission of noise levels as high as 120 dB(A). Further discussed, were five possible methods of retarder noise control that might conceivably be employed individually or in concert. With such information it might be argued that a status quo level of 120 dB(A) may be appropriate at this time and subsequently reduced to approximately 80 dB(A) as the technology of retarder noise control advances over the next few years. At this time, however, it is the Agency's position that retarder noise is an element of fixed facility railroad yard noise which, as such, can best be controlled by measures which do not in themselves affect the movement of trains and therefore do not require national uniformity of treatment. Such noise control measures might include, for example, the erection of noise barriers. The Agency's study of railroad yard noise indicates that concern for noise from railroad yards is more local than national. This is due in large part to the location of the number of yards in non-urban areas and the relatively small number of hump yards (130). Accordingly, the establishment of a uniform national standard could potentially incur significant costs to the railroads with only limited environmental impact resulting in terms of population relief from undesirable noise levels.

In summary, the principal reasons for proposing to not regulate retarders at this time are:

1. The technology and cost information on retarder source control is not adequate at this time to justify inclusion in proposed regulations.
2. Application of barriers (which is a general technology applicable to many noise sources) to reduce retarder noise is more appropriately handled by local or State jurisdiction on a case-by-case basis.
3. EPA studies of models of environmental benefit resulting from reducing retarder noise imply only a small benefit on a national basis. This is due largely to the relatively small number of hump yards. (See Appendices C and D).

SECTION 6

GENERAL PROCEDURE TO MEASURE RAILROAD NOISE

INTRODUCTION

In developing this Background Document/Environmental Explanation and proposed standard, EPA has reviewed several methods which may be used to measure railroad noise emissions. The procedures used by EPA to measure railroad noise conform in general with the measurement procedures described in this section. The Agency believes this procedure to be reasonable for the purpose of measuring railroad noise, and suggests it for use by other parties in the measurement of such noise emission.

If issue is taken with the data supporting the railroad standards proposed by EPA, such data as may be submitted to the Agency in support of the respondent's position should be based on similar measurement methods or procedures. The equivalency or correlation between different measurement practices must be clearly explained in order to permit adequate comparisons with the data and levels in the proposed regulation.

It is recommended that technically competent personnel select the equipment to be used for the test measurements. Proper test instrumentation and experienced personnel is essential to obtain valid measurements. Operating manuals or other literature furnished by the instrument manufacturer should be referred to, for both recommended operation of the instruments and precautions to be observed.

MEASUREMENT INSTRUMENTATION

A sound level meter that meets all the requirements of American National Standard S1.4-1971 for a Type I instrument and all requirements of International Electrotechnical Commission (IEC) Publication 179(1965) should be used with the meter set to "fast" response. Alternative/additional measurement instrumentation, such as a magnetic tape recorder or a graphic level recorder, may be used for conducting the measurements, provided that the overall performance of the measurement system conforms to the requirement of this Measurement Instrumentation Section over the frequency range from 25 Hz to 10K Hz. In conducting the measurements of sound level, the general requirements and procedures of American National Standard S1.13-1971 should be followed. These publications are available from the American National Standards Institute, Inc., 1420 Broadway, New York, New York 10018.

A wind screen that does not introduce measurement uncertainties in excess of plus or minus 0.5 dB(A), should be used at all times. No sound level measurements should be taken when the wind speed near the microphone exceeds 20 km/hr (12 mph).

The sound level meter, or other measurement instrumentation, should be calibrated (e.g., by means of a pistonphone) at one or more frequencies, at the beginning and end of each series of measurements. The calibrator should produce a sound pressure level, at the microphone diaphragm, that is known within a precision of plus or minus 0.5 decibel. The calibrator should be checked monthly to verify that its output has not changed.

A complete frequency response calibration of the instrumentation over the entire frequency range of 25 Hz to 10K Hz should be performed at least monthly using methodology of sufficient precision and accuracy to determine compliance with American National Standard S1-4-1971 and IEC 179. This calibration shall consist, at a minimum, of an overall frequency response calibration and an attenuator (gain control) calibration plus a measurement of dynamic range and instrument noise floor.

TEST SITE PHYSICAL, ACOUSTICAL, WEATHER AND BACKGROUND NOISE CONDITIONS

In general, the test site should be selected such that the locomotive or train radiates sound over the ground plane of an open space free of large, sound reflecting objects, such as barriers, hills, signboards, parked vehicles, bridges or buildings within the boundaries described by Figure 1 (rail car or locomotive noise pass-by test) and Figure 2 (for stationary test). In addition, the following specific conditions are also suggested:

1. The track bed within the test site described in Figures 6-1 or 6-2 should be visible by direct line of sight from a position 4 feet above the ground at the microphone location, which is also described in Figures 6-1 or 6-2.
2. The terrain between the vehicle under test and measuring microphone should be relatively free of ground covering having excessive sound absorption characteristics.
3. The ground elevation at the microphone location should be within plus or minus 3 meters (10 feet) of the elevation of the track bed at the location in-line with the microphone.
4. Within the test section, the track should exhibit less than a 2 degree curve [or a radius of curvature greater than 873 meters (2,865 feet)]. This does not apply during a stationary test. The track should have tie and ballast in good condition and preferably welded rails, and be free of special track work such as turnouts or crossovers, and bridges or trestles.
5. Measurements should not be made during precipitation.
6. Maximum background noise at the microphone location of Figure 6-1 or 6-2, immediately before and after the test, should be at least 10 dB(A) below the level measured during the test. Measurements should be made with the sound meter set to fast response.

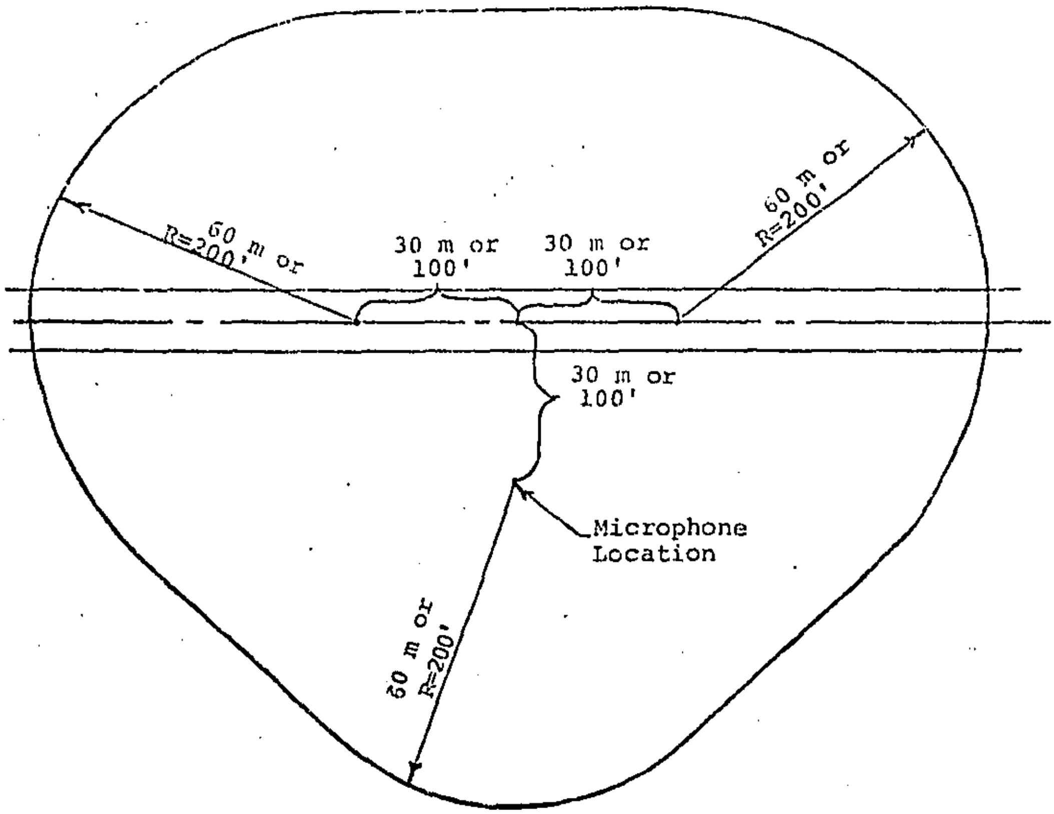

Figure 6-1. Test Site Clearance Requirements for Wayside Rail Car Noise Pass-by Test

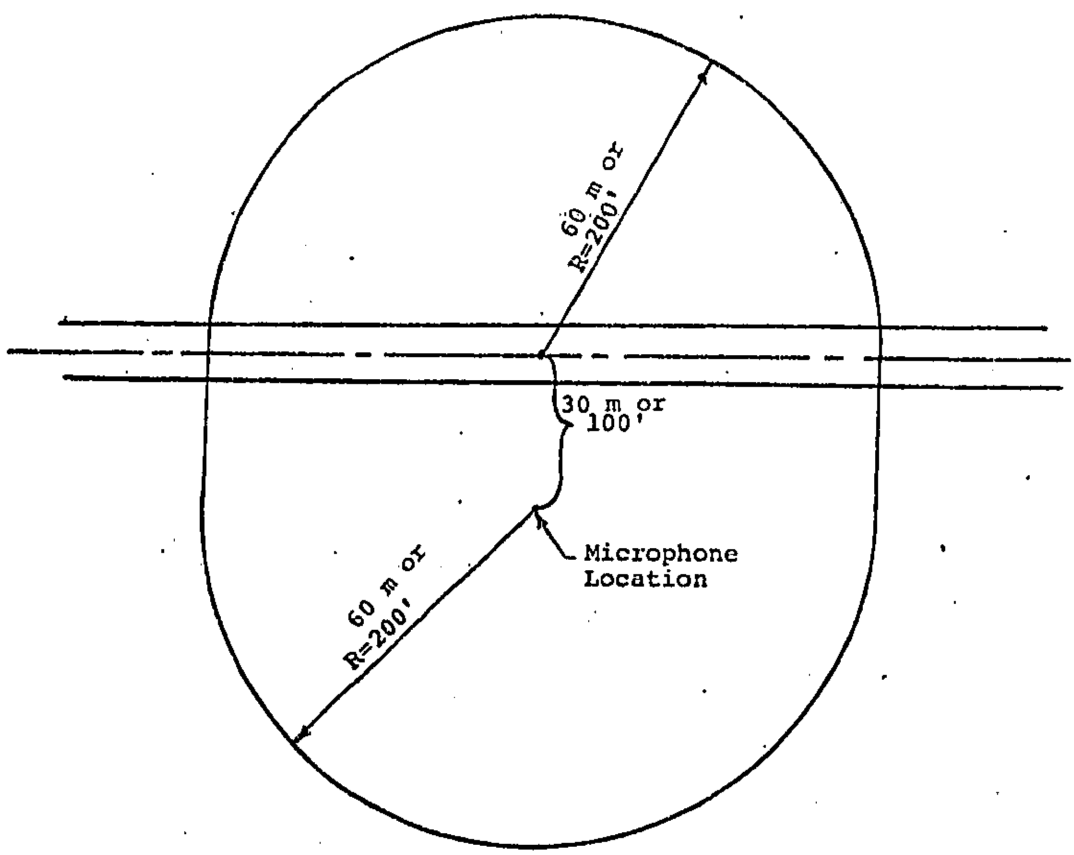

Figure 6-2. Test Site Clearance Requirement for Locomotive Stationary Test

7. Corrections for measurements at varying altitudes should be made in accordance with recommendations of the instrumentations manufacturers for altitudes greater than 1,000 meters (3,000 feet) above sea level.

PROCEDURES FOR THE MEASUREMENT OF LOCOMOTIVE AND RAIL CAR NOISE EMISSIONS

Introduction

One procedure for the measurement of locomotive noise is to connect the locomotive to a load cell where it can be loaded by feeding its electrical power into resistor grids. Since a load cell may not always be available or conform to test site requirements (see Figure 6-2), alternative ways of measuring locomotive noise often are used. These include stationary self-load testing for locomotives which are so equipped, and pass-by measurements of locomotives. The procedures relating to rail car noise emissions are for the pass-by condition.

General Requirements

The noise emitted by the locomotive should be measured from both sides when connected to a load cell or under self-load test, if possible. The test site should be selected in accordance with requirements of the previous section on physical, acoustical, weather and background noise conditions. Measurement on both sides of the locomotive would not be done for uncontrolled pass-by measurements.

For the stationary locomotive tests, the microphone should be positioned at a point on a line normal to the track and 30 meters (100 feet) from the center of the locomotive.

For moving rail car and locomotive tests, the microphone should be 30 meters (100 feet) from the track center line.

In all cases the microphone should be positioned 4 feet above the ground, with its diaphragm oriented toward the source in accordance with the manufacturer's recommendations to provide the most uniform frequency response.

The observer should be at least 3 meters (10 feet) from the microphone. Under no circumstances should an observer stand between the microphone and the source whose sound level is being measured.

To assure that adequate information is collected for each test it is recommended that the following data be recorded:

1. Name and precise location of test site
2. Locomotive: manufacturer, type, model, serial number and horsepower rating
3. A-weighted sound pressure levels as determined in the test described below
4. Altitude, above sea level, of the test site
5. Prevailing wind speed and direction at the time of the test

6. Date and time of day of the test
7. Name and identification of the person(s) making the test
8. Model and serial number of test instrumentation.

Two types of sound measurement tests seem particularly applicable for rail carrier noise emissions. These are the load cell test for stationary locomotives, and the wayside test for moving locomotives and rail cars. For load cell tests, measurements should be repeated at least three times for each side of the locomotive which is measured. The highest of the two arithmetic means, of the sound levels observed for each side, should be the sound level recorded. This is not possible for uncontrolled pass-by measurements. Only one measurement need be made for the uncontrolled wayside noise pass-by test for locomotives and rail cars.

Locomotive Load Cell and Self-Load Noise Emission Measurement

Measurement should be made at several throttle settings, with engine cooling fans operating; however, as a minimum, settings corresponding to idle and maximum engine power should be mandatory. The maximum engine power setting for most locomotives will correspond to setting eight. The sound level meter should be observed for thirty seconds after the test throttle setting is established. The maximum sound level observed during that time should be recorded.

Locomotive Pass-by Noise Emission Measurement

Locomotive noise measurements should begin when the locomotive, or combination of locomotives, is within 60 meters (200 feet) of the measuring position (as measured along the track) and continue until the last locomotive has passed at least 150 meters (500 feet) or is 10 rail car lengths away from the measuring point. The maximum sound level observed in this manner should be recorded. Locomotive acoustical warning devices such as horns, whistles and bells should be excluded in selecting the maximum sound level observed.

Rail Car Pass-by Test Noise Emission Measurement

Rail car noise measurements should begin when the locomotive or combination of locomotives has passed a distance of 300 meters (1,000 feet) or 20 rail cars beyond the measuring position. There should be no other locomotives within 300 meters (1,000 feet) or 20 rail car lengths from the measuring point. The maximum sound level observed in this manner should be recorded.

SECTION 7

ECONOMIC EFFECTS OF A RETROFIT PROGRAM

INTRODUCTION

The imposition of a railroad muffler retrofit program will affect both the railroads and the industries that purchase transportation services. Minimal changes in transportation patterns may be expected as a result of a retrofit program since increases in cost per ton mile of freight moved are estimated to be small. The purpose of this portion of the background document is to examine the possible magnitude of such effects; their consequences in terms of railroad viability and the transportation of commodities; and techniques by which adverse economic impacts might be avoided.

The study presented here relies on a number of information sources and makes a number of assumptions in the course of arriving at quantitative estimates of impact. Data on costs of materials and labor for retrofit program were obtained chiefly from muffler manufacturers and railroad personnel. Information on locomotive maintenance requirements was likewise obtained from the railroads. Operating and financial statistics for individual roads and the industry as a whole came from reports of the Interstate Commerce Commission. To project the ultimate economic effects of incurred costs, assumptions were required concerning future trends in railroad activity. In some cases for which a range of assumptions was possible, the alternative least favorable in terms of impact was chosen; in this sense, the analysis represents somewhat of a "worst case" approach. Wherever assumptions are made, however, they are substantiated to the extent allowed by existing data.

THE IMPACT ON THE RAILROAD INDUSTRY

General Impact

The engineering data gathered from discussions with various manufacturers and railroad operating personnel were used to estimate the direct cost of muffler retrofit by locomotive type and manufacturer. The differences in construction between switcher and road locomotives required that these be treated separately. The three categories of direct cost are mufflers, additional hardware, and labor. Since each make of locomotive is somewhat unique, it was necessary to make separate analyses of each type. The costs are shown in Table 7-1. The retrofit costs associated with the various types of locomotives are based on the designs of several common types, which make up about 90% of the population. For some locomotives, retrofit costs may be significantly higher than the figures shown here. This may be the case, for example, for several hundred units which, although originally conforming to one of the common designs, have been heavily modified during service so that their configurations now present difficult hardware problems to a muffler installer. Also, there are some 1,000 older road locomotives manufactured by Alco and Fairbanks-Morse and owned by a total of 22 railroads, the design of which may render muffler installation difficult. The Agency has been advised that these units are, in fact, in the process of being replaced. Thus this discussion assumes that such units will be retired from service during the compliance period.

The estimates of the direct cost of mufflers and additional materials were gathered from locomotive and muffler manufacturers; the sources of the data on required labor input were locomotive manufacturers, muffler manufacturers, and management personnel of selected railroads.

An hourly wage rate of $5.80 per hour was arrived at by taking total compensation of maintenance personnel as reported in annual ICC summaries and dividing by total hours worked.* Although this wage rate probably includes some overtime compensation, it may be an accurate

TABLE 7-1
MUFFLER COSTS* PER LOCOMOTIVE
(Source: Manufacturers' and Operators' Estimates)

Time of Installation	Locomotive Manufacturer and Type				
	GM Road	GM Switcher	GE Road	Other Road	Other Switcher
New Production	$3000 (RB) 2500 (TC)	$200 - 500	$1500	-----	-----
Muffler Only	1500	200 - 500	1500	1500	500 - 800
Additional Hardware	200 - 500	-----	1500 - 2500	1500 - 2500	-----
Labor @ 5.80/hr	464 - 1163	46	187	187	46
Total	$2164 - 3163	$246 - 546	$3187 - 4187	$3187 - 4187	$546 - 846

(RB) = Rootes Blown
(TC) = Turbocharged

*All railroad data presented in this section come from Interstate Commerce Commission, *Transportation Statistics in the U.S.* (1971) unless otherwise specified.

reflection of the true labor cost, since some retrofitting may be done at the overtime rate. We assume that the current mix of straight time and overtime will be used in the retrofit program.

No capital costs for maintenance facilities were assigned to the retrofit program. Annual compensation statistics and discussions with the Association of American Railroads indicate that the roads have been generally cutting back their maintenance staff over the last decade, while not necessarily reducing the size of their plant.* Frequently, therefore, excess physical capacity would be available for a retrofit program. In an economic, although not necessarily an accounting sense, such excess capacity can be utilized at zero cost.

The next step was to determine how many of each type of locomotive are in service. The May 1973 issue of *Railway Locomotives and Cars* lists the make and horsepower of each locomotive in service by railroad. In most cases, the horsepower of the engine could be used to determine whether it is a switcher or road locomotive. General Motors (GM) produces both a 1500-hp switcher and a 1500-hp road locomotive, but because road locomotives outnumber switchers by about seven to one, we assumed all General Motors 1500-hp locomotives to be road locomotives. This biased the cost estimates upward by a small amount. Table 7-2 shows the distribution of locomotives by type and manufacturer both nationally and for each of the three ICC regions.

TABLE 7-2

DISTRIBUTION OF LOCOMOTIVES BY MANUFACTURER, TYPE, AND REGION
(Source: "Railway Motive Power, 1973," *Railway Locomotives and Cars*, May 1973)

Manufacturer and Type	Region			
	Total	East (29 Roads)*	South (8 Roads)*	West (22 Roads)*
GM Road	16,155	7,006	2,026	7,123
GM Switcher	2,811	1,462	304	1,045
GE Road	1,930	878	230	822
Other Road	1,737	1,052	289	396
Other Switcher	1,504	734	139	631

*Number of roads in each district obtained from ICC, *op. cit.* Other listings of roads may not tally with this one, due to varying methods of accounting for mergers, subsidiaries, etc.

*Sources in the AAR state that this may not be the case for roads which have recently modernized their plants and which may have divested themselves of some unneeded facilities. In these cases, according to the AAR, the cost of installing or renting the needed plant and equipment may significantly increase retrofit costs. Unfortunately, precise estimates of capital stock in maintenance facilities do not exist.

Total direct cost of the retrofit program was obtained by multiplying the cost per locomotive by the number of locomotives.* This is given in Table 7-3 in terms of minimum and maximum costs for each region and for the entire nation.

TABLE 7-3

TOTAL DIRECT COST OF RETROFIT PROGRAM
(Millions of Dollars)

Region	Locomotive Manufacturer and Type					Total
	GM Road	GM Switcher	GE Road	Other Road	Other Switcher	
East						
max.	$22.160	$0.798	$3.676	$4.405	$0.621	$31.660
min.	15.161	0.360	2.798	3.353	0.401	22.073
West						
max.	22.530	0.570	3.442	1.659	0.534	28.735
min.	15.414	0.257	2.620	1.262	0.345	19.898
South						
max.	6.411	0.166	0.963	1.210	0.118	8.868
min.	4.386	0.075	0.733	0.921	0.076	6.191
National						
max.						69.263
min.						48.162

The annual direct costs in Table 7-4 were derived from Table 7-3 by dividing total cost by the number of years allowed to complete the retrofit program. In addition, the annual cost for 2- and 5-year compliance periods is shown as a percentage of the 1971 net operating revenue. It should be noted that we are assuming 2 and 5 years beginning at the time the muffler becomes available.

*Normally, some locomotives would be retired during the compliance period and, therefore, would not incur retrofit costs. (Their replacements would presumably have been quieted at the factory.) This consideration has not been included here, because it is difficult to forecast replacement rates in the light of an endemic shortage of motive power such as presently exists. If we assume instead that past retirement rates (about 2000 units per year from 1965 through 1969) are cut in half due to the shortage of locomotives, this will result in 5000 fewer units needing muffler retrofit for a 5-year compliance period and 2000 fewer over a 2-year period. The total cost estimates projected above would then be high by about 20% and 8% for the two compliance periods, respectively.

TABLE 7-4
ANNUAL DIRECT COST OF 2- AND 5-YEAR RETROFIT PROGRAMS

Region	Total Direct Cost (thousands of dollars)				Cost as Percentage of Net Revenue			
	2-Year		5-Year		2-Year		5-Year	
	Max.	Min.	Max.	Min	Max.	Min.	Max.	Min.
National	34,632	24,082	13,853	9,633	1.35	0.94	0.54	0.38
East	15,830	11,037	6,332	4,415	2.04	1.42	0.82	0.57
South	4,434	3,096	1,774	1,238	0.82	0.58	0.33	0.23
West	14,368	9,949	5,747	3,980	1.09	0.75	0.44	0.30

Generally, mufflers will not be available until 2 years after the regulation is promulgated, so that the 2-year program will not be completed until 4 years after promulgation, and the 5-year program until 7 years after promulgation.

It appears that the direct cost of a retrofit program will not constitute a significant burden on the railroads. Total direct cost is invariant with respect to compliance period, although annual cost is not. Annual cost is, therefore, probably a more relevant measure of the financial impact on the railroads.

The direct cost of retrofitting mufflers is only part of the total cost, however. If retrofitting requires that locomotives be taken out of service and if the railroads have no excess capacity with respect to locomotives then there will be some loss of revenue. At present, most railroads are operating at full capacity. The number of locomotives has decreased slightly from 1965 to 1973 (from 27,988 to 27,041) although total horsepower did increase from 52 million in 1971 to 55 million in 1973. It appears, therefore, that capacity has remained about constant or decreased slightly while demand has increased. It seems unlikely that the present high volume of grain shipments will continue beyond a year. Other factors, however, indicate that the current high levels of capacity utilization will probably continue into the future.

One of the developments that will tend to keep rail transportation at a high level of capacity utilization is the "energy crisis." A general fuel shortage favors the railroads over other modes of transportation. An increase in coal output, which seems inevitable, would stimulate rail freight volume. Coal, because of its low value per ton, is hauled almost exclusively by rail.

A further impact of a general fuel shortage would be to potentially degrade the quality and cost of truck transport relative to rail service. Restricted speed limits could induce delays and uncertainties in truck schedules. Fuel price increases would have a greater adverse impact on trucks than on rail, since trucks use 3.2 times as much diesel oil per ton mile of freight. As a result, transportation demand would tend to shift from trucks to rail. The net effect of these considerations is to support the assumption that railroads will be operating at close to full capacity for the next 5 or so years. This means that locomotive downtime due to retrofit may likely result in lost revenues.*

The time lost may be significantly reduced by scheduling retrofits during regular locomotive maintenance. Nationally, the average maintenance cycle is 4 years for an intermediate overhaul and 8 years for a heavy overhaul. The length of the cycle for an individual railroad is a function of

*One way in which operators may overcome this problem is to buy new locomotives to take the place of those being retrofitted. Such a procedure would virtually eliminate the indirect cost associated with the retrofit. This is an option, however, only if the locomotive manufacturers can produce the extra units. At present, according to locomotive manufacturers, locomotive production is below demand even though production facilities are operating at full capacity. It is reasonable to assume that conditions of motor power shortage relative to demand for transportation will persist throughout the compliance period, resulting in lost revenue when units are removed for retrofit.

locomotive mileage. Table 7-5 shows the national average adjusted regionally to reflect different average locomotive miles per year. The maintenance cycle is shortest in the West where locomotives travel more miles per year and longest in the East where miles per year are lowest.

TABLE 7-5

AVERAGE MAINTENANCE INTERVAL BY DISTRICT (years)
(Source: 1971 ICC Statistics and Operators' Estimates)

Type of Maintenance	Regional Average Maintenance Interval (Years)*			
	National	East	South	West
Intermediate	4.0	5.5	4.0	3.5
Heavy	8.0	11.0	8.0	7.0

*These figures do not include the effects of deferred maintenance as practiced by some roads in financial distress.

An intermediate overhaul generally takes about 2 to 3 days, while a heavy overhaul takes about 14 days. The estimated time required to retrofit a muffler ranges from 3 days for a General Motors road locomotive to 1 day for a switcher. Table 7-6 shows the number of lost locomotive days "charged" to retrofit under different conditions. Line 1, for example, gives lost days by type of locomotive if the locomotive is taken out of service specifically for retrofit. One can see that there are no lost days for any type of locomotive if all retrofitting is done during heavy overhaul.

TABLE 7-6

DAYS LOST DUE TO RETROFIT
(Source: Manufacturers' and Operators' Estimates)

Basis of Retrofit*	Locomotive Manufacturer and Type				
	GM Road	GM Switcher	GE Road	Other Road	Other Switcher
If done by itself	3	1	2	2	1
If done during regular intermediate overhauls	1	0	0	0	0
If done during regular heavy overhaul	0	0	0	0	0

*Assumes no lost time due to travel to and from shop and no muffler retrofitting done during emergency repairs.

As is shown, the total lost locomotive time due to muffler retrofits depends on how many locomotives can be treated during the normal maintenance cycle. Table 7-7 shows the expression used to compute total lost days for each line or district. The first term represents the time lost by GM road locomotives undergoing intermediate overhaul. The remaining three terms account for time lost by those locomotives that will not be due for routine maintenence during the compliance period and which, therefore, must be specially called in for muffler retrofit. (Recall from Table 7-6 that, except for GM road locomotives, units undergoing intermediate or heavy overhaul will experience no extra time lost due to retrofitting a muffler.)

TABLE 7-7

EQUATION FOR TOTAL LOST TIME PER DISTRICT

$$
LT = \left.\begin{array}{l}
\left[N_{GM} \times \dfrac{1}{2T_m} \times Y \times 1 \text{ day}\right] \\
+ \left[N_{GM} \times \left(1 - \dfrac{Y}{T_m}\right) \times 3 \text{ days}\right] \\
+ \left[N_{GEO} \times \left(1 - \dfrac{Y}{T_m}\right) \times 2 \text{ days}\right] \\
+ \left[N_{SW} \times \left(1 - \dfrac{Y}{T_m}\right) \times 1 \text{ day}\right]
\end{array}\right\} \text{ for } \left(1 - \frac{Y}{T_m}\right) > 0
$$

$$
= \frac{1}{2} N_{GM} \times 1 \text{ day} \qquad \text{for } \left(1 - \frac{Y}{T_m}\right) \leq 0
$$

where Y = number of years allowed for retrofit

N_{GM} = number of GM road locomotives

N_{GEO} = number of GE and "other" road locomotives

N_{SW} = total number of switchers of all makes

T_m = time interval for "Intermediate" maintenance

The equation in Table 7-7 has been used to compute lost locomotive days for each region. These have been summed to give a national total. The figures are shown in Table 7-8. Two compliance periods are used to illustrate the decrease in lost time with a longer retrofit period. We see from the table that increasing the period from 2 to 5 years results in a decrease of the lost locomotive days per year by 70 percent.

A change in the compliance period affects only the number of lost locomotive days; the direct cost of the retrofit program does not change. If we take the total number of lost locomotive days resulting from a 2-year period and assign it the number 1, then the total number of lost days for a 3-year program is 0.76, the total of a 4-year program is 0.52, and the total of a 5-year program is 0.29. As the compliance period is lengthened, lost locomotive days decrease; thus, the indirect cost of the program decreases.

The calculations of lost locomotive days must be translated into dollar costs. A number of problems arise in calculating the value of a locomotive. First, should a distinction be made between road locomotives and switchers? It seems desirable to treat the transportation revenue earned by rail service as being earned by both road and switch engines, since the lack of either (if both are used to full capacity) would cause a reduction in service. We have therefore assumed that each has the same value per day.

Secondly, what value should be assigned to a locomotive day? If all roads are operating at full capacity, then removing a locomotive causes a daily loss of revenue amounting to the value of one locomotive day. A locomotive day is thus evaluated at the value of the average product. This technique is further justified in capital theory, which states that the value of a piece of capital is the present value of its discounted future stream of earnings, that is, the present value of the marginal product.

TABLE 7-8

LOST LOCOMOTIVE DAYS BY REGION AND COMPLIANCE PERIOD

Compliance Period	Lost Locomotive Days	Region			
		National*	East (29 roads)	South (8 roads)	West (22 roads)
2-year program	Yearly	17,048	9,252	2,143	6,378
	Total	34,096	18,504	4,286	17,048
5-year program	Yearly	2,044	1,129	203	712
	Total	10,220	5,645	1,013	3,562

*Locomotive days lost nationally is not the sum of the three regions, since the national was calculated using an average maintenance cycle and the regional was adjusted to reflect different utilization rates.

Given the conditions stated above, the value of a locomotive day was calculated by taking total transportation revenue and dividing by the total number of locomotive days available. Table 7-9 shows these calculations nationally and regionally. Table 7-10 gives estimates of the indirect costs of a 2- and 5-year retrofit program by incorporating the lost locomotive days from Table 7-8 and the value of a locomotive day from Table 7-9. Note that the shorter the compliance period the larger the total indirect costs. This is a function of the increase in the number of lost locomotive days as the compliance period is shortened.

TABLE 7-9

REGIONAL ANNUAL REVENUE PER LOCOMOTIVE DAY

	Region			
	National	East	South	West
Total tranportation revenue (millions of $)	$12,417	$4,497	$2,121	$5,799
Transportation revenue per locomotive day ($)	1,251	1,186	1,256	1,304

TABLE 7-10

ESTIMATED LOST REVENUE DUE TO RETROFIT
(Thousands of Dollars)

Region	2-Year Program*		5-Year Program	
	Per Year	Total	Per Year	Total
National	21,982	43,963	2,557	12,785
East	10,973	21,946	1,338	6,690
South	2,692	5,383	254	1,270
West	8,317	16,634	928	4,640

Table 7-11 arrives at the annual net retrofit cost by combining the direct and indirect costs and subtracting the reduction in operating costs that would occur as a result of a reduction in traffic. Cost reductions were determined from the ICC detailed accounts and include the following:

Account No.	Description
365	Dispatching Trains
367	Weighing, Inspection, & Demurrage Bureaus
368	Coal and Ore Wharves
371	Yard Conductors & Brakemen
373	Yard Enginemen
374	Yard Switching Fuel
382	Train Enginemen
383	Train Fuel
387	Trainmen
388	Train Supplies and Fuel
395	Employees' Health and Welfare Bureaus

The estimates of cost reductions used here are much lower than those used by the ICC.* They have claimed that 80 percent of costs are out of pocket or variable costs. This might be true if railroads were curtailing service in the face of falling demand. Variable cost may constitute 80 percent of total cost, but the situation dealt with here is an unplanned reduction in capacity in the face of full utilization of equipment. Under these circumstances, it seems unlikely that the railroads would curtail other operations but rather that they would attempt to offset locomotive shortages by changes in labor and equipment usage patterns. In addition, if there are adjustment costs and since the cutback in capacity is temporary, the railroads would be expected to respond differently from a situation in which the reduction was anticipated to be of longer duration. Table 7-12 gives the total net cost of the 2- and 5-year programs. Again, it points up the cost differential associated with different compliance periods. Much of the computed retrofit cost is the result of lost revenue to the railroads. Figure 7-1 shows the breakdown of annual cost into direct and indirect components for compliance periods of 2 to 5 years.

*See U.S. Interstate Commerce Commission, Bureau of Accounts, *Explanation of Rail Cost Finding Procedures and Principles Relating to the Use of Costs*. St. 7-63, Washington, D.C., 1 November 1963 and U.S. Interstate Commission, "Rules to Govern the Assembling and Presenting of Cost Evidence." Docket No. 34013,321 I.C.C. 238 Order of April 16, 1962.

TABLE 7-11

ANNUAL NET COST OF RETROFIT
(Thousands of Dollars)

Direct Cost	National	East	South	West
2-year program				
max	$34,632	$15,830	$4,434	$14,368
min	24,082	11,037	3,096	9,949
5-year program				
max	13,853	6,332	1,774	5,747
min	9,633	4,415	1,238	3,980
Indirect Cost				
2-year program	21,982	10,973	2,692	8,317
5-year program	2,557	1,338	254	928
Reduction in Operating Costs				
2-year program	4,964	2,748	555	1,856
5-year program	597	335	53	207
Net Cost				
2-year program				
max	51,650	24,055	6,571	20,829
min	41,100	19,262	5,233	16,410
5-year program				
max	15,813	7,335	1,975	6,468
min	11,593	5,418	1,439	4,701

TABLE 7-12

TOTAL NET COST OF RETROFIT PROGRAM
(Thousands of Dollars)*

Compliance Period	National		East		South		West	
	Max	Min	Max	Min	Max	Min	Max	Min
2 years	103,300	82,200	48,110	38,524	13,142	10,466	41,658	32,820
3 years*	95,221	74,121						
4 years*	87,143	66,043						
5 years	79,065	57,965	36,675	27,090	8,875	7,195	32,340	23,505

*These represent linear interpolations of the 2- and 5-year programs.

The annual costs shown in Table 7-11 are best understood in the context of total operating revenue for each region. Table 7-13 shows that the eastern roads would pay a higher percentage of total revenue toward a retrofit program than would the other regions.

Annual retrofit cost as a percentage of net operating revenue* gives the best indication of the rail industry's ability to pay for a retrofit program (see Table 7-14). Retrofit constitutes a small percentage of net operating revenue both nationally and regionally. As we have seen earlier, however, the eastern railroads will pay the highest percentage of net revenue for the retrofit program. This partly reflects the fact that eastern roads as a group tend to earn less profit than roads in other regions.

TABLE 7-13

ANNUAL RETROFIT COST AS A PERCENTAGE OF 1971 TOTAL OPERATING REVENUE

Compliance Period	National		East		South		West	
	Max	Min	Max	Min	Max	Min	Max	Min
2 years	0.42%	0.33%	0.53%	0.43%	0.31%	0.25%	0.36%	0.28%
5 years	0.13%	0.09%	0.16%	0.12%	0.09%	0.07%	0.11%	0.08%

*Net operating revenue is defined as transportation revenue minus variable transportation costs. Subtracting rents, taxes, and interest payments from net operating revenue gives net operating income, or profit from freight operations.

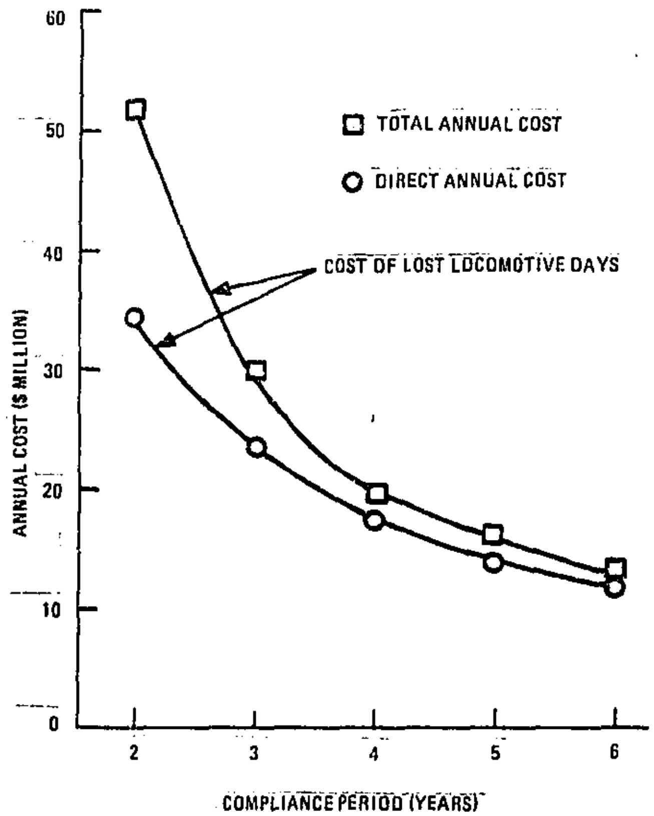

Figure 7-1. Cost of Retrofit Program as a Function of Compliance Period

TABLE 7-14

ANNUAL RETROFIT COST AS A PERCENTAGE OF 1971 NET OPERATING REVENUE

Compliance Period	National		East		South		West	
	Max	Min	Max	Min	Max	Min	Max	Min
2 years	1.96%	1.56%	2.48%	0.31%	1.22%	0.97%	1.58%	1.24%
5 years	0.60%	0.44%	0.95%	0.70%	0.38%	0.27%	0.49%	0.36%

Bankrupt roads constitute a special subset for which financial and operating problems are substantially different than for normal roads; these will be treated elsewhere.

In order to give a more detailed picture of the industry's ability to pay for a retrofit program, program cost as a percent of net operating revenue has been computed for each Class I railroad (including bankrupt roads but excluding those with negative net revenues). Figure 7-2 shows how the railroads are distributed with respect to cost-to-net revenue ratio. The figure shows that the impact of a 2-year program is much greater than that of a 5-year program.

The Impact on Marginal Railroads

The adverse effects of extra operating costs is greater on firms in financial distress than those that are healthy. This is of concern in the case of the railroads, because a number of them face difficulties in maintaining profitable operations. It is important to estimate the number of railroads that may have trouble paying the cost of a retrofit program even though the magnitudes of the expenses involved in such a program are small relative to other expenses faced by the railroads. (For example, a 30 percent increase in the price of diesel fuel would increase operating costs by roughly $125 million.* This would represent from 2.5 to 12 times the annual cost of a muffler retrofit program, depending on the compliance period allowed.)

This section attempts to gauge the extent of the problem posed in paying for a retrofit program by determining how many railroads are in financial distress. This is done by computing, for each road, several financial ratios that are generally accepted as indicating the financial condition of a business enterprise. A summary of the number of roads with unfavorable values for each ratio is then given. This technique does not give a quantitative definition of which railroads cannot afford a retrofit program. At best, it gives a rank-ordering. The cutoff value that determines "financial distress" is arbitrary.

*This figure is computed by using as a baseline the total cost of fuel for all Class I railroads in 1971, which was $417 million (ICC, op. cit.)

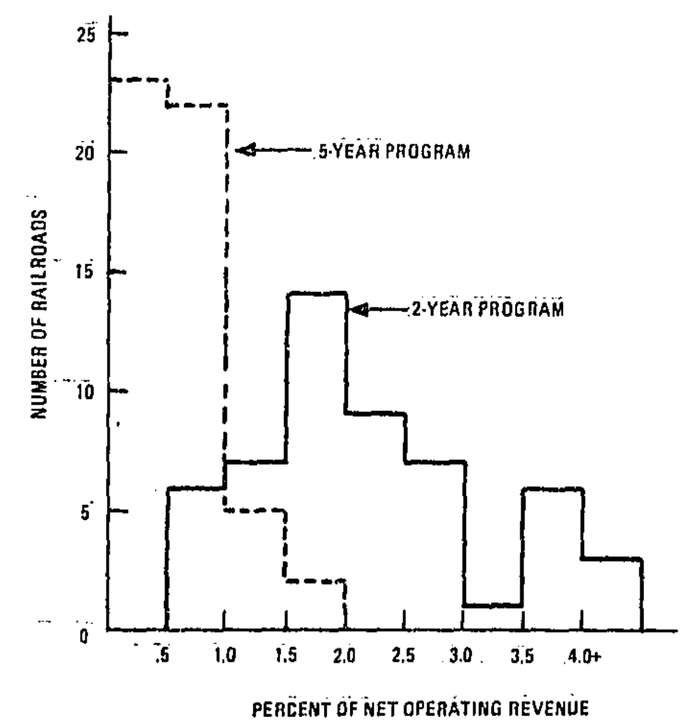

Figure 7-2. Distribution of Railroads by Retrofit Cost as a Percent of Net Operating Revenue for 2- and 5-year Compliance Periods. (Maximum Total Cost Assumed. Bankrupt Roads Included; Made with Negative Net Operating Revenue Excluded.)

The following financial ratios were computed:

a. Current assets/total assets
b. Operating ratio (operating expenses/operating revenues)
c. Total liabilities less stockholders' equity/total assets
d. Income after fixed charges/total assets
e. Retained earnings/total assets
f. Net income/total assets
g. Net income/operating revenue

All bankrupt roads are excluded from this discussion, which is concerned only with roads that have not been declared bankrupt but which may be in financial distress.

In most cases these ratios parallel those used by Edward Altman (1971). Ratios a and b are measures of the liquidity* of a railroad, while b, d, f, and g are measures of profitability and efficiency. Ratio c measures solvency.

With respect to ratio *a*, the analysis seems inconclusive. A large number of roads had ratios of current to total assets in excess of three standard deviations from the mean. This indicates that the distribution of values of this ratio did not approximate a normal distribution. This being the case, ratio *a* does not constitute a valid indicator of which roads may be in distress.

The analysis of ratio *e* (retained earnings/total assets) indicated that 14 railroads have negative retained earnings, while two have zero, showing that these roads lack liquidity. While internal financing may not be important in the rail industry, the negative retained earnings indicates that these roads are drawing down cash reserves.**

The most commonly used measure of profitability is operating ratio *b*, the ratio of operating revenue to operating expenses. Three roads have operating ratios greater than 1, indicating that expenses exceed revenue. An additional seven roads have operating ratios more than three standard deviations higher than the mean. Certainly the three roads and possibly some of the seven must be considered to be in an adverse position. Ratios *f* and *g* are similar measures, in that a road with a negative net income will have a negative ratio for both *f* and *g*. Six roads have negative net incomes. In addition, two other roads must be considered to be poor performers as measured by the ratio of net income to total assets (*f*).

Ratio *d* indicates that nine roads have negative income and two have zero income after fixed charges. These roads are unprofitable by definition. The ratio of total liabilities (less stockholders' equity) to total assets *c* appears to have also yielded inconclusive results. One road stands out as being extremely poor by this measure, and there are four other roads for which this ratio is greater than 1.

---

*Liquidity is the ability of a firm to convert assets into cash.

**This may also represent an insufficient amount of funds allocated to depreciation.

A word of caution should be issued in the interpretation of any ratio that uses total assets. Under the "betterment" accounting procedure, total assets tend to be inflated. However, to the extent that this bias is uniform throughout the industry, it is possible to compare different roads. It is not possible to compare these ratios with other firms outside the rail industry.

Table 7-15 summarizes the above findings with respect to the named ratios. As was mentioned before, the table lists "worst performers" as indicated by each ratio, the cutoff point being rather arbitrary. More significant is Table 7-16, which shows how many of the railroads contained in the previous table appear under more than one ratio. Table 7-16 shows that 12 roads are in distress with respect to three or more indicators; it can reasonably be presumed that these 12, at least, could have difficulty in financing a retrofit program.

The Impact on Bankrupt Railroads

Of the 71 Class I line-haul railroads in the United States, seven are bankrupt: Boston and Maine, Central Railroad of New Jersey, Erie Lackawanna, Lehigh Valley, Penn Central Transportation Co., the Reading Co., and Ann Arbor. These seven railroads operate about 20% of the locomotives owned by Class I railroads in the U.S. Not surprisingly, the total cost of retrofit for these roads (see Table 7-17) is about 20% of the total cost for the entire muffler retrofit program.

These railroads will have difficulty financing the cost of a muffler retrofit program. There is no question that the financial positions of these roads are bad. All six have negative net income, and are currently meeting their deficits in part by drawing down cash reserves. Many of these roads are currently receiving some form of subsidy, and all are in default on interest payments, bonds, and/or taxes.

THE IMPACT ON USERS OF RAIL TRANSPORTATION

The effect of a muffler retrofit program may be felt by the railroads' users in either or both of two ways. First, the possibility exists that the railroads may try to recover their retrofit expenses through a rate increase. Second, the withdrawal of locomotives from service could result in reduced hauling capacity and a consequent decline in the quality of service. Either of these developments would tend to encourage some shippers to seek elsewhere for transportation services. This section examines the possible magnitude of these effects.

The Effect On Railway Freight Rates

The ability of the rail industry to recapture the cost of a muffler retrofit program depends on the characteristics of the market it faces. The establishment of Amtrak and the low volume (and high price elasticity) of passenger service probably precludes the railroads from recovering any of the retrofit costs through increases in passenger fares; rather, increased revenues would be more likely to come from increasing freight rates.

TABLE 7-15

NUMBER OF RAILROADS IN UNFAVORABLE FINANCIAL POSITION RELATIVE TO EIGHT INDICATORS

(For Each Indicator, Railroads Listed in Order of Increasingly Favorable Position)

Indicator	Number of Roads in Unfavorable Position
A. Current assets/total assets	Inconclusive
B. Operating ratio	4 roads' greater than 1 (expenses > revenues) 4 roads' between 1 and .85
C. Total liabilities (less stockholders' equity)/total assets	3 roads' greater than 1 2 roads' equal 1 2 roads' between .99 and .71
D. Income after fixed charges/ total assets	8 roads' negative 1 road's zero
E. Retained earnings/total assets	13 roads' negative 1 road's zero
F. Net income/total assets	4 roads' negative 4 roads' zero 2 roads' positive but less than .011
G. Net income/operating revenue	4 roads' negative 2 roads' zero 2 roads' positive but less than .031

TABLE 7-16

NUMBER OF RAILROADS DESIGNATED AS BEING IN FINANCIAL DIFFICULTY BY ONE OR MORE FINANCIAL INDICATORS

Number of Financial Indicators, N, in Table 7-15	Number of Railroads Appearing under N Indicators in Table 7-15
1	7
2	2
3	6
4	3
5	2
6	1

TABLE 7-17

NET COST OF MUFFLER RETROFIT PROGRAM FOR THE SEVEN BANKRUPT CALSS I RAILROADS

Length of Program	Annual Cost		Total Cost	
	Max	Min	Max	Min
2 Years	$10,569,000	$8,393,000	$21,139,000	$16,786,000
5 years	3,197,000	2,326,000	15,984,000	11,631,000

Freight rate increases must be approved by the Interstate Commerce Commission. Inquiries to the ICC indicate that the Commission places no *a priori* limits on the magnitude of rate increases that may be requested. It is entirely the railroad industry's prerogative to decide if requests for rate increases are to be submitted to cover the costs shown in Table 7-12. Any cost factor could form a legitimate basis for increasing rates to recover costs. Furthermore, the Commission is considering environmental aspects in its rate determination. As a result of litigation involving the environmental effects of various rate structures, the ICC has prepared several Environmental Impact Statements showing their concern.*

In summary, there are strong indications that the rate increases that could be requested by railroad companies to defray the costs of noise reduction would fall within the practice of the ICC. No *a priori* bias would be applied by ICC agents, and they could be expected to act with a positive attitude toward the objective of improving the quality of the environment.

To place the level of expenditure and possible freight rate increase in perspective, previous cost increases and subsequent rate increases may be used for reference. In the ICC report served 4 October 1972, in Ex Parte 281, a rate increase for railroad freight was authorized. The railroads claimed in their rate request that expenses had increased $1.312 billion from January 1971 to April 1972. The authorized rate increases were

National Average	3.44%**
East	3.60%
South	3.10%
West	3.44%

These increases, if fully applied, would have increased revenue by $426 million; however, the most usual case is that they are not fully applied. The industry estimates that only 85% or $349 million will actually be realized.***

Since the rate increase of September 10, 1972, costs have risen by $930 million. About 80% of this rise has stemmed from wage increases and increased payroll taxes. In light of these higher costs, in April of 1973 the railroads applied for a 5% rate increase. The maximum cost of the 2-year muffler retrofit program is about $51 million, which is only 5.5% of the $930 million cost increase that led to the request for a 5% rate increase. The rail industry claims that if the entire $930 million cost increase is to be recovered, it will require a 7.5% increase in rates.****

*See ICC Docket, Ex Parte 281 and Ex Parte 344F, Supplement 927.

**The national average was calculated by using regional data.

***These figures come from estimates made by the rail industry. They assume that the elasticity of demand is zero--an unlikely situation. The question of elasticity is considered later in this section.

****Again, this estimate assumes that the elasticity of demand for rail service is zero.

The amount of the recoverable costs and the attendant freight rate increase necessary will depend on the elasticity of demand for rail freight service.* The annual (maximum) retrofit costs for the 2-year program represent about 0.4% of 1971 freight revenue, while the 5-year (minimum) program represents only about 0.1% of freight revenue (see Table 7-13).

Data from Friedlander (1969, p.73) for 1961 have been used to calculate an overall rail freight demand elasticity of −0.7. Using this elasticity, we can estimate the increase in freight rates necessary to offset the increased costs. The freight increases are shown in Table 7-18. Also shown in the percent these increases would represent of the 1971 average rate per ton mile, which was $.01594.

TABLE 7-18

RATE INCREASE THAT WOULD ENABLE RAILROADS TO RECOVER RETROFIT EXPENSES

	Rate Increase (Cents per Ton Mile)	Percent of 1971 Average Freight Rate
2-year		
max	.0232	1.46%
min	.0184	1.15
5-year		
max	.0076	0.48
min	.0057	0.36

These rate increases must be interpreted carefully. They were calculated by using demand elasticities derived from 1961 data; since then a number of changes have taken place that would probably increase the elasticity of demand for rail service. First, the near-completion of the interstate highway system has improved the service rendered by trucks and has reduced operating costs. Second, the rise in interest rates has made the cost of holding inventories higher and might have made shippers more sensitive to other service characteristics, causing a downward shift in the demand curve and potentially increasing its elasticity. Third, shifts among the various commodity classes of freight might have resulted in an increase in the elasticity. For example, if the price elasticity of demand for rail service is higher for mineral ores than for manufactured products and if the share of mineral ores has increased relative to manufactured products, then the overall elasticity would have increased.

*Elasticity of demand is the ratio of the percent rise in quantity demanded to the percent rise in price. An elasticity coefficient of −.1, therefore, indicates that a 10% price increase would result in a 1% decrease in demand.

We have attempted to make some estimates of the new elasticity, taking into account the shift in the distribution of commodities. The results should be interpreted only as tentative. We have used the 1961 elasticities for each commodity group but have weighted them by the 1971 commodity distribution.

Data from Friedlander (*op. cit.*, p. 73) have been used to obtain the following elasticities for the five major commodity groups:

Commodity	Elasticity
Agriculture	0.5
Animal products	0.6
Products of forests	0.9
Products of mines	1.2
Manufacturing and other	0.7

These figures represent the pre-1964 commodity classifications used by the ICC. In order to determine the current elasticity of demand, we used these commodity group elasticities and weighted them by the current distribution of freight within these groups. These weighting factors are as follows:

Commodity	Weight
Agriculture	.097
Animal products	.0002
Products of forests	.144
Products of mines	.420
Manufacturing and other	.387

To determine the distribution, it was necessary to take the current freight classifications and assign them to one of these categories.

The overall elasticity was calculated to be -0.953, significantly more than the estimate of -0.7 obtained from Friedlander's data. Even more interesting is the distribution of elasticities by district. To arrive at these estimates, it was necessary to assume that the rate per ton mile for each of the 1971 commodity classifications was equal for each of the three districts. Although this is not the case, we believe the errors to be quite small. The estimated elasticities are:

East	-0.99
South	-0.95
West	-0.83

These figures indicate that the eastern roads, which are in financial difficulty, would have the most trouble recovering the cost of a retrofit program. The western roads, which as a group are the most profitable, would recover the cost of a retrofit program most easily.

Given the energy crisis, however, even this tentative analysis may not be valid. As discussed earlier railroads use less energy per ton mile of freight moved than trucks, pipelines or airlines. As a result, railroads would be impacted less than these other competitive modes by increases in fuel costs.

It is not possible to predict accurately at this point, the effect of any rate increases the ICC might grant to the railroads to recover the costs of a retrofit program. The possible effects of increased rates on demands for rail service are directly related to the energy situation. If competitive modes of transportation (i.e., trucks, pipelines, and airlines) are more severely impacted by increased fuel rates, the fact that railroads increased their rates to cover the costs of a retrofit program might well be insignificant.

The Effect on Quality of Service

It has been shown above (see Introduction) that, in order to accomplish a retrofit program within a compliance period of 5 years or less, some locomotives would likely have to be withdrawn from service in addition to those undergoing maintenance by the usual schedules. The number of locomotive days taken up in this manner is given in Table 7-19, in absolute numbers and as a percentage of locomotive days available. If, under normal conditions, the railroads are operating at or near full capacity, then the figures shown in the table represent the upper bound of lost freight-hauling capability.

TABLE 7-19
ANNUAL LOCOMOTIVE DAYS TAKEN UP BY RETROFIT PROGRAM

Compliance Period	Locomotive Days	Region			
		National	East	South	West
2-year	Absolute	17,048	9,252	2,143	6,378
	% of Total Available	.194%	.225%	.197%	.174%
5-year	Absolute	2,044	1,129	203	712
	% of Total Available	.023%	.027%	.0187%	.0195%

The impact of decreased hauling capability on the various commodities shipped by rail depends on how the railroads react to the capacity decrease. There are two ways in which demand for rail service can be made to equal the available supply: non-price rationing or price rationing.

In the case of non-price rationing, the railroads could simply allow service to decline in quality while maintaining the same rates. The resulting delays and uncertainties in the transportation network would have differential impacts on the various commodities being shipped; those items highly sensitive to the quality of service will tend to be diverted to other modes of transportation. Commodities in this category are high-valued products, for which transportation charges are a small fraction of total value, and perishables.

Price rationing involves raising the price of service (with the approval of the ICC) in order to decrease demand to the level of the new, reduced capacity. Such a policy would affect commodities sensitive to freight rates; examples of these would be mineral ores and semifinished products. Such goods would tend to be shipped by other modes, or the quantity shipped would be reduced.

The probable magnitude of the effect of price rationing can be estimated. Table 7-19 shows that, in the worst case, capacity would decline by about .2% nationally. Assuming (from p. 7-22) that the elasticity of demand for rail transportation is about -.7 gives a price rise of .28% necessary to effect the required reduction in demand. This amounts to an average increase of .004 cents per ton mile relative to the 1971 average freight rate. This increase is fairly small, so minimal changes in transportation patterns may be expected as a result of the retrofit program.

SUMMARY AND CONCLUSIONS

Impact on the Railroad Industry

Cost. The cost of a muffler retrofit program is highly sensitive to the compliance period allowed. Maximum total cost for a 2-year program is estimated to be $103 million. Allowing 5 years for compliance would reduce the total cost to approximately $79 million.

Change in net revenues. The impact of a 2-year program would be to reduce overall Class I railroad annual net operating revenues by about 2%.

Effect on prices. For the railroads to recover the expense of a retrofit program would require an average freight rate increase of approximately .023 cents per ton mile in the 2-year case and .008 cents per ton mile in the 5-year case. These figures represent, respectively, 1.46% and .48% of the 1971 average freight rate.

Effect on capacity. A 2-year retrofit program would result in an annual loss of as many as 17,000 locomotive days, or about .2% of the total available, for the duration of the program. This would drop to about .02% for a 5-year program.

Impact on marginal railroads. Approximately a dozen railroads are in financial difficulties, as indicated by the computed values of a number of standard financial ratios. These roads may have difficulty in raising the funds necessary to pay for a retrofit program.

Impact on bankrupt railroads. Six roads are presently bankrupt, and may not be able to finance a retrofit program without an external source of funds. The total program cost for these roads would be $21 million for a 2-year program and $16 million for a 5-year program.

Impact on Users of Rail Services

Prices. Increases in freight rates would tend to encourage some shippers to seek alternate modes of transportation. This would occur primarily among shippers of commodities whose price is sensitive to transportation cost, such as semifinished products. It is not likely, however, that the small rate increases foreseen by this study would cause any major hardships or dislocations.

The energy crisis may make any railroad rate increases insignificant compared with competitive modes of transportation, which would be more severely impacted by rising fuel costs.

Quality of service. A decrease in the haulage capacity of the railroads may result in the diversion of some freight to other modes of transport. Which commodities would be affected depends on how the railroad decided to reduce demand to the level of supply. If rates were raised, the effect would be the same as discussed in the previous paragraph. If rates remained constant but shipping delays were allowed to develop, commodities sensitive to transit time (such as perishables) would be most affected. Such diversions, however, will tend to be localized and on a small scale in view of the small reductions in capacity anticipated.

SECTION 8

ENVIRONMENTAL EFFECTS OF PROPOSED REGULATIONS

INTRODUCTION

The proposed regulations will immediately stop the noise emitted by railroad trains from increasing and over a 4-year period will progressively reduce the noise presently emitted by railroad locomotives. As a result, the number of people currently subjected to annoying levels of railroad noise will be reduced.

IMPACT RELATED TO ACOUSTICAL ENVIRONMENT

Several studies have been conducted to estimate the reduction in noise levels, and the number of people who will potentially benefit as a result of the noise control standards proposed.

Case Studies of Railroad Lines

Ten cities with widely varying populations were selected to make detailed comparisons of train traffic with population densities near railroad tracks and with the type of land use adjacent to tracks (see Table 8-1). Such comparisons provide a basis for determining how many people are exposed to railroad noise, how often they are exposed, and what activities they are engaged in at the time.

The schedules of trains moving over the railroad lines were determined from *The Official Guide of the Railways*, July 1973, or from employee timetables. Estimates of speed maxima and minima were taken from employee timetables or obtained from railroad employees. Speeds for AMTRACK trains were not obtained. The period between 10:00 p.m. and 7:00 a.m. was designated as "night," and the rest of each 24-hour period was designated as "day," Table 8-2 summarizes the results of the ten case studies.

Analysis of Train Noise Impact

There are three major noise sources that contribute to L_{DN} (see Enclosure A for definition of L_{DN}) at points along and away from railroad tracks: locomotives, wheel/rail interaction, and horns or whistles.

TABLE 8-1
LAND USE NEAR RAILROAD LINES

City and State	Land Use Within 500 Ft of Track (Percent)			
	Residential	Business	Industrial & Other	Mileage Studied
Newton, Mass.	75	21	4	6
Boston, Mass.	59	9	32	7
Valparaiso, Ind.	43	8	49	9
St. Joseph, Mo.	42	13	45	26
Akron, Ohio	40	23	37	25
Somerville, Mass.	30	18	51	7
Michigan City, Ind.	29	15	56	17
Kalamazoo, Mich.	22	5	73	20
Altoona, Pa.	16	18	65	6
Ft. Lauderdale, Fla.	12	22	66	21
Lewiston, Maine	12	19	68	11
Denver, Colo.	12	3	85	51
Cheyenne, Wyo.	9	11	79	15
Cambridge, Mass.	8	24	68	9
Macon, Ga.	6	4	90	25
Average	28	14	58	Total 255

TABLE 8-2
TRAIN TRAFFIC AND COMMUNITY CHARACTERISTICS NEAR TYPICAL RAILROAD LINES

CITY & STATE	POPULATION	NUMBER OF FREIGHT TRAINS DAY	NUMBER OF FREIGHT TRAINS NIGHT	MAXIMUM FREIGHT SPEED (mph)	NUMBER OF PASSENGER TRAINS DAY	NUMBER OF PASSENGER TRAINS NIGHT	MAXIMUM PASSENGER SPEED (mph)	LAND USE (%) RESIDENTIAL	LAND USE (%) BUSINESS	LAND USE (%) OTHER	NO. OF PEOPLE PER SQUARE MI. WITHIN 500 FT	MILEAGE STUDIED LAND USE	MILEAGE STUDIED POPULATION
Akron, Ohio	542,775	22	18	55	0	0		40	23	37	1,662	25	31
Altoona, Pa.	81,795	7	5	50	2	2	70	16	18	65	3,090	6	12
Boston, Mass.	961,071	0	8	40	0	0	–	59	9	32	20,660	7	7
Cheyenne, Wyo.	40,914	?	?	?	2	0	?	9	11	79	1,471	15	9
Columbus, Ind.	27,141	1	1	50	0	0		?	?	?	730		20
Denver, Colo.	1,047,311	24	10	60	4	0	?	12	3	85	3,027	51	26
Durham, N.C.	100,764	11	1	65	0	0	–	?	?	?	1,760		31
Michigan City, Ind.	39,369	5	2	50	2	0	50	29	15	56	608	17	43
Newton, Mass.	91,066	7	1	50	0	0	–	75	21	4	5,320	6	6
Valparaiso, Ind.	20,020	19	10	60	0	0	–	43	8	49	1,528	9	9

Figure 8-1 shows some L_{DN} profiles that were calculated by applying the prediction techniques to actual operations on a specific railroad line. The profiles shown in Figure 8-1 were calculated from the following data supplied by Penn Central:

10:00 p.m. and 7:00 a.m.
6 freight trains
each 14 loaded cars and 10 empty cars
40 mph
and
7:00 a.m. and 10:00 p.m.
36 passenger trains, each
40 mph

Passenger trains with eight cars correspond to the national average passenger loading of cars (Moody, 1971). The curve for two cars is displayed in order to demonstrate the influence of the number of cars on the results.

Since there are no crossings along the branch picked for this study, no whistle noise was considered. In addition to the usual geometric attenuation, atmospheric absorption and ground surface attenuation (Beranek, 1971) were included in the calculation for Figure 8-1 (See enclosure B to this Section.).

Figure 8-2 shows L_{DN} profiles that were calculated for the average of all the train movements in the U.S. The profiles were calculated from the following data (Moody, 1971);

Urban Areas

4 freight trains by day, 2 by night, each 33 mph, 40 cars 3800 tons

2 passenger trains by day, 0 by night, each 36 mph, 6 cars

Nonurban Areas

3 freights by day, 2 by night, each 33 mph, 40 cars, 3800 tons

0 passenger trains

Figures 8-3 through 8-6 provided examples of the impact on the community of a program to equip locomotive exhausts with mufflers. Figure 8-3 shows that a muffler that provides 10 dB(A) of quieting will nearly halve the distance to which people are exposed to L_{DN} of 55 or more by train traffic on the Dorchester Branch of Penn Central (assuming that no other sources of locomotive noise produce levels comparable to exhaust noise levels). Figure 8-4 shows that there is a reduction of 24,000 people exposed to L_{DN} of 55 or more by train traffic on the 7.2-mile-long Dorchester Branch. Figure 8-5 is based on national average train traffic and also shows that a muffler that quiets locomotive exhaust noise by 10 dB(A) will more than halve the distance to which people are

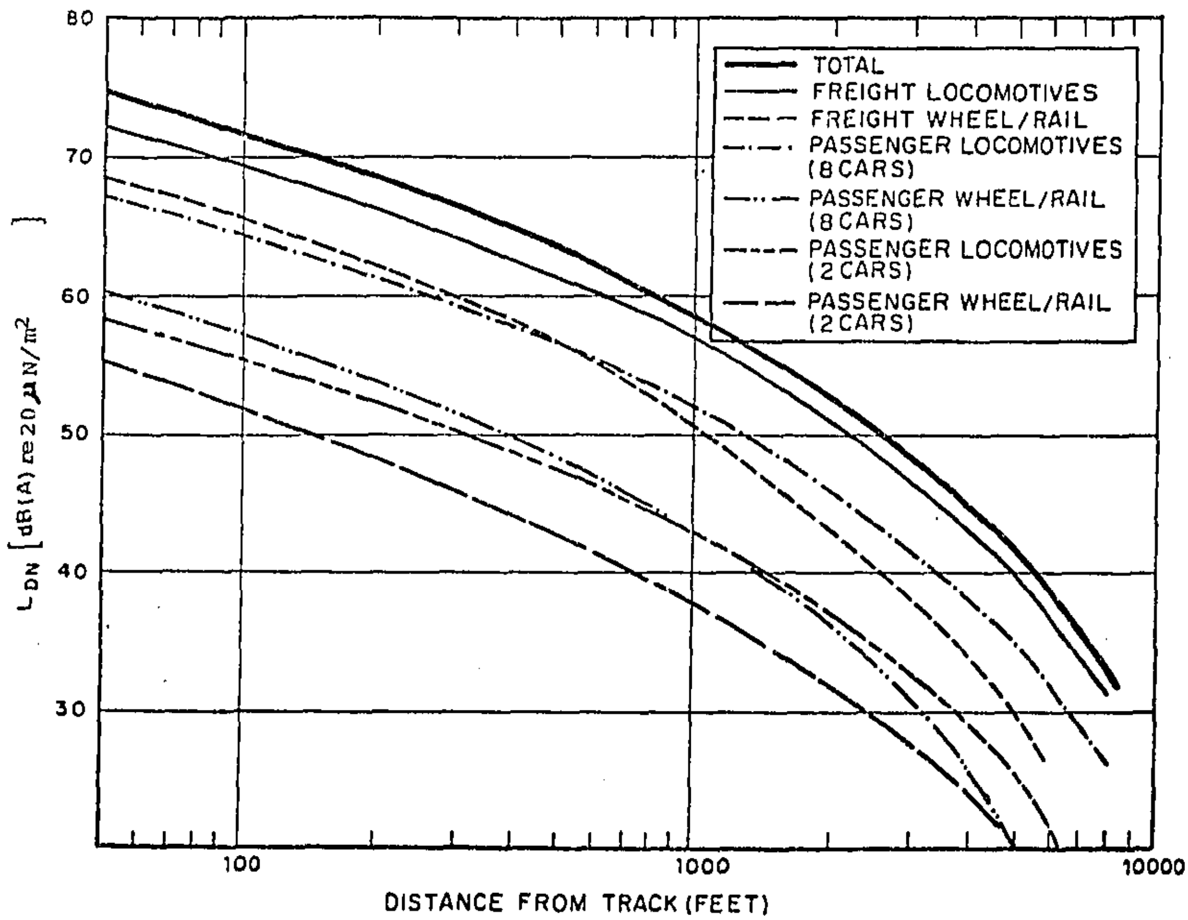

Figure 8-1. L_{DN} vs Distance From the Track for the Dorchester Branch of Penn Central

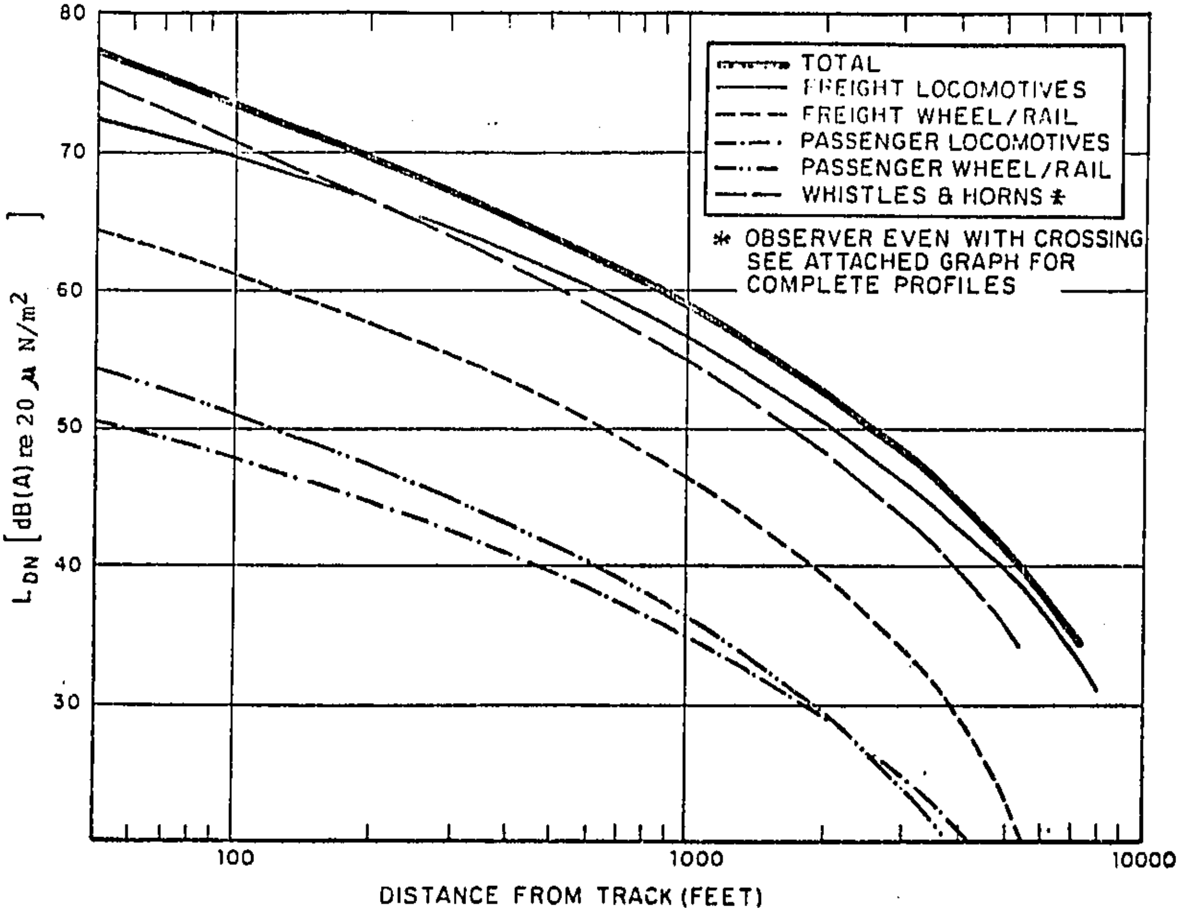

Figure 8-2. L_{DN} vs Distance From Track for National Average Train Traffic

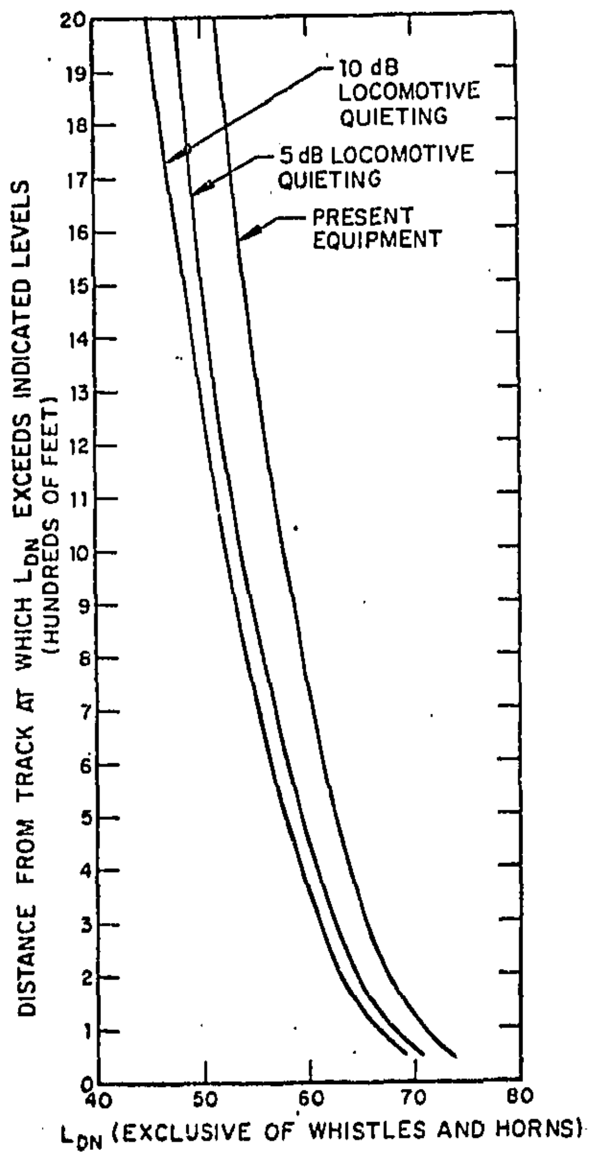

Figure 8-3. Distance From Track at Which Various L_{DN} Occur Around the Dorchester Branch of the Penn Central

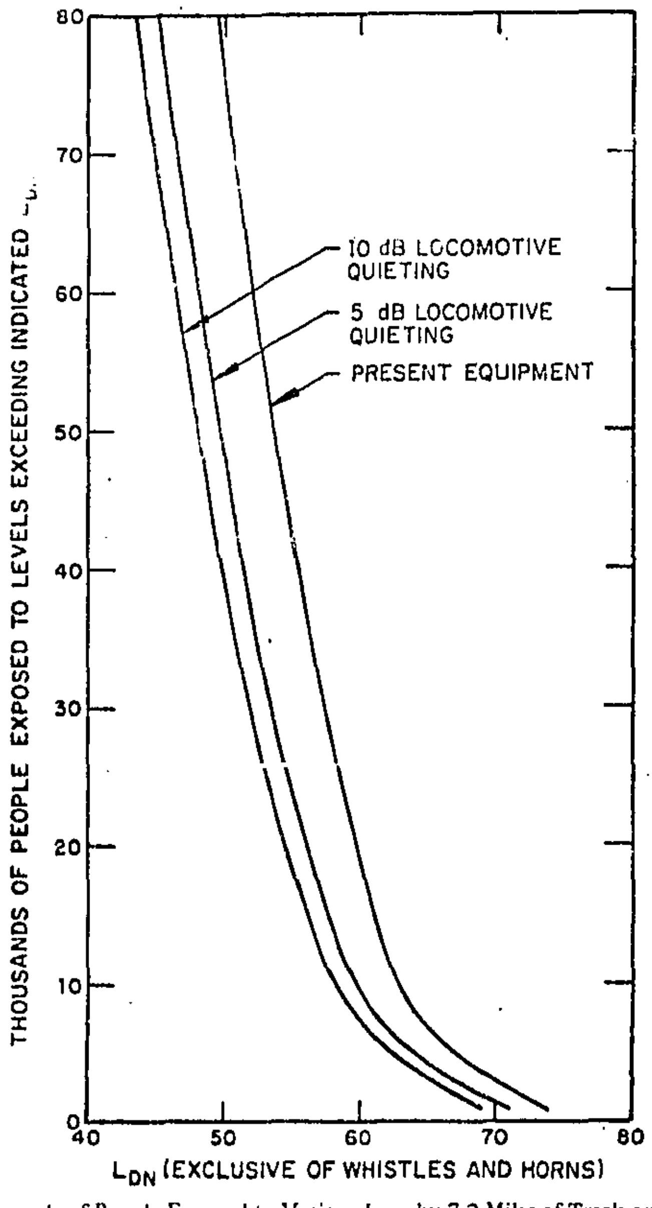

Figure 8-4. Thousands of People Exposed to Various L_{DN} by 7.2 Miles of Track on the Dorchester Branch of the Penn Central

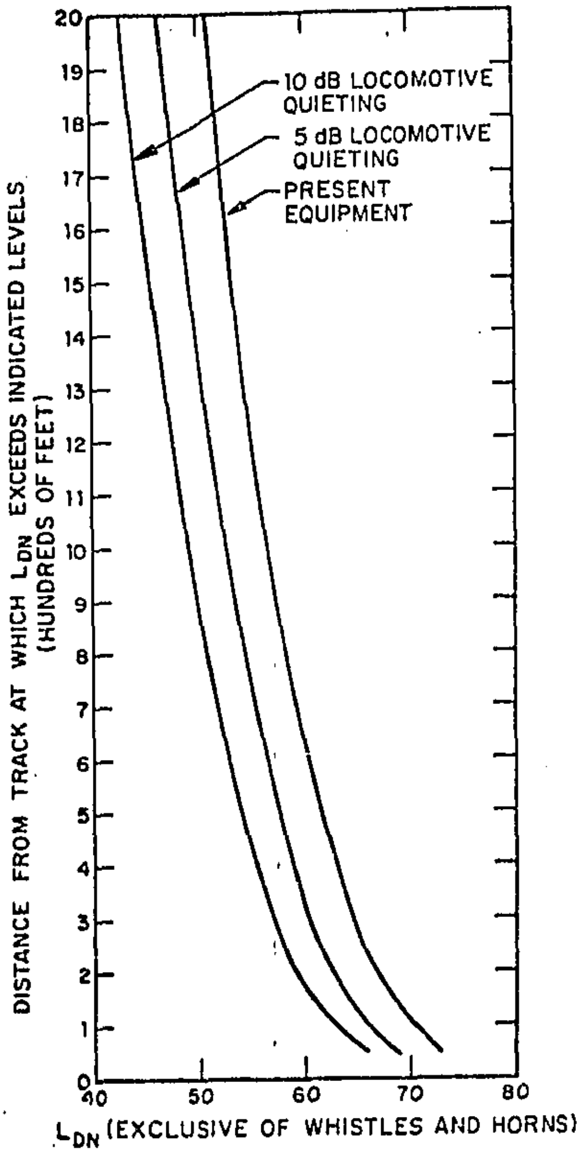

Figure 8-5. Distance From Track at Which Various L_{DN} Occur Due to National Average Train Traffic

exposed to L_{DN} of 55 or more (assuming that no other sources of locomotive noise produce levels comparable to exhaust noise levels). Figure 8-6 shows that there is a corresponding 5.1 million reduction in the number of people exposed to L_{DN} of 55 or more based on national average train traffic.

Population densities used to construct Figures 8-3 and 8-6 were obtained from the U.S. Department of Commerce, Bureau of the Census. The census results show 28,098 people living within 1000 feet of the 7.2 miles of track comprising the Dorchester Branch of Penn Central. The population density in the first 500 feet next to the line was taken to be one-half of the density for the entire region, in keeping with national trends.

The figures for the number of people exposed to noise from national average train traffic were based on estimates of 30,000 miles of railroad rights-of-way in urban areas in the U.S. Urban areas are defined as the 40 Standard Metropolitan Statistical Areas (SMSAs) having average population densitites in excess of 500 people per square mile and a total population greater than 250,000. The 40 SMSAs defined above have a total land area of 58,200 square miles and a total population of 71,082,000, for an average population density of 1220 people per square mile. This figure must be modified, however, as there tends to be a concentration of industrial, commercial, and other non-residential activities in the vicinity of rail lines. Land use and zoning maps indicate that the residential population density in the vicinity of a railroad line tends to be about 50% of the average density for the entire region.

IMPACT RELATED TO LAND

These regulations will have no adverse effects relative to land.

IMPACT RELATED TO WATER

These regulations will have no effect on water quality or supply.

IMPACT RELATED TO AIR

The use of more efficient exhaust muffling systems can cause a change in the back pressure to the engine and may result in a change in the exhaust emissions level. The data, at present, are insufficient to make other than a general statement concerning the directions the various emission levels take when a different back pressure is applied, since the behavior of the various engines and exhaust emission control systems vary widely. However, internal combustion engine exhaust emissions are affected by changes in exhaust system back pressure, as evidenced by the tests of gasoline engines at the University of Michigan (Bolt, Bergin, Verper, 1973), and they must be considered. It is important to note, however, that motor carrier exhaust emissions are approximately 3.7 times higher than rail carrier exhaust emissions per ton mile of goods transported (Battelle Laboratories, 1971), indicating that in the overall balance rail carriers are already more efficient than motor carriers, from an exhaust emission standpoint.

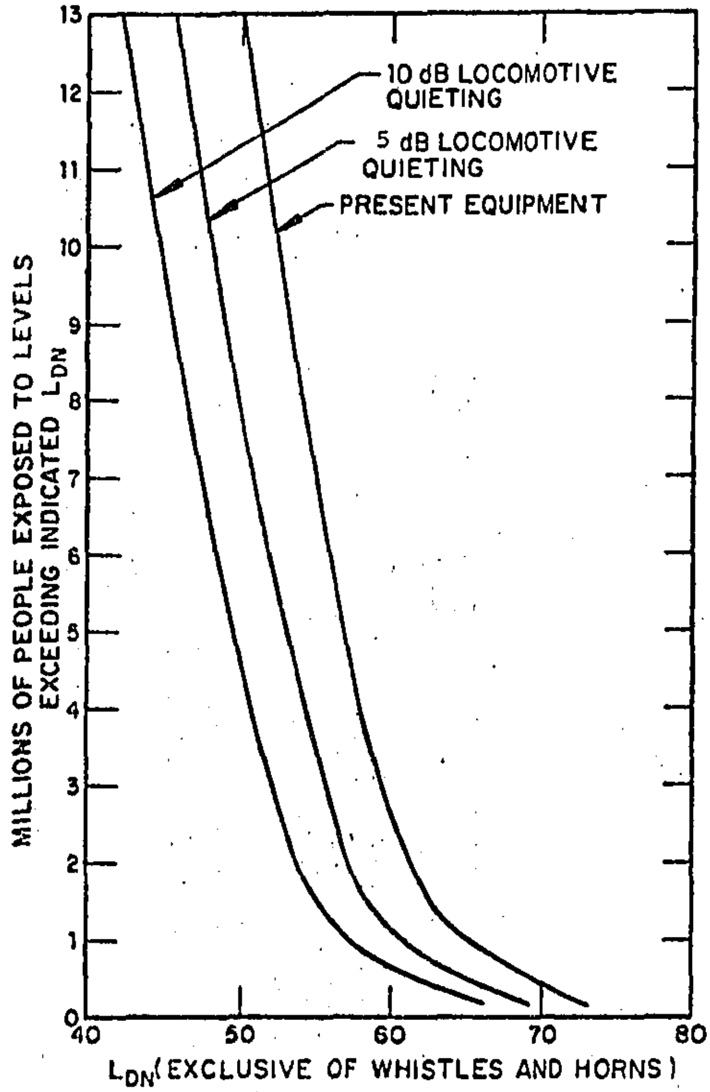

Figure 8-6. Millions of People Exposed to Various L_{DN} by National Average Train Traffic

It must also be noted that promulgating stricter rail carrier noise regulations at this time may inadvertently divert cargo traffic from the rails toward motor carriers due to difficulties in compliance with regulations, thereby causing an increase in total exhaust emissions to the atmosphere, as well as increasing noise emissions. Based on the analysis presented, problems such as this are not expected to arise as a result of the proposed regulations.

ENCLOSURE A: "DAY NIGHT EQUIVALENT NOISE LEVEL" (L_{DN})

L_{DN} is a modified energy-equivalent sound level. The energy-equivalent sound level L_{EQ} is the level of the continuous sound associated with an amount of energy equal to the sum of the energies of a collection of discontinuous sounds. L_{EQ} is defined by

$$L_{EQ} = 10 \log \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} 10^{NL/10} \, dt$$

where NL is the instantaneous overall noise level in dB(A) at time t, and the time period of interest is from time t_1 to time t_2. L_{DN} is determined precisely like L_{EQ}, except that all noise levels NL measured at night (between 10:00 p.m. and 7:00 a.m.) are increased by 10 dB(A) before being entered into the above equation.

ENCLOSURE B: EXCESS ATTENUATION OF RAILROAD NOISE

Many mechanisms cause attentuation of sound beyond that caused by geometric spreading, including molecular absorption in the air, precipitation, barriers, ground cover, wind, and temperature and humidity gradients. The attenuation varies with location, time of day, and season of the year. To account for the attenuation produced by these highly variable sources, it is necessary to compile detailed records of wind, temperature, humidity, precipitation, and even cloud cover on a statistical or probabilistic basis. The following discussion is directed at a base case that includes two sources of excess attenuation that can be relied upon: atmospheric molecular absorption and attenuation associated with variations in the physical characteristics of the atmosphere near the ground. Both attenuations vary with frequency. The attenuation factors were evaluated for reference conditions of 50°F and 50% relative humidity.

Figure 8-7 shows how atmospheric molecular absorption and variations of atmospheric characteristics near the ground change the shape of the locomotive noise spectrum. The high frequencies become less important as the sound travels outward from the source. The attenuation of the overall sound level (logarithmically summed octave-band sound levels) was found to be about 2dB per thousand ft out to 4000 ft. That value was used to calculate the propagation of locomotive noise described in this report. The value for the effective overall attenuation coefficient for locomotive noise is about the same for throttle position 8 and throttle position 1.

Figure 8-8 shows how the frequency-dependent attenuations change the shape of the spectrum of wheel/ rail noise. Notice that here, too, the high frequencies become less important as the sound

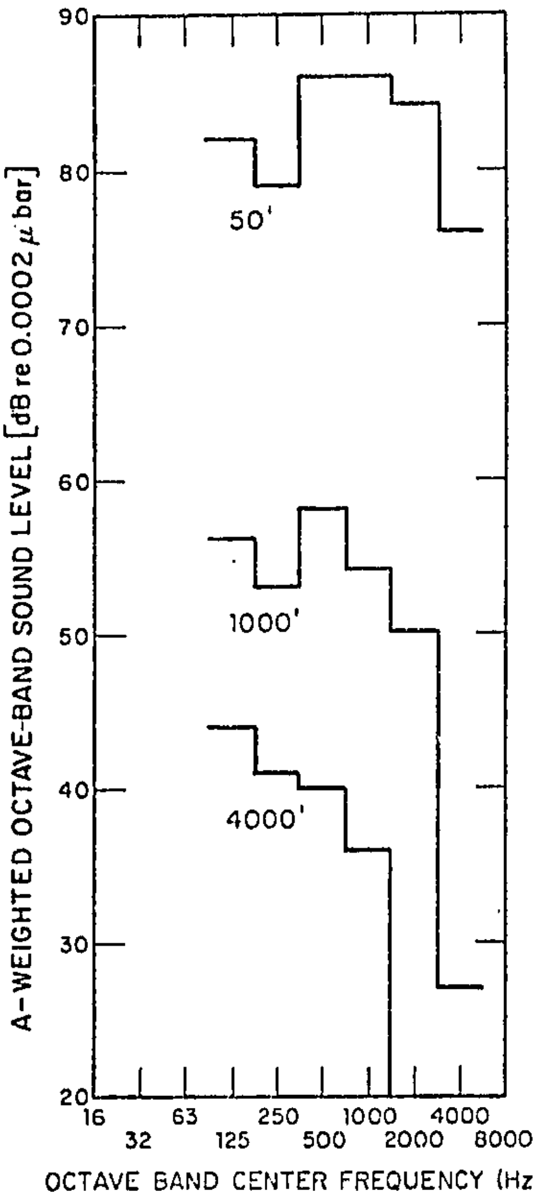

Figure 8-7. Influence of Frequency-Dependent Attenuations on Locomotive Noise Spectrum (See Figure A.1.7b for Comparison)

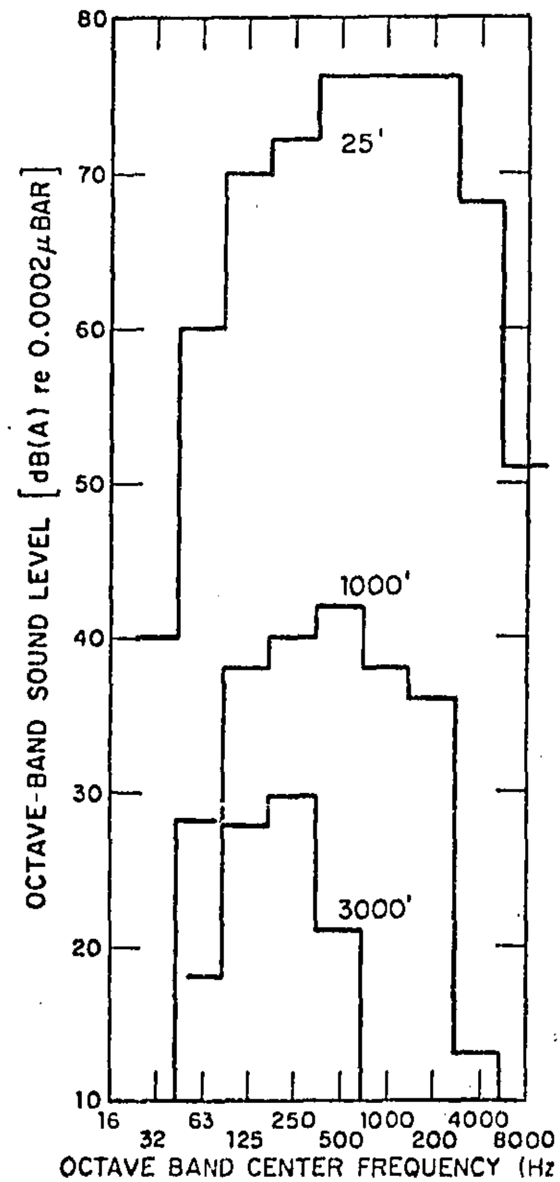

Figure 8-8. Influence of Frequency-Dependent Attenuations on Wheel/Rail Noise, Train No. 6, Region 2 (See Figure B.1.13 for Comparison)

travels outward from the source. The attenuation of the overall sound level (logarithmically summed octave-band sound levels) was about 3 dB per thousand ft out to 3000 ft. That value was used to calculate the propagation of locomotive noise described in this Background Document.

SECTION 9

SELECTION OF THE PROPOSED REGULATIONS

PROBLEM ADDRESSED AND APPROACH

Problem Addressed

The problem addressed in the proposed noise emission regulations is the development of noise emission regulations that will control railroad noise and Federally preempt conflicting State and local noise emission regulations, taking into consideration that (1) State and local governments have the primary responsibility to protect the environment from noise and (2) Federal special local conditions authorizations may be authorized in the case of use or operational regulations if the State and local regulation in question is not in conflict with the noise emission regulations established under Section 17.

Approach

In order to develop these noise emission regulations, the following approach, based on the statutory requirements of the Noise Control Act of 1972, was utilized:

1. Determination of the sources of railroad noise to be Federally regulated
2. Determination of the best available technology to achieve noise reduction
3. Determination of the cost of compliance to the railroad industry with possible noise emission regulations
4. Determination of the environmental and economic impact of possible noise emission regulations
5. Selection of the appropriate noise emission standards.

REGULATORY APPROACHES CONSIDERED

"Status Quo" Regulations Alternative

Status quo regulations for both locomotives and railroad car noise could be proposed that would preempt State and local regulations. These status quo regulations would not reduce noise but rather limit it to present levels and would have no financial impact on the railroads beyond standard maintenance already required. The function of status quo regulations is, therefore, one in which the intent of the Federal government to revise the status quo regulations is an implicit statement that such future revision will result in reduction in noise levels with probable concurrent financial impact on the railroad industry. Thus, a status quo regulation placed on certain equipment and facilities would establish the direction and intent of Federal regulation on those sources in the future. The rationale for the issuance of status quo regulations would be that the financial impact of more stringent regulations at this time would be unreasonably high relative to the noise reduction achieved. Also, if noise abatement technology were not available, status quo regulations could be established to place a ceiling on noise emissions and allow time for further technology development.

Future Noise Standards Regulations Alternative

The data gathered by EPA indicate that it is feasible to reduce railroad noise with presently available technology at a reasonable cost. However, the shortest feasible time to apply this technology on a retrofit basis at a reasonable cost is 4 years. Thus, a regulation requiring the application of this technology could be promulgated with an effective date 4 years in the future.

Section 17 provides for Federal preemption of State and local regulations upon the effective date of the Federal standards. Therefore, during the 4-year period required for the application of technology, State and local regulations could be established and enforced.

Noise Reduction in Combination with Status Quo Regulations Alternative

As pointed out in the previous alternative, if a regulation were promulgated with an effective date some time in the future, State and local regulations would not be preempted until this date. However, it is not feasible for a noise reduction regulation on trains to be effective in less than 4 years when based on available technology and cost. It, therefore, would appear unreasonable to expect quieting of trains during this period. However, it is not unreasonable to expect that equipment be maintained properly to eliminate unnecessary noise. To accomplish this, a status quo regulation based on proper maintenance practice could be made effective earlier. This would not have substantial economic impact, nor would it produce significant noise reduction. It would, however, ensure that noise will not increase during the period prior to the installation of noise abatement equipment. Further, it would preclude the State and local governments from establishing what might be unreasonable equipment standards during this interim period.

REGULATORY APPROACH SELECTED BY EPA

The Environmental Protection Agency has chosen to adopt the last alternative discussed. It is believed that this approach is the most environmentally sound alternative and one that fulfills the requirements of Section 17.

DISCUSSION OF PROPOSED REGULATIONS

The proposed noise emission regulations will establish standards for noise emissions from locomotives and railroad cars engaged in interstate commerce by railroad. The proposed standards specify sound levels measured at a distance of 30 meters (100 feet) from the centerline of the railroad track. Measurements will be made in decibels on the A-weighted scale, using the fast meter response. The general measurement procedure used to obtain the data upon which the standards are based is presented in more detail in Section 6.

All locomotives to which the proposed regulation is applicable are to meet the following noise emission standards for the locomotive at rest and in motion:

Locomotive at Rest

Effective 270 days after promulgation of the regulations, under stationary test, 93 dB(A) at any throttle setting and 73 dB(A) at idle, when measured over any surface.

Effective 4 years after promulgation of the regulations 87 dB(A) at any throttle setting and 67 dB(A) at idle, when measured over any surface.

Locomotive in Motion

Effective 270 days after the promulgation of the regulations, 96 dB(A) at any operating condition, when measured over any surface.

Effective 4 years after the promulgation of these regulations, 90 dB(A), at any operating condition, when measured over any surface.

Rail Car

Effective 270 days after promulgation of these regulations, all railroad cars or combination of railroad cars operated by surface carriers engaged in interstate commerce by railroad are to meet a noise emission standard of 88 dB(A) at speeds up to and including 72 km/hr (45 mph) and 93 dB(A) at speeds greater than 72 km/hr (45 mph) when measured over any surface.

Based upon the strict language of the Noise Control Act of 1972, its legislative history, and other relevant data, "best available technology" and "cost of compliance" have been defined as follows:

"Best available technology" is that noise abatement technology available for application to equipment and facilities of surface carriers engaged in interstate commerce by railroad which produces meaningful reduction in the noise produced by such equipment and facilities. "Available" is further defined to include:

1. Technology which has been demonstrated and is currently known to be feasible
2. Technology for which there will be a production capacity to produce the estimated number of parts required in reasonable time to allow for distribution and installation prior to the effective date of the regulation.
3. Technology that is compatible with all safety regulations and takes into account operational considerations, including maintenance, and other pollution control equipment.

"Cost of compliance" is the cost of identifying what action must be taken to meet the specified noise emission level, the cost of taking that action, and any additional cost of operation and maintenance caused by that action.

Currently existing technology known to reduce locomotive noise consists of (a) fan modification, (b) engine casing modification, and (c) muffler retrofit. Applications of fan modification and [illegible] casing modification were not included in establishing the noise emission levels in the proposed regulations because of lack of equipment availability, prohibitive and limited cost data, and low relative effectiveness in noise reduction. Muffler retrofit to the locomotive engine exhaust system was determined to be the only method that meets the criteria established above for "best" available technology."

Currently existing technology known to reduce railroad car noise consists of (a) replacement of the bolted rail with the welded rail, (b) structural maintenance to railroad car bodies, and (c) elimination of flat spots on wheels. The proposed noise emission regulation did not include replacement of the bolted rail with the welded rail and structural maintenance to railroad car bodies because of prohibitive cost and lack of data. Elimination of flat spots on wheels and irregularities on rails can be achieved through effective normal maintenance, without added cost for compliance.

Conclusion. The only standards that can be adequately based on "best available technology" and "cost of compliance" at this time are (1) the muffler retrofit to control locomotive exhaust and (2) effective railroad car maintenance. The proposed regulations, therefore, require locomotives to eventually meet a noise emission standard that results in significant reduction in noise which can be achieved through the installation of exhaust mufflers. The proposed railroad car noise emission standard is designed to ensure that railroad cars will be properly maintained so that train noise levels will be as low as the available technology permits.

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Railroad Contacts

Personnel in the operations departments of the following railroads were contacted in the course of this study.

AMTRAK
Atchison, Topeka, and Santa Fe
Baltimore and Ohio
Boston and Maine
Burlington Northern
Chesapeake and Ohio
Chicago, Milwaukee, St. Paul, and Pacific
Chicago and North Western
Chicago, Rock Island, and Pacific
Denver and Rio Grande Western
Durham and Southern
Gulf, Mobile, and Ohio
Illinoise Central Gulf
Louisville & Nashville
Norfolk Southern
Norfolk and Western
Penn Central
Union Pacific

Yard superintendents, yard masters, or engineering department personnel with the following railroad companies were contacted in the course of this study.

Chicago, Milwaukee, St. Paul, and Pacific Railroad Yards,
Bensenville, Illinoise

Chesapeake & Ohio/Baltimore & Ohio Railroad Yard,
Walbridge, Ohio

Illinois, Central and Gulf Railroad Yard
Markham, Illinois and Centreville, Illinois

Norfolk & Western Railroad Yard,
Bluefield, West Virginia

Penn Central Railroad Yard,
Elkhart, Indiana

Boston and Maine Railroad Yard,
Mechanicville, New York

Southern Pacific Railroad Yard,
Roseville, California

Union Pacific Railroad Yard,
Cheyenne, Wyoming

Burlington Northern Railroad
Chicago, Illinois and St. Paul, Minnesota

Miscellaneous contacts in the railroad, or related, industry

Association of American Railroads, Research and Test Department
Washington, D.C.

General Electric Company
Erie, Pennsylvania

General Electric Company Sales
Chicago, Illinois

General Motors/EMD
Lagrange, Illinois

APPENDIX A

MAJOR TYPES OF DIESEL-ELECTRIC LOCOMOTIVES IN CURRENT U.S. SERVICE (1 JANUARY 1973)

Manufacturer	Type	Model	H.P.	Turbo-charged	Muffler Type	Number Sold	Years	Number In Servic Class I	Class I
neral Motors	Switcher	NW2	1000	No	A	1119	39–49		
lectro-Motive		NW3,5	1000	No	A	20	39–47	721	137
Division)		SW1	600	No	A	660	39–56		
		SW8	800	No	A	306	50–54		
		SW600	600	No	A	15	54–62	628	107
		SW900	900	No	A	260	54–65		
		SW7	1200	No	A	493	49–51		
		SW9	1200	No	A	786	51–53	1618	335
		SW1200	1200	No	A	737	54–66		
		SW1000	1000	No	A	168+	66–	168+	--
		SW1500	1500	No	A	546+	66–	546+	--
	General Purpose	GP/SD 7/7B	1500	No	B	2803	49–54	2550	133
	Special Duty	GP/SD 9/9B	1750	No	B	4072	54–59	3603	21
	Road Switcher	GP/SD 18/28	1800	No	B	426	59–65	400	9
		GP 20	2000	Yes	C	335	59–62	300	7
		SD 24/24B	2400	Yes	C	224	58–63	200	6
		GP 30/30B	2250	Yes	C	946	61–63	940	--
		GP/SD/35	2500	Yes	C	1645	63–66	1642	3
		GP/SD 38	2000	No	B	1103+	66–	1103+	3

Manufacturer	Type	Model	H.P.	Turbo-charged	Muffler Type	Number Sold	Years	Number In Ser Class I	Clas
General Motors (Electro-Motive Division)	Road Switcher	GP 39	2300	Yes	C	87	69-70	[illegible]	
		GP/SD 40	3000	Yes	C	2217+	66-	2213+	
		SD 45	3600	Yes	C	1362+	65-	1362+	--
		DD 35A/35B	5000	Yes	2C	45	[illegible]	45	--
		DDA 40X	6600	Yes	2C	47	[illegible]	47	--
	Streamlined Cab/Booster Freight/Passenger	FTA/FTB	1350	No	[illegible]	[illegible]	39-45	[illegible]	--
		F2A/F2B	1350	No	B	[illegible]	46		
		F3A/F3B	1500	No	B	1801	45-49	440	--
		F7A/F7B	1500	No	B	3982	49-53	1207	--
		F9A/F9B	1750	No	B	235	[illegible]-57	205	--
	Passenger Only (Twin Engines)	E7A/7B	2000	No	-	510	45-49	245	--
		E8A/E8B	2250	No	-	457	49-53	226	--
		E9A/E9B	2400	No	-	144	54-63	88	--
General Electric	Switcher	44 ton	400	No	-	334	40-56	18	
		70 ton	500-660	Yes	-	193	46-58		[illegible]
		95 ton	500-660	Yes	-	46	49-56		
	Road Switcher	U25B/C	2500	Yes	D	591	59-65	524	--
		U28B/C	2800	Yes	D	219	66	219	--
		U23B/C	2250	Yes	D	212+	68-	212+	--

Manufacturer	Type	Model	H.P.	Turbo-charged	Muffler Type	Number Sold	Years	Number In Servi Class I	Class
General Electric	Road Switcher	U30B/C	3000	Yes	D	470+	66–	470+	--
		U33B/C	3300	Yes	D	497	67–	497+	--
		U36B/C	3600	Yes	D	157	69–	157+	--
		U50B/C	5000	Yes	2D	66	63–70	66	--
lco	Switcher	S1/3	660	No	-	653	40–53	92	36
		S6	900	Yes	E	100	55–60		
		T6	1000	Yes	E	55	58–69		
		S2/4	1000	Yes	E	2012	40–61	681	203
	Road Switcher	RS1/RSD1	1000	Yes	E	497	41–60		
		RS2	1500	Yes	E	400	46–50	76	5
		RS2/3	1600	Yes	E	1312	50–56	564	30
		RSD4/5	1600	Yes	E	203	51–56		
		RS11/12/36	1800	Yes	D	436	56–63	348	11
		C415	1500	Yes	D	26	66–68	26	--
		RS32 C-420	2000	Yes	D	164	61–68	121	1
		RSD7/15	2400	Yes	D	102	54–60	119	--
		RSD27 C-424	2400	Yes	D	80	59–67		--
		C-425	2500	Yes	D	91	64–66	89	--
		C-628	2750	Yes	D	135	63–68	91	--

A-4

Manufacturer	Type	Model	H.P.	Turbo-charged	Muffler Type	Number Sold	Years	Number In Ser Class I	Clas
Alco	Road Switcher	C-430/630	3000	Yes	D	93	66-68	84	--
		C-636	3600	Yes	D	34	67-68	31	--
	Streamlined	FA/FB1	1500	Yes	-	581	46-50	--	--
	Cab/Booster	FA/FB/2	1600	Yes	-	491	50-56	--	--
		PA/PB1	2000	Yes	-	210	46-50	--	--
		PA/PB1/2/3	2250	Yes	-	84	50-53	--	--
Baldwin Lima Hamilton	Switcher	S-8	800	No		61	50-54	22	15
		DS-4-4-10	1000	Yes		433	46-51	136	46
		S-12	1200	Yes		449	51-56	190	35
	Road Switcher	RS-12	1200	Yes		46	51-56		
		DRS-N-16 RS-N16	1600	Yes		447	47-55	36	29
	Streamlined	RF16/16B	1600	Yes		160	50-53		
Fairbanks Morse	Switcher	H10-44	1000	No		197	44-49	40	6
		H17-44	1200	No		306	50-58	164	3
	Road Switcher	H16-44/66	1600	No		384	50-63	105	--
		H24-66	2400	No		105	53-56	31	--
Whitcomb	Switcher		600					--	3
Plymouth	Switcher		300					1	3
Cooper Bessemer	Switcher		1200						7

Manufacturer	Type	Model	H.P.	Turbo-charged	Muffler Type	Number Sold	Years	Number In Serv[illegible] Class I	Class[illegible]
[illegible]			0					21	--
Cummins	Switcher		470						[illegible]
H.K. Porter	Switcher		500						[illegible]

APPENDIX B

REVIEW OF THE USE OF AUDIBLE TRAIN MOUNTED WARNING DEVICES AT PROTECTED RAILROAD HIGHWAY CROSSINGS

REVIEW OF THE USE OF AUDIBLE TRAIN MOUNTED WARNING DEVICES AT PROTECTED RAILROAD - HIGHWAY CROSSINGS

B.1 Requirements For the Use of Audible Warning Devices

The stopping distance of trains is much longer than that of motor vehicles, they are much more difficult to reaccelerate, and due to their length they often overlap more than one road intersection at a time. Therefore, trains have traditionally had the right-of-way at level crossings, while motorists are expected to look out for trains and give way. The burden is then placed upon the railroad to assist the motorist in determining when a train passage is imminent. The traditional method of doing this is to sound a whistle and/or bell and keep a headlight burning on the head ends of all trains, and to mark the crossing in some manner so as to attract the attention of approaching travelers.

Public Railroad-Highway grade crossings may be equipped with one of the following, which are classified herein into the three major headings shown:

(a) Unprotected

(1) Unilluminated stop-look-listen sign or "cross buck" at the crossing generally accompanied by striping and words painted on the road surface and passive prewarning signs in advance of the crossing.

(2) As above, plus continuous (night time) illumination of the crossing and/or the signs.

(3) As above plus flashing amber caution lights.

(4) Any of the above, plus "rumble strips" on the road surface.

(b) Protected (no gates)

This group of systems may employ combinations of the signs, lights, markings, etc. from (a) above, but is distinguished by the addition of:

(1) Flashing lights generally plus bells, which are actuated upon the approach of the trains(s) by virtue of automatic electrical signals attached to the tracks. These systems are arranged to be fail-safe, in that most internal failures cause the signal to indicate the approach of a train.

(2) Traffic lights may be used in some places, in lieu of the characteristic flashing crossing lights, but also conveying the intelligence that a train(s) is in fact in the vicinity.

(3) Watchmen, stationed at the crossing, or trainmen walking with their train, will "flag" motorists or may activate lights or other devices.

(c) Protected With Gates

In addition to active signals and advance warnings as in (b) physical barriers are automatically dropped in the motorists' path upon the approach of the train(s), often with lights attached thereto.

These gates may interrupt only the approaching highway lanes (half gates) or both lanes on each side (to discourage driving around) and may be supplemented by small pedestrian gates at walkways. However, these gates are not constructed so as to physically restrain vehicles, but are really a type of "sign", intended to assure driver attention and realization that a train is to be expected. Gates are commonly used at busy crossings where there are two or more tracks, to add a degree of protection against motorists proceeding as soon as one train has passed, when there may be one approaching on another track.

The cost of installation of crossing signals varies widely and depends greatly upon particular local circumstances. Modest installations with gates average about $30,000, and may be as high as $60,000. The annual cost of inspecting, maintaining, and repairing protected crossings is about $1,000 each, not including the cost of roadway and track work.

Complete grade separations may cost hundreds of thousands of dollars, or even millions, and while many are being constructed, the number is not statistically significant within the context of the overall problem. (When separations are installed, it is usually possible to arrange for the outright closing of a few nearby crossings, thus expanding the safety benefit of this large investment.)

The level of crossing protection installed at a particular location is determined by the hazard involved which is effected by the amount of road traffic, the number and speed of trains passing and topography. This may be determined by the judgement of local officials, the railroad managements, or both and is often established simply by a past record of accidents at a crossing in question. The investment in crossing equipment may be the responsibility of the railroad, the State or local government, the Federal government or any combination thereof. This question has been the subject of much controversy in the past, and is in a state of flux at present, with the trend being toward greater government responsibility although some railroads continue to spend large sums of their own money on new systems every year. Automatic signal system maintenance has always been the responsibility of the railroad.

Train-born signals to warn motorists and pedestrians of the approach of trains are required by most States. Federal safety regulations are confined to the inspection of such devices on locomotives, to the end that - if present - they shall be suitably located and in good working order (Safety Appliance Act, 45 USCA; 49 Code of Fed. Regulation 121, 234, 236, 428, 429). The Federal government has shunned greater regulatory responsibility in this field in the past. There is a very significant

Federal research and promotional effort underway to improve grade corssing safety, however.

The State laws requiring train-born signals do not quanlify their loudness. It is common for the State laws to quatify the requirement to apply all <u>public</u> crossings <u>except</u> in municipalities, leaving the use of horms or bells in towns and cities to local discretion.

A survey of the 48 contiguous States yields the following summary of information regarding their regulations:

.. Requirements for sound signals at public crossings imposed by:

Statute	38
Public Utility Commission	1 (Calif.)
Common Law	3
Penal Code	1 (N. Y.)
None or no information	5
	48

.. Requirement at private crossing: - if view is obstructed 1

.. Signals to consist of:

Whistle or bell	24
Whistle and bell	7
Whistle	6
Bell only	2 (Fla. & R.I.)[a]

(a) Florida restriction to bells applies in incorporated areas and is accompanied by a speed restriction of 12 mph.

.. Distance at which signal is to be sounded:

Beginning at a minimum of distance (35 States varying from 660 feet in Michigan to 1500 feet in South Carolina, with an average of 1,265, the most common being 1,320 feet (80 rods).

Beginning at a maximum distance (3 States): Montana 1,320, Ohio 1,650, and Virginia 1,800 feet.

To continue until train:

Reaches crossing	35
Is entirely over crossing	3

.. Exception of some form provided for incorporated areas in at least 15 States:

California, Lowa, Indiana, Kentucky, Michigan, Minnesota, Missours, New Jersey, New York, Nevada, Utah, Virginia, Washington, Wisconsin, and Florida.

.. Exception provided at crossing with:

Gates and/or watchmen - Delaware

Flashing lights and bells - Illinois

(More is said about exceptions in a later section of this report.)

Railroad operating rules reflect the ordinances in effect in the areas through which they pass, generally encouraging the use of warning signals at the discretion of the operator to avoid accidents, but admonishing against unnecessary soundings. Specific supplementary advice is contained in Standard Rule 14, which is adopted by many carriers, requiring the sounding of signals in all situations where two or more trains are at or approaching a crossing simultaneously, due to the extra hazard consequent to the limited view and preoccupation of approaching motorists and pedestrians when they see or hear just one of the trains.

Two good examples of State requirements for the sounding of warning signals at crossings are those of California and West Virginia, attached hereto as Appendix A1, A2, and B, respectively.

Over and above statutory and regulatory requirements for the use of warning signals on trains, the judiciary and juries have tended to assume that there is a burden upon the operators of railroads to employ such devices. Numerous judgments have been made against railroads in court cases wherein the sufficiency of warnings were questioned, particularly by juries and seemingly to a relatively greater degree in California. As a result, railroads are reluctant to dispense with any ordinary action which might be construed to be a contributing factor in crossing accidents. More will be said on this topic in a later section.

In addition to requirements for warning travellers at level crossings, the State of New Jersey Public Utilities Commission has ordered that passenger carrying railroads operating in that State sound a horn or whistle prior to stopping at or passing through a passenger station on a track adjacent to a platform. (January 20, 1972, Docket 7010-525) Subsequent modifications limited this requirement to one long blast, during daylight hours, and then only when the engineer has reason to believe persons may be in the vicinity of such platforms.

B.2 Railroad - Highway Accidents

There are over 220,000 public rail highway crossings at grade in the United States, of which 22% are actively protected (Categories 2 and 3). (There are also about 150,000 private crossings.)

In 1972 there were almost 12,000 public crossing accidents, resulting in 1,260 deaths. These totals have been decreasing slowly since 1966. In 67% of these accidents the train struck a motor vehicle, in 28% a motor vehicle struck trains and in 5% trains struck pedestrians or there

NOTE: Figures in this section are taken from references (4) and (5). Accident figures sometimes differ between references due to the $750 cost baseline for reporting accidents to the Federal Railroad Administration. Crossing figures may differ due to the inclusion or exclusion of private crossings.

were no trains involved. 39% of the collisions occurred at crossings provided with gates, watchman, audible and/or visible signals, while 61% were at crossings having signs which did not indicate the approach of trains (Category 1).

63% of the collisions occurred during daylight, and 37% at night. It is believed that about 67% of motor vehicle traffic flows in the daytime, 33% at night, suggesting a slightly higher crossing hazard at night (37% of the collisions with 33% of the traffic).

Automobiles constituted 73% of the motor vehicles involved, trucks 25%, motorcycles 1.3% and buses 0.3%.

When motor vehicles struck sides of trains, they usually contacted the front portion thereof, particularly during daylight; the propensity to strike elsewhere increases at night. The side of train category appear to be twice as hazardous at night, in that 53% of them occur then, with 33% of the traffic, with the peak occurring between midnight and 2 a.m. In fact, when these are deducted from the total, the train-strikes-vehicle collisions are in about equal proportion to the traffic distribution, day and night.

The propensity for accodents at actively protected crossings is also greater at night than in daylight, per unit of traffic, perhaps indicating that driver alterness is a more significant factor in these cases.

TABLE 1. SUMMARY OF PUBLIC CROSSING TYPES, LOCATIONS AND ACCIDENTS (1970)

	URBAN	RURAL	TOTAL
GATES (category 3)	5970	2970	8940
SIGNALS (category 2)	18050	14620	32670
OTHER OR MANNED	4240	2680	6920
TOTAL ACTIVE	28260	20270	48530
(ACCIDENTS)	(3624)	(1533)	(5157)
PASSIVE (category 1)	50860	12385	17471
(ACCIDENTS)	(3827)	(3428)	(7255)
GRAND TOTAL	79120	144120	223240
(ACCIDENTS)	(7451)	(4961)	(12412)

There were 70 fatalities in 1972 at gates, and 440 total at all active crossings, somewhat less than one per 100 crossings.

Accident rates and severity are significantly higher at actively protected crossings, indicating that the greater hazards where they are installed are not fully compensated for by the increased protection. The rates are also higher in urban areas than rural, for both active and passive crossings, so that in the very areas where noise exposure is greatest, the safety situation is worst.

It could also be argued that the accidents which occurred in spite of the active protection demonstrate the ineffectiveness or waste of warnings such as train horns in such areas.

While vehicle traffic, train traffic and speed continue to increase, protection installations are also increasing, and the total number of crossings is decreasing. The 1973 Highway Act provides a total of $175 million over a three year period for crossing safety, on a 90/10 Federal share basis, or a potential total of $193 million, of which at least half is to be spent on active protection systems. Gate installations constitute about 30% of all new protection, and since such systems cost about $30,000 on the average, approximately 1,000 more gate installations should occur during this three year period, in addition to those installed at railroad initiative. The Northeast Corridor is already on its way to being totally without level crossings of any kind.

NOTE: Reports of crossing statistics vary from year to year, are often based on different reporting criteria and may be for either public and private crossings.

B.3 The Impact and Effectiveness of Locomotive Horns

Acoustical Characteristics and Noise Impact

The audibility of air horns, the predominant warning devices which are the subject of attention herein, has been investigated (1) as part of a DOT program to make crossing warning systems more effective. It was found that the horns which are presently employed are not very effective, and to be so it would be necessary to increase their loudness, "warbling" and/or the use of as many as 5 chimes (pitches) have been recommended. Obviously, since the whole purpose is to gain attention and instill a sense of imminent danger and alertness in persons located at 1/4 mile distance, such signals are bound to be disturbing - by definition.

Figure 1 shows the approximate noise pattern of an average locomotive horn. In order to increase motorist impact to a degree sufficient to be of real value, the loudness would need to be increased as much as 23 dB, resulting in a loudness of 128 dB at 100 feet. (The A and C weighted loudness of the common air horns are almost identical; no distinction is made in the literature).

Loudness at 90° from the direction of movement is 5 to 10 dB less than straight ahead and it is possible that this pattern could be improved somewhat, but the loudness should be substantially maintained to at least 30° each side of center due to the variation in angle of approach of railroads and highways.

This problem of audible warning is shared with emergency vehicle sirens. Fire, police and rescue units have a parallel problem. With motor vehicle windows closed, in modern, acoustically well constructed vehicles, and with road noises and/or air conditioning, radios, etc. competing with the warning devices, at least 105 dB is needed outside a vehicle in order to gain the attention of most drivers. Research is underway to determine the feasibility of installing warning devices <u>inside</u> motor vehicles, which would be actuated by the approach of a train or an emergency vehicle.

In Figure 1 are shown the acoustical characteristics of the common railroad air horns, the orientation of train and vehicles in a set of relatively high speed encounters, such that the motor vehicles shown would have a reasonable stopping distance to the point and instant of train passage at a crossing. Table 2 lists the required noise levels at vehicles travelling at various speeds (exterior background noise assumed dominated by running noise of vehicle) to gain the attention of the drivers; the 50% attention column nearly corresponds to the average

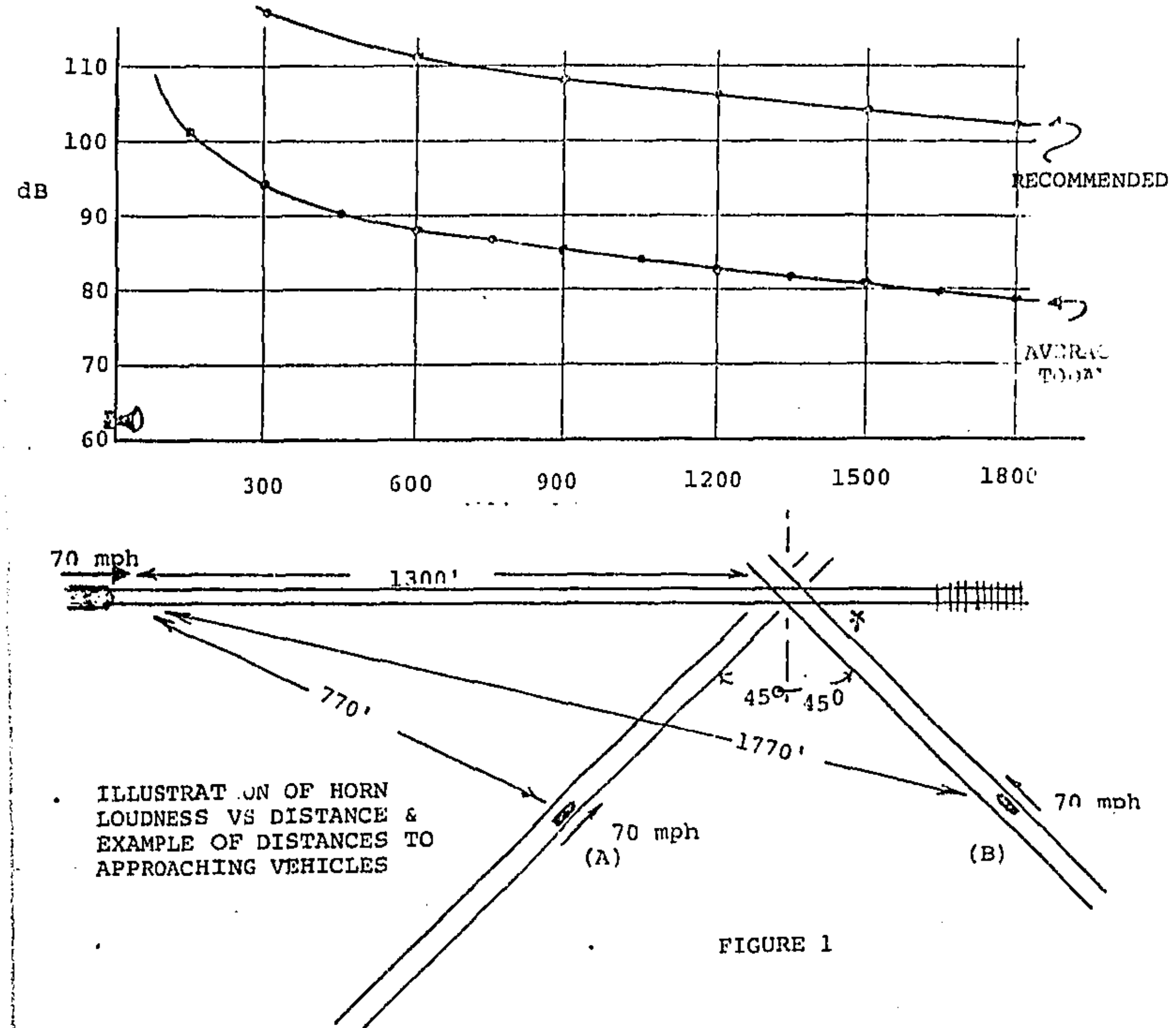


ILLUSTRATION OF HORN LOUDNESS VS DISTANCE & EXAMPLE OF DISTANCES TO APPROACHING VEHICLES

FIGURE 1

TABLE 2

VEHICLE SPEED	dB OUTSIDE VEHICLE FOR % FOR DRIVERS TO NOTICE	
	50%	98%
≥ 35 mph	83	101
36 - 50 mph	87	105
51 - 65 mph	91	109

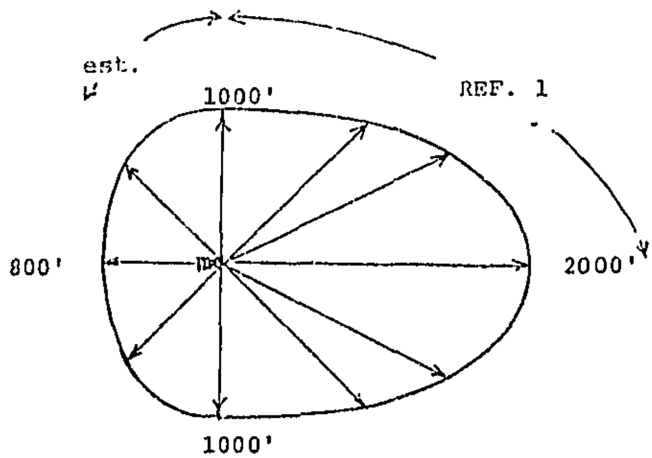
(SOURCE: REF 1) STANDARD DEVIATION - 6dB situation today. To alert 98% of the drivers at (B) it would be necessary to increase the sound levels by about 30 dB, resulting in a level at 100 feet abreast of the locomotive of about 130 dB.

Figure 2(a) illustrates the noise pattern which characterizes most horns in use today, and Figure 2(b) depicts the areas lying within an envelope in which the noise from a horn being blown for a crossing will equal or exceed 77 dB for some period with each train passage. The 77 dB figure is chosen rather arbitrarily, largely because it corresponds to a 1,000 foot boundary adjacent to the track, which is compatible with the modest data available on residential population alongside railroads. It is also a reasonable number as regards nuisance levels of intermittent noise intrusion, being used herein merely for the purpose of approximating the scope of the impact of warning device noise.

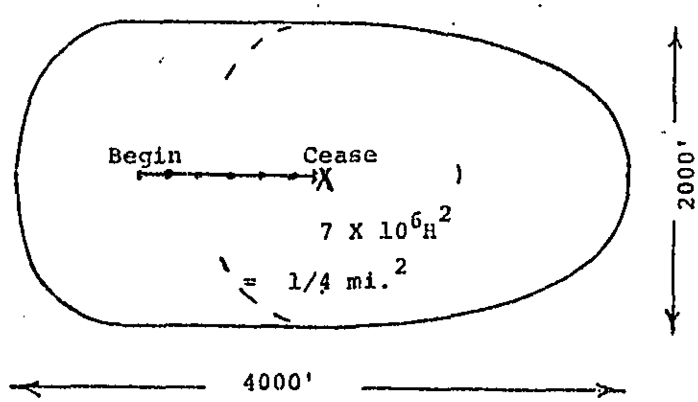
Some 202 miles of railroad route in 12 areas of 10 cities of varying overall size, selected randomly, have been reviewed. The population within 1,000 feet of the railroads in this examination average 2,410. Therefore, in urban areas, about 600 persons are usually exposed to 77 dB from an instant up to 10 or 15 seconds each time a train passes a level crossing.

LOCOMOTIVE HORNS - AVERAGE NOISE PROPAGATION UNDER

IDEAL CONDITIONS



a) 77 dB Profile



b) Area subjected to 77dB level or more

Based upon extension of profile along route

FIGURE 2

Table 3

			% of Population
1.	Unprotected	33.0 million	16
2.	Signalled	13.7	6
3.	Gated	(3.7)	(2)
	Total	46.7 million	22

(Signalled includes gated)

This would indicate that one-fifth of the total population is "within hearing" of a grade crossing. In fact, the noise patterns are probably much less severe than shown here, due to topographical features, and many of the protected as well as some of the unprotected crossings are covered by restrictive ordinances, so that probably more like 10-15% of the people are exposed to the 77 dB or greater level used here for illustration (exterior to dwellings, etc.).

If the use of horns was prohibited at all actively protected crossings, 30% of these exposures would be avoided. If such a restriction was confined to crossing with gates, 8% of the exposures would be avoided. These abatement measures would be noticeable to about 3% or 1% of the population, respectively, allowing for attenuation locally and background noise and the fact that many crossings are already covered by such rules.

Assuming that the use of signals and gates corresponds to the higher hazard levels or volume classes as depicted by the Department of Transportation, the number of daily train and vehicle passages at the crossings in question has been estimated as shown in Table 4.

Table 4

	Daily Trains	Daily Vehicles
Total over signalled crossings	950,000	160,000,000
Average per signalled crossing	20	3,300
Total over gated crossings	200,000	70,000,000
Average per grated crossing	22	7,800

If the average train sounds its horn over a period of 12 seconds, the average citizen within 1,000 feet will experience the noise at 77 dB or more for an average of 8 seconds. At gated crossings where horn blowing occurs 22 times per day, the equivalent energy produced (L_{eq}) is 50.1 dB, whereas at signalled crossings where it occurs only 20 times per day, the equivalent energy would be 49.7 dB.

People residing within hearing of grade crossings are generally conditioned to the sound, which tonewise is not particularly disturbing. The most common casual notice of the use of horns at crossings is expressed by persons staying at motels, which are not infrequently located on highways which parallel railroads and are near road crossings. Being otherwise unaccustomed to the sound, it is quite noticeable, particularly at night.

Warning Effectiveness of Horns

As noted above, at present only about half of all motorists can notice the sound of a train horn when they are driving and their windows are closed, even under ideal conditions. And the alerting capability - even if the horn is noticeable - is still less. It is impossible to determine how many accidents have been prevented by the routine sounding of horns, although it is apparent from the experience of train drivers that many accidents have been averted by the ad hoc sounding of horns, while an even greater number have occurred in spite of it. However, these comments are directed to all crossings, passive (unprotected) as well as active (protected). It is unlikely that either routine or ad hoc use of horns at crossings where lights are flashing and bells are ringing at the crossing significantly improves ordinary driver attention, particularly where gates are lowered as well. On the other hand, some drivers and most pedestrians can hear the horn when it is sounded. Also, in those occasional incidents where a vehicle is stalled on a crossing the horn may serve to divert people from continued efforts to move their vehicle and to depart forthwith on foot. But in the latter case, sounding on a routine basis is probably not necessary.

Attached hereto as Enclosures C, D, and E are (abridged) reports on three rather typical grade crossing accidents wherein the accidents occurred in spite of crossing signals and the sounding of warnings by the train. These are selected somewhat randomly, to illustrate by example a kind of crossing accident which is all too common.

B.4 Prohibition against the use of audible devices

It is already quite common for the routine sounding of horns or whistles to be prohibited, except in emergencies. It is also common for these prohibitions not to be enforced. A careful search for cases where such prohibitions appeared to, or were claimed to contribute to an accident has not yielded evidence of a single such situation.

Among the localities which restrict the use of horns are those listed in Table 5.

Table 5. Some Localities with Restrictions

	Notes
The State of Florida	(2)
The State of Illinois	(1)
The State of Massachusetts	
Chicago, Illinois	(1) (2) (3)
Houston, Texas	(1) (2)
Minneapolis, Minnesota	
Buffalo, New York	(1) (2)
Philadelphia, Pennsylvania	
Knoxville, Tennessee	(1) (2)
Durham, North Carolina	(2)
Mason City, Iowa	(3)
Warren Pennsylvania	
Elkhart, Indiana	
Toledo, Ohio	
Columbus, Ohio	
Akron, Ohio	
Lynchburg, Virginia	(1) (2)
San Bernadino, California	(1)
South Holland, Illinois	
Elmhurst, Illinois	
Lockport, N.Y.	
Rochester, N.Y.	

(1) Contacted local authorities in course of this study.

(2) Specific Information contained in Enclosure F.

(3) Not enforced.

The 15 states where requirements to use horns are excepted, but not necessarily prohibited, in incorporated areas are:

Table 6.

California*	New Jersey
Florida	New York*
Iowa*	Nevada*
Kansas	Utah
Kentucky*	Virginia*
Michigan*	Washington
Minnesota	Wisconsin

(*also have local-option provision)

In 4 additional states there is a local option provision, allowing cities and towns to relieve requirements:

Table 7.

Illinois	North Carolina
Indiana	West Virginia

Two states permit silent running at crossings with certain protection systems:

.. Delaware: warning requirements do not apply when crossing is protected by watchman or gates.

.. Illinois: requirements do not apply when crossing is protected by automatic signals (with or without gates).

One of the most comprehensive Noise Control Regulations thus far drafted in the United States is that of the State of Illinois. As it stands, its property line limitations would affect the use of audible crossing warning devices except that its Rule 208, Exceptions, states: "Rules 202 through 207 inclusive shall not apply to sound emitted from emergency warning devices and unregulated safety relief valves."

Thus, it can be seen that there is considerable precedent for placing constraints upon the use of audible warnings, with no apparent adverse effects. However, they are not uniformly enforced, and where enforced, the carrier generally receives written instructions from the constraining authority, and is nevertheless impowered to sound warnings "in emergencies"..."in the event of impending accident"... etc.

B.5 Judicial Background

Tort litigation constitutes the bulk of the legal or judicial history of grade crossing safety responsibility. Abstracts of 2500 cases throughout the United States during the period 1946 to 1966 have been surveyed (3), checking into 300 possibly related to the question at hand.

In addition, 5 cases were cited by a cooperating railroad as illustrative of the railroad liability question. One of these was found to be inapplicable to the question at hand, three were decided in favor of the railroad. In the other, a jury found for the plaintiff, although a whistle had in fact been sounded. Of these, 21 appeared to be somewhat related and the case records were reviewed. Nothing was unearthed which would appear to deter Federal or local constraints on audible traincarried devices at protected crossings.

Several themes are woven through the opinions rendered in the many cases on record. These are certainly not uniformly respected, but they are sufficiently common as to be noticeable:

.. Safety provisions, including warnings, should be compensurate with the specifics of local conditions.

.. The railroad is expected to give "adequate and timely" warning of the approach of a train. The railroad's case is often intended to show that their warning could have been heard by an attentive motorist.

.. To be cause for placing liability, an omission on the part of the carrier generally must be shown to have contributed to the event in question.

.. Motorists are generally expected to be cautious at crossings, to the extent even of stopping or look "and listen".

.. Contributory negligence on the part of a motorist is generally taken into account.

The fact remains, however, that courts, especially juries, have extracted severe payments from railroads, seeming usually to give plaintiffs the benefit of all doubt. For this reason, railroad companies are understandably at pains to make any changes which could conceivably be construed as a reduction in safety precaution (or increase in hazard). Also, the employees charged with operating trains are usually subject to prosecution under criminal law if negligence and/or violation of a statute might be involved, and are thus inclined to err in the direction of sounding their warning devices, not to mention their sincere personal desire to avoid injury to even the negligent public, as well as themselves. (Collision between trains and large trucks, especially those carrying hazardous materials, are very dangerous to the occupants of the train.) A possible fine for violation of a noise ordinance is not nearly as imposing a threat as the liablility, criminal action and conscience which accompany the threat of collision.

B.6 Summary

One of the railroad noise sources which has been commented upon in the course of interstate rail carrier regulatory development by this Agency's Office of Noise Abatement and Control, is that of railroad train horns which are sounded routinely at grade crossings. It has been suggested that such sounding be prohibited in cases where automatic, active protection is in operation at the crossing itself, particularly where this protection includes gates.

However, it remains that the routine sounding of horns might be contributing to the prevention of some accidents. Certainly, a small segment of the population is exposed to serious noise intrusion thereby and a reduction in their welfare, particularly at night. But it is the Agency's position at this time, that it would be imprudent to single out and restrict night time use of horns, since the crossing hazard with regard to driver behavior is, if anything, worse at night.

In view of the questionable value of train horns for warning highway drivers, particularly at locations having active crossing signals, it may be appropriate to encourage the abolition of routine use of horns at crossings so equipped, particularly but not necessarily only those with gates. The circumstances which determine hazard levels as well as noise intrusion vary widely and are peculiar to local circumstances. It is therefore concluded that regulation of railroad warning be best left to the option of local authorities at this time, recommending thereto that consideration be given to restrictions upon the routine sounding of train horns at protected crossings.

REFERENCES

1. The Visibility and Audibility of Trains Approaching Rail-Highway Grade Crossings; J. P. Amelius, N. Korobow; NTIS-PB-202668.

2. Driver Information Systems for Highway-Railway Grade Crossings; K. W. Heathington, T. Urbanik.

3. American Digest System, 6th and 7th Dicennial Digests.

4. Rail Highway Grade Crossing Accidents from the Year 1972, Department of Transportation, Federal Railroad Administration.

5. Report to Congress on Railroad-Highway Safety, No. II, Department of Transportation, FRA/FHWA.

ENCLOSURE A

Public Utilities Code Annotated of the
State of California
Adopted May 31, 1951
Page 784

ARTICLE 8
CRIMES

Collateral References

§ 7678. Omission to sound bell or whistle. Every person in charge of a locomotive-engine who, before crossing any traveled public way, omits to cause a bell to ring or steam whistle, air siren, or air whistle to sound at the distance of at least 80 rods from the crossing, and up to it, is guilty of a misdemeanor.

Legislative History

Enacted 1951. Based on former Pen C § 390, as amended by Stats 1949 ch 391 § 1 p 733, without substantial change.

Collateral References

Cal Jur 2d Railroads § 44.
McKinney's Cal Dig Railroads § 71.
Am Jur Railroads § § 357 et seq.

PUBLIC UTILITIES CODE, STATE OF CALIFORNIA
(Abridged)

7604. A bell, of at least 20 pounds weight, shall be placed on each locomotive engine, and shall be rung at a distance of at least 80 rods from the place where the railroad crosses any street, road or highway, and be kept ringing until it has crossed the street, road, or highway; or a steam whistle, air siren, or an air whistle shall be attached, and be sounded except in cities, at the like distance; etc.

ENCLOSURE B

THE WEST VIRGINIA CODE

(Abridged)

§ 31-2-9. Warning of approach of train at crossings; crossing railroad tracks.

A bell or steam whistle shall be placed on each locomotive engine, which shall be rung or whistled by the engineer or fireman, at a distance of at least sixty rods from the place where the railroad crosses any public street or highway, and be kept ringing or whistling for a time sufficient to give due notice of the approach of such train before such street or highway is reached, and any failure so to do is a misdemeanor punishable by a fine of not exceeding one hundred dollars; and the corporation owning or operating the railroad shall be liable to any party injured for all damages sustained by reason of such neglect.

I. Scope of Statute as to Warnings.
- **A. General Consideration.**
- **B. Does Not Apply to Trespassers.**
- **C. Does Not Apply to Employees.**

II. Failure to Give Warnings as Negligence; Contributory Negligence.

III. Evidence.

I. SCOPE OF STATUTE AS TO WARNINGS.

A. General Consideration.

Michie's Jurisprudence.—For full treatment of accidents at crossings, see 15 M.J., Railroads, §§ 69-101. As to duty to give signal by bell or whistle, see 15 M.J., Railroads, §§ 81-83.

ALR references. — Railroad company's negligence in respect to maintaining flagman at crossing, 16 ALR 1273; 71 ALR 1160.

Duty of railroad company to maintain flagman at crossing, 24 ALR2d 1161.

Admissibility of evidence of train speed prior to grade-crossing accident, and competency of witness to testify thereto, 63 ALR2d [illegible].

The common-law requirement as to signals is fully as exacting as the statutory duty. What the notice and warning to the public shall be depends, under the common law, upon the circumstances of each case; but some adequate methods of apprising travelers of the crossing must be practiced. Niland v. Monongahela & West Penn Pub. Serv. Co., 106 W. Va. 528, 147 S.E. 478 (1928).

Both bell and whistle are not required without statute. — There is no absolute requirement upon a railroad company to blow a whistle and ring a bell at a crossing unless made so by statute. Niland v. Monongahela & West Penn Pub. Serv. Co., 106 W. Va. 523, 147 S.E. 478 (1928).

The methods of apprising travelers of a crossing almost universally adopted are by the ringing of a bell or the sounding of a whistle, but in order to make both obligatory, the use of both must be called for by a statute. Niland v. Monongahela & West Penn Pub. Serv. Co., 106 W. Va. 528, 147 S.E. 478 (1928).

Provisions of section are minimum requirements.—The provisions of this section as to warning signals are of broad application and are minimum requirements, and in every case the compliance with this statute, plus the presence of an efficiently operating crossing-bell will not (apart from the question of contributory negligence of the plaintiff) constitute an ironclad defense to the railroad, under all circumstances. Baltimore & O.R.R. v. Deneen, 161 F.2d 674 (4th Cir. 1947).

Travelers have the right to assume that trains will give the usual signals at crossings. Morris v. Baltimore & O.R.R., 107 W. Va. 97, 147 S.E. 547 (1929).

But railroad only owes duty to signal as required by statute.—The driver of an automobile on a public crossing is an invitee, and the railway company is bound only to use reasonable care not to collide with the automobile, and owes only the duty to give the signals provided by statute. Chesapeake & O. Ry. v. Hartwell, 142 W. Va. 318, 95 S.E.2d 462 (1956).

As this section is intended to protect [illegible] on highway.—The duty imposed [illegible] to sound a bell or whistle when [illegible] a public crossing does not [illegible] a railroad company to give such [illegible] then at the [illegible] [illegible] are [illegible] [illegible] employees of the [illegible], but to persons who [illegible] use the railroad tracks as parts [illegible] highway. Jones v. Virginian

II. FAILURE TO GIVE WARNINGS AS NEGLIGENCE; CONTRIBUTORY NEGLIGENCE.

Violation of section is negligence.—The failure to give proper signals of the approach of a train to a railroad crossing as required by this section would constitute negligence on the part of a defendant railroad. Cavendish v. Chesapeake & O. Ry., 95 W. Va. 490, 121 S.E. 498 (1924).

But does not impose liability unless it proximately causes injury.—Liability for injury to baby of 13 months could not be based on failure to give signals since the failure was not the proximate cause of the injury. Virginian Ry. v. Armentrout, 158 F.2d 358 (4th Cir. 1946).

Failure to ring the bell or blow the whistle at crossings, though required by law, will not render the company liable, unless that be the proximate cause of the injury. Beyel v. Newport News & Miss. Valley R.R., 34 W. Va. 538, 12 S.E. 532 (1890).

Thus, railroad is not liable if contributory negligence is proximate cause.—Where one is injured by carelessly driving on a railroad crossing in front of a moving engine or train, the proximate cause of his injury must be regarded as his contributory negligence, and not the negligence of the railroad company in failing to ring the bell or blow the whistle. Cline v. McAdoo, 85 W. Va. 524, 102 S.E. 218 (1920).

Where the only evidence was that the warning signals required by this section were not given, and that the failure to do so constituted negligence on the part of defendant, it was held that notwithstanding defendant's negligence, if deceased's contributory negligence is established as a matter of law, plaintiff can have no recovery. Arrowood v. Norfolk & W. Ry., 127 W. Va. 310, 32 S.E.2d 634 (1944).

And signal requirement does not relieve traveler of exercising ordinary care.—Failure to ring bell or blow a whistle [illegible] by this section, [illegible] [illegible] this [illegible] [illegible] way crossing a railroad track from the exercise of such reasonable care and caution as the law requires, to ascertain whether a train is approaching the crossing. Beyel v. Newport News & Miss. Valley R.R., 34 W. Va. 538, 12 S.E. 532 (1890); Hassford v. Pittsburg, Cincinnati, Chicago & St. Louis Ry., 70 W. Va. 280, 73 S.E. 926 (1912); Cline v. McAdoo, 85 W. Va. 524, 102 S.E. 218 (1920); Robinson v. Chesapeake & O. Ry., 90 W. Va. 411, 110 S.E. 870, 22 A.L.R. 892 (1922); Cavendish v. Chesapeake & O. Ry., 95 W. Va. 490, 121 S.E. 498 (1924); Gray v. Norfolk & W. Ry., 99 W. Va. 575, 130 S.E. 139 (1925); Berkeley v. Chesapeake & O. Ry., 43 W. Va. 11, 26 S.E. 349 (1896).

Though a traveler has the right to assume that warning signals required by this section will be given, failure to give them will not excuse him from exercising ordinary care, and taking the necessary precautions for his safety. Arrowood v. Norfolk & W. Ry., 127 W. Va. 310, 32 S.E.2d 634 (1944).

III. EVIDENCE.

The burden of proving that signals were not given rests upon the plaintiff. Parsons v. New York Cent. R.R., 127 W. Va. 619, 34 S.E.2d 334 (1945).

No conflict in evidence where some witnesses heard signals and some did not.—The fact that witnesses have heard signals given by a locomotive approaching a crossing warning travelers of danger, is not necessarily in conflict with the evidence of other witnesses who did not hear them; for the observation of the fact by those who heard is consistent with the failure of the others to hear them. Cavendish v. Chesapeake & O. Ry., 95 W. Va. 490, 121 S.E. 498 (1924).

Unless witnesses not hearing had equal opportunity to do so. — Testimony with reference to the statutory warning signals which only goes so far as to establish that the witnesses did not hear the bell rung and the whistle sounded is not in conflict with the testimony of other witnesses who testified that in fact the whistle was blown and the bell rung. An exception to the foregoing rule arises where there was equal opportunity of a witness to hear the signals and special circumstances [illegible] the attention [illegible] the failure to give [illegible] v. Baltimore & O.R.R., 137 W. Va. 374, 74 S.E.2d 767 (1953).

Witnesses in position to observe but not hearing signals are entitled to peculiar weight.—Where the witnesses were in a position to observe with unusual care the circumstances surrounding the accident, their testimony as to the neglect to sound the customary warnings by bell or whistle, or both, within a reasonable distance from the crossing, a duty dictated by reason and required by this section, is entitled to peculiar weight. Cas[illegible]dorph v. Hines, 89 W. Va. 448, 109 S.E. 774 (1921), citing Carnefix v. Kanawha & Mich. R.R., 73 W. Va. 534, 82 S.E. 2[illegible] (1914); Southern Ry. v. Bryant, 95 Va. 213, 28 S.E. 183 (1897).

Thus, denial that signals were given may produce jury question.—The testimony of one witness, who denies that a railroad whistle was sounded on a given occasion, is as positive evidence as the testimony of another who affirms the fact, where each has equal opportunity of hearing and the attention of the former because of special circumstances is equally drawn with that of the latter to the sounding of the whistle. The denial by the one and the affirmance by the other produces a conflict of evidence, which it is the province of the jury to determine. Tawney v. Kirkhart, 130 W. Va. 550, 44 S.E.2d 634 (1947).

Whether a conflict arises between positive and negative evidence of this character depends upon the facts and circumstances of each case, from which it may be determined whether such negative evidence has any probative value. Cavendish v. Chesapeake & O. Ry., 95 W. Va. 490, 121 S.E. 498 (1924); Tawney v. Kirkhart, 130 W. Va. 550, 44 S.E. 634 (1947).

Since, if evidence conflicts, question is for jury.—Where the evidence as to blowing the whistle and ringing the bell is in conflict, the question of fact is one to be determined by the jury. Kelley v. Kanawha & Mich. Ry., 99 W. Va. 50[illegible] S.E. 677 (1925); Tawney v. Kirkhart, 1[illegible] W. Va. 550, 44 S.E.2d 634 (1947).

Where the evidence conflicts and is credible, the question is one for the jury. Parsons v. New York Cent. R.R., 127 W. Va. 619, 34 S.E.2d 334 (1945).

Where the evidence conflicts as to whether proper signals by ringing [illegible] whistles were given, [illegible] verdict of the [illegible] supported by the evidence [illegible] v. Norfolk & W. Ry., 100 W. Va. [illegible] S.E. 563 (1926).

Question of traveler's contributory negligence held for jury.—See Ar[illegible] v. Norfolk & W. Ry., 127 W. Va. 310, 2 S.E.2d 634 (1944).

Evidence held insufficient to submit railroad's negligence to jury. — In action for injuries sustained in crossing collision evidence was insufficient to justify submission to jury of question of railroad's negligence in failure to comply with this section. Baltimore & O.R.R. v. Deneen, 161 F.2d 674 (4th Cir. 1947).

Evidence held sufficient to sustain verdict for either party. — Conflicting evidence on question of whether railroad gave statutory warning signals required by this section was sufficient on both sides to have sustained a verdict in favor of either party. Tawney v. Kirkhart, 130 W. Va. 550, 44 S.E.2d 634 (1947).

Evidence held to favor railroad's compliance with section.—In Krodel v. Baltimore & O.R.R., 99 W. Va. 374, 128 S.E. 824 (1925), there was some conflict of testimony as to sounding the whistle and ringing the bell at a railroad crossing, but it was held that the weight was in favor that the defendant complied with the statute.

ENCLOSURE C

MULTIDISCIPLINARY ACCIDENT INVESTIGATION

Case No. UC852D

(Abridged)

Prepared by

University of California
Los Angeles, California

UCLA COLLISION INVESTIGATION PROGRAM

VEHICLE COLLISION REPORT

Prepared for the U.S. Department of Transportation
National Highway Safety Bureau,
Under Contract FH-11-6690

Certain information contained in this report is obtained from indirect sources.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily of the National Highway Safety Bureau.

U. C. 852D

1. STANDARD CASE SUMMARY

1.1 SUMMARY TEXT

IDENTIFICATION: This train versus automobile collision occurred on a Thursday at 10:51 a.m. at a combination intersection/railroad crossing in California. Maximum occupant injury severity: critical (06) Collision causation: driver inattention.

AMBIENCE: Day; weather clear and dry; roadway dry.

ROADWAY: A straight, asphalt, undivided roadway, 75 ft. wide with curbs, in a suburban area with speed limit of 35 mph. The collision site is at a railroad crossing, 25 feet before a T-intersection. The road has a negligible crown, and is upgrade at the site. The roadway has three intersections within one-quarter mile of this intersection.

TRAFFIC CONTROLS: The lanes are separated by broken white lines with opposing lanes divided by double-double yellow lines. There is a railroad automatic signal and a traffic signal at the railroad crossing. There were no crossing gates at the time of the collision. Four auto/train collisions at this site in past 3 yrs.

VEHICLES: Vehicle #1: Freight train weighing approximately 400 tons. Vehicle #2: 1967 Cadillac Coupe de Ville two-door hardtop with power windows and seat. No apparent defects. Collision damage to right door causing intrusion of 12". Occupant contact with intruding door and train. Deformation Index: 03RPMW2.

OCCUPANTS: Vehicle #2: Driver: 59-year-old female, height, 64", weight, 160 lbs. Lap belt in use. No HBD or drugs. Injuries: fractured rib, lumbar back strain, abrasions, and contusion.

Right Front: 63-year-old female. No restraint in use. No HBD or drugs. Injuries: compound, depressed skull fracture with cerebral contusion, abrasions and contusions over body.

DESCRIPTION:

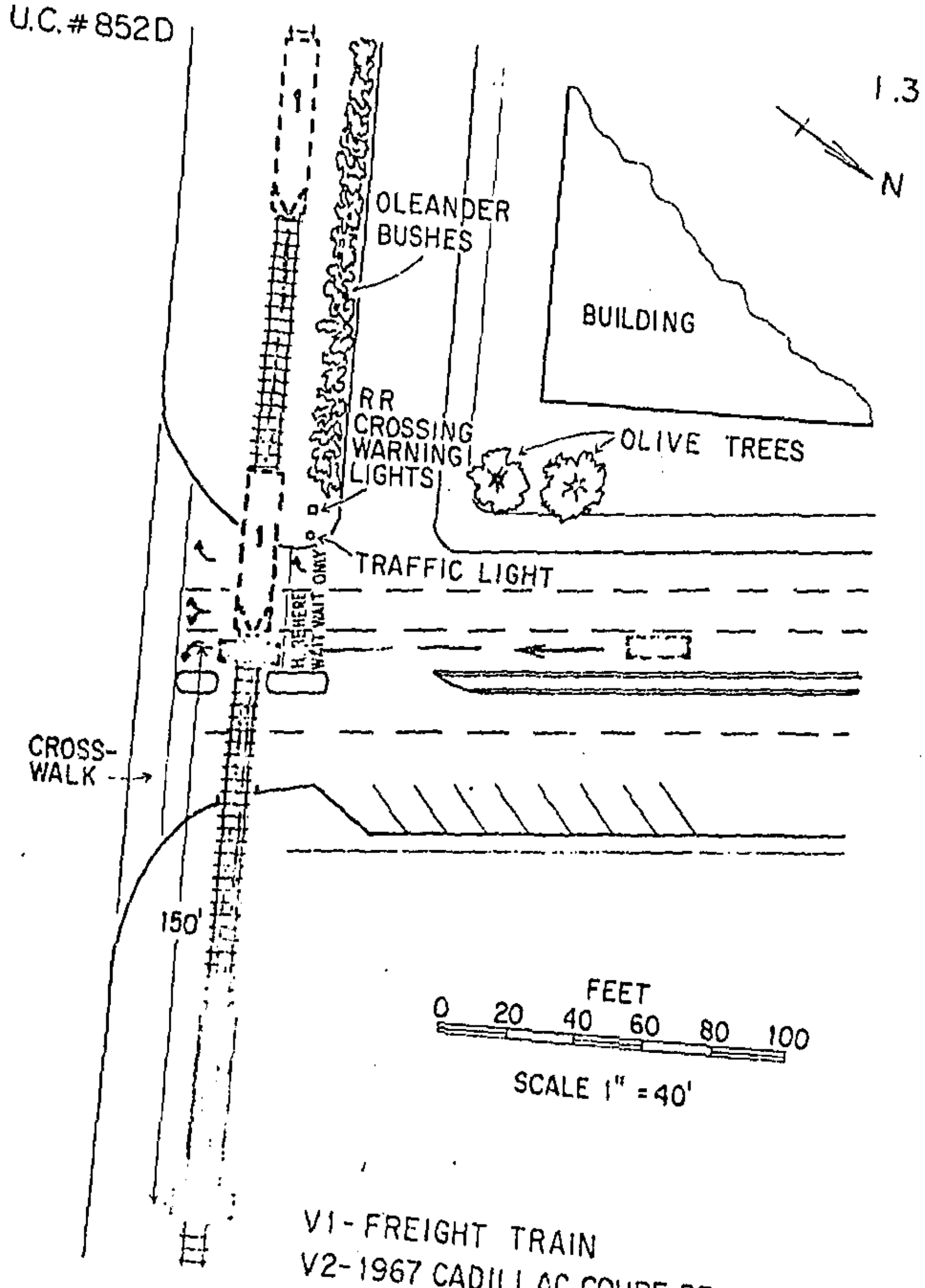
Pre-collision: Vehicle #2, the Cadillac, approaching the T-intersection, failed to stop at the railroad crossing in spite of the warning lights and bell. Slowing for the red light at the intersection, the Cadillac entered the tracks, into the path of the train. The train was eastbound at approximately 15 mph, approaching the crossing. The train engineer was sounding the whistle and applied his brakes when he saw the Cadillac in crossing.

Collision: The train struck the Cadillac in the right side, pushing it 150 ft. along the railroad tracks. The Cadillac remained in a position at a right angle to the railroad tracks. Occupants of the Cadillac moved to the right, and the right front occupant was struck by the intruding train.

Post-collision: Occupants were hospitalized. Railroad crossing gates were later installed at the crossing.

1.2 CAUSAL FACTORS, CONCLUSIONS, RECOMMENDATIONS:

Matrix cell (*indicates positive factor)	Explanation
1	Driver inattention and/or distraction appear to be the chief cause of this collision.
4	Air conditioning on, with windows rolled up, makes it difficult to hear train or warning bells.
5	Right door penetration of 12" due to side impact. Door metal torn in area of hinges.
5	It is recommended that integrated side structures be employed, combining strength of frame, door sill, body pillars and roof.
5*	Right door latch and hinges did not fail.
7	Driver's view of oncoming train partially blocked by shrubbery along tracks.
7	Vehicles were allowed to stop on railroad tracks while waiting to turn at intersection.
7	It is recommended that visibility of oncoming trains be maximized by removing obstructions. Vehicles should not be allowed to wait on railroad tracks.
8*	Railroad crossing gate was installed and light locations were altered after the collision.



V1 - FREIGHT TRAIN
V2 - 1967 CADILLAC COUPE DE VILLE

ENCLOSURE D

SOUTHWEST RESEARCH INSTITUTE

CASE SUMMARY
(MV-TRAIN–INTERSECTION COLLISION)
Case No. 7173

(Abridged)

IDENTIFICATION

This accident occurred at the MKT railroad grade crossing on Eisenhauer Rd. at IH35 in San Antonio, Bexar County, Texas, on Thursday, September 30, 1971 at 1335 hours, involving the collision of a diesel freight engine and a 1970 four-door station wagon with a lone driver. The westbound automobile was struck on its left side by the northbound locomotive. The area is residential. The accident was injury-producing; AIS Severity Code No. 3.

AMBIENCE

It was daytime with partly cloudy skies, 85°F dry bulb, 57 percent relative humidity, 10-mph breeze blowing from the southeast; the road surfaces were dry and clear of debris and loose gravel.

HIGHWAY

Eisenhauer Rd. is a major access artery between the interstate loop expressway system and the residential areas of northeast San Antonio. It is a 41-ft-wide, four-lane, two-way roadway with an asphalt surface of the intermediate type in good condition. The road is divided at this immediate area of the IH35 access road–Eisenhauer Rd. intersection by 6-in.-high concrete channelizing islands. The traffic lanes are 10 ft wide. Eisenhauer Rd. runs east-west and is bounded on both sides by a 6-in. curb. The road is straight and level. It is not crowned. The coefficient of friction on the dry surface was 0.61. A southbound, one-way, two-lane 24-ft-wide frontage road runs 60 ft east and parallel to a mainline, single track railroad right-of-way, both intersecting Eisenhauer Rd. at this point. An exit ramp from IH35 is immediately north of this intersection and an entrance ramp is immediately south. These ramps connect IH35 to the frontage road.

TRAFFIC CONTROLS

The posted speed limit on Eisenhauer Rd. is 30 mph. The speed limit is 40 mph on the frontage road. A railroad company-imposed speed limit of 25 mph is assigned for 0.5 mile each side of the crossing. Traffic control devices consist of pavement markings, 6-in.-high channelizing islands, regulatory, warning, and guide signs. There are two flashing amber lights, 36-in.-diameter yellow railroad advance warning signs, and black-on-white railroad crossbucks. There are neither traffic control signal(s) in the area nor a flashing red light or bell warning signals, gates, or guards to provide immediate warning of an approaching train.

VEHICLES

No. 1. 1968 GP40 Electromotive diesel freight engine. The 3-yr-old engine is considered to be in good operating condition with no indicated defects. Minor secondary damage includes bent brakeman's steps, bent coupling actuator lever, and airhose torn loose, secondary vehicle deformation index 12FDLW1. The retail repair cost was nil.

No. 2. 1970 Oldsmobile Vista Cruiser, four-door, three-seat, yellow station wagon; odometer reading 22,224 miles; valid Texas Motor Vehicle Inspection sticker with a damaged illegible date; equipped with a standard 350-cu in. eight-cylinder gasoline engine; automatic transmission, power steering, and power front disc-type brakes; radio, heater, air conditioner, and tape deck; padded armrests, sunvisor, seat back tops, interior rearview mirror, windshield interbeam, and instrument panel. Three seatbelts and two shoulder straps for front bench-type seat and three seatbelts for the second bench-type seat. The shoulder straps were in the stored position. No defects were apparent or indicated. The last vehicle maintenance w performed at 13,663 miles on January 21, 1971 and included lubrication and oil and filter change. Primar contact damage was 16-in. sheet metal and frame deformation to the left side, primary vehicle deformatn index 09LPAW5. Secondary damage was to the tires, rear bumper, and roof. The retail replacement val was $3075 (total less $200 salvage value).

OCCUPANTS

Vehicle No. 1, Engineer: 46-yr-old white male, 71 in., 155 lb (estimated). An interview was no obtained. He was familiar with the vehicle and the route traveled.

Injury: None.

Vehicle No. 2, Occupant No. 02, Driver: 42-yr-old white female of Latin-American extraction, 62 in., 132 lb. She has been driving 20 yr and currently drives approximately 9000 miles/yr. She was en route from her husband's office to home, a distance of 10 miles. The accident occurred 1 mile from her destination. She had no definite ETA. She was familiar with the vehicle and with the route traveled. She has had no formal driver's education. Her physical condition was excellent. Her precrash state was rested with no stress; she was inattentive to her driving task. Lap and shoulder restraints were available, but not in use.

Injury: Severe (not life-threatening). AIS Severity Code No. 3.

STANDARDS

The following Highway Safety Program Standards (HSPS) and/or Motor Vehicle Program Standards (MVPS) were relevant to this case:

HSPS No. 4–*Driver Education Use of Occupant Restraints, Radio, and Failure to Look for Tra*
HSPS No. 9–*Identification and Surveillance of Accident Locations*
HSPS No. 13–*Traffic C ntrol Devices*
MVPS No. 201–*Occupant Protection in Interior Impact*
MVPS No. 214–*Side Door Strength.*

DESCRIPTION

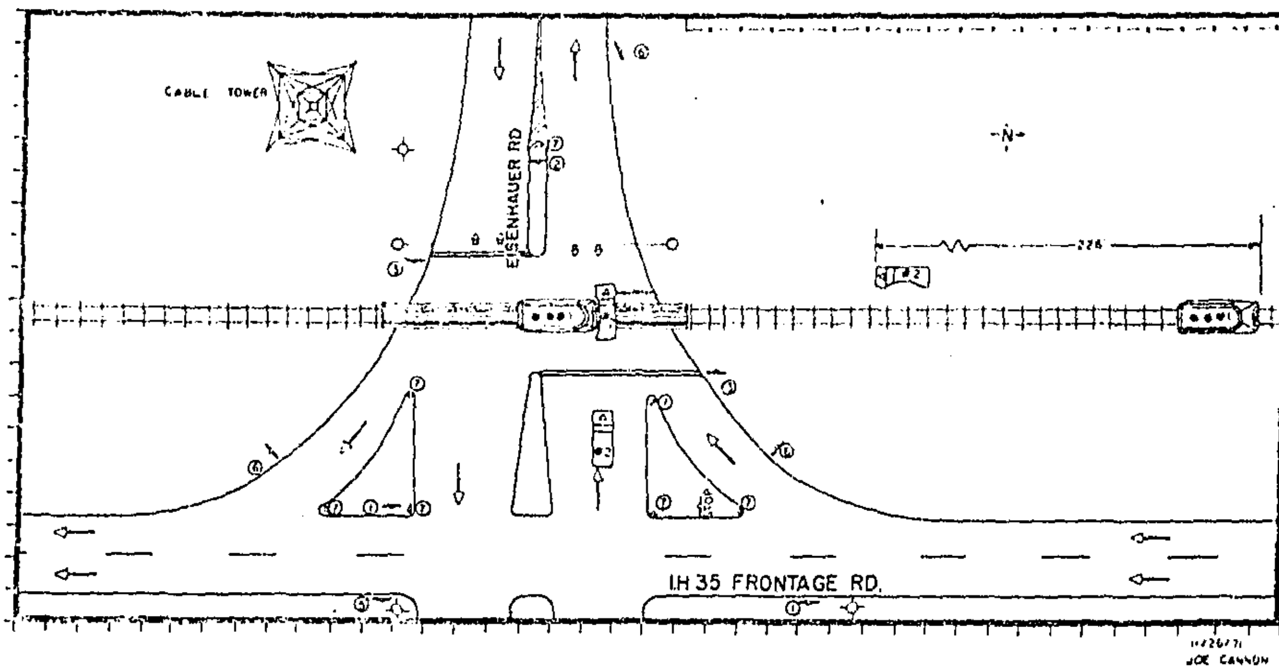
Precrash: The driver of vehicle No. 2 (passenger car) was traveling to her home from her husband's office. She had left northbound IH35 and turned west onto Eisenhaurr Rd., passing under the IH35 overpass. She crossed the southbound frontage road at a relatively low speed (estimated not more than 25 mph) and drove in front of vehicle No. 1 (diesel freight engine), which was moving north at about 25 mph with its horn blowing for the crossing. There were no skidmarks from vehicle No. 2 prior to impact. The car radio was in operation.

Crash: Impact occurred on the left side of vehicle No. 2, centered approximately at the "A" pillar line, as it crossed the railroad track in front of vehicle No. 1. The coupler of the freight engine forced in the forward portion of the door structure, firewall, cowl, and instrument panel structure. Other portions of the front structure of the engine - brakeman's steps and brackets - forced in the doors, floor, and frame left siderail to a depth of 16 inches. The passenger vehicle was pushed northward on the railroad right of way. It then yawed left and came to rest 88 ft from the impact point, parallel to and 7 ft west of the tracks facing the crossing. The unrestrained driver was first thrown left against the incaving side structure of the car. Then she was thrown to the right. Vehicle No. 1 stopped 314 ft from the point of impact.

Postcrash: The driver of vehicle No. 2 was not ejected from the vehicle. She was removed from vehicle No. 2 through the right front door without complications. She was taken to the hospital by ambulance approximately 20 min after the crash. Because the automobile came to rest a considerable distance from the roadway, there was no appreciable interference with traffic. A wrecker had no complications in picking up the vehicle and towing it away. Since the locomotive was not significantly damaged, it was able to proceed. Traffic on Eisenhauer Rd. was estimated at 15 vehicles/min; on the frontage road, traffic was estimated at 5 vehicles/min.

CAUSAL FACTORS, CONCLUSIONS, AND RECOMMENDATIONS

Matrix Cell (* Indicates Positive Factors)	Explanation
1	Driver No. 02 was inattentive and did not observe normal precautions when approaching the railroad track.
1	Driver No. 02 had her radio on and windows up, which may have prevented or seriously interfered with her ability to hear the train's signal horn.
1	The engineer may have been speeding, with respect to the company-imposed limit of 25 mph, 40 to 50 mph. This is the situation if the train brakes were adequate and if the engineer maintained a locked brake mode throughout the stopping sequence.
2	Driver No. 02 was not wearing the available seatbelt or shoulder strap.
3	Driving in a veil of interior noise (radio, air conditioner, etc.) with the windows closed should be discouraged in driver education programs.
4	The train should have been capable of stopping within 104 ft from 25 mph. The 314-ft stopping distance, from the point of impact, suggests that either the driver did not fully apply the brakes at some point during the collision sequence or that the brakes were not performing adequately.
*5	Occupant injuries from impact against interior surfaces and protuberances were mitigated as a result of adequate padding and interior design.
7	This site has an extremely high accident rate; however, more adequate traffic control by a train-approach signal system has not yet been authorized.



0 20 40 60
SCALE (FEET)

LEGEND

1. ONEWAY
2. KEEP RIGHT
3. RAILROAD CROSSBUCK
4. NO PARKING ANYTIME
5. IH 35 SOUTHBOUND
6. YIELD
7. REFLECTOR

COLLISION SCENE SCHEMATIC

ENCLOSURE E

Maryland Medical-Legal Foundation

Office of the Chief Medical Examiner

State of Maryland

Truck/Train Impact

Case # MMF 72-24

(Abridged)

MULTIDISCIPLINARY ACCIDENT INVESTIGATION SUMMARY

IDENTIFICATION OF COLLISION

The highway is a state road traversing north and south in the southeast portion of an industrial section of Baltimore County. The accident occurred in September of 1972 at 0400 hours on a Friday involving a tractor trailer and a freight train at a front to side impact. The accident caused fatal injuries to the driver of the tractor trailer.

INJURY SEVERITY SCALE: Driver of Vehicle #1 FATAL-AIS-8

AMBIENCE

Night; no illumination; misty; 58 degrees F.; 60% relative humidity; wind 10 m.p.h. from the northwest; visibility of 500 feet; road surface was wet; coefficient of friction .55 dry (measured) and .45 wet (estimated).

HIGHWAY

The highway on which the accident occurred is a major arterial state road with a total width of 106 feet consisting of two 12 foot lanes going north and two 12 foot lanes going south divided by a 48 foot grass median. The roadway is of black top macadam with an 8 foot shoulder on the east side and a 2 foot shoulder on the west side. The roadway is straight and level. There is no artificial lighting and within ½ mile there are two intersections; one being 800 feet south of the railroad crossing and the other being 600 feet north. There are 9 telephone and transit poles within ½ mile. The accident history at this point within a year previous is 6 property damage and 3 personal injury accidents with an average daily traffic of 22,500 vehicles.

TRAFFIC CONTROLS

The speed limit is posted at 55 m.p.h. and there are intermittent lane lines with solid edge lines painted in the roadway. There are standard railroad crossing signs and lights at the right side of the road with overhead signals actuated by the train.

VEHICLES INVOLVED

Vehicle #1 was a 1969 G.M.C. Tractor, two-door, red in color with an odometer reading of 49,760 miles. There is no inspection data but the vehicle was well maintained by the company garage. The vehicle was equipped with manual steering, manual transmission, air brakes (drum type), seat belts (being used by the driver when the accident occurred). There was no previous damage noted. Damage to Vehicle #1 on impacting the train at an eleven o'clock principal impact force was to the left front causing a sheet metal crush of 38 inches. The bumper, grille, fender and hood deformed rearward into the engine compartment whereby the engine separated from mounts. The left front wheel and assembly moved rearward. The seats moved forward and the driver impacted the steering wheel and column with his chest and his head impacted the left A-Pillar as it was deformed inward and rearward. After the initial impact a second impact of 06 hours principal force occurred as the trailer sheared from the fifth wheel and impacted the rear of the cab with a sheet metal crush of 18 inches compressing the cab interior by 50% pinning the operator in.

VEHICLE DEFORMATION INDEX: Principal Impact - 11 FLAW-4
Secondary Impact - 06 BDHW-4

Vehicle #2 was a General Motors E.M.D. type locomotive pulling 47 box cars and it sustained minor damage to the right front side.

VEHICLE DEFORMATION INDEX: 02 RFMW-1

OCCUPANT DATA

The driver of Vehicle #1 was a 46 year old white male, 68 inches tall, weighing 115 pounds having 30 years driving experience at approximately 15,000 miles per year. At the time of accident he was enroute from his place of employment with a delivery for a distant city expected to arrive 5 hours after the accident occurred. The accident occurred within 5 miles from the origin. He was familiar with the vehicle and the area having used both daily for the past several years. His physical condition was normal as was his mental condition. There was no alcohol or drug involvement and seat belts were available and in use by the operator. During the accident the driver sustained the following injuries: fractures of skull, ribs, pelvis and extremities, contusions of lungs with hemothorax, laceration of heart, laceration of liver and spleen with hemoperitoneum, rupture of bladder; and contusions of hippocampi and temporal lobe of brain. (AIS-8)

The driver of Vehicle #2 (train) was a 57 year old white male, weight and height unknown having 40 years driving experience with 15 years as a railroad engineer. His driving record is good with 10,000 miles per year plus rail usage undetermined. He is familiar with the engine using same three to four times weekly. At the time he was shifting cars along the railroad from yard to yard. His engineering ability was taught to him by the railroad company. There were no drugs or alcohol involved. There were no restraints available and no injuries. There were three passengers on the train and they were not injured or restrained. Passenger #1 was a white male, 56 years of age and he was seated in the front center. Passenger #2 was a white male, 36 years of age and he was seated in the front right. Passenger #3 was a white male, 54 years of age and he was seated in the rear left.

STANDARDS

1. FHSPS #9 - Identification and Surveilance of Accident Locations. The railroad crossing is well protected with traffic signals actuated by the train, but it is so little used that drivers attempt to beat the train. It is recommended that gates be installed at the railroad crossing..

COLLISION DESCRIPTION

Pre-Crash

The driver of Vehicle #1 reported to work at the usual time, 0130 hours, and had proceeded from the terminal to deliver a load of hardware to a distant city. He was operating the vehicle northbound on a state road at an estimated speed of 45 to 50 m.p.h. and when he approached the east/west railroad crossing he failed to stop for the signals and collided with the right front side of a slow moving freight train. The freight train was proceeding eastbound at an approximated speed of 8 to 10 m.p.h. There is no evidence to show that the driver of Vehicle #1 tried to take any evasive action, however, the operator of the train did apply his air brakes for an emergency stop.

Crash

Vehicle #1 impacted the right front side of the train with its left front at an eleven o'clock principal force impact with a secondary impact force of 06 o'clock when the trailer sheared off the fifth wheel and impacted the rear of the truck cab. As the vehicle rotated 25^{o} clockwise, and coming to rest 42 feet east of the impact, the driver, who was restrained, moved forward and to the left impacting the steering wheel and the left A-Pillar and was impacted from the rear by the cab body and seat.

Vehicle #2 was impacted at the right side at front initial impact force at 02 o'clock deforming the entrance steps and the hand rail. The unrestrained occupants were well to the rear of the impact point and suffered no effects of the accident. The driver of the train applied his air brakes for an emergency stop and the train remained on the rails coming to a stop 168 feet east of the impact.

Post-Crash

Vehicle #1 came to rest 42 feet east of the impact facing east off the roadway and Vehicle #2 came to rest 158 feet east of the impact, on rails. The operator and passengers of Vehicle #2 were unhurt. The operator of Vehicle #1, due to the compression of the truck cab from the front and rear impacts, was pinned in the cab. Emergency rescue equipment of the Police and Fire Departments were called, responding within 10 minutes and proceeded to cut the metal attempting to free the driver. Due to severe deformation, extrication was difficult and took two hours to free the driver. He was pronounced dead at the scene and was taken to the Office of the Chief Medical Examiner. During the rescue operation, traffic was tied up in both directions and suitable detours were maintained by the police. A two company was contacted to clear the scene of the truck and debris. The truck was towed to the terminal and the train was moved under its own power. The scene was cleared and open for traffic within four hours.

CAUSAL FACTORS, CONCLUSIONS AND RECOMMENDATIONS

ACCIDENT CAUSATION

Matrix Cell	Explanation
	Primary Cause
1	Driver of Vehicle #1 failed to perceive the approaching train and danger of going through signals. (Definite)
	Severity Increasing
1	Driver of Vehicle #1 made no attempt at evasive action. (Definite)
	Relevant Conditions
1	Driver of Vehicle #1 was apparently preoccupied with thoughts of his trip. (Probable)
7	The crossing was well protected with actuated signals (at side and overhead) but it allows room for passage. (Probable)

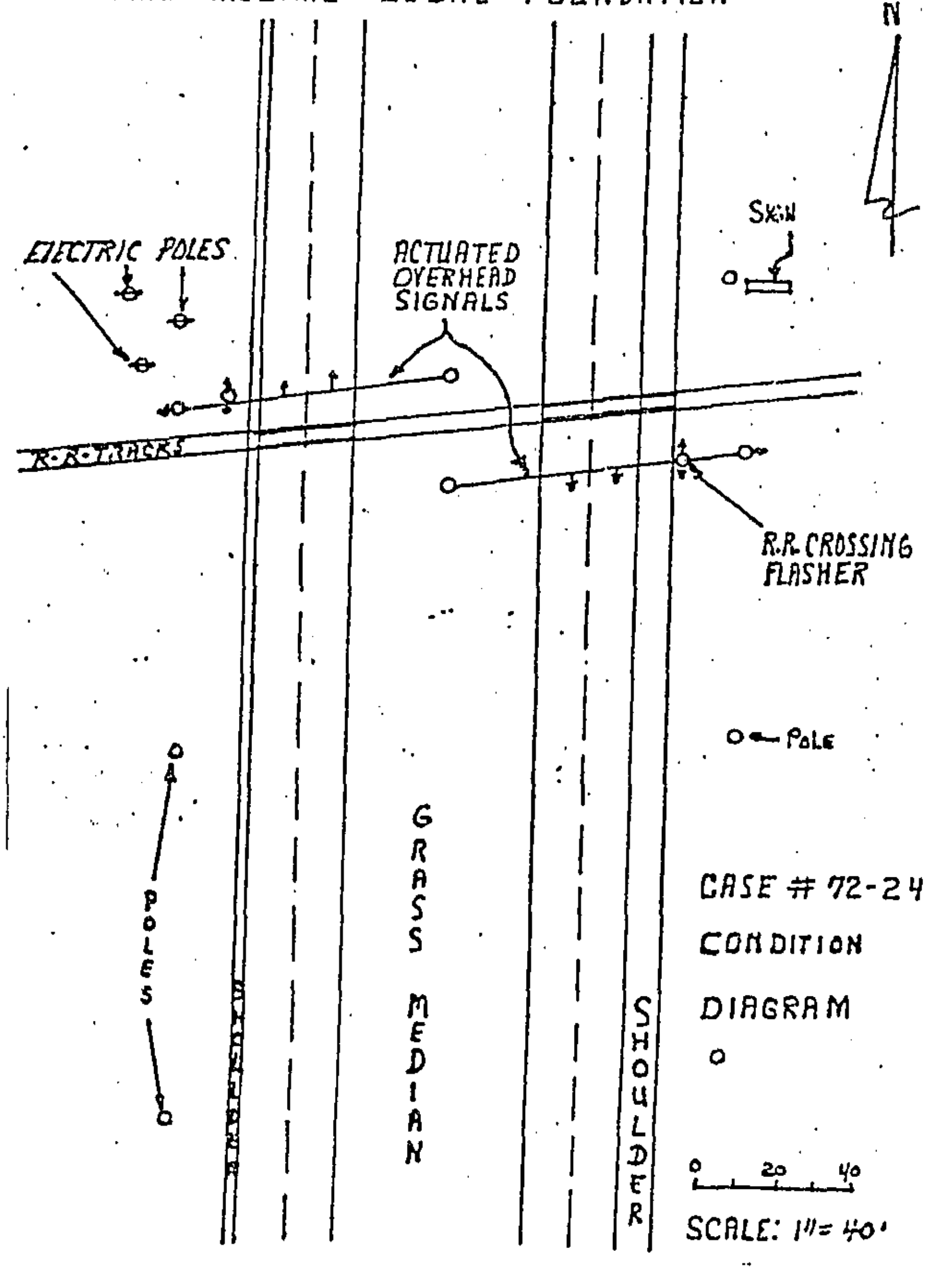
INJURY CAUSATION

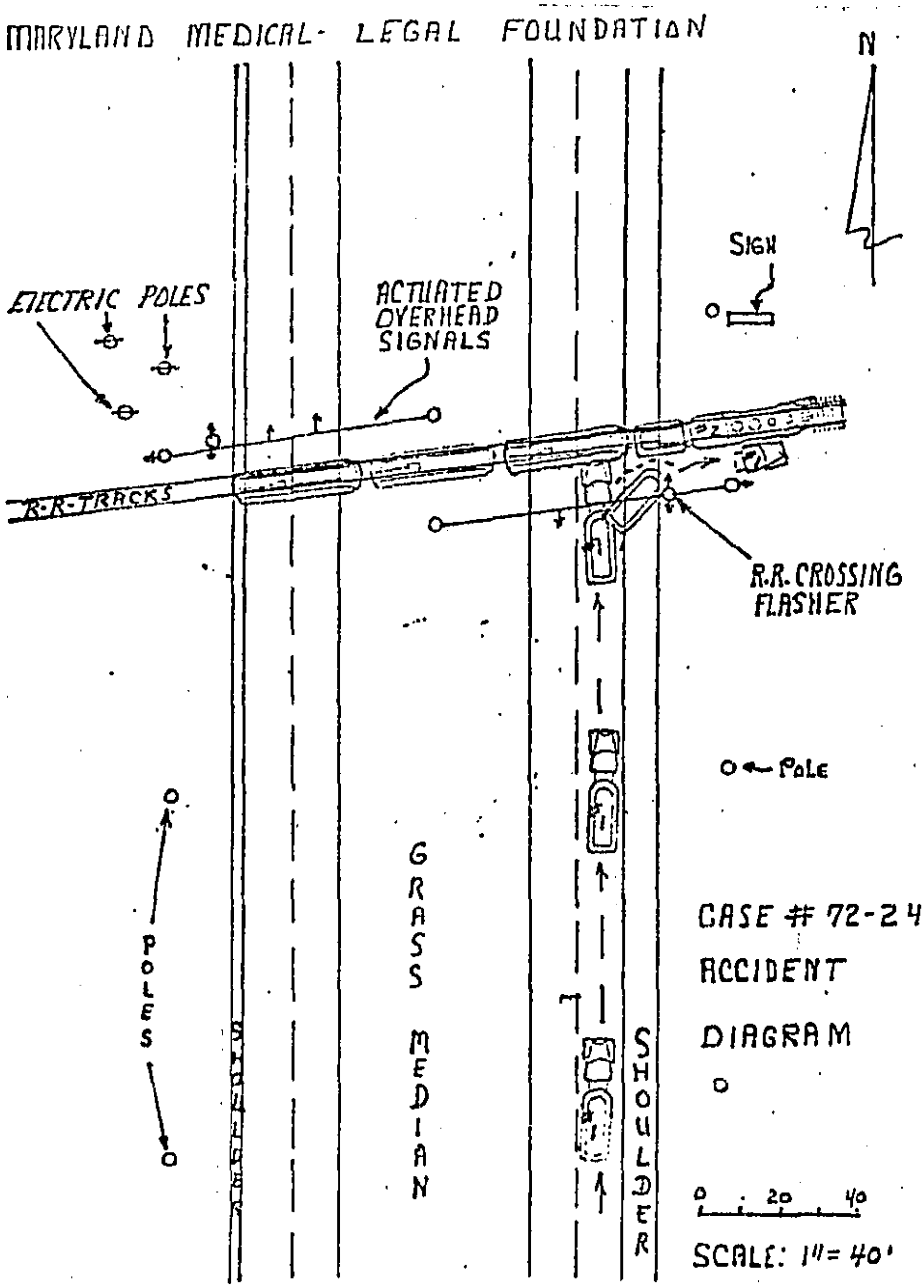
Matrix Cell	Explanation
2	Driver of Vehicle #1 was wearing available restraints but they were of no use in this case. (Probable)
5	The collapse of Vehicle #1 from front and rear impacts added to severe injury. (Definite)

POST-CRASH FACTORS

Matrix Cell	Explanation
3	Ambulance and rescue arrival within 10 minutes, but extrication was difficult taking two hours with metal saws. (Definite)
6	The load of Vehicle #1 shifted after the initial impact. (Definite)
9	There were no fires or explosions, detours were set and maintained adequately, and the clean-up operation took four hours. (Definite)

MARYLAND MEDICAL- LEGAL FOUNDATION




MARYLAND MEDICAL-LEGAL FOUNDATION
N
SIGN
ELECTRIC POLES
ACTUATED OVERHEAD SIGNALS
R-R-TRACKS
R.R. CROSSING FLASHER
POLE
POLES
GRASS MEDIAN
SHOULDER
CASE # 72-24
ACCIDENT DIAGRAM
0 20 40
SCALE: 1" = 40'

ENCLOSURE F

Durham City Code
Durham, N.C.

Ch. 18 § 9 Locomotive Whistle.

It shall be unlawful for any person to blow or allow to be blown any locomotive whistle under his control within the city limits. (Code 1940, C. 28, § 8.)

Knoxville City Code
Knoxville, Tenn.

Ch. 33 § 8 Blowing Whistles.

It shall be unlawful for any person operating or in charge of a locomotive engine within the corporate limits of the city to blow the whistle on the same except as may be absolutely necessary in the use of the signals as laid down by the rules and regulations of railway companies, or as required by the laws of the state. (10-21-04.)

Houston City Code
Houston, Texas

Sec. 1843 Blowing Whistles; Blowing out Boiler

All persons are prohibited from blowing any whistles on any locomotive, or single blasts therefrom, within the limits of the city, for a longer period of time than five seconds, except when there is imminent danger of an accident. All persons are prohibited from blowing off or blowing out a boiler when crossing any public street or other thoroughfare within the limits of the city. Each and every person violat- ... any provision of this section shall be fined in any sum, upon conviction, not less than five dollars and not exceeding fifty dollars.

Mason City, Iowa

26-29 Sounding of Locomotive Whistles

It shall be unlawful for any person to cause or permit any locomotive whistle to be sounded within the limits of the City except for the purpose of making necessary signals required by law or required for the safe operation of the railway, and where requisite signals cannot be made by other means. (R '16, Sec. 545.)

Chicago, Illinois

188-44. No person owning or operating a railroad shall cause or allow the whistle of any locomotive engine to be sounded within the city, except necessary brake signals and such as may be absolutely necessary to prevent injury to life and property.

Each locomotive engine shall be equipped with a bell-ringing device which shall at all times be maintained in repair and which shall cause the bell of the engine to be rung automatically. The bell of each locomotive engine shall be rung continuously while such locomotive is running within the city, excepting bells on locomotives running upon those railroad tracks enclosed by walls or fences, or enclosed by a wall on one side and public waters on the other side, and excepting bells on locomotives running upon those portions of the railroad track which have been elevated. In the case of these exceptions, no bell shall be rung or whistle blown except as signals of danger.

Buffalo, New York

Chapter V. RAILROADS

#4. It shall not be lawful for any person in the employ of any railroad company operating within the limits of the city to permit the whistle of the locomotive under his control to be blown, except for necessary signal purposes. Any person violating the provisions of this section shall pay a penalty of $25.00 for such offense.

NOTE: This restriction is generally associated with a train speed restriction of 6 MPH and the use of flagmen.

Lynchburg, Virginia

CITY CODE SUPPLEMENT (Railroad)

Sec. 3809. Sounding whistles or horns.

The sounding or blowing of locomotive whistles or horns within the corporate limits of the city of Lynchburg is hereby prohibited, except as may be necessary for the transmission of signals or in emergency to prevent accidents.

The provisions of this section shall not apply to the two crossings of the tracks of the Chesapeake and Ohio Railway

Company at Reusens, in the vicinity of the E. J. Lavino Company, because of the lack of sight distance and warning ... ices at these crossings.

Any violation of this ordinance shall be punished by a fine of not less than five dollars nor more than ten dollars for each offense. (1931, §704; 6-8-42; 8=28-56; 10-9-56)

State of Illinois

Under authority delegated to it by the State Legislature (114-59), the Illinois Commerce Commission adopted General Order #176 on August 15, 1957, excusing the sounding of horns and whistles at crossings protected by flashing lights. This has now been incorporated in General Order No, 138, Revised, August 22, 1973, Rule 501.

State of Florida

§351.03 limits signals to bells only in incorporated areas, with an accompanying speed limit of 12 mph.

COMMISSIONERS
VERNON L. STURGEON, PRESIDENT
WILLIAM SYMONS, JR.
J. P. VUKASIN, JR.
THOMAS MORAN
D. W. HOLMES

ADDRESS ALL COMMUNICATIONS
TO THE COMMISSION
CALIFORNIA STATE BUILDING
SAN FRANCISCO, CALIFORNIA 94102
TELEPHONE: (415) 557- 1945

Public Utilities Commission

STATE OF CALIFORNIA

November 10, 1972

FILE NO. IC 79403

Honorable Arlen Gregorio
The State Senate
12th District, San Mateo County
State Capitol
Sacramento, CA 95814

NOV 13 1972

Dear Senator Gregorio:

Subsequent to receipt of your letter of October 4, 1972, our representative has discussed the use of train whistles approaching railroad grade crossings with Mr. John Gilroy and Ms. Charlotte Schultz of your staff.

As discussed with them, it may be necessary to sound the train whistle even at crossings equipped with automatic gates for the following reasons:

1. Possibility of a malfunction of the automatic grade crossing protection due to being struck by vehicles, vandalism or failure of track circuitry or signal apparatus.

2. Rail highway crossings are frequently traversed by bicyclists and pedestrians after the protective devices have been actuated by an approaching train.

3. Impatient motorists sometimes ignore crossing signals and have been known to drive around protective gate arms in an attempt to avoid being delayed by a train.

4. Liability on the part of the railroads for failure to use every means available to avoid an accident.

In view of the above, the staff feels that in the interest of safety, the railroads should not be prohibited from using the train whistles to warn persons that a train is approaching.

Yours very truly,

PUBLIC UTILITIES COMMISSION

By William R. Johnson

WILLIAM R. JOHNSON, Secretary

APPENDIX C

OPERATING RAILROAD RETARDER YARDS IN THE UNITED STATES

OPERATING RAILROAD RETARDER YARDS IN THE UNITED STATES
(CLASS I Railroads)

State	Yard	Railroad	Number of Tracks
Alabama	Birmingham	L&N	40
	Birmingham	Sou	56
	Sheffield	Sou	32
Arkansas	N. Little Rock	M. P.	64
	Pine Bluff	St. L. S. W.	30
California	City of Industry	S. P.	12
	East Los Angeles	U. P.	16
	Los Angeles	S. P.	40
	Richmond	S. P.	8
	Roseville	S. P.	49
	West Colton	S. P.	56
Colorado	Grand Jct.	D&RGW	31
	Pueblo	AT&SF	16
Connecticut	Cedar Hill (East)	P. C.	45
	Cedar Hill (West)	P. C.	38
Florida	Tampa	S. C. L.	8
Georgia	Atlanta	Sou	12
	Atlanta	Sou	65
	Atlanta	L&N	24
	Macon	Sou	50
Idaho	Pocatello	U. P.	40

State	Yard	Railroad	Number of Tracks
Illinois	Bensenville	C.M.S.P.&P.	70
	Blue Island	I. H. B.	42
	Chicago, Clearing (East)	B. R. Chgo	44
	Chicago, Clearing (West)	B. R. Chgo	36
	Chicago, Cicero	B. N.	43
	Chicago, Corwith	AT&SF	32
	Chicago, 59th St.	P. C.	42
	E. St. Louis	A. & S.	42
	E. St. Louis	I. C. G.	26
	Galesburg (East)	B. N.	49
	Galesburg (West)	B. N.	35
	Madison	T. R. R. A.	34
	Markam	I. C. G.	64
	Markam	I. C. G.	45
	Proviso	C. N. W.	59
	Silvio	C. R. I. P.	50
Indiana	Elkhart	P. C.	72
	Gary	E. J. & E.	58
	Gibson (South)	I. H. B.	30
	Gibson (North)	I. H. B.	30
	Indianapolis	P. C.	64
Kansas	Argentine (East)	AT&SF	48
	Argentine (West)	AT&SF	56
	Armourdale	C. R. I. P.	40
Kentucky	DeCoursey (North)	L&N	20
	DeCoursey (South)	L&N	24
	Russell	C&O/B&O	32
	Stevens	C&O/B&O	15
Louisiana	Geismer	I. C. G.	6
Maryland	Cumberland (West)	C&O/B&O	32
	Cumberland (East)	C&O/B&O	16
Massachusetts	Boston	B&M	22

State	Yard	Railroad	Number of Tracks
Michigan	Detroit	DT&I	36
	West Detroit	P. C.	31
Minnesota	Minneapolis	B. N.	63
	St. Paul	C.M.S.P.&P.	40
Missouri	Kansas City (East)	M. P.	42
	Kansas City (West)	M. P.	32
	N. Kansas City	B. N.	42
Montana	Missoula	B. N.	9
Nebraska	Lincoln	B. N.	36
	N. Platte	U. P.	62
	N. Platte (West)	U. P.	42
New Jersey	Morrisville	P. C.	38
	Pavonia	P. C.	32
New York	Buffalo	E. L.	56
	Buffalo	P. C.	63
	DeWitt	P. C.	27
	Mechanicville	B&M	36
North Carolina	Hamlet	S. C. L.	58
North Dakota	Minot	B. N.	40
Ohio	Bellevue	N&W	42
	Columbus	P. C.	40
	Grandview	P. C.	9
	Marion	E. L.	24
	Portsmouth	N&W	18
	Portsmouth (West)	N&W	35
	Sharonville	P. C.	35
	Stanley	P. C.	42
	Walkridge	C&O/B&O	68
	Willard	C&O/B&O	52
Oklahoma	Tulsa	S. L. S. F.	40

State	Yard	Railroad	Number of Tracks
Oregon	Eugene	S. P.	32
Pennsylvania	Allentown	CNJ/LV	19
	Connellsville	C&O/B&O	15
	Conway (East)	P. C.	54
	Conway (West)	P. C.	56
	Enola (East)	P. C.	33
	Enola (West)	P. C.	36
	Pittsburgh	U. R. R.	23
	Pittsburgh	Mon-Conn.	22
	Rutherford (East)	Reading	33
	Rutherford (West)	Reading	18
Tennessee	Chattanooga	Sou	50
	Knoxville	Sou	46
	Memphis	S. L. S. F.	50
	Nashville	L&N	56
Texas	Beaumont	S. P.	12
	Fort Worth	M. P./T. P.	44
	Houston	S. P.	48
Virginia	Alexandria (North)	R. F. P.	49
	Alexandria (South)	R. F. P.	39
	Bluefield	N&W	13
	Lamperts Point (empty)	N&W	36
	Lamperts Point (loaded)	N&W	36
	Lamperts Point	N&W	30
	Newport News	C&O/B&O	15
	Roanoke	N&W	56
Washington	Pasco	B. N.	47
	Seattle	B. N.	16

State	Yard	Railroad	Number of Tracks
Wisconsin	Milwaukee	C.M.S.P.&P.	35

Abbreviations of Railroad Names Used in this Table*

L&N – Louisville and Nashville
Sou – Southern
M.P. – Missouri Pacific
St. L.S.W. – St. Louis Southwestern
S.P. – Southern Pacific
U.P. – Union Pacific
D&RGW – Denver and Rio Grande Western
AT&SF – Atchison, Topeka and Santa Fe
P.C. – Penn Central
S.C.L. – Seaboard Coast Line
C.M.S.P.&P. – Chicago, Milwaukee, St. Paul and Pacific
I.H.B. – Indiana Harbor Belt Railway
B.R. Chgo – Belt Railway of Chicago
B.N. – Burlington Northern
I.C.G. – Illinois Central Gulf
A. & S. – Alton and Southern
T.R.R.A. – Terminal Railroad Assoc. of St. Louis
C.N.W. – Chicago and North Western
C.R.I.P. – Chicago, Rock Island and Pacific
E.J. & E. – Elgin, Joliet, and Eastern
C&O/B&O – Chesapeake and Ohio Baltimore and Ohio
B&M – Boston and Maine
D.T.&I. – Detroit, Toldeo, and Ironton
E.L. – Erie Lackawanna
N&W – Norfolk and Western
S.L.S.F. – St. Louis San Francisco
CNJ/LV – Central Railroad of New Jersey Lehigh Valley
U.R.R. – Union Railroad
Mon-Conn. – Monongahela Connecting
Reading – Reading Company
M.P./T.P. – Missouri Pacific/Texas Pacific
R.F.P. – Richmond, Fredericksburg and Potomac

*These abbreviations reflect mergers; the abbreviations on the accompanying map frequently do not reflect mergers.

APPENDIX D

SUMMARY OF YARD NOISE IMPACT STUDY

SUMMARY OF YARD NOISE IMPACT STUDY

INTRODUCTION

The rail yard modeling study of noise impact on people used data collected at the Cicero Yard of the Burlington Northern near Chicago Illinois. The study included the analysis of eight railroad yards from a population density and yard layout standpoint which led to the selection of the Cicero Yard for more detailed analysis. Characteristics of the noise emitted from the Cicero Yard under a range of operating conditions were studied and a model of the yard was developed. The model was then used to predict the impact on people (environmental noise levels) of various noise abatement activities on different aspects of the Cicero Yard operation.

CASE STUDIES OF RAILROAD YARDS

Eight yards having a wide range of characteristics were selected in order to compare yard traffic with population densities near them. Such a comparison provides a basis for determining the number and frequency of exposure of people to noise from railroad yards. Figures D.1 - D.8 are maps of the yards that were studied. Although no detailed studies of the zoning around the yards were attempted, the maps provide some indication of land use. The configuration of the yards and the traffic through the yards were determined by telephoning the yard superintendants or the yard masters. Table D.1 summarizes the population and traffic data for the yards.

The population information was taken from the *1970 Census of Housing, Block Statistics* for each city. The total populations for the cities studied were obtained from the *1970 Census of Population, U.S. Summary.* Population densities were derived for strips 250 or 500 ft wide for the entire length of the yards and/or for a total of 2000 ft from the retarders. Often, separate population density estimates were made for each side of a yard, since people are not evenly distributed around yards. Figures D.1 - D.8 contain graphs of the population distribution for each area.

The population of the cities in which the yards are located ranges from 67,058 (Cicero) to 1,800 (Roseville). Population cannot be considered an index of urbanization since all of the towns are in urbanized areas generally outside a larger urban city. No yard located in a "rural" area was studied as sufficiently detailed population statistics were not available for a yard located in other than urbanized areas.

STATISTICAL ANALYSIS OF NOISE NEAR RAILROAD YARDS

Many methods of describing community noise have been proposed, studied, and evaluated, but the most suitable method for describing environmental noise and its effect on people, in EPA's

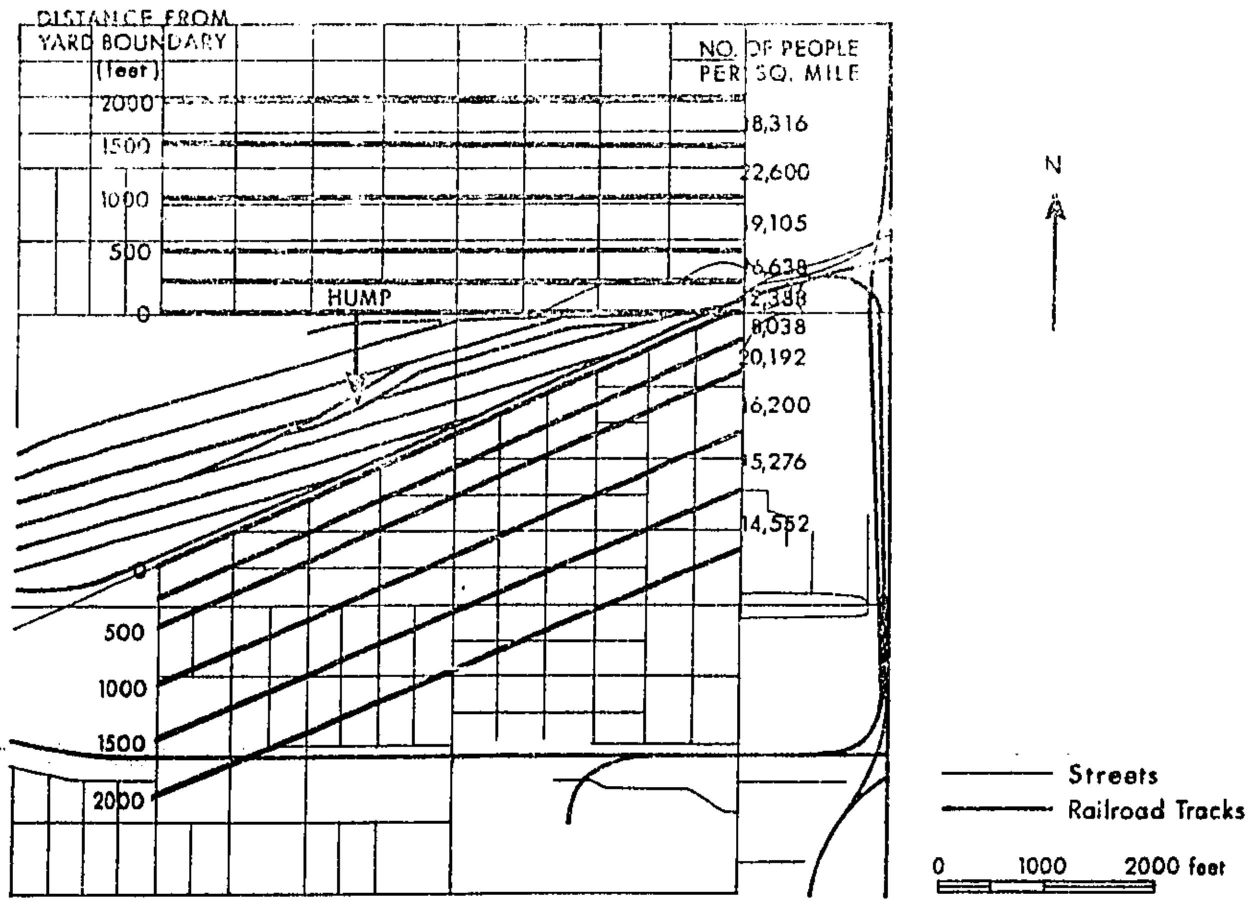


FIG D.1. MAP AND POPULATION DENSITY PROFILES FOR THE CICERO, ILLINOIS HUMP YARD.

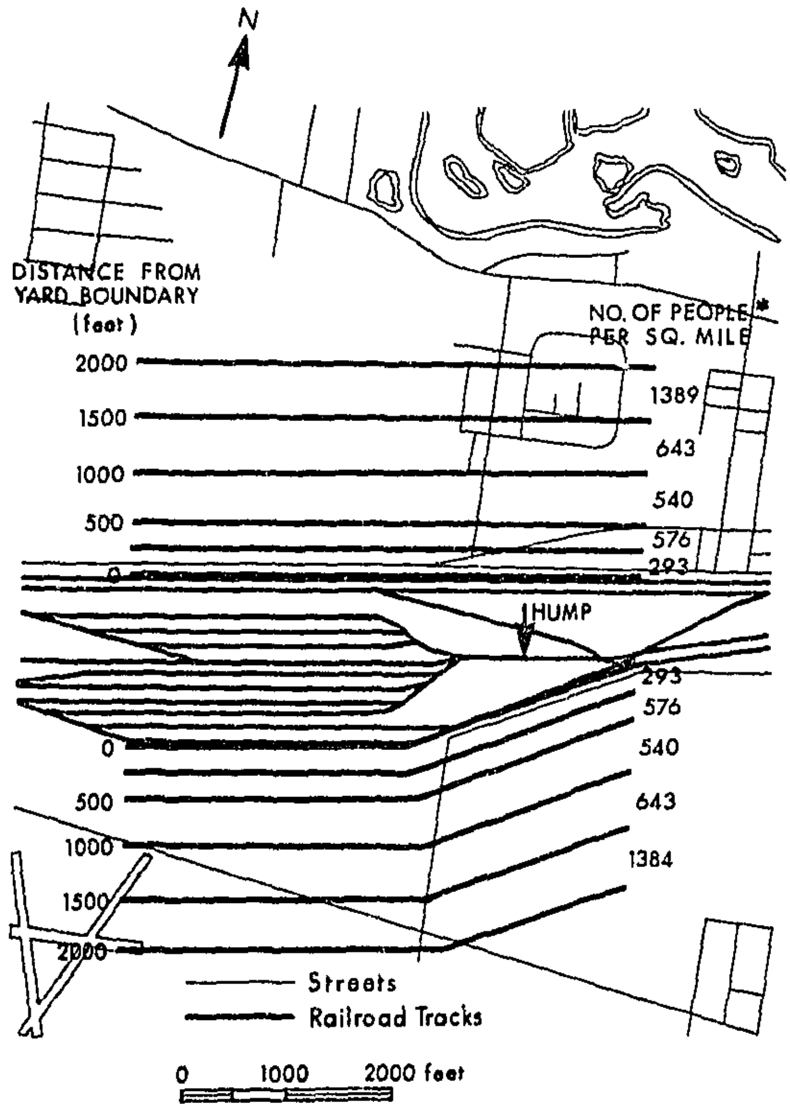


FIG. D.2. MAP AND POPULATION DENSITY PROFILES FOR THE ELKHART, INDIANA HUMP YARD.

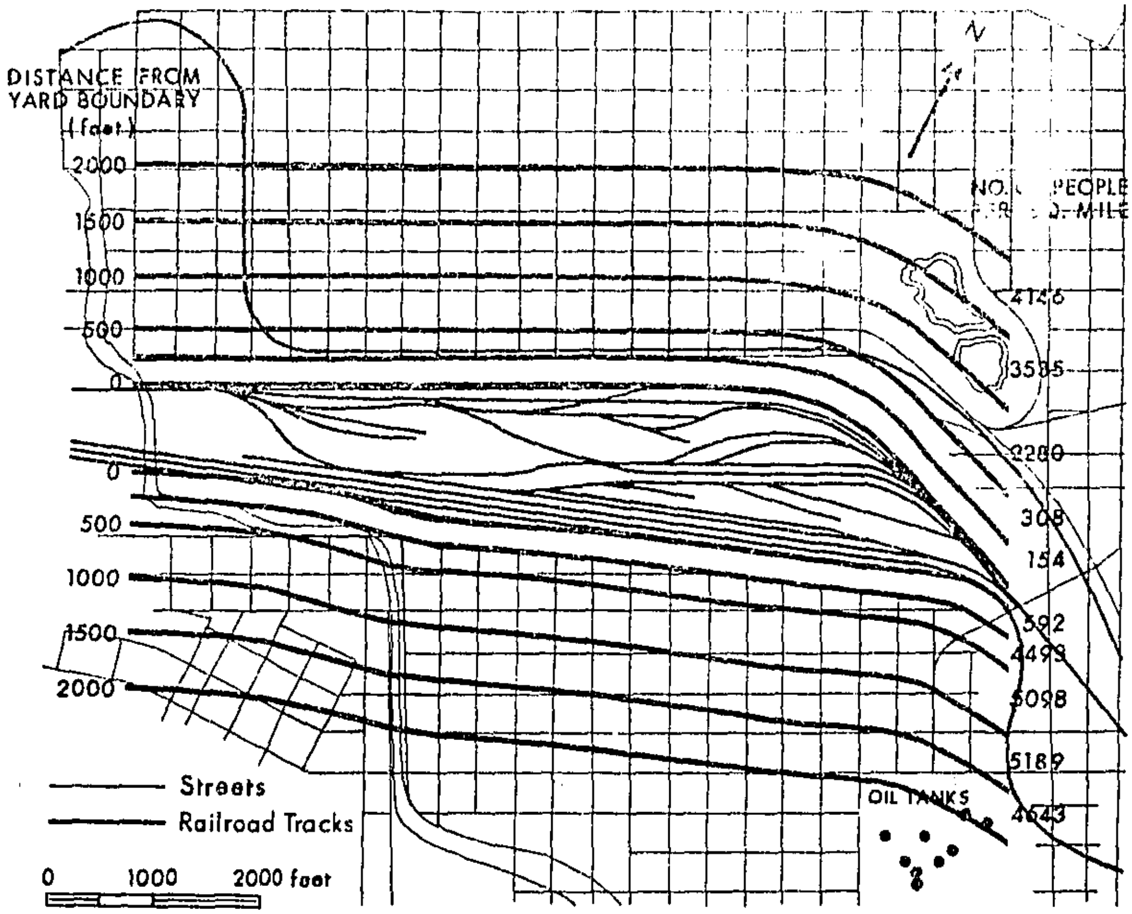


FIG. D.3. MAP AND POPULATION DENSITY PROFILES FOR THE CHEYENNE, WYOMING FLAT YARD.

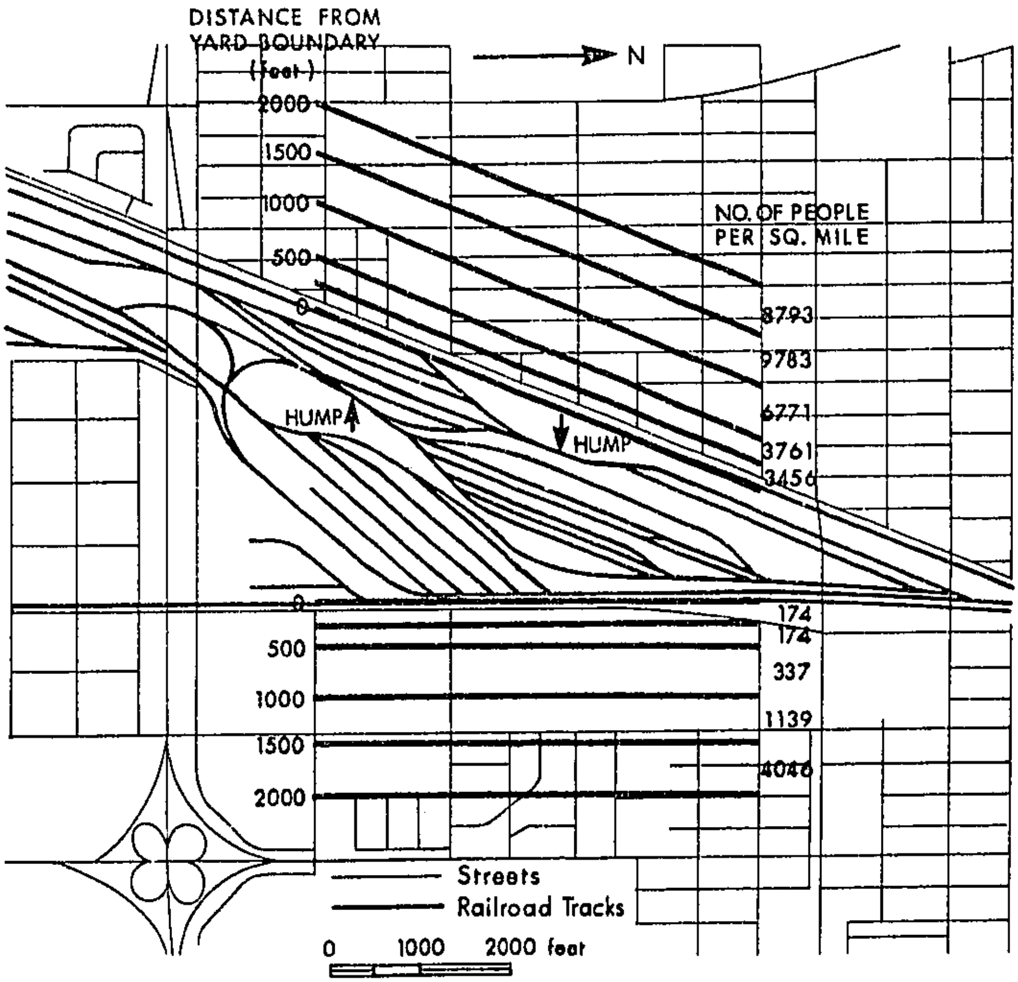


FIG. D.4. MAP AND POPULATION DENSITY PROFILES FOR THE MARKHAM, ILLINOIS HUMP YARD.

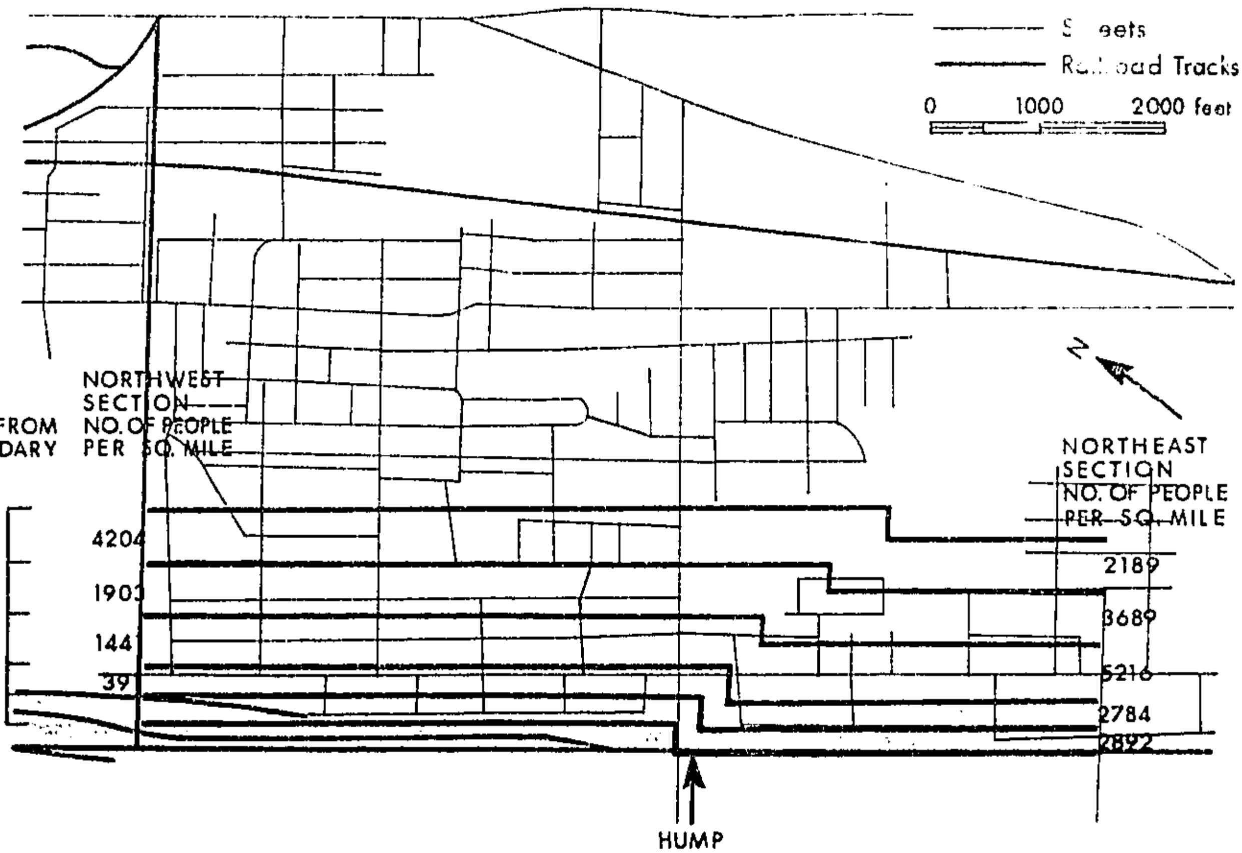


Fig. D.5. MAP AND POPULATION DENSITY FOR THE CENTREVILLE, ILLINOIS HUMP YARD.

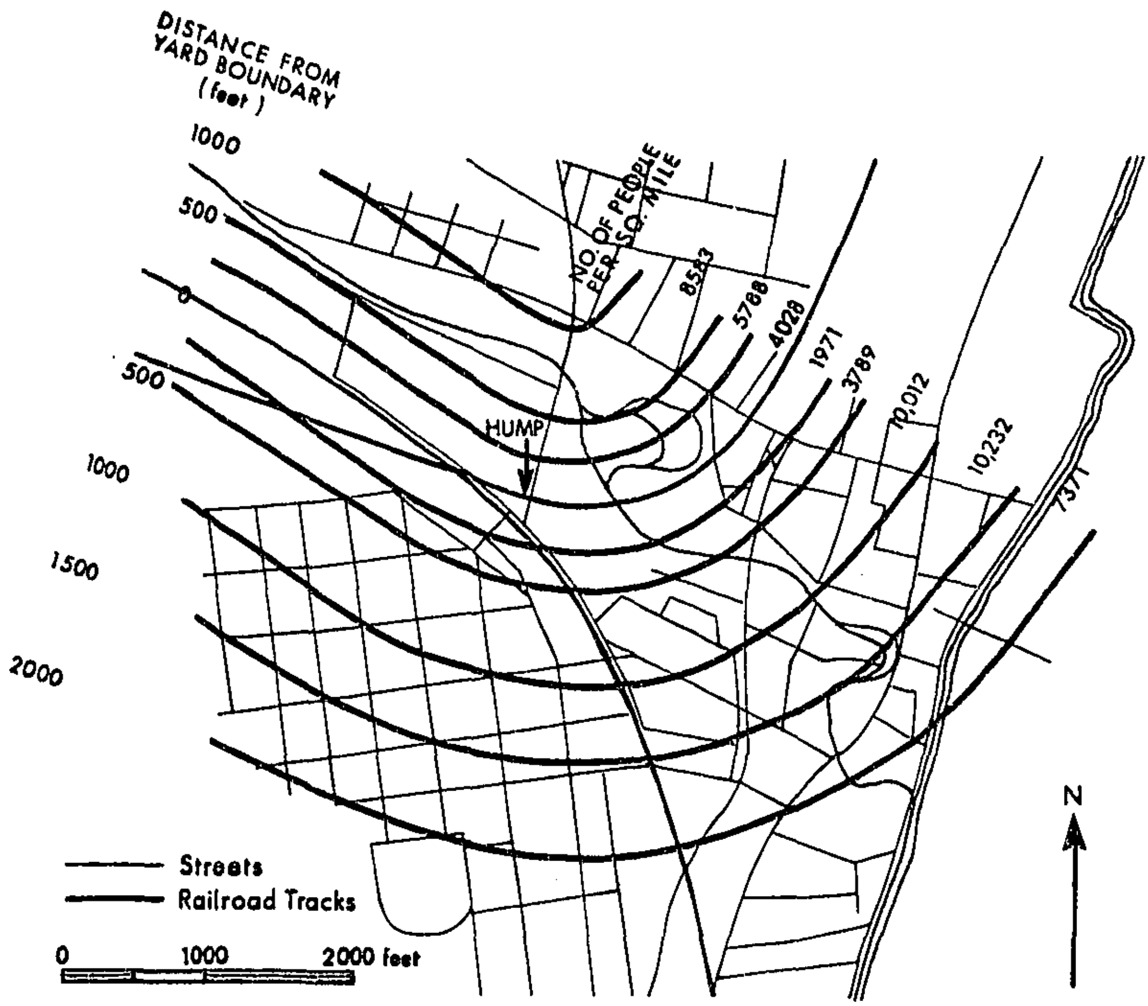


FIG. D.6. MAP AND POPULATION DENSITY PROFILES FOR THE MECHANICVILLE, NEW YORK HUMP YARD.

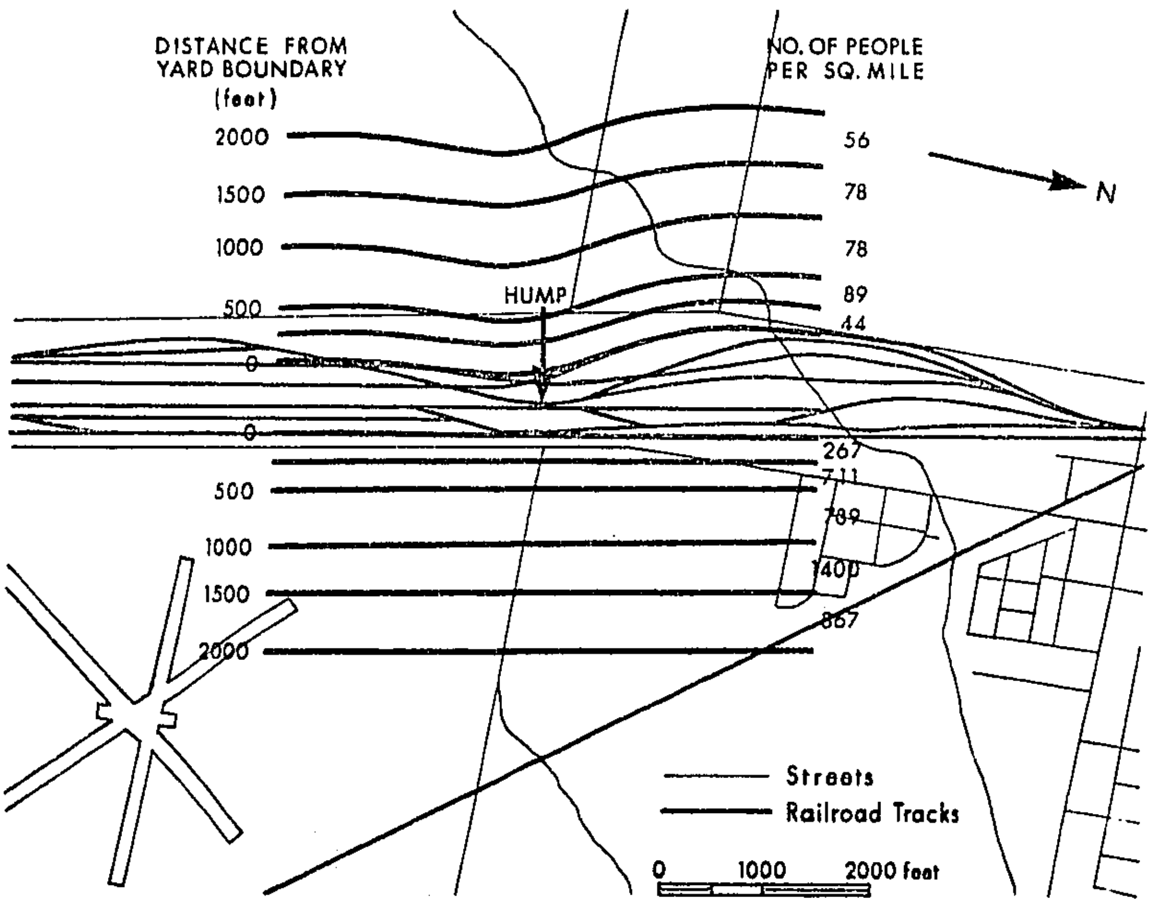


FIG. D.7. MAP AND POPULATION DENSITY PROFILES FOR THE WALBRIDGE, OHIO HUMP YARD.

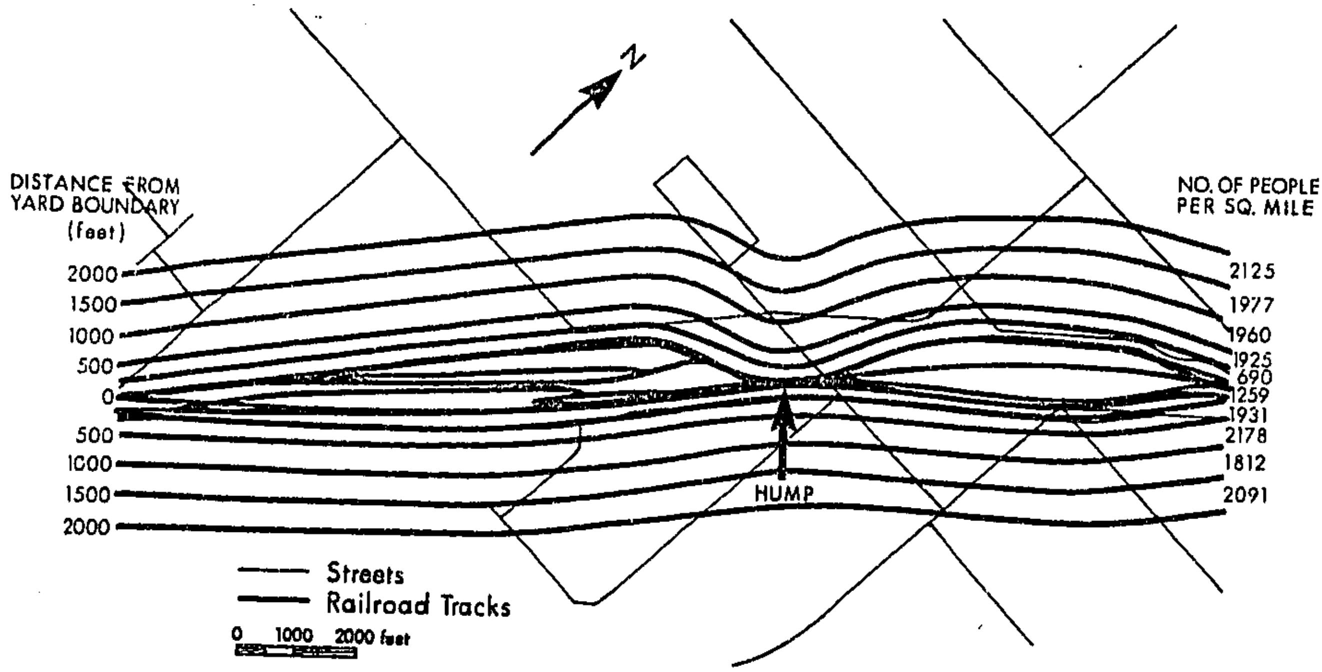


FIG. D.8. MAP AND POPULATION DENSITY PROFILES FOR THE ROSEVILLE, CALIFORNIA HUMP YARD.

TABLE D-1 POPULATION DENSITY AND RAILROAD CAR TRAFFIC FOR VARIOUS RAILROAD YARDS

City and State Yard Operator	Total Population	No. of Cars Per Day	No. of People Per Square Mile Within: 0-250'	250'-500'	500'-1000'	1000'-1500'	1500'-2000'		Comments
[illegible], Ill.	67,059	1000	12,383	16,638	19,105	22,600	18,316	North Section	[illegible]
[illegible] North.			6,038	20,192	16,200	15,276	14,552	South Section	[illegible] group retarders
[illegible]hart, Ind.	43,152	6800	293	576	540	643	1,384		7[illegible] tracks 1200 cars/day [illegible] manual [illegible] Airport nearby
enn. Central									
heyenne, Wyo.	40,152	4000	592	4,493	5,098	5,189	4,643	South Section	Flat yard; [illegible] entire length of the [illegible]
nion Pacific			154	308	2,280	3,535	4,146	North Section	
arkham, Ill.	15,997	3200-3400	174	174	337	1,139	4,046	East Section	45 tracks two [illegible], [illegible] intermediate, [illegible] group retarders; [illegible] cars/day [illegible] retarder, no inert retarders
Il., Central & Gulf			3,456	3,761	6,771	9,783	8,793	West Section	
entreville, Ill.	11,978	3300-4000	2,892	2,784	5,216	3,089	2,189	Northeast Section	30 tracks one master, [illegible] group retarders 1200 cars/day through retarders manual or automatic release inerts
Il., Central & Gulf				391	1,411	1,903	4,204	Northwest Section	
echanicville, N.Y.	6,247	800	1,971	3,789	10,012	10,232	7,371	South Section	one master & [illegible] group retarders 36 tracks, 19 in use; 19 inert retarders
oston & Maine			4,028	5,788	8,583			North Section	
albridge, Ohio	3,028	1500	44	89	78	78	56	Western Section	68 tracks one master & 6 group retarders; no inert retarders Airport nearby
altimore & Ohio			267	711	789	1,400	867	Eastern Section	
seville, Calif.	17,895	6500	1,259	1,931	2,178	1,812	2,091	Southeast Section (entire yard)	49 tracks two humps, two master retarders 7 group retarders 49 spring-loaded inert retarders
uthern Pacific			690	1,925	1,960	1,977	2,125	Northwest Section (entire yard)	
			170	319	263	642	389	Southeast Section (opposite retarders)	
			1,276	2,468	3,947	4,053	2,516	Northwest Section (opposite retarders)	

judgment, is the day/night sound level (re: Levels Document). L_{dn} may be obtained from an analysis of statittical records of noise (Schultz, 1972). Details of this procedure are in enclosure A of section 8 of this document. "Time records" usually means magnetic tape recordings made at the measurement site with rugged, portable, high-quality tape recorders. Permanent recordings permit processing a given noise record in several different ways, freeing the investigator from the restrictions imposed by the particular analysis that might be suitable in the field.

Figure D.9 shows portions of a time history of noise measured around 5:00 a.m. near residences about 400 ft from the boundary of a railroad yard. The record from which Figure D.9 was constructed was produced by playing a magnetic tape recording of the noise through an A-weighting network into a graphic level recorder. The figures show some significant noise events that are not associated with railroad operations. Those events must be iliminated from statistical analysis of the information on the tapes if the results are to be descriptive of railroad noise only.

An edited tape, from which all non-railroad noises were removed, was prepared by selectively interrupting a re-recording of the original tape. Both the unedited and the edited tapes of railroad noise were processed using an electronic statistical analyzer and a digital computer, to produce statistical analyses like the one shown in Figure D.10a. The tape which was generated is shown in Figure D.9. Figure D.10b shows the result of a statistical analysis of the edited version of the tape that generated Figure D.10a. The solid lines in Figure D.10b represent the data from Figure D.10a.

Figure D.10b shows that editing out extraneous events did not cause large changes in the statistical properties of the recorded noise, and the effect is typical of cases for which editing was possible. For times when the community was active, it was impossible to discriminate between noises due to railroad operations and other noises.

Figure D.11 shows the results of a statistical analysis of an edited tape recording of noises at the boundary of a busy yard. Even though a few diesel trucks traveled along a street adjacent to the boundary, editing the recorded sounds produced negligible changes in their statistical properties.

Figures D.12a and D.12b demonstrate a contrasting situation. Figure D.12a shows the results of statistical analysis of an unedited tape recording of noises at the boundary of the yard described above during a period of relative inactivity. Since much of the noise in the vicinity was extraneous (mostly diesel trucks), editing changed the statistical properties of the recorded noise. Figure D.12b shows the effect of editing this tape. Even though there were few readily noticeable railroad noises during the period covered by Figure D.12, the continuous background noise is higher at the boundary of the yard than in the community, illustrating the contributions of continuously idling locomotives and other noises associated with the activities of men and machines assigned to the yard.

"Energy Mean Level" is one of the parameters shown in the computer listings in Figures D.10 through D.12. That parameter, usually called "L_{EQ}" is the level of the continuous sound that

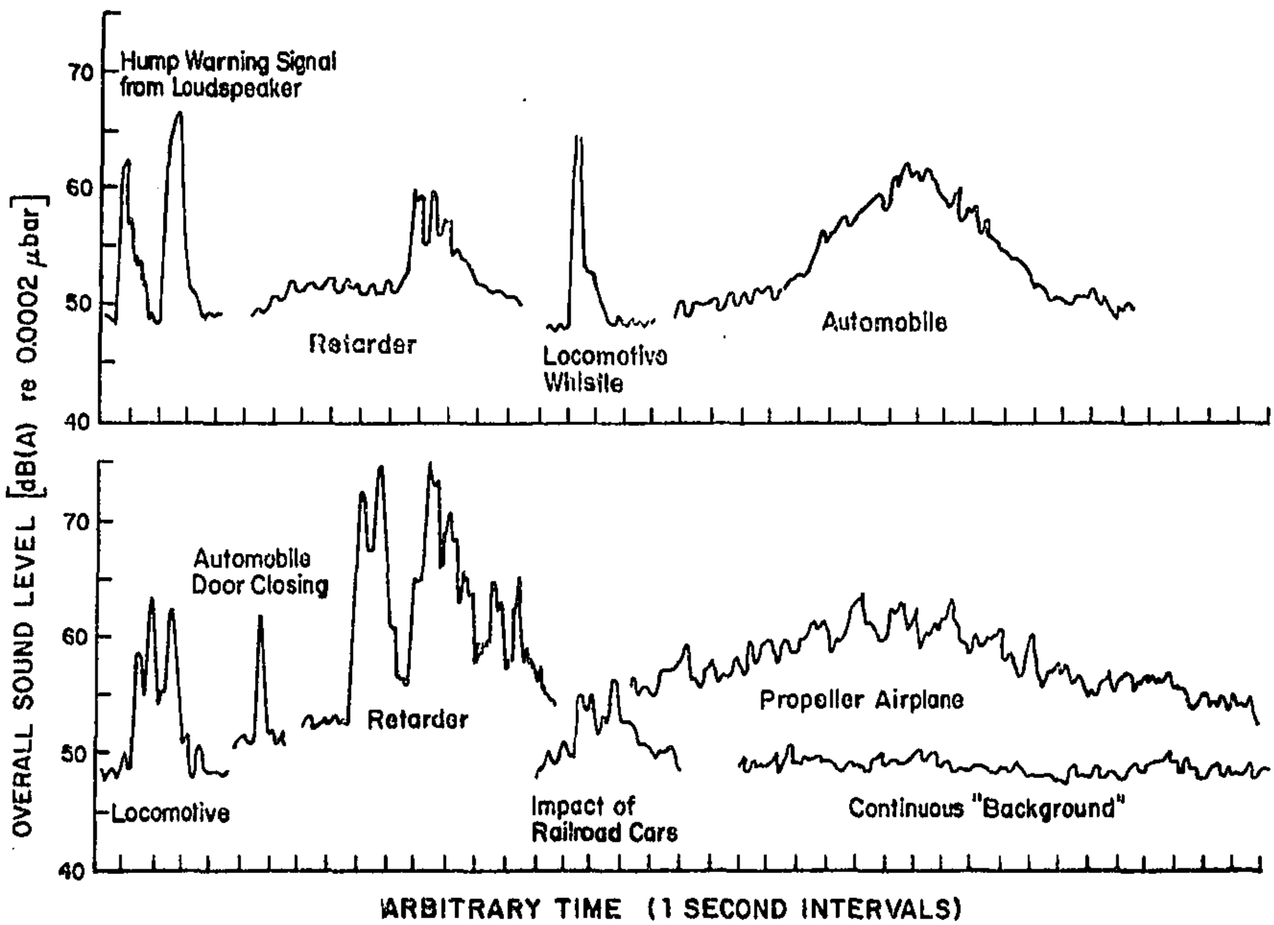
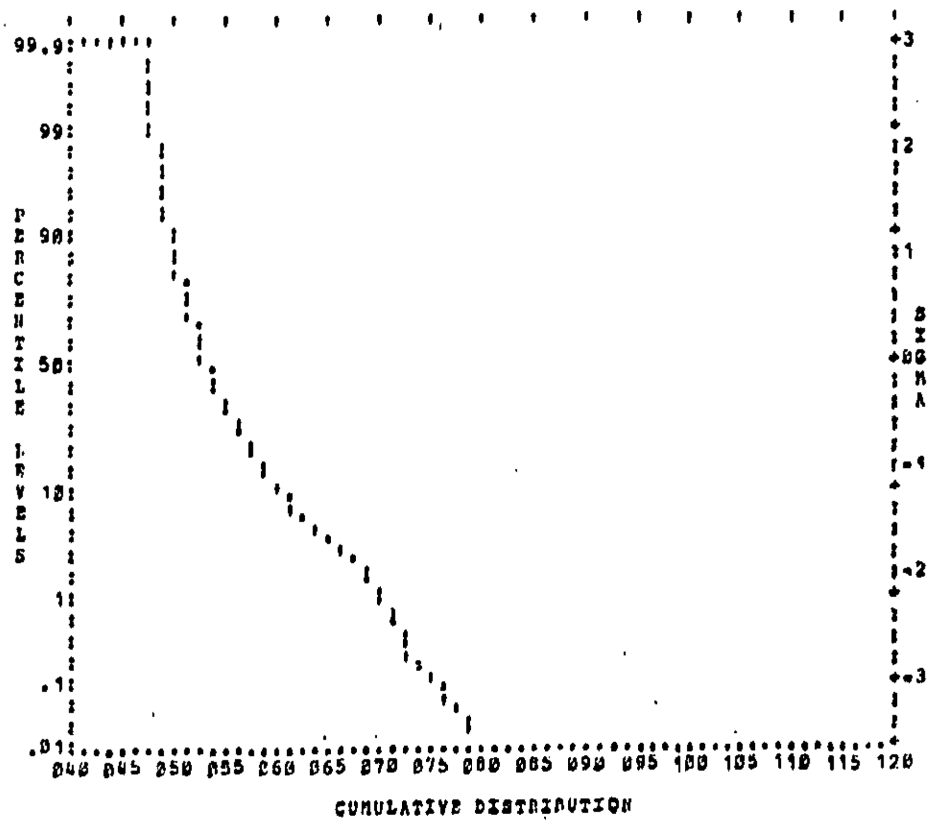


FIG. D.9. SELECTED EVENTS FROM A TIME HISTORY OF NOISE IN A COMMUN'TY 400 FT FROM THE BOUNDARY OF A RAILROAD HUMP YARD.

GRAPHICAL OUTPUT OF STATISTICAL NOISE DATA

CICERO YARD, MAY 17,1973, 5:20 A.M., WEST 34TH ST.

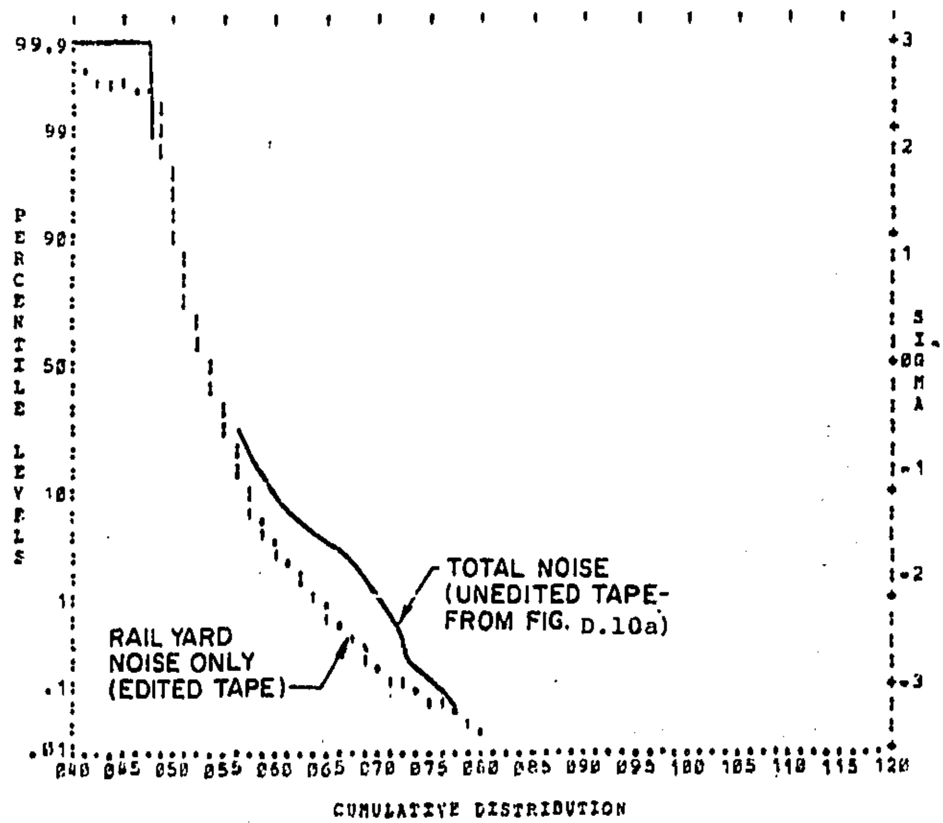


MAXIMUM NOISE LEVEL = 82.5
MINIMUM NOISE LEVEL = 31.3
NOISE POLLUTION LEVEL = 71.1
STANDARD DEVIATION = 4.9
ENERGY MEAN LEVEL = 58.6

FIG. D.10a. STATISTICS OF NOISE IN A COMMUNITY 400 FT FROM THE BOUNDARY OF A RAILROAD YARD (TOTAL NOISE; UNEDITED TAPE).

GRAPHICAL OUTPUT OF STATISTICAL NOISE DATA

CICERO YARD, MAY 17,1973, 5:20 A.M., WEST 30TH ST.
(EDITED)

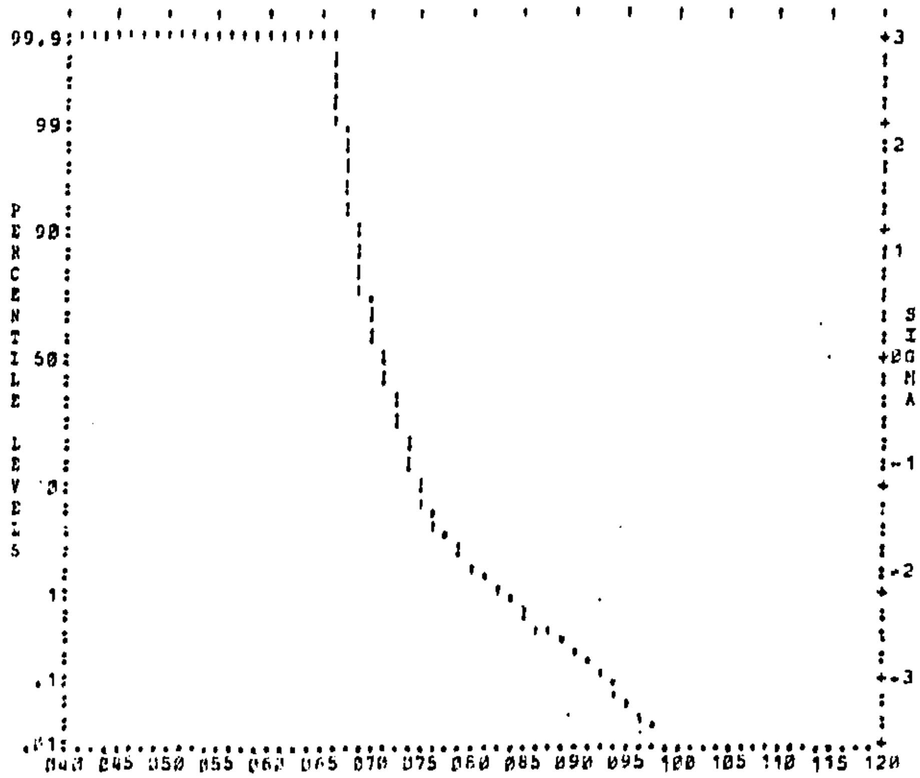


MAXIMUM NOISE LEVEL	=	80.0
MINIMUM NOISE LEVEL	=	31.3
NOISE POLLUTION LEVEL	=	64.3
STANDARD DEVIATION	=	3.5
ENERGY MEAN LEVEL	=	55.8

FIG. D.10b. STATISTICS OF NOISE IN A COMMUNITY 400 FT FROM THE BOUNDARY OF A RAILROAD YARD (COMPARISON OF EDITED AND UNEDITED TAPES).

GRAPHICAL OUTPUT OF STATISTICAL NOISE DATA

CICERO YARD, MAY 17, 1973, 5:18 A.M., OGDEN AVE, (EDITED)

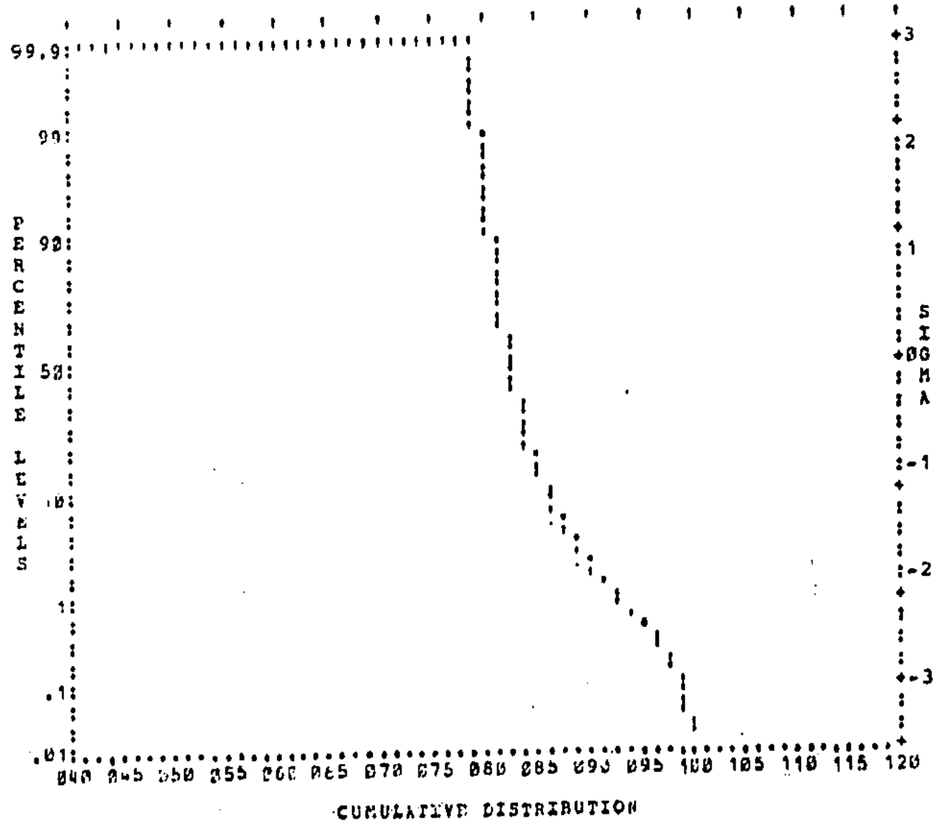


MAXIMUM NOISE LEVEL	=	97.5
MINIMUM NOISE LEVEL	=	65.0
NOISE POLLUTION LEVEL	=	82.6
STANDARD DEVIATION	=	3.3
ENERGY MEAN LEVEL	=	74.0

FIG. D.11. STATISTICS OF NOISE AT THE BOUNDARY OF A RAILROAD YARD WHILE THE YARD WAS BUSY (RAILROAD NOISE ONLY; EDITED TAPE).

GRAPHICAL OUTPUT OF STATISTICAL NOISE DATA

CICERO YARD, MAY 17,1973, 3:30 A.M., OGDEN AVE.

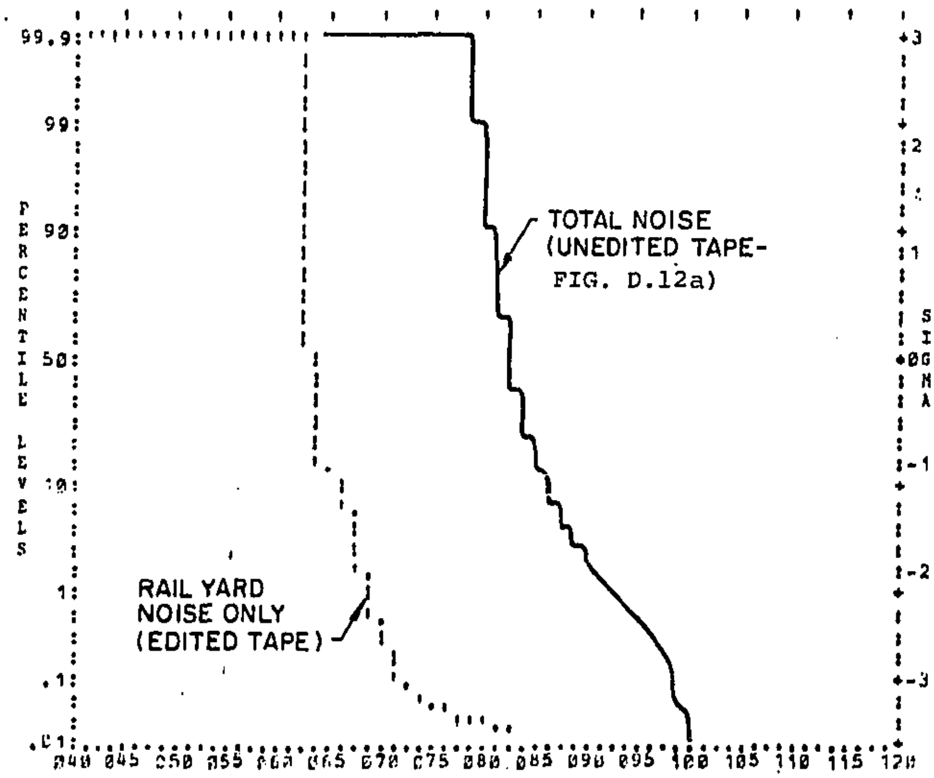


MAXIMUM NOISE LEVEL	=	98.8
MINIMUM NOISE LEVEL	=	77.5
NOISE POLLUTION LEVEL	=	98.7
STANDARD DEVIATION	=	2.7
ENERGY MEAN LEVEL	=	83.9

FIG. D.12a. STATISTICS OF NOISE AT THE BOUNDARY OF A RAILROAD YARD WHILE THE YARD WAS QUIET (TOTAL NOISE; UNEDITED TAPE).

GRAPHICAL OUTPUT OF STATISTICAL NOISE DATA

CICERO YARD, MAY 17,1973, 3:30 A.M., OGDEN AVE,
(EDITED)



MAXIMUM NOISE LEVEL	=	93.8
MINIMUM NOISE LEVEL	=	62.5
NOISE POLLUTION LEVEL	=	68.0
STANDARD DEVIATION	=	1.6
ENERGY MEAN LEVEL	=	64.0
PERCENTILE LEVELS: L1	=	69.1
L4.2	=	67.4
L10	=	66.5
L33.3	=	63.5
L50	=	63.3
L90	=	62.7
L99	=	62.5
TRAFFIC NOISE INDEX	=	47.9

FIG. D.12b. STATISTICS OF NOISE AT THE BOUNDARY OF A RAILROAD YARD WHILE THE YARD WAS QUIET (COMPARISON OF EDITED AND UNEDITED TAPES).

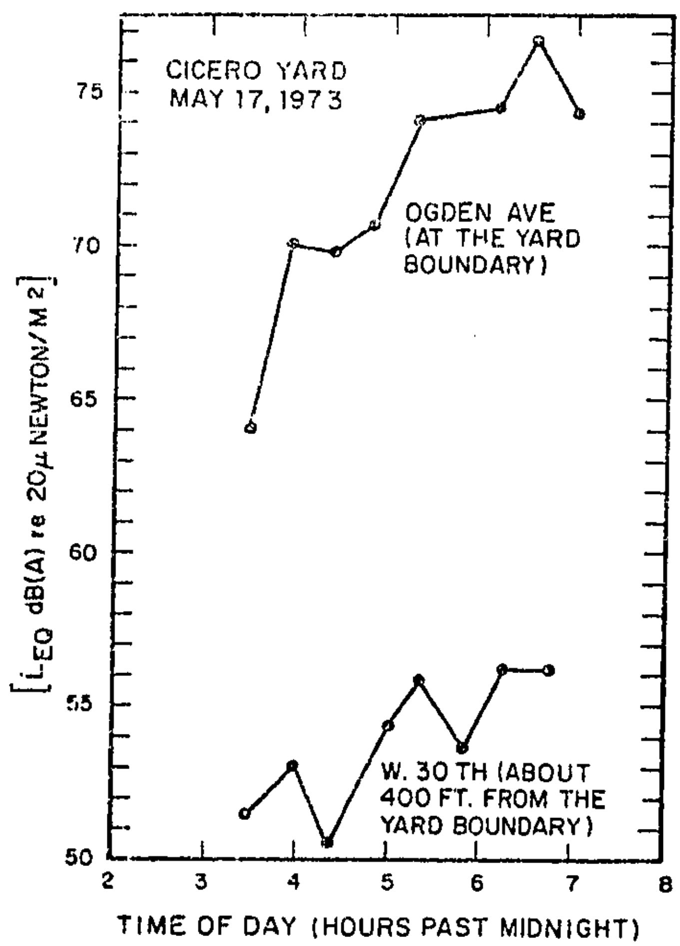


FIG. D.13. MEASURED L_{EQ} VS TIME OF DAY FOR POINTS IN AND NEAR A RAILROAD YARD (20-MIN RECORDINGS, SAMPLED 10 TIMES/ SEC).

would be associated with an amount of energy equal to the sum of the energies of a collection of discontinuous sounds. The discontinuous sounds are analyzed for a specified period of time, and L_{EQ} is calculated for that same period. Figure D-13 shows plots of the computer-calculated L_{EQ}'s for the observations described above.

MODELING YARD NOISE IMPACT ON PEOPLE

The two types of railroad switching yards are flat yards and hump yards. In a flat railroad yard there are two major sources of noise – locomotives and car impact. In hump yards the squeal caused by cars passing through retarders is significant.

The development of a yard noise model for this Background Document involves the computation of L_{DN}* for yards which (1) describes the activities of locomotives, (2) determines the probabilities of occurrence of various levels of retarder squeal and car impact noise, and (3) integrates the cumulative acoustic energy that is developed at a given point in the space surrounding the yard.

Figure D.14a shows calculated L_{DN} profiles for group retarders in a typical yard – the Cicero Yard in Chicago. Figure D.14b shows L_{DN} profiles for car-car impacts. Figure D.14c shows L_{DN} profiles for locomotive operations in the yard.

The calculated L_{DN} profiles in Figure D.14 are based on observed levels and frequencies of occurrence of various noises. In addition to the usual geometric attenuation, atmospheric absorption and ground attenuation effects (Beranek, 1971) were included in the construction of the figure. The levels for the individual noise events at the measurement points shown in Figure D.14 were consistent with the points of origin of the events also shown in Figure D.14.

The noise levels for retarders and rail car impacts are considerably lower than those for locomotives, so that the total noise levels from all sources is approximately that of locomotives alone, as shown in Figure D.14. The noise levels determined from magnetic tape recordings of noise emissions at the West 30th measurement point are also in good agreement with the total noise emission levels (approximated by locomotive noise), as noted in Figure D.14c.

Retarder noise levels and impact noise levels in Figure D.14 generally would be dominant at community observation points if the locomotive noise levels were lowered by 10 dB(A). Thus, retarder and car impact noise will replace locomotive noise as the most obtrusive noise in the community near the Cicero Yard, if locomotive exhausts can be muffled sufficiently to lower their noise by 10 dB(A) (assuming that no other sources of locomotive noise produce levels comparable to exhaust noise levels).

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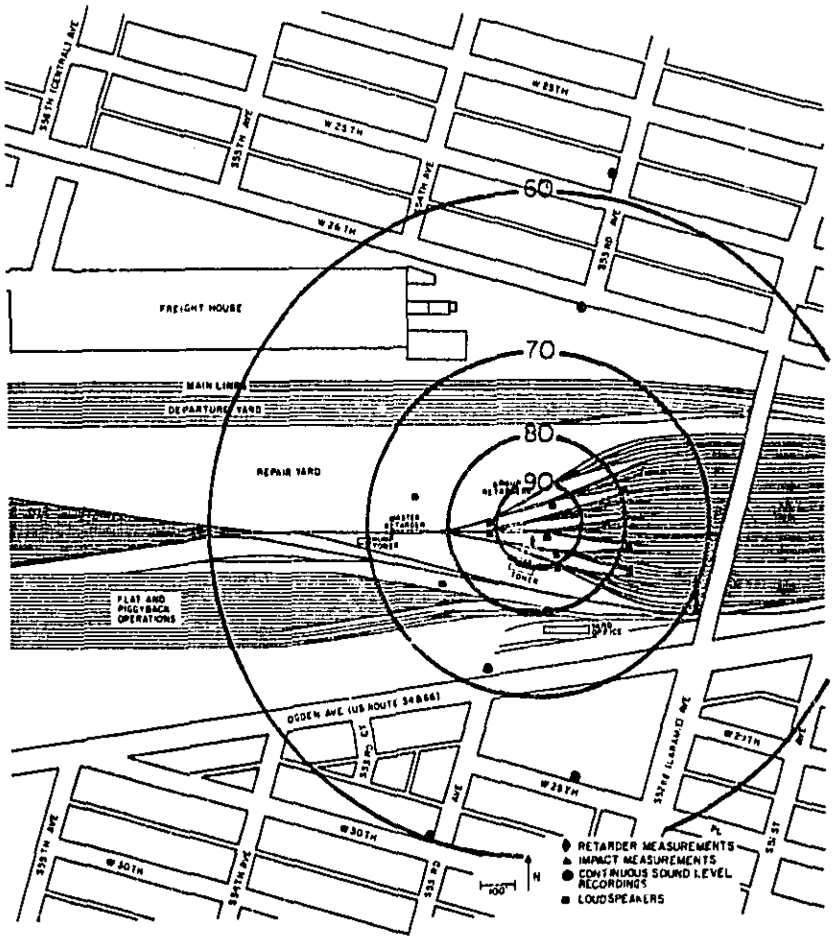
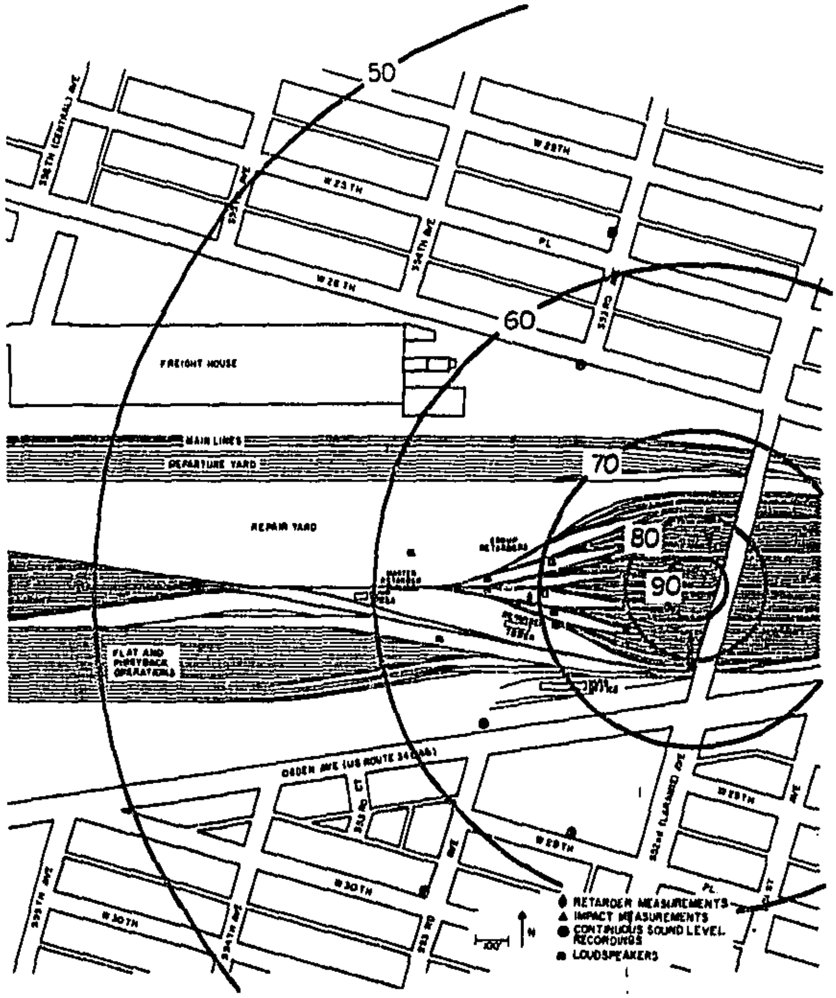
*Enclosure A of section 8.



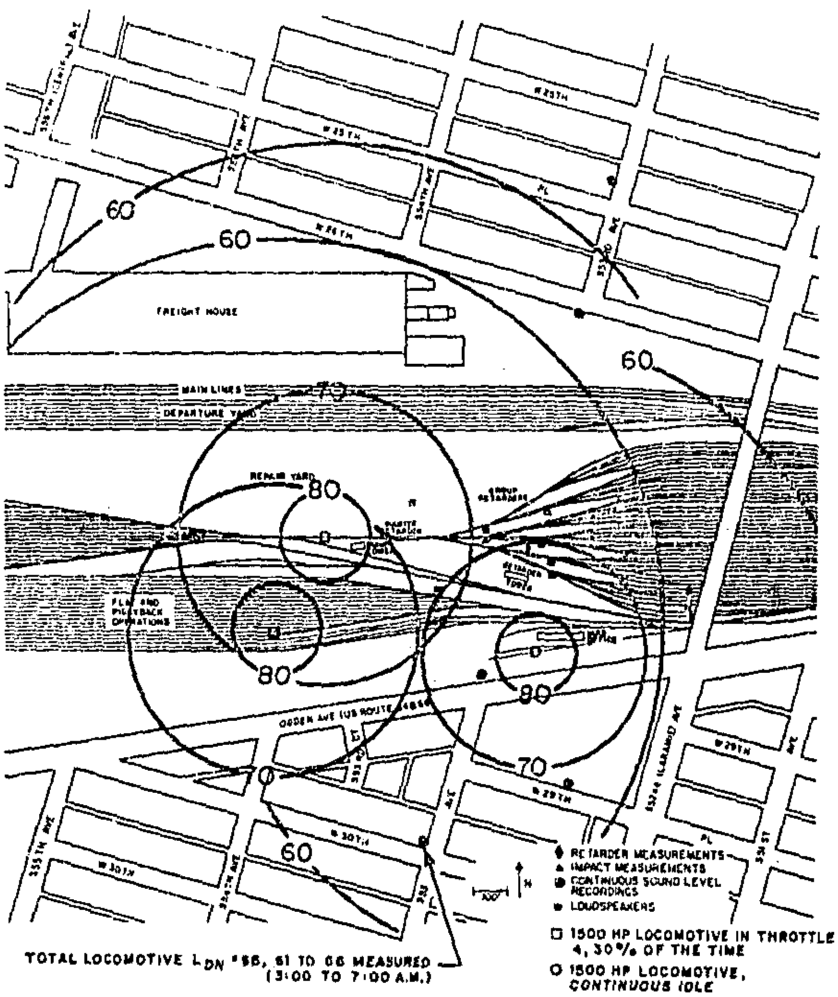
(a) Retarder Squeals

FIG. D.14a. L_{DN} PROFILES FOR BURLINGTON NORTHERN'S CICERO YARD



(b) Impacts

FIG. D.14b. (CONT.)



(c) Locomotives

FIG. D.14c. (CONT.)

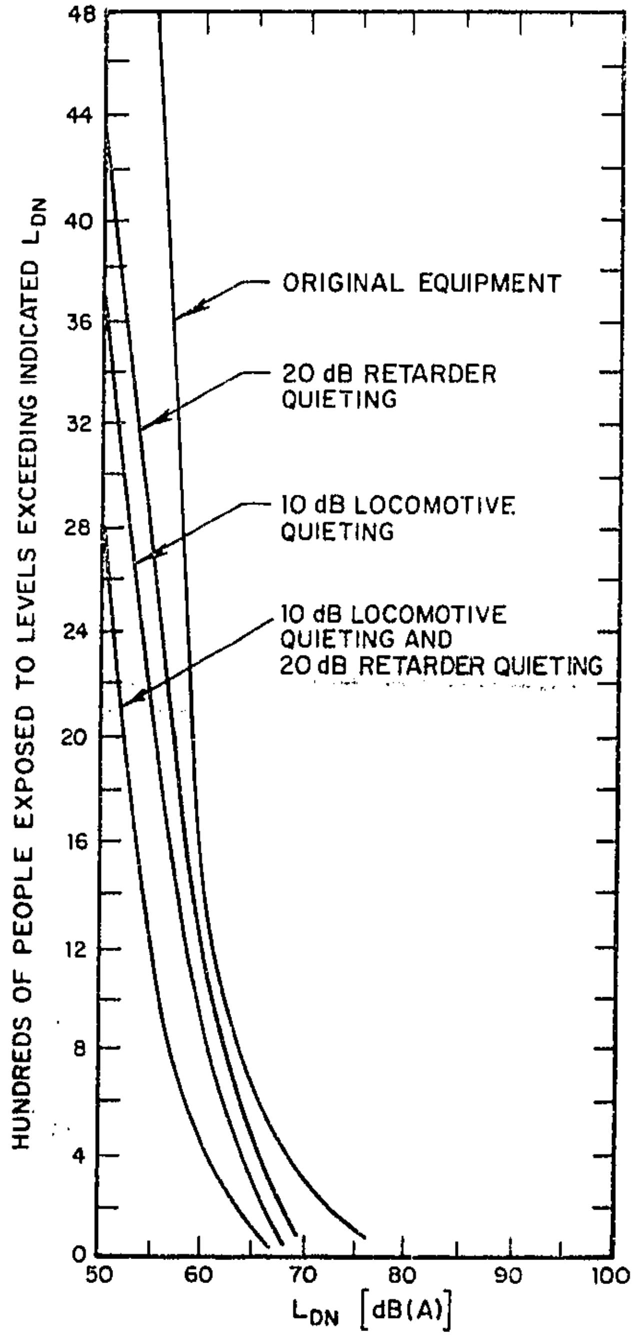


FIG. D.15 NUMBER OF PEOPLE EXPOSED TO VARIOUS L_{DN} BY CICERO YARD OPERATIONS.

Figure D.15 shows the number of people exposed to various L_{dn} around the Cicero Yard.*

Figure D.15 indicates that a muffler which quiets locomotive exhaust noise by 10 dB(A) will decrease by 400 the number of people exposed to L_{dn} of 65 or more from the Cicero Yard operations (assuming that no other sources of locomotive noise produce levels comparable to exhaust noise levels). The figure also shows that barriers providing a 20 dB(A) reduction of retarder noise would decrease by 200 the number of people exposed to L_{dn} of 65 or more.

Analysis in more detail of Figure D.15 shows that at the time of the study, at the Cicero Yard approximately 4,800 people or more were exposed to noise levels higher than the L_{dn} 55 noise level identified in the Levels Document (EPA/ONAC report number 550/9-74-004) as being protective of public health and welfare. Approximately 60 of these individuals were exposed to noise levels at $L_{dn} = 75$, which clearly is in the region where hearing loss may be a potential threat, according to the Levels Document, which identifies the potential hearing loss level at $L_{eq(24)} = 70$ (approximately $L_{dn} = 73$).

The application of mufflers which quiet locomotive exhaust noise by 10 dB(A) is predicted to reduce the number of exposed people (to an L_{dn} of 55 or greater) from 4,800 to 2,000, which is a 58% improvement. From a hearing conservation point of view, the number of exposed people to an L_{dn} of 75 would shrink to zero, or a 100% improvement.

Similarly, the predicted effect of the application of barriers to retarders (see Figure D.15) would be a reduction in the number of people exposed to levels greater than L_{dn} 55 to 2,800, which is a 42% improvement. From a hearing conservation point of view, the number of exposed people would shrink to 0, which is a 100% improvement.

*Population densities for use in construction of Figure D.15 were obtained from the U.S. Department of Commerce, Bureau of the Census.